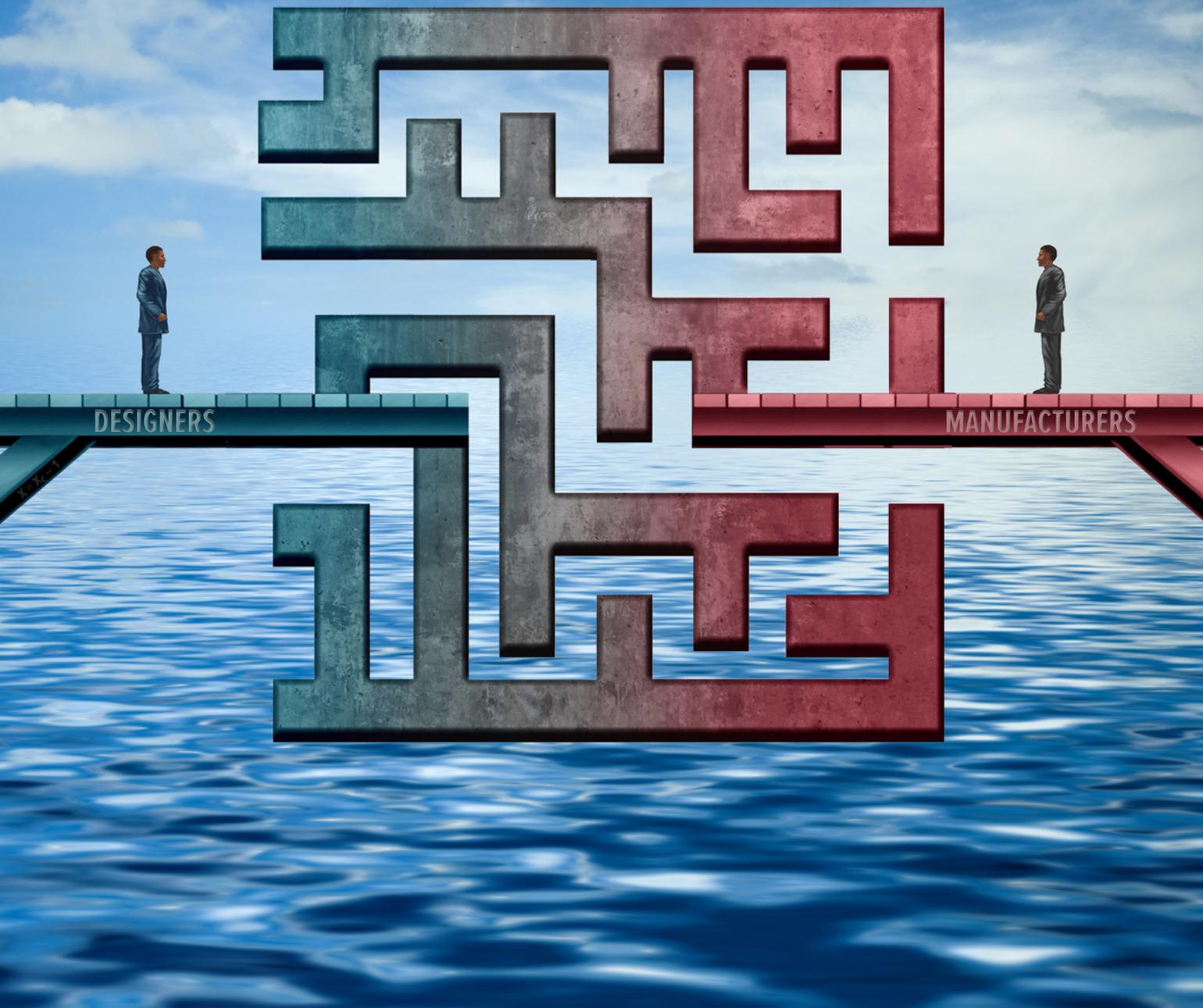


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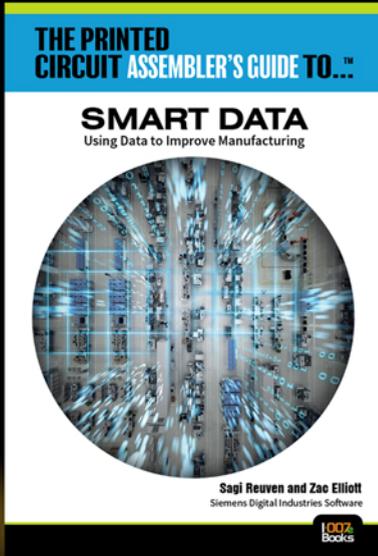


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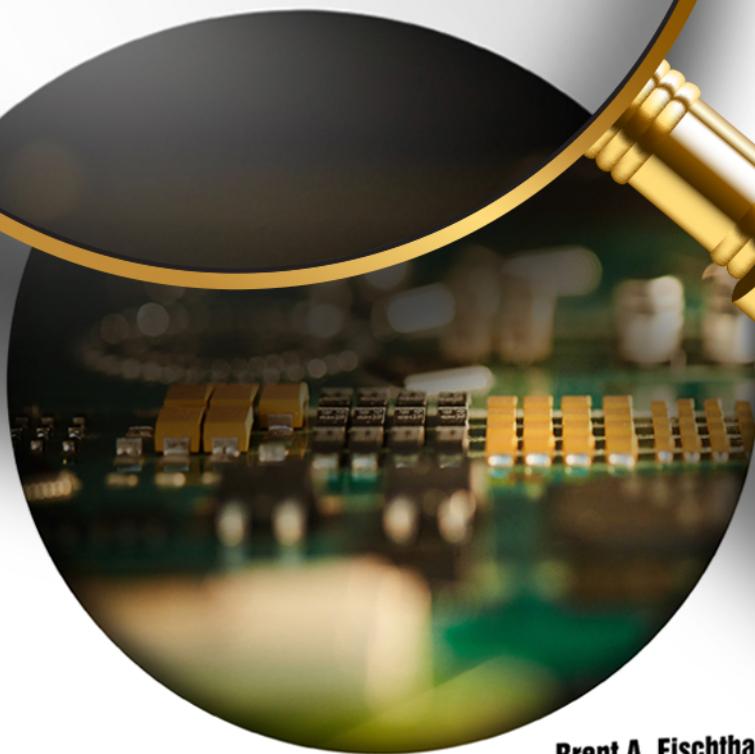
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Designer/EMS Communication

This issue defines just some of the communication gaps and needs between EMS and designers. Our interviews and articles highlight the tools and methods that help to bridge the gaps in the communication channel.



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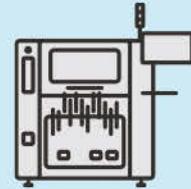
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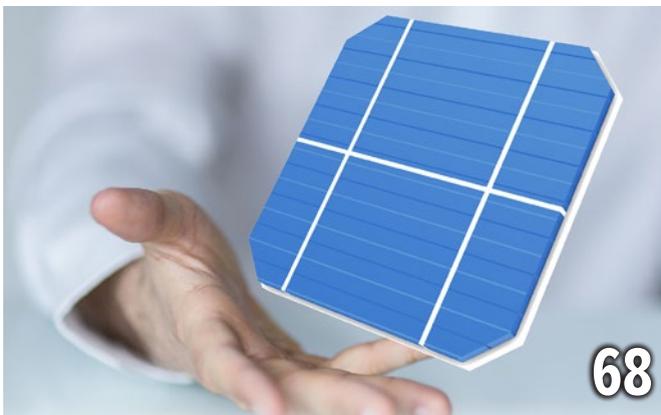
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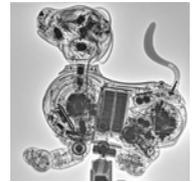
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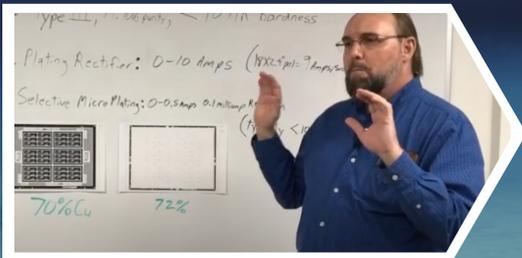
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The Designer to EMS Communication Process

Nolan's Notes

by Nolan Johnson, I-CONNECT007

In July, SEMI reported^[1] that the Electronic System Design (ESD) industry revenue rose to \$3.15 billion in Q1 2021, a 17% increase. The ESD Alliance, a community within the SEMI organization, called it the strongest first-quarter growth ever. Of note, printed circuit board and multi-chip module tools saw a 15.3% increase in revenue to \$289 million, and the four-quarter moving average for PCB and MCM revenues rose to 5.3%. ESD growth was detected in all global regions except Japan; the Americas saw the most revenue in dollars, while Asia Pacific showed the highest percentage change.

Clearly, design tool investment continues, and this is good. The challenge, however, is to make sure that the tools are doing the right jobs. Are the tools restricting themselves to delivering new bells and

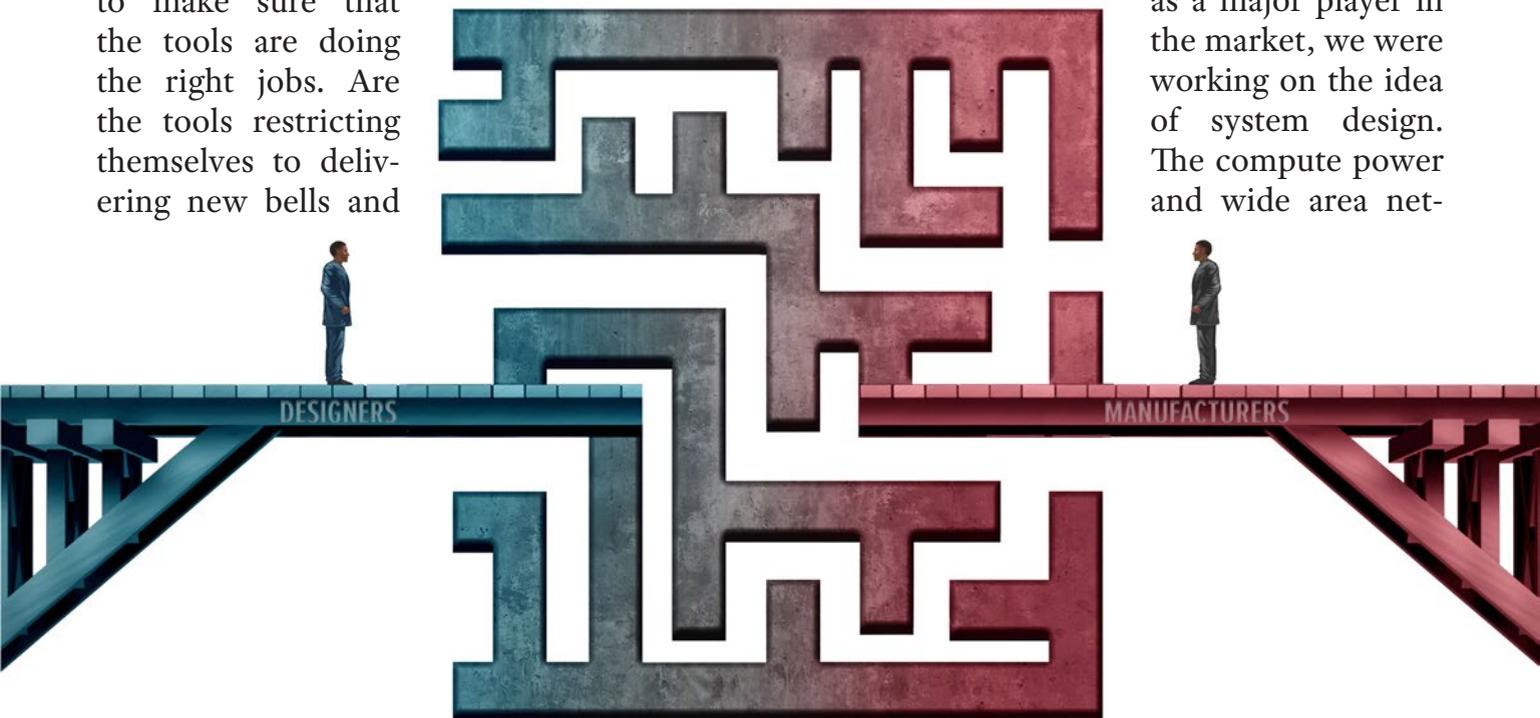
whistles to the designer's bag of in-tool design tricks, or are the tools helping to optimize the entire process of design and manufacture?

Design tools, like designers themselves, are at the apex of the manufacturing chain. What happens in design has a profound trickle-down effect on the effectiveness and efficiencies further on in the process. Everybody knows this. And everybody points to "communication" as a key issue in the manufacturing chain as well.

The apparent inertia in this space seems almost insurmountable.

CAD tool developers have been working toward "system design" for most of the history of the sector. Early in my career when I wrote code at an EDA startup that now is recognized

as a major player in the market, we were working on the idea of system design. The compute power and wide area net-



work resources necessary to realize the vision of full mechatronic system design just weren't available then, but we were working on it. Personally, I'm fascinated to watch the progress toward true system design currently underway; the engineering digital twin seems to be taking shape within the CAD tool frameworks.

Trouble is, those same software companies are looking right past the manufacturing digital twin, which is equally as important and just as strongly influenced by the design itself. If the CAD tools took an even more active leadership role in developing the digital twin for manufacturing, the savings and efficiencies throughout the industry could result in millions (billions?) of U.S. dollars saved. One can find manufacturing digital twins in use in other industries, and often built as a proprietary system.

Nobody's blaming the EDA companies, of course. It's just business: the electrical engineers on the design teams buy the tools; it's the OEMs who fund the development of that software. The manufacturers don't. In other words, the design teams are the primary customer; manufacturers are merely interested stakeholders. This means that, until design teams start to push for tools that make their communications with manufacturing easier, clearer, and more efficient, not much is going to change. The software companies need to be shown that there's revenue in funding the development of an industry standard manufacturing digital twin.

That's the question, isn't it? How does the industry monetize the manufacturing digi-

tal twin so that the appropriate players will be motivated to realize the vision? At present we can't even seem to move beyond Gerber files to more complete and secure file formats, let alone build out a cross-platform digital schema. There's money in the market; semiconductor proves that point. Somehow, somewhere, that same level of attention and investment needs to find the printed circuit industry as well.

This conundrum encompasses much more ground than we can cover in just one issue. This month, therefore, we're focusing on the communication between designers and the EMS providers. Our goal is to help define the communication gaps and needs between EMS and designers, and highlight the tools, procedures, and thought processes that help to fill that gap. If, at the end of this issue, we've given you food for thought—and a practical idea or two—then we've achieved our goal.

If you have comments on our coverage, or suggestions for what we should be covering, we'd like to hear from you at editorial@iconnect007.com. SMT007

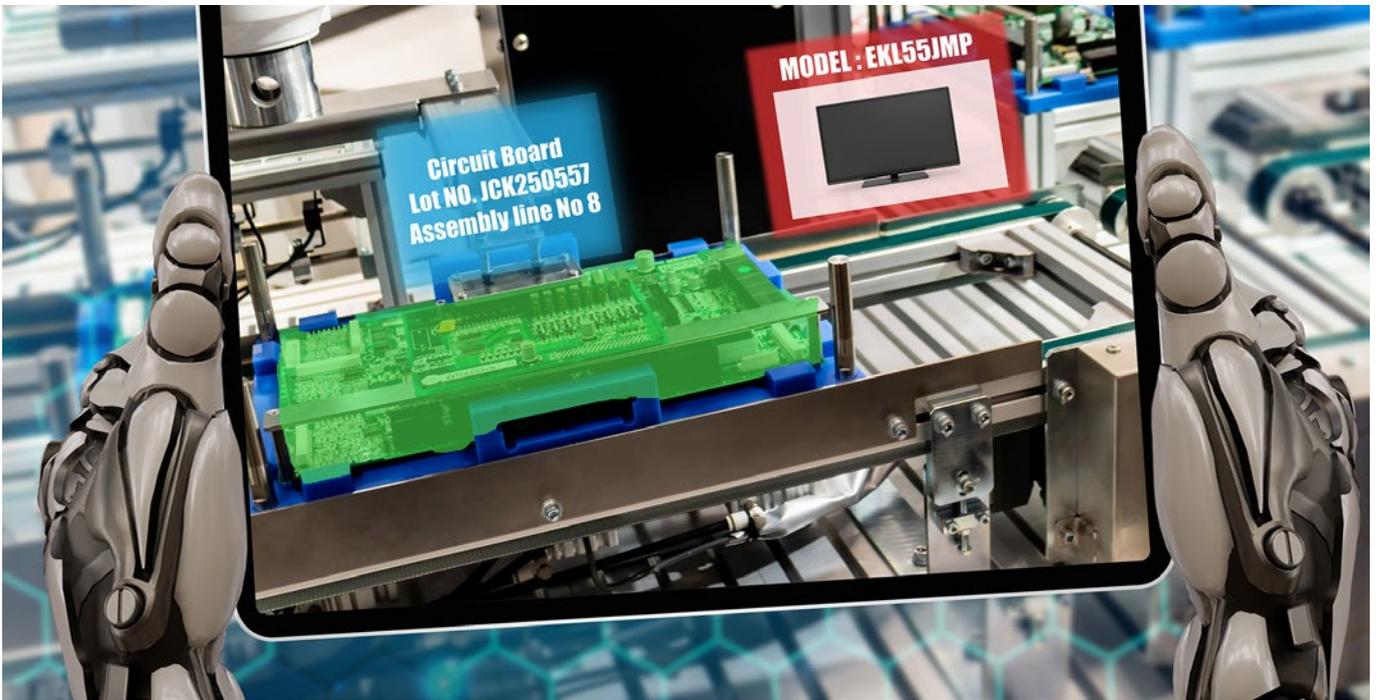
References

1. [Electronic System Design Industry Reports 17% Revenue Growth in Q1 2021](#), July 16, I-Connect007.



Nolan Johnson is managing editor of *SMT007 Magazine*. Nolan brings 30 years of career experience focused almost entirely on electronics design and manufacturing. To contact Johnson, [click here](#).

A dark blue banner with a textured background. On the left, the text 'jobCONNECT007' is displayed in a large, bold font, with 'job' in blue, 'CONNECT' in white, and '007' in yellow. Below this, the text 'Companies seeking talent with circuit board industry experience post their jobs with us.' is written in white. On the right side, there is a large magnifying glass graphic with a blue handle and frame. Inside the lens of the magnifying glass, the website address 'jobconnect007.com' is written in white.



A Deep Dive into Digital Twin

Feature Interview by the I-Connect007 Editorial Team

The I-Connect007 Editorial Team spoke with Michael Ford to explore his vision and reality of the digital twin as a communication mechanism.

Nolan Johnson: Michael, what is your current definition of digital twin?

Michael Ford: My gut reaction was to say that any computer program is, in a sense, a digital twin. If you're running Microsoft Word, you're using a digital twin. That's because what you see is what you get; you print a document out and it looks exactly the way you saw it on the screen. But that's really simplifying the real intent of the term "digital twin" and why it was created, which is to allow people to understand how the digital world can be useful in reducing cost and waste in the physical world, reducing physical commitments through the use of digital tools, including product design,

manufacturing process preparation, planning, execution of a machine, line and factory, and watching a project evolve end to end in the digital domain. The physical product manufactured and in the market is exactly as you envisioned in your design brief. Just like your print-out, the physical result looks the same as you saw on screen.

Johnson: In that sense, we've been working with digital twin ideas since the very beginning of the ECAD industry back in the late '70s, given that the original idea was to design and simulate electronically, so that we didn't have to use a breadboard.

Ford: Yes, exactly.

Johnson: When you're out in the field now, are you running into different interpretations of digital twin? You already pointed out that anything could be called a digital twin. Within our industry, though, are there variations of the term?



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Michael Ford

Ford: There are. I think the term “digital twin” has become a buzzword.

There are those who are seeking to use the digital twin as a way of solving problems in ways that have not been possible before. Here is where a multitude of digital twin applications become interesting. Originally, digital twin started with design, with an afterthought given to manufacturing. We wanted to have a viewable 3D model, for example, of a car without having to build something made from clay, which sounds a little bit old-fashioned today, right?

So why not model it in three dimensions on the screen, to be able to see and understand how all the components fit and interact, to model how everything works together? This is where the digital twin first became famous, but now we’ve moved on to other applications, including getting into manufacturing itself, where we would like to be able to see, in a digital sense, exactly how, and how well, every new product would be made.

This is the next logical step, and just the start of a long road of future digital twin applications. You ultimately may have thousands

of digital twin-based applications for things such as capacity or capability planning, quality yield management, as well as solutions with narrower scopes, such as the understanding of how materials are used that affect the performance of the end-product, the operation of a certain machine or process, the variation of spacing between electronic and mechanical components and their effect on heat transfer, rigidity etc. All these are different examples of applications that exist where digital twin solutions are coming.

The problem today, however, is that these digital twins are individual. They are not interoperable with each other. Effectively you’re stuck with your old “single-use” computer programs. The real principle of digital twin is to make data and results from solutions interoperable. One example of this is in the use of data from manufacturing for design. A good designer would like to understand real manufacturing constraints, so that they can improve their design, but designers typically don’t understand manufacturing-speak, and would find it hard to understand the many kinds of data that they would receive. We therefore need to create a schema, if you like, an architecture, that allows solutions that are outside of one domain, to be able to understand the data of another. The result is that solutions in design, manufacturing and the marketplace can all understand each other. We then have a continuous flow of information across what used to be silos.

Johnson: Which is then presented in a way such that a non-expert in one domain can use the information to help their expertise in their own domain.

Ford: Exactly.

Barry Matties: If you want to streamline the process and the relationship, you need better communication. The digital twin is the communication link or the universal translator,

if you will. It forces communication. Especially as we develop these digital factories, the need for communication in the digital twin is there. And it forces that communication when we start manufacturing from a recipe-driven digital twin. How does this help the EMS and designer communicate? What are the benefits? What are the drawbacks? What do we need to do?

Ford: In the EMS scenario, there is the complication of disparate design, PLM, ERP, and MES systems all trying to work together to come up with data for some form of quotation. All the data contextualized together is what the EMS company really wants, and is what a human team has to do today, but how do you make a translation and connect context between them? They are all individual solutions; they're all proprietary. They all deal with things in slightly different ways, each giving great values and benefits, but without speaking a common language. To that end, the digital twin from IPC is the definition of the single architecture and language that they can use to communicate.

On the design side this would start with, for example, the design intent, featuring specifications and rules, together with associated electronic design file; 3D mechanical CAD file; design bill of materials, 3D models of materials used on the board, all of which forms a package, digital twin data, such that all solutions needed to process the data can understand the formats and use the data interoperably. The ERP application is going to add to the digital twin data, because they will select and purchase materials that are locally available, and that are functional and cost-effective. Now, these can be checked using the digital twin, such that any alternatives or substitutes will actually fit on the circuit board and be as effective as the originals suggested. As ERP must choose components from different vendors; you're going to have a different footprint. Electronic functionality may be a given, but

do they physically fit? Are the leads compatible with the pads that are created? Immediately you can see how problems happen if certain checks are not made. The question is how to get the approval from design that these different parts are good to use.

The digital twin is then again in use, even though the design was made months ago and was signed off. If you start changing the shapes of components used, the designer can't be responsible for anything that happens. This puts the risk on the manufacturer, but they have motivation to decide to do something.

Now, using the digital twin, all the information about the design and the design intent is available. The sign-off for a material change in the BOM can be done by any suitable application, not necessarily the original design and designer, using the data in the digital twin. The design rules, the layout and everything physical about the design is available as part of the digital twin. If an application has permission to use that data, the EMS company can start to do the analysis of effects of changes themselves. The designers are happy because they've included their rules and they know that those rules are going to be followed. Unless there's an exception, they're not going to get called.

Matties: Part of the communication recommendation is that the designer needs to know who is manufacturing the board upfront so that they can work to their capabilities. Often the designers do not know that. The question is, how do we get the EMS and the bare board fabricator to put their capabilities out so that designers can design to the fabricator's capabilities? Our understanding is that those capabilities aren't always available publicly, anyway.

Ford: This is a very interesting area because with the digital twin, as IPC has set it out, you have elements of digital twin for design and for manufacturing. In the manufacturing digital twin, there is a complete description of the enterprise, broken down into sites, con-

figurations, specific machines and capabilities, throughput indicators, etc. Even digital twins of machines themselves can be included. In theory, an EMS or fab could say, “Here is my digital twin for manufacturing. I’m going to send it to my design customer.” Now the problem: this information is proprietary, and it has associated intellectual property. There is always the risk when exchanging data such as that which contains IP, because if that data gets into the wrong hands, it creates all kinds of competitive and security problems.

How do you then secure that data? We’re looking at some rather interesting new digital techniques out there. One is called verifiable credentials. For example, let’s say a young person tries to go into a bar. In the U.S., they need to be 21 years old. The person turns up at the door, and is told, “You need to be 21.” Now, the person doesn’t want to say their age, and certainly not disclose their date of birth. They don’t want to share any private information at all. Let’s say, however, that this person has a secure digital twin of themselves somewhere in the cloud. The requirement to enter the bar is given to the digital twin, likely in the form of a question. Can this person enter the bar? Yes or no? And we hope the answer will come back, “Yes.” In this interaction, no private information has been exchanged, other than the fact that this person wants to go into



the bar and is thinking that they are eligible, which we knew already. No actual information whatsoever has been divulged between the parties. The person’s information has been kept private.

What we’re working on now is a set of these verifiable credentials that provides needed information about design and manufacturing, but which does not expose private information that needs to be protected. This next step of the digital twin evolution is to work out how privacy can be assured such that information can be exchanged, and in theory, used to the fullest extent, without this risk of loss of privacy.

Matties: From the designer’s desk, if they’re doing this step-by-step through a process, they could go through each step and validate their design decision.

Ford: That’s a great example because there would be solutions based on the digital twin where the designer says, “I want to put this particular chip here. Here’s my part number, here’s my location and orientation.” He then presses a button, or gets automatically, a determination of manufacturability. This would work by referencing the manufacturing site’s digital twins, using verifiable credentials to ask something that could be summarized as, “Is this okay?” The solution would be working on the private data, understanding whether this was okay or not, and simply coming back with the answer to say, “You’re good,” or not.

Matties: If they did that for every step of the manufacturing process, their digital twin becomes a “live” DFM tool.

Ford: Exactly. It’s an interesting application of the digital twin, because it is an ability for people to be able to run these private functions, within private solutions in a way that shares data interoperably. It works both ways, design to manufacturing and back, and even out into the market.



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Matties: The designer validates step-by-step, contributing to the digital twin, and can see that this board passes DFM. You're digitally validating and fabricating before it even gets to the fab. Does this then bring the responsibility of purchase—or at least vendor selection—to the designer? Because we hear, oftentimes, it's the purchasing agent making the purchasing decision and not the designer or engineer, which can create a problem.

Ford: In reality, a digital twin would be adopted that contains a variety of manufacturing configurations, made from potentially many vendors. Policies would have to be in place to define what to do if any specific configuration from a potential vendor would not work correctly where certain design decisions are made. This is also the reality today, which results in poor manufacturing performance. With the digital twin, these issues are avoided at source. You can see how these things happen.

On the materials side, selection decisions depend on the product and the designer. In some cases, approved vendor lists are very design specific, but the requirements of which are not communicated in a good way today. Current instructions will specify to use vendor A, B, and C. When the manufacturer must say, "A, B, and C aren't available here right now, so I'd like to use vendor D. Is it actually possible? Was vendor D considered? Who am I going to call? Who should I ask?" Decision makers today must understand the difference between vendor D, and vendors A, B, or C, and the reason why vendor D was not included in the first place, for which the information is not always available.

Matties: The nuance of a design could create a problem with vendor two vs. vendor one, for example, even though they're on the AVL. But if they had this digital twin, they could be running the step-by-step process with each of their AVL partners at the same time. This would drive the decision back to the designer, not the purchasing agent.

Ford: It could also be a digital twin solution that purchasing uses, based on the interoperability of the design digital twin data. That solution should be able to make the same decisions as the original designer would have.

One challenge with this currently is that information about materials is not always accurate and is not available to the degree of precision that is often needed. Component documentation is often still usually on pieces of paper, including PDF documents, even though, all the materials are of course designed electronically. What we are looking at to help in this area is another new standard that is coming soon from IPC. I do keep talking about these new standards. There is a model-based design (MBD) standard coming from IPC in which the component manufacturers themselves will be able to output their existing component design data into a standard format, which can then be used interoperably as part of the digital twin.

The IPC-2581 DPMX design data committee is also looking into this new MBD standard to enhance the DFX approach in both directions. Firstly, doing the sanity check that everything will work with your selected partners, and second, analyzing data coming back from manufacturing, as they have the new DFX data definition within the IPC-2581 revision C.

Plus, if you're looking at the data after the fact, using the traceability data, which is also a part of the digital twin manufacturing, you can then start to say things like, "I'd like to report material vendor A's performance against vendor B's performance, with respect to this particular kind of symptom or fault that I had on the line." That's completely possible, and can be used to refine the rules for the choice of vendor.

Matties: The designer validates the chip suppliers and component suppliers are publishing all their modeling. We're talking about a lot of discipline, aren't we?

Ford: I don't think so. I prefer to think of it as increased automation. If we can stop people from touching data, handling data, changing data, measuring things, manipulating things, it all becomes simpler, with less work, less mistakes, which people actually like. If you have a model-based design of a component, and you simply load that into, for example, a design tool able to perform DFM, or, you have DFM running in a manufacturing site, or even if you are creating a parts data library for the pick-and-place or inspection machines, then it makes life easier for everyone, because you don't need to be a data "hunter-gatherer" for all the different pieces of information that you need. For the manufacturer, you now create one MBD data record automatically, rather than having to format, publish, and distribute specifications in various different languages and formats. There is also the element of enhanced privacy. Quite a potential ROI.

Matties: Communication makes life easier for everybody, yet we don't do it well.

Ford: We don't. I could be speaking Japanese to you right now on our Zoom call, which could still be regarded as great communication, because we can see and hear each other perfectly. But there is the small problem that you wouldn't understand a word I was saying. It's the data content definition, the language, that is the important thing for communication. The rest is a means to an end. Manufacturing people speak manufacturing, design people speak design. You need to have a standard lan-

guage that spans design and manufacturing. This is being created as part of the IPC digital twin, so that you can have solutions on either side that understand each other's data.

Matties: Well, that goes back to my earlier description of digital twin as the universal translator.

Ford: Effectively, yes, that is right; we are defining the common way in which information is represented and interpreted. That's what the standard does. There is then no need for "middleware" translations. Now it is up to people to be inventive with their solutions.

Matties: If digital twin is the solution to solving communication, what are the headwinds? What's keeping us from really making this happen?

Ford: It's the momentum within the industry. You see intelligent design formats such as the IPC-2581 standard, and de-facto standards such as ODB++, yet many years

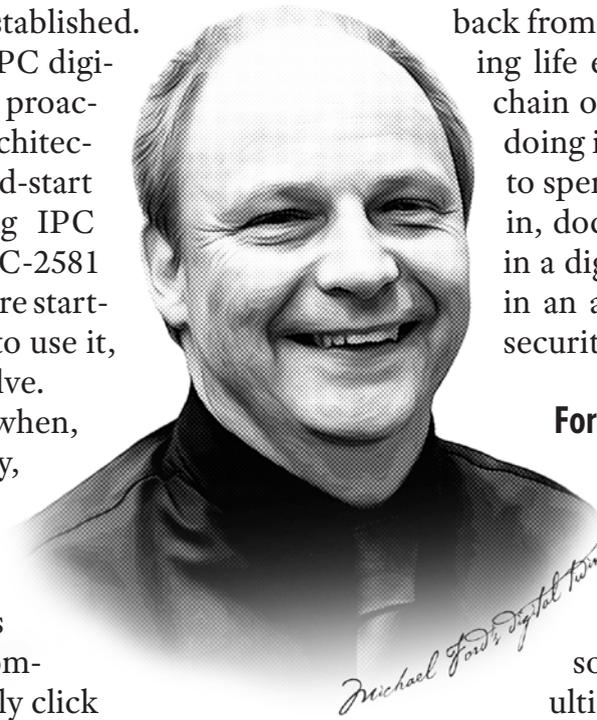
later, people are still using Gerber, plus a load of disparate files, drawings and lists of various items, which later require reverse engineering. Why? It is simply their prior education and experience, their understanding of what works. Solution providers need to be aware of what is available and developing now, and should target their solutions to be inclusive of the digital twin standard, but who goes first? You need industry momentum to



actually get these things established. The nice thing about the IPC digital twin is that we've been proactive, and we've put this architecture out there, with a head-start based on various existing IPC standards such as the IPC-2581 DPMX, CFX, etc. People are starting to buy into it already, to use it, and it will continue to evolve.

But I dream of the day when, if I were an EMS company, I would receive a request for quotation from a customer that would give me a secure address for access to a digital twin of a customer's product. I would simply click the link, and my digital twin of the factory would suddenly come alive and work with the digital twin of the product. It would collect all the necessary data, work out solutions, and then simply pop up information about this site, this price, this yield, this date, that site, that price, that date, that yield. I would be able to say, "I prefer to do this one." And then immediately feed back a quotation to the customer, within a couple of minutes. This is a dream that I will probably never see, but this is the kind of direction I'd like the industry to go in, where using the digital twin means that you don't need to have human interference, and you don't need to share private information or IP. The tool is simply there as a kind of dashboard in front of you to control your EMS business.

Matties: When I mentioned discipline, I think this is where the discipline really must be, the commitment to building the files and the infrastructure within your own organization to do that and then to maintain it. You were talking about when a component comes off the assembly line and the mold is slightly different, you have to be disciplined to go in and update those files as something that's super critical. You're not necessarily going to see a revenue feed-



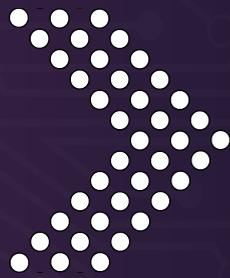
back from that effort, but you're making life easier for the entire supply chain or manufacturing process by doing it. We're asking the industry to spend a lot of resource to come in, document all their capabilities in a digital format, and then put it in an accessible file and trust the security that goes along with it.

Ford: When you put it like that, it sounds like quite a big ask, but my approach is that to getting these standards put into place, where customers demand solutions that use them, there ultimately has to be a benefit for each individual player throughout the whole chain. Where everybody understands how they are benefiting from these new digital "best practices," then they will realize their own ROI on this. I think at IPC APEX EXPO we're going to see in the "Factory of the Future" presentations track that we're trying to push the vision toward this. And that would be an excellent forum in which to discuss and go through this whole thing with a live physical audience again. As data becomes interoperable, certain aspects of the business process need to follow.

Matties: Did you have any final thoughts that you want to share on any of these topics today, Michael?

Ford: I think we've covered everything pretty well. Thanks. It's been a great opportunity to talk about this. It's great to talk especially on all of these solutions and digital twin, that's great conversation. **SMT007**

Michael Ford is the senior director of emerging industry strategy for Aegis Software, and an I-Connect007 columnist. To read his columns or contact Ford, [click here](#).



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EMS/Designer Relationships: Building Communication

Feature Interview by the I-Connect007
Editorial Team

In this interview with contract manufacturing expert John Vaughan and design expert Kelly Dack, they discuss the EMS/designer relationship and the communication that must take place for that to be successful.

Nolan Johnson: In the designer and EMS relationship, what really should happen during job set-up?

Kelly Dack: I can chime in here with one word: communication. It should be communication beforehand, communication during, and perhaps feedback after.

Barry Matties: Kelly, we've heard communication for years and years. There are different levels of communication; one note is that most often communication is needed when you're switching to a new EMS or you're bringing a new job into an EMS. But if it's an ongoing relationship, is communication the big issue?

John Vaughan: Obviously, there are a couple of types of relationships in the business. Some are transactional, and some are partnership driven. It begins at the business capture stage. I put a lot of responsibility on people who sell the product for our company, so it needs to be treated as the discovery phase. We tend to do a lot of military-related business. I want to know what the prime contract is, and what the funding looks like out of the DoD. As far as the NDAA is concerned, I want to know where the product is in their life cycle. I want to know their appetite for change. Then you really get into the communication phase. I want to understand the existing supply chain alignments, particularly as it relates to components and any pricing registrations that they may have.

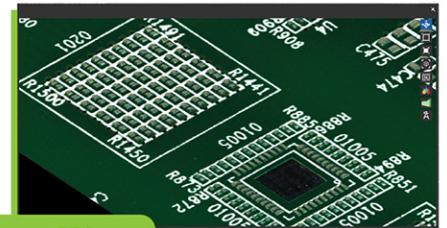
My experience has been that the most successful companies have really strong cross-functional alignments across the program and/or project. To Kelly's point, the OEM engineers need to be in constant communication and working closely with the design and layout guys who in turn have to be working

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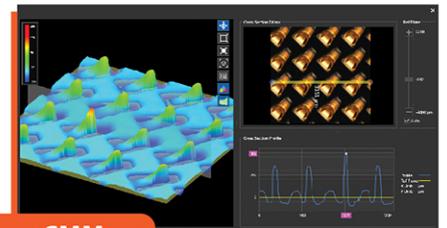
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very closely with the PCB fabricators. Even the EMS guys must define what the aspirations for the product or the program are. I think that the transactional business becomes more difficult when people are primarily shopping price or one-offs. But when you're building a business and you're building partnerships, all those things matter a lot on the front end to understand.



Kelly Dack

Dack: In the context of new design, one of the challenges between both designer and supplier, and why I emphasize communication, is that so often the designers have no idea where the board is going to be built in a production phase. They're usually tied in with bare board suppliers for prototype supply, and therein may lie a seed of potential problems having to do with capability. Designers are in touch with prototype supplier capability and will tend to design their layouts to achieve that capability. That's what we do—incorporate design for manufacturability. But when the manufacturability changes—the shift changes from prototype to production—that is where we often have the biggest challenge.

Capabilities change between onshore prototype manufacturing and offshore production manufacturing; they're different things that designers don't realize suppliers deal with every day. The problem can be identified as poor DFM caused by missing communication.

Vaughan: I agree 100%, Kelly. That was my point as far as the cross-functional alignment within the organization, within the OEM. Often, those guys are siloed up; as you said, the design guys are doing their thing, the files become complete, and then it's tossed over the wall in their own organization to the procurement group that really isn't considering all the items that

the designer was considering. They're defaulting to whoever their supply chain partner happens to be for fab. I think those two parties have to be really well aligned internally in the organization for it to be successful.

Matties: If it's an ongoing relationship, though, the purchasing agent is going to use the AVL (approved vendor list). Your designer should know where it's going.

Vaughan: Yes, but even on an AVL there could be very different capabilities within that. Just because there's three printed circuit board fabricators on the AVL, they don't have the same equipment set or capabilities, and in many cases, they are using different material suppliers or different processes. There is much variability there. I've seen the most success when the design team is lined up with the board fabricator early on, and they're a part of that team for impedance modeling, stackups, material selection, and all those things. All that should be happening in concert, in my opinion.

Matties: Kelly, you've been on the design side, and you've probably been in both circumstances where you've known the fabricator and where you have not known the fabricator. What's the contrast between those two?

Dack: The contrast can only be parsed out by examining the different levels of communication. When I say communication, I mean what is communicated through documentation.

Matties: There has been a longtime conversation about communication. What's going to shift that? Eventually you must communicate once your purchasing agent chooses the vendor and there's a problem. The vendor stops

and they force the communication. What's going to trigger this to change?

Vaughan: One thing about change that holds some promise is the idea of a portal. Say it's a design portal, and if you have the capability while you're designing and the API hooks are there into distribution or the component supply chain where you can visually see the lead times and availability of the components that you're designing, you have that piece.

If you're communicating with your printed circuit board fabricator then you can also do concurrent activities in and around material selections, stackups, and capability assessments. If you also have the EMS provider residing in the portal that's part of this system, then you have really increased visibility by virtue of doing the daily tasks and you're forced to interface and communicate. I hope that makes sense. I'm sure there's a couple of you who know what I'm talking about.

Matties: It does, but again, this requires you to know who your provider will be up front. Are you moving that decision point down to the designer and out of the purchasing agent's hand?

Dack: It's a chronic problem. This is where the realm of communication—the specs from manufacturing, or engineering, or the industry—come into play. There is a block of information that for years has been sorted out, defined, and published in hopes of getting a lasso around manufacturing capability vs. design. The first point of communication, if we were to bullet list these things, would be design specification and a designer hanging their design on known design specifications and then trying to design around them. We have the industry coming



John Vaughan

together many times a year trying to refine these specs and update these specs to current manufacturing capabilities. Once a spec is published, the designer should be able to look into these specifications, understand them, and base their design layouts on these known capabilities.

Matties: What is the role of the EMS in all of that?

Vaughan: As an industry, we've defined long ago that we needed to overcommunicate, and we haven't done a great job of that. Our engineers at the EMS company usually interface directly with the OEM's engineers, and to a lesser degree, with whomever is responsible for the design activity.

I'm not sure on this call we're going to solve how we make people better communicators. Kelly is spot on. It really is that simple. People who have been doing this for a long time want to build deep relationships. You want to have that, maybe not 24-hour access, but you need to have a point person on each side of that relationship that is driven to pull all the answers together. All the standards in the world aren't going to define how all these one-off, really custom situations, are managed. In the end, it comes down to people and communication. Try as we may to force computers into that equation to be the workforce, it comes down to people wanting to be a part of the experience, being knowledgeable, and wanting to perform at a higher level in their respective goals.

Matties: One of the things we just hear constantly, for the bare board fabricator in particular, is they don't like to publish their capabilities for the world to see. They hold them close to their chest, if you will. Are EMS companies more open about their capabilities?

Vaughan: Absolutely not. That really becomes prescriptive. Commoditized might not be the right word but close to commoditized is absolutely the right word. It has become such a race to the bottom from a price perspective in the EMS sector that really the only way you can differentiate is to develop techniques and processes in your assembly instructions and in your test methodology that sets you apart from your competitors. It's pretty routine on the EMS side of the equation that even if a DoD prime comes back to the EMS guy and says, "We need you to share all your process methodology, all your assembly instructions, all that information about how you developed the stencil, and what your methodology was there," you'll find most EMS providers will be very reluctant to give up that information. That is the form of IP at the EMS level.

Matties: Is that a barrier to communication, though?

Dack: What they publish is part of the problem. What EMS providers or bare board suppliers commonly publish are their capabilities in the form of maximum producibility capabilities. They will publish the smallest-sized lines and spacing that they can achieve. This is where the problem starts because the second half of the problem is designers interpreting that as a free license to go ahead and design to those numbers without any regard to, "Wait a second, those are bleeding edge numbers which may have some hype involved to pull in business."

Matties: Are EMS companies doing the same?

Vaughan: We have seen it once or twice, but it's not routine in the EMS sector. It is a little more routine in the fabrication side of the industry. To clarify, most people would say standard process, advanced, and emerging. You might get three different answers for that line width. One might be four mils, and then three mils, and then two mils or whatever the case

may be. If you're really open and you're really sharing what you're capable of, that's the way you should portray it. Not as Kelly said, where some guys are just going to overhype it, over-market it, and say, "We do two mil lines and spaces." You don't do it in every instance.

Matties: Right, and you don't do it with high yield either.

Dack: And you don't do it with three-ounce copper.

Vaughan: That's correct. All of the above.

Matties: There are so many variables, it's got to be incredibly difficult to have a smooth process.

Vaughan: Yes, it's changed in recent years. But going back not that long ago, it often surprised me how often a printed circuit board designer had never been inside a printed circuit board fabrication operation.

Matties: We hear that all the time as well.

Vaughan: I think that's changing somewhat. Obviously, absent the COVID environment, but pre-COVID and certainly as we exit that, I'm hopeful that trend will continue because I don't think there's anything more valuable than the person that's entrusted with developing leading edge technology designs to come spend the day or two days in a fabrication operation, meet with the engineers, and really understand what the real world is on the other side of the equation.

Andy Shaughnessy: Kelly, I was at DesignCon a couple of years ago and you kept getting calls about a design problem that just wouldn't go away. It was going overseas for volume, and you said designers sometimes don't understand how things are different when you're designing for high volume vs. designing for



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proto. What are some of the problems giving designers headaches when they switch from prototype to high volume?

Dack: Yes, the first thing I can think of—and it happened over and over at a previous EMS supplier I worked for—had to do with communication of the design specification for copper. Copper is a major component on the board and if we don't specify it, or we specify it unclearly, it causes big problems for manufacturability down the line. The supplier has to meet a specification. If the specification is not clear, the CAM department is going to have to give you a phone call. This has to do with something as simple as specifying copper as base copper in the stackup vs. finished copper in the stackup. We like to design to finished specification. We like to make our current-carrying calculations and our impedance calculations based on what the finished copper will be; however, that's subjective to the supplier where we have it manufactured.

For instance, if we have a board manufactured at a high-end prototype shop onshore, and we ask for a full ounce of copper in the via holes, we can expect a full ounce of copper. And that can relate to current-carrying capacity. However, if we don't specify that properly, and we just make an assumption, "Everybody supplies a full ounce of copper or a thousandths thickness of copper," and we make that assumption without a specification, then there is a potential problem when that board goes offshore. There's an understanding with offshore suppli-

ers that they manufacture strictly to specification. And the fab might take something like an IPC-6012 Class 2 spec and go right to the part where it shows minimum/maximum of plating thicknesses and orient their processes from a timing standpoint and a cost standpoint, right to the minimum. I think it goes down to 80% of what we think we're going to get. I'm bad at standing math. It'd be 80% of a mil. That's a big one.

Matties: How is digital twin, the automated or the AI factory 4.0, affecting this? Because with a digital twin, you have to have all these things answered and a recipe built in computer before you even send it to a fabricator or an EMS. Is that going to be more the case in the near future?

Vaughan: I don't have a lot of experience in that area, but as the new technology comes online, we're seeing it all connected, whether it be CFX or some other platform, but we all see the IoT and digital twin conversation gaining traction. It's on its way.

Johnson: John, you were talking about a software environment that could help facilitate communication, the transfer of the information up and down the supply chain. Then, a few minutes later, we talked about how fabs and the EMS suppliers tend to hold some of their capabilities to their vest, considering it intellectual property.

If, in a software environment, we're creating a place for that communication for the designer, the designer is going to need some software modeling—simulation, if you will—of what will happen further down the manufacturing chain. The designer should be able to see DFM rules that are detailed, characterizing what the fab can actually achieve on the board. They'll need to see manufacturing capabilities and so forth, for part selection, if they're making those decisions. That's the rub: the software is going to require the participants in the

supply chain to be detailed. But doesn't that let out their secrets?

Vaughan: You're right on point with that. In the environments that are being proposed by at least two of the top design offerings right now, you're electing to be a participant in their platform if you're a fabricator. In our case at Summit, you're electing to be in that platform, and there are absolutely criteria and protocol for being a participant in that platform. All the attributes that you just underscored are absolutely required and would be part of that platform. The difference is all that would be under your contractual relationship and under a broader non-disclosure agreement as opposed to just publishing it on the internet for all to see. It would be on the design side.

On the design side there's a subset of participants and for the fabricator there's a very defined listing of who those fabricators are. It's the same thing on the EMS side of the equation. You're exactly right, Nolan, that the part of being involved in that alignment is you have to be willing to share and document what all that looks like inside of your environment so that people can make the right decisions.

Shaughnessy: Kelly, a couple of years ago you said, only half-jokingly, that you were the "designer whisperer" between design and assembly because you spoke both languages. What are the biggest misconceptions that designers have about assembly and vice versa? What about the assembly guys about design?

Dack: That's a good question. The job is to reach out to designers, and it couples with another gig I have as a trainer and instructor of design curriculum from IPC. The idea is to reach out to designers to bring them the information that we only wish the assemblers and suppliers would bring to the designer. Our intent is to fill in the gaps of knowledge and experience with "gotchas" over years and years. That's what these curricula are based upon. They fill in the

blanks of what suppliers need from designers and what designers need from suppliers. It starts with the concept of bringing all stakeholders together at the beginning of a project. If you could get a big table and sit everybody down and let everybody express their requirements and capabilities, you would end up with a more successful project.

Johnson: Does that actually happen in real life?

Dack: Absolutely. It depends on how progressive your company is. Right now, I've got to say, I'm very happy with the increasing stakeholder consciousness. The term stakeholder is used at the company I work for now, and it is so nice to be just down the hall from five different assembly lines. I wish I were a little more in touch with—and I'm sure I will be—our suppliers for bare boards. I have a stakeholder in the company here who is in direct contact daily with the bare board suppliers and who does a good job of conveying the information. I'm very excited about that.

Johnson: What I'm hearing is that you've got somebody on your team who's responsible for all the communications to a particular part of the manufacturing chain—the fabricators, the EMS suppliers, components, or whatever. You have a champion, somebody whose job it is to be that communication to all of your potential people in your supply chain.

Dack: Yes. I don't think it's officially responsible by title, but it's by company culture.

Johnson: I could see that vendor relationship as a place where cross-functional teams break down. When you're trying to put a representative from every company together and have that conversation, that gets tricky. It's hard to hold a cadre of companies together. But if you have a champion inside your company that is responsible for those relationships and that communication, you can work with your

champions to keep it together, keep it stable, and have a good cross-functional team to launch a product.

Dack: I think that whole concept is underutilized, or not understood. I think we compartmentalize too often in corporations. The term “throwing it over the wall” stems from that.

Vaughan: I would say that, in a perverse way, technology is driving us to communicate more effectively now because gone are the days of the standard eight- to 10-layer circuit board that many, many shops can fabricate. But more and more of the designs that we see certainly are 30+ layers, they have mixed materials, and there’s five or six sequential laminations required; they’re full of blind and buried vias, special features, and two- and two-and-a-half mil lines and spaces. Those are all challenges at the bare printed circuit board level. But then there are challenges that are also experienced at the EMS level, where there’s a lot of very specific process parameters that they have to consider. Something as simple as new vias, for example. You’ve got to plate them, you’ve got to make them flat, you’ve got to do a lot of things, or if you just leave those vias in the thermals, of course that paste is going to slide through the holes and starve the pad of solder, and that’s going to create solder balls, and on it goes.

For every design decision that’s made now, the implications at both the fabricator and the EMS provider are really unique and really challenging. I think the OEMs know that. I see a lot more collaboration—willingness to collaborate, have lengthy discussions, and overcome—now in the current operating environment, if that makes sense.

Johnson: You’re describing what I’ve always called defensive design, where you anticipate the problems, anticipate the changes over time, and design to defend against them. Designing so that you could easily swap out a quad pack



for a BGA, for example. It seems like more of that kind of forethought is now required. Is that true and how do we communicate that to designers?

Dack: I have a term I coined and did a presentation on called “practical packaging density plus.” Because we have practical packaging density, that gets us where we need to go. The tendency is to put too much bread in the breadbox. But if we can, from the concept stage—where the industrial designers are wielding their pastels on the whiteboard dreaming up a concept—add a little “plus” in there with regard to space, technology, materials, and availability, then that gives you the flexibility for future redesign. It’s practical packaging density plus. I’ll have to resurrect that idea for a future article soon.

Johnson: Thanks gentlemen, for your time.

Dack: Happy to help.

Vaughan: I really enjoyed talking to everyone again. Thanks. **SMT007**

John Vaughan is vice president of strategic markets at Summit Interconnect.

Kelly Dack is a PCB designer, CID+, and an I-Connect007 columnist. To read his column, *The Digital Layout* [click here](#).



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Communicating Effectively with EMS Providers

Feature Article by Charles Capers
ZENTECH DALLAS

For the past several decades, OEMs have used outside EMS providers to build a multitude of products from PCBAs to complete box and cable assemblies. Communicating effectively is the key to success in getting products from concept to reality. For companies that want to form a good working relationship with EMS providers, there are several steps that should be followed to ensure a successful product build. This is especially true if you are working with suppliers in different parts of the world. This article will focus on effective communication methods between the OEM and EMS provider and discuss some very simple ways to avoid some of the pitfalls associated with outsourced services.

Statement of Work (SOW)

The SOW is a very common document in the military and aerospace side of the electronics manufacturing world. The SOW spells out exactly what the customer expects from the supplier. Details will include specifications to adhere to, ITAR restrictions, flow-downs, revision levels, quality notes, deliverables, reporting requirements, FAI requirements, and any

other special instructions not found in any other documentation. On the commercial side of the fence, SOWs are generally non-existent and it's up to the EMS provider to piecemeal all the instructions together from a multitude of email notes and instructions. Inevitably, something will get missed and/or will not be communicated to the shop floor. Basically, the SOW defines the rules of engagement.

Apart from a detailed SOW, a complete input package is the most important part of the quote and build process and should include as much information as possible. This will allow the EMS provider to produce an accurate quote and identify any possible areas of concern.

Input Package

Organization is the key to a good input package. A concise input package should include, but is not limited to the following items:

- BOM (Excel format)
- Output data (IPC-2581, ODB++, Gerber, IPC-D-356 netlist, X-Y data, etc.)
- Fabrication drawings (PDF or DXF)
- Assembly drawings (PDF or DXF)
- Test requirements
- Project notes

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BOM

The bill of materials should include item numbers, quantities, reference designators, part manufacturer, manufacturer's part number, and part or package description. Excel format is the preferred format and allows an easy way to import into a multitude of different systems.

Output Data

Although there are several options, Gerber data still seems to be the industry standard that everyone gravitates toward. The problem with Gerber data is that it does not contain any useful intelligent information. Intelligent data outputs include ODB++, and IPC-2581.

Fabrication and Assembly Drawings

The key to a successful build is documentation. Include notes, surface finish, materials, build instructions, visual details, labeling and marking formats, etc.

Test Requirements

This could be as simple as stating if flying probe or bed-of-nails/ICT test is required or a full set of instructions for functional test. Also state if a functional test set or a test fixture will be provided to the supplier.

Project Notes

Although notes should be included in the fab and assembly drawings, some prefer to provide additional notes not found on the drawings. Notes can be a vital part in conveying specific assembly details such as solder/flux type, labeling format, serial numbering, wash instructions, and so on.

Other Items to Consider

Specifications

I am a huge fan of industry specifications. IPC and SMTA provide a plethora of information from PCB layout to bare board fabrication and final board assembly. An experi-

enced layout expert will study and understand best practices for completing a design that allows the fabricator and the EMS provider to complete the subsequent processes once the design phase is complete. Unfortunately, many engineers and designers do not understand the details and processes involved in getting a design from the CAD system to a finished product. A truly good designer must know a little bit about chemistry, physics, thermodynamics, materials, etc. Any competent EMS company will be able to build product that adheres to the industry standards.

Avoid Making Changes During the Assembly Cycle

On-the-fly changes cost time and money and can sometimes cause a lot of unnecessary confusion. Plan ahead to avoid making component or circuit changes during the assembly phase. With the current supply chain constraints, make sure the materials you choose for the project are readily available or have a list of alternate part numbers available to choose from. Last minute changes create schedule delays and increased costs associated with the project. What that means to an EMS provider is an interruption in the normal production flow and having to re-organize other project schedules to accommodate the new manufacturing criteria.

Pre-production Meetings

If the luxury of time is on your side, then pre-production meetings are a great idea. These meetings will allow everyone involved to voice any concerns or questions, review documentation, and discuss the overall scope of the project. Remote group meetings can easily be arranged via Zoom, Teams, or some other platform of your choosing.

Put Everything in Writing

EMS providers work on hundreds of projects each year, so giving any type of verbal instruction or direction to the salesperson or program manager could be devastating. It's always best

to follow up conversations in writing via email or some other type of written document or communication.

Conclusion

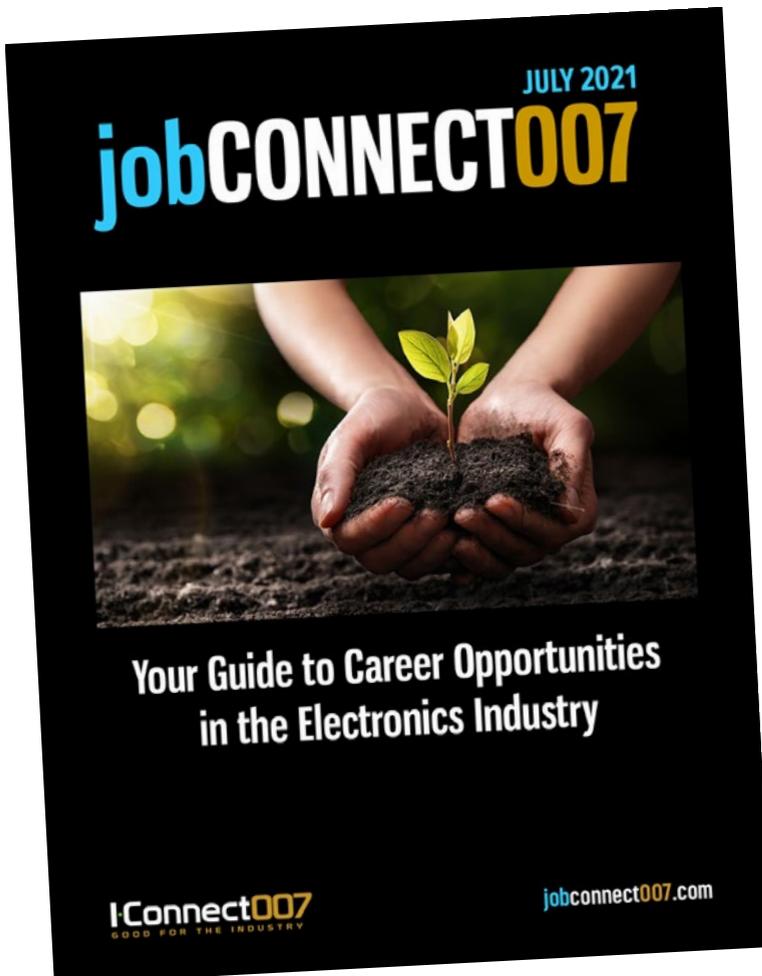
From start to finish, a detailed set of instructions and a well-organized input package can save time, effort, and money while eliminating rework and omissions at every interval of the product development cycle. The only way to avoid unwanted obstacles along the way is to organize input packages in a way that will facilitate accurate results every time. Your service providers will appreciate the extra time you put into providing a perfect data package. **SMT007**



Charles Capers is the VP and general manager at Zentech Dallas. He has started and managed several award-winning companies in his 35+ years in the electronics industry. He is well versed across

multiple disciplines including circuit board design, manufacturing, and assembly. He is an IPC certified interconnect designer (CID+) with over 30 years of design experience. He has published several articles for industry magazines and has been a featured speaker at PCB West/East in past years.

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ing system to provide some experience and a better understanding of how these devices can work in your environment. Here are some considerations and comments to keep in mind as you start your exploration of IIoT.

- Keep in mind that this is an experiment and the devices you install may not become a permanent part of your new IIoT-enabled systems environment. Of course, you'll want to choose wisely and hope to get a direct return on this investment but don't let those concerns stop your project before it begins or limit your choices along the way.
- That said, this project, like all others, needs a plan. Follow standard project management processes to outline the goal and objectives of the project, timeline, budget, names of participants and what their responsibilities will be, and how the project will be managed, with status tracking, team meetings, and reporting processes clearly spelled out.
- Expect a payback. While it may sound contradictory to the first point above, there should be a (written) business purpose for the IIoT you are planning to install. Keep the expectations modest,

however. Your first foray into IIoT should be aimed at replacing existing manual reporting with automated data collection and providing convenient access to real-time data in the plant and warehouse. Don't try to plow new ground as this will overshadow the real purpose which is to gain experience with IIoT technology and learn how to bring it into your working environment.

- Document what you've learned—and not just the technological details. Pay attention to how the devices change the nature of the workplace and the activities of the workers. Was there resistance from the workforce or did they welcome the new tools? Did it really make their jobs easier or more efficient or was it seen as an additional burden? What was the actual benefit (ROI) once these devices were in use? This will be important to know when you develop the business case for further investment in IIoT.

These are just a few considerations to keep in mind as you plan your initial experiments with IIoT. The most important consideration is this: IIoT and Manufacturing 4.0 are fast becoming a requirement if you want to stay competitive and relevant in your industry.



Start now to get comfortable with IIoT, then develop a plan to incorporate more connected devices into your system evolution toward Manufacturing 4.0.

IIoT in the Plant or Warehouse

Each company considering a move to incorporate IIoT into their business will have different reasons for doing so. While some will be focused on improving workflow and throughput in the plant, others will focus on material control and visibility in the plant and warehouse, and many will pursue both. Whatever the priorities, they are looking for real-time tracking of activities and events, increased access to more comprehensive information throughout the organization, and establishing or expanding the data collection and management infrastructure necessary to support many of the functions of Manufacturing 4.0 including digital manufacturing, the digital thread, advanced planning that relies on simulation and machine learning, and more.

Here are some considerations and observations to keep in mind as you start planning for your implementation of IIoT:

- No company would (or should) expend money and resources without knowing how that investment will benefit the business—generate a return on that investment. In addition, having a clearly stated goal helps to plan the project and steer its management—every activity can be evaluated in terms of how it contributes to the overall goals.
- **Scope:** One of the biggest factors in failure to complete a project successfully is the phenomenon commonly known as “scope creep.” This happens when a project keeps growing beyond the initial objectives until it fails to meet those objectives, runs out of funding and must be terminated before completion, misses scheduled dates because of the lack of focus, and/or suffers

massive cost overruns. Undoubtedly, you will see a lot of tempting new ideas and technologies that seem like a great idea (with seemingly just a little impact on the original project). Resist the temptation. Success with the first project will bolster your case for a phase II follow-on that can incorporate some of the great ideas you develop along the way.

- **Existing systems and networks:** Unless you are planning to replace your existing ERP, MES, and other major systems, one of your first considerations should be how these existing systems will fit in with and support the new IIoT technology. If current systems are not amenable to the IIoT data input and outputs you’re planning, either change your plans or replace those systems before embarking on your IIoT initiative. Trying to force-fit IIoT into systems that are not well-suited for them is a much bigger and more difficult task than you can imagine.
- **Technical issues:** Taking the compatibility issue a bit deeper, carefully choose suppliers, protocols, and security that will serve your needs today and have the best prospects for moving with you into the future as your needs grow and technology evolves. Nobody can predict with any level of certainty how technology will change so choosing technologies and protocols is less important than choosing partners (suppliers) that show a commitment to keeping their products up-to-date, providing outstanding customer service and support, and have the financial strength and stability to succeed in their markets over the long term.
- **The people side:** Always remember that you are investing in tools that will help operations go more smoothly, reduce costs, improve customer service, and help workers and users do their jobs. No matter



how “intuitive” or “user friendly” your new tech is purported to be, users will need training and an understanding of what the systems do and how. They will need to know what they are seeing and just what the systems are telling them in order to trust them and put them to effective use. There is a natural human reluctance to things that are new and things that they don’t understand. The best way to gain acceptance (and enthusiasm) for a technology project is to involve the users early as the systems are initially envisioned and planned. You’ll want to encourage a feeling of ownership among the user community so they will be invested in the systems’ success. They will also be the ones who can tell you if and how the new systems will enhance their effectiveness (or not)—extremely valuable information especially at the early planning stages.

To be successful, system implementations of this kind take a multi-disciplinary team—users, IT, management, suppliers and technical consultants—and a well-managed project with a strong project leader.

Adding IIoT in the plant is, in many ways, a continuation of a long-running process of bringing systems support closer to the realities of the plant floor. Manual reporting was supplanted by bar-code scanners and touch-screens; paper documentation is giving way to workstation terminals; voice recognition enables hands-free operation. Now IIoT is collecting more data (without additional burden on workers) and making more information available through wearables, tablets, smartphones and other devices.

It’s not quite so clear-cut beyond the walls of the plant and warehouse, however. When items ship—be it a small package, pallet, container or truckload—there is typically little or no information coming back to the plant or warehouse except notice of delivery, and even that is not common and usually not very timely.

IIoT changes all that. Location-aware devices coupled with detailed tracking of each item, case, pallet, and container (and environmental conditions for quality control) offers a whole new level of supply chain management including such capabilities as the redirection of enroute goods to places where they might be more needed. And that’s in addition to better management of the sup-

ply chain from knowing demand, inventory locations and levels, and shipment progress more precisely.

IIoT in the Supply Chain

Adding IIoT into your supply chain can be more of a challenge than adding devices to in-plant networks. This is plowing new ground as there isn't a history and infrastructure for reporting to work from; there are no existing networks and systems to add to; the devices will be installed and operating in locations outside of the plant/warehouse where there is little or no control. That said, the points made in the previous blog relative to in-plant IIoT apply here too:

- **Scope:** One of the biggest factors in failure to complete a project successfully is the phenomenon commonly known as “scope creep.” Lay out a plan and stay focused—don't be distracted by additional opportunities that come into view. Save them for phase II.
- **Existing systems and networks:** While the interfaces to existing systems are still required and present challenges, it is a different situation with supply chain data. Activity reports can usually be brought in through open interfaces incorporated in most systems, so that part should be relatively straightforward. The bigger issue is having software that can truly use the data. Modern supply chain systems—including inventory optimization, demand planning, analytics, etc.—thrive on near-real-time data and the ability to apply advanced algorithms, simulation, and machine learning to plan and manage supply chains.
- **Technical issues:** With supply chain IIoT, the biggest technical issues are communications (often relying primarily on cellular data communications) and security. As with internal data, carefully choose suppliers, protocols, and security that will

serve your needs today and have the best prospects for moving with you into the future as your needs grow and technology evolves. Nobody can predict with any level of certainty how technology will change so choosing technologies and protocols is less important than choosing partners (suppliers) that show a commitment to keeping their products up to date, providing outstanding customer service and support, and have the financial strength and stability to succeed in their markets over the long term.

- **The people side:** Your organization may be new to the abovementioned supply chain systems and their value is so apparent that user resistance should be minimal, but even so, don't neglect the need for education and training. No matter how “intuitive” or “user friendly” a system is purported to be, users will need an understanding of what the systems do and how. They will need to know what they are seeing and just what the systems are telling them in order to trust them and put them to effective use. Involve the users early on as the systems are initially envisioned and planned. Encourage a feeling of ownership among the user community so they will be invested in the systems' success.

Modern supply chains in today's global, highly competitive markets are complex and dynamic. The systems that have been developed to plan and manage these supply chains rely heavily, as all systems do, on data that is as accurate and timely as possible. IIoT helps gather and manage that data so IIoT has become a big component of supply chain management. **SMT007**



Dave Turbide is an independent consultant, educator and freelance writer serving both the developers and users of software and systems for manufacturers.

We Must TALK to Each Other



Feature Article by Dan Beaulieu
DB MANAGEMENT

“What we have here is a failure to communicate.”
— Strother Martin, *Cool Hand Luke*

Sometimes when I hear that line (during one of the thousand times I have watched that movie), I can’t help but think that old Strother was in our business. That is to say that printed circuit board designers and board builders have always battled with an inability to communicate.

A few years back I had the responsibility of managing a division of three design service bureaus for a company which also owned a board shop division. These two divisions—the design centers and the board shop—were *very* separate entities. Not only had most of the designers never been to their own board shop, but they didn’t have much of an interest in doing so, ever.

Now don’t get me wrong, they were terrific designers and nice people, but somewhere during their training they had been warned about board shops; they had been told to

ignore those who actually built the boards because those people didn’t know anything. They were taught that the designers were in charge and could design the boards any way they wanted.

What was especially daunting about that philosophy was that we were selling a new and unique service we called “Total Concept,” which meant that we were selling design and fabrication to customers. As you can imagine, that service never took off. Only about 10% of our business was Total Concept. I always thought it was an idea whose time had not yet come, which is probably true since an increasing number of customers today want a complete, synergistic solution that includes design, fabrication, and assembly. Back then, not so much.

Furthermore, the designers were the board shop’s worst customers; the board shop was the designer’s worst vendor. After a while, when the designers did sell the Total Concept service, they were using other board houses rather than their own.

Of course, in a Total Concept process, there was the need for the design teams to commu-

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nicate with assembly companies. This conversation is more essential than ever in a Total Concept approach because we are not only talking about the bare board, but also the component callouts as well. “How is all that going to work?” I asked myself. These designers did not even want to talk to the people building the bare board. What the heck were they going to do with the assemblers who are one step further removed? It was a tough situation, to be sure.

Things have gotten much better than those days of yore. For one, designers and board shops are communicating better than they ever have. That’s because both entities genuinely want to learn about the other. They want to work together and understand one another’s disciplines.

We see many more designers visiting board shops to get a better understanding of how boards are built.

We see many more designers visiting board shops to get a better understanding of how boards are built. We are seeing more board fabricators offering webinars, seminars, and lunch-and-learns so designers can get a better understanding of how the boards they design are built. I have seen several articles, features, and presentations where designers and board builders are working together and learning from one another.

Now, with the increase in demand for Total Concept, designers, board builders, and assemblers are not only communicating, but they are doing so in the spirit of mutual respect and cooperation. It’s as if they have all finally realized that, in the end, they can produce a much better product by developing a cooperative relationship.

In some cases, the three entities are working so well together that they’re building products concurrently rather than consecutively. The designer is providing board parameters to the board builder before the design is even completed, allowing the builder to buy and prep the material in advance.

The designer is also working closely with the assembler to make sure they agree on which components to choose so those can be ordered in advance.

In these times of laminate and component shortages, this cooperative effort between the three disciplines is more effective and beneficial than ever. The board builder can advise the designer about which laminate to call out based on availability; it’s the same for the assembler and the availability of components. This only makes sense.

This new kind of cooperative spirit could not have come at a better time. Our post-COVID (I hope) world has created several factors that require this cooperation. First, there are the shortages of laminates and components that I just mentioned, while a true explosion of new and innovative products has created a need for very quick and efficient new product introduction (NPI) services. The best way to accomplish that is the ability to go from concept to reality in days; the best way to do that is to work with a company that either provides all the services under one roof or has a strong partnership with the other two disciplines, like a board builder that has a partnership with a designer and an assembler.

Maybe the days of failure to communicate are gone and buried with good old Strother Martin, may he rest in peace. **SMT007**



Dan Beaulieu is president of D.B. Management Group, and an I-Connect007 columnist. To read past columns or contact Beaulieu, [click here](#).

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The EMS/Designer Relationship: Kelly's Story

Feature Interview Excerpt from the
I-Connect007 Editorial Team

In a recent discussion with John Vaughan and Kelly Dack (see page 20), we explored how parts availability information can reverberate back to the design team in unexpected ways. Dack starts this topic by pointing out a real-world situation that happens almost daily at a production EMS facility. In this part of the interview, Dack details how a parts availability issue can restart the design all the way back with the OEM design team.

Barry Matties: Kelly, you've been on the design side, and you've probably been in both circumstances where you've known the fabricator and where you have not known the fabricator at the beginning of the design process. What's the contrast between those two?

Kelly Dack: The contrast is the different levels of communication. When I say communication, I mean documentation.

I've got a story that will explain the challenge. There's a big shortage in the supply chains right now forcing us to swap out chips. Chips are becoming unavailable. In the EMS



Kelly Dack

industry, there is a lot of redesign required because of chip availability issues. A board that's been designed for five or eight years around a chip packaged in a quad-flatpack is suddenly unavailable and the only replacement may be a half millimeter pitch BGA. An outside designer, typically, will incorporate that new half millimeter pitch BGA into the existing design and lo and behold, they have to use a different scale in their routing technology.

The designer takes the existing 0.006" wide line and reduces it to get it down to 3.5 mil to break out of the BGA. That's fine; it looks great on the screen. However, the fabricator, who has been building this board for years and years, doesn't have the level of outer layer capability for print, etch, and plate of a three and a half mil line. Now what? That's the problem. The designer says, "Any of our bare board prototype suppliers can do that." Which is true. The existing offshore supplier, however, cannot.

This is the communication element. We must figure out a viable solution for the disconnect

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between the designer and the fab that builds this board. There are several ways to approach this. Could the designer have used via-in-pad or HDI technology to break out from this 0.56 millimeter pitch BGA? The supplier could make those adjustments, but the supplier can't do outerlayer three mil, three-and-three spacing using the same stackup. The one ounce base copper is just too thick.

There are so many opportunities for disconnect after a design has been released for production and goes through change. Communication is the only way to see the project with success upfront. In other words, if the designer had access to the capability of the supplier building the board, the designer could have chosen the proper stackup and routing solution. Instead, because the designer chose a route without communication, it forced the EMS supplier to go source the board with viable material thickness, which is going to shoot the cost, quoting, and timing all over the map.

There are so many opportunities for disconnect after a design has been released for production and goes through change.

John Vaughan: Early alignment is critical in my view, so that it doesn't end up with purchasing driving the decision-making process. Had the designer aligned early on with the PCB fabricator, that would have solved the issue, right?

Dack: Yes.

Matties: How much time would that have saved?

Dack: Everything is quick time to market; time is of the essence. So, when we discover that a chip is obsolete, or isn't accessible, the clock is still ticking on the project. Typically, it can take a week or two in a production environment just to receive all the quoting back, then to get commitment for availability of the new part. I wouldn't be surprised if it takes more than four to six weeks to implement a change like that.

Matties: That's very costly.

Nolan Johnson: And yet this is more prevalent than it has ever been historically in our industry—all these components on extended lead time. Designers must manage, redesign, and even completely reconfigure their vendor list in order to deliver on this new design. There is so much to communicate.

Vaughan: That's another opportunity for communication, you're exactly right. Lead times matter, particularly in this component market, because running at the typical rhythm in design, designers are typically under the gun and behind schedule before they've even begun. I'm sure Kelly can attest to that. If you're looking at the bill of materials for the components that are required as the design activity is launching, and you see items with 20-week lead times, there's really not a pressing need to make some of those complex decisions without all the forethought that you typically would find yourself having to make if you're a designer, in my opinion.

Dack: Well said.

Matties: Kelly, in your story, you may have known your capability, but if suddenly you can't get a component or you have to do something on the fly, doesn't that mean that, at the end, all bets are off?

Dack: Yes. That's a time shift. Start with specification. Start the design, from day one, with

specification targeting the product specification. What is the design supposed to do? How will we get it to perform? Once that's captured on the front end—way before the layout ever starts—now we move to design specification and we mold that concept into a product that can be laid out and manufactured anywhere based on its performance class. When the design is prototyped, that's the first phase of weeding out any potential design or engineering type problems. And then, once the prototype problems are resolved, it takes its natural progression of ramping up into production. At that point, communication with regard to ordering the specified product continues to intensify between supplier management and the potential suppliers.

Now, what you mentioned comes into play, Barry. We start over. Once something goes obsolete, we go back to the design stage to make the change. That's where communication has to go back the other way. We've designed for specification but now, suddenly, the specification went away, and the bill of material changed, the potential replacement products changed. What do we do now? Now the communication must go back the other direction. Where is that board being created? Is that fixed? Do we want to keep it with that fabricator? Supplier management, at that point, can bring everybody together, including the designer, to solve the problem with the part. I think that would be the way to do it. The designer would know the supplier, would come in touch with the capabilities, and sort it out from there.

Matties: How is digital twin, the automated or the AI factory 4.0, if you will, affecting this? Because with a digital twin, you must have all these things answered and a recipe built in computer before you even send it to a fabricator or an EMS. Is that going to be more the case soon?

Vaughan: As the new technology's coming

online, we're seeing it all connected through, whether it be CFX or some other platform, but we all see the IoT and digital twin conversation gaining traction. It's on its way.

Concluding Comments from the I-Connect007 Editorial Team:

Revisions to a product throughout its life-cycle are normal. Traditionally, these redesigns are thought of as driven by parts obsolescence and end-of-life announcements, which are often announced well ahead of time. A moment's thought, though, and one realizes that part EOL is simply a special case, a permanent unavailability condition. Extended temporary availability issues can require an identical response, but come with little to no warning.

Kelly's example makes this similarity clear: lead times are now a key factor in causing printed circuit assemblies to be redesigned to use new and different parts just to keep in production. And this redesign can easily force a printed circuit respin to accommodate a new chip. It can also trigger a firmware or software respin to accommodate any changes in component function as well.

The amount of communication involved here can be daunting as the depth of the changes slowly reveal themselves, snowballing the scope and effort in what started as a simple update to a production product.

It is easy to imagine the EMS team realizing the problem. As long as an alternate part can be sourced that can be certified as fit/form/function compatible, the solution is easy. It isn't always easy, though. In a recent conversation with Screaming Circuits' Duane Benson (an I-Connect007 columnist), he pointed out that even amongst parts in the same product line (Arduino microcontrollers in the same family with different amounts of RAM on board, for instance) may have widely different pinouts on the package. In other words, even a simple

bump-up to a higher-RAM version of the same controller would trigger a board redesign.

This puts the EMS company in the role of the initial problem owner, communicating to both the fab and the OEM design team, seeking a proper project owner with decision-making authority.

Back at the OEM design team, however, a redesign such as this was likely not anticipated, so it was not planned for in the department's project schedule, resource juggling begins, and the communication commences.

As we look to the future of the digital twin, and the emerging ability to capture design intent along with the design data itself, we can expect to see incremental improvements in this communication dynamic.

For more insight into how digital twin can improve the communication between designers and EMS, turn to page 10 to read "A Deep Dive into Digital Twin," an interview with Michael Ford. **SMT007**

Air-powered Computer Memory Helps Soft Robot Control Movements

Engineers at UC Riverside have unveiled an air-powered computer memory that can be used to control soft robots. The innovation overcomes one of the biggest obstacles to advancing soft robotics: the fundamental mismatch between pneumatics and electronics.

Pneumatic soft robots use pressurized air to move soft, rubbery limbs and grippers and are superior to traditional rigid robots for performing delicate tasks. They are also safer for humans to be around.

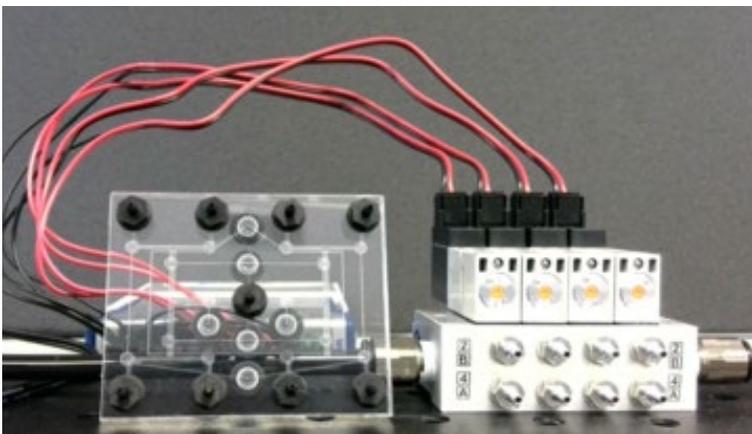
But existing systems for controlling pneumatic soft robots still use electronic valves and computers to maintain the position of the robot's moving parts. To advance soft robotics toward the future, a team led by bioengineering doctoral student Shane Hoang, his advisor, bioengineering professor William Grover, computer science professor Philip Brisk, and mechanical engineering professor Konstantinos Karydis, looked back to the past.

"Pneumatic logic" predates electronic computers and once provided advanced levels of control in a variety of products, from thermostats and other components of climate control systems to player pianos in the early 1900s. In pneumatic logic, air, not electricity, flows through circuits or channels and air pressure is used to represent on/off or true/false. In modern computers, these logical states are represented by 1 and 0 in code to trigger or end electrical charges.

Pneumatic soft robots need a way to remember and maintain the positions of their moving parts. The researchers realized that if they could create a pneumatic logic "memory" for a soft robot, they could eliminate the electronic memory currently used for that purpose.

The researchers made their pneumatic random-access memory, or RAM, chip using microfluidic valves instead of electronic transistors. The microfluidic valves were originally designed to control the flow of liquids on microfluidic chips, but they can also control the flow of air. The valves remain sealed against a pressure differential even when disconnected from an air supply line, creating trapped pressure differentials that function as memories and maintain the states of a robot's actuators. Dense arrays of these valves can perform advanced operations and reduce the expensive, bulky, and power-consuming electronic hardware typically used to control pneumatic robots.

(Source: UC Riverside)



ein Electronics Industry News and Market Highlights



Siemens' MindSphere Selected by TotalEnergies for IoT monitoring of its NGV Stations ▶

Siemens Digital Industries Software announced that TotalEnergies Gas Mobility has selected MindSphere®, the industrial IoT as a service solution from Siemens, to collect, monitor and analyze data across its network of Natural Gas for Vehicle refueling stations.

KLA Launches Automotive Products to Improve Chip Yield and Reliability ▶

KLA Corporation announced the launch of four new products for automotive chip manufacturing: the 8935 high productivity patterned wafer inspection system, the C205 broadband plasma patterned wafer inspection system, the Surfscan® SP A2/A3 unpatterned wafer inspection systems, and I-PAT® inline defect part average testing screening solution.

Russian Government Announces Competitive Selection of AI Research Centers ▶

The Russian government will allocate 5.4 billion rubles for establishing and supporting AI research centers in Russia. The competitive selection of candidate centers announced by Deputy Prime Minister Dmitry Chernyshenko started on July 15.

NVIDIA, Google Cloud to Create Industry's First AI-on-5G Lab ▶

NVIDIA announced that it is partnering with Google Cloud to establish the industry's first AI-on-5G Innovation Lab, enabling network infrastructure players and AI software partners to develop, test and adopt solutions that

will help accelerate the creation of smart cities, smart factories and other advanced 5G and AI applications.

New Semiconductor Fabs to Spur Surge in Equipment Spending ▶

Semiconductor manufacturers worldwide will have started construction on 19 new high-volume fabs by the end of this year and break ground on another 10 in 2022 to meet accelerating demand for chips across a wide range of markets SEMI highlighted in its quarterly World Fab Forecast report.

University of Waterloo Launches Canada's First Driverless, Autonomous 5G Shuttle ▶

The University of Waterloo is showcasing the operation of a driverless, autonomous shuttle research program that will transport students and staff around campus.

Cadence Report Reveals Majority Believe Hyperconnectivity Will Positively Impact Their Lives ▶

A majority of consumers believe hyperconnectivity driven by hyperscale computing will positively impact them within five years, according to a new report from Cadence Design Systems, Inc.

Camtek Secures \$10M Order from Leading CMOS Image Sensor Manufacturer ▶

Camtek Ltd. announced that it received a multiple systems' order from a leading CMOS Image Sensor (CIS) manufacturer totaling \$10 million.

A How-to Guide: Avoiding Pitfalls When Purchasing SMT Equipment

The Manifest

by Emmalee Gagnon, MANNCORP

The purchase of equipment for your SMT line should be an efficient and pleasant experience. In this column, we will discuss how to ensure that procuring your new SMT equipment contributes as much enjoyment—as well as increased profit margin—just by following these two key steps.

Step 1: Decide if You Want New or Used Equipment

When weighing your equipment options, you first must decide what you want more: a lower up-front cost or ensured reliability. Choosing used equipment will save your company money, but unexpected problems with the purchased machine may occur. With new equipment, the initial investment will be more, but you can set high expectations for the longevity and quality of the machine.

If you choose used equipment

The main risk you take when choosing pre-owned machinery is that major, unforeseen problems may end up costing more (through services, repairs, and equipment downtime) than buying new. To avoid this issue, there are some things you can consider and receive documentation to safeguard your purchase.

Before buying, you should ask:

- When was the machine built?
 - Look for an official ID tag with the date-of-manufacture listed (Figure 1). If it was built 10 years ago or more, there is a chance the manufacturer may no



Figure 1: Example of an official ID tag.

longer support it and replacement parts may be difficult to find.

- How many hours was the machine run?
 - The more use a machine has had, the more wear and tear it has received. It is best if the seller replaces all heavily worn parts and updates the machine.
- Are there signs of a degraded physical condition?
 - Check for evidence of rust, chipped paint, or broken plexiglass on the machine; these superficial issues could be indicators of deeper problems with the equipment and should be addressed. Plus, after sitting for an extended time, the equipment may need a recalibration.
- Did the previous owner keep service logs?

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the
little
things



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A machine that received regular maintenance will likely be in better shape, and the logs will demonstrate the frequency.

Does the machine come with a warranty?

- When purchasing from a used equipment dealer, they often will not make any guarantees.
 - Look for a supplier who offers at least a six-month warranty to be sure you are purchasing from a reputable seller. Check with the original manufacturer to see if it is supported.
- Is the software up to date?
 - Review the operating system the machine is running and check whether it is obsolete. If it runs Windows, there likely will not be an issue. If it is something like DOS or Linux, there may be some difficulties. Further questions include: What version is it running? Can it be run with a newer version? What hardware does it use? Many older machines can only be run with older computers, so it is important to find out these answers.
- Does the supplier have a presence in your country?
 - To avoid the fees and delays of importing, make sure the supplier has a physical location in your country, and check that they will be transferring the machine from within your country. It is also important to note that used equipment might not have its original shipping brackets, which can result in the machine being incorrectly secured during shipping.

Expert Tip: In instances where a machine fails to meet certain standards or is missing important materials (such as the manuals or service logs), but you would still like to buy the machine, failure areas can be used to negotiate a deal.

If you choose new equipment

With new machines, the main goal of the buyer should be to ensure they are purchasing from a reliable equipment supplier. If the supplier is providing equipment directly from the original manufacturer (or are the manufacturer themselves), it will be more likely that they will understand their products. Having access to those knowledgeable technicians—especially ones who can speak English—will make a world of difference, because your team will have help if anything goes awry.

Before buying, you should ask:

- What does the equipment purchase include?
 - Reputable providers will typically include a standard one- to two-year warranty (which covers all necessary part replacements), setup of the equipment and training for your team (whether in-person or remote), and virtual demos of the software prior to purchase. It can also be good to ask if an extended warranty is available, and what it would cost to receive it.
- Will this equipment meet your company's needs?
 - Speak with a representative at the equipment supplier who can field your concerns and expectations for the machine; they should be able to explain whether the equipment you are interested in will meet your company's specifications. If some specs are not met, this should be made clear to you, agreed upon, and included in the contract you are provided.
- Is the software user-friendly?
 - If possible, you should review the software in real-time. Seeing it run virtually will allow you to gauge the difficulty and determine the expected learning curve for your team members. It is also important to note whether the software will be regularly updated and whether

there will be an on-call technician available to help with troubleshooting.

- Will the machine be able to integrate with existing equipment?
 - If your company has existing SMT equipment in use, you should check that the machine being added is from the same manufacturer—or at least is compatible when run in-line. It is usually best to purchase your entire line from one vendor so they can guarantee integration.
- When will the machine be delivered?
 - The timeline from date of purchase to the equipment being up and running should be outlined for you by the supplier. If the machinery is coming from overseas, there may be long delays prior to install. It is best to choose an equipment supplier that already has your machine in your area to reduce the length of time before receiving the shipment.
- At what point does the machine transfer to FOB delivery?
 - The supplier should specify when the obligations, costs, and risk involved in the delivery of the machine will shift from being their responsibility to yours. This will help you understand up front what it will cost to get the equipment to your facility and who will be responsible for any damages at different points in the process.

Step 2: Do Your Due Diligence

Whether you choose new or used equipment, you should be confident in the reliability of the machine and the reliability of the support you will receive. This combination of reliable equipment and reliable customer service from your supplier will make the entire experience of having in-house production easier and more fruitful. By knowing what signs to look for in a reliable machine, and what services to expect from your SMT equipment provider, you will have less equipment down-

time and on-call technicians at-the-ready for any rare problems that do occur.

Expert Tip: Before purchasing any machine (new or used), you should ask what requirements your facility will have to meet to accommodate the equipment.

Aspects of that accommodation include:

- What power connection is needed?
- What types of hardware are required?
- Does it need controlled air and humidity levels?
- Will the temperature be suitable?
- Will plumbing be required for operation?

Machine Reliability

The reliability of a machine being purchased is of utmost importance (Figure 2). No one wants to go through the entire buying process of a major piece of equipment only to have it fail on them. Machine downtime is a costly and, unfortunately, a common problem facing businesses with in-house production. This can be especially impactful on small businesses running limited equipment. If you are depending on a single pick-and-place machine and it is suddenly not in working condition, the entire ecosystem of production is thrown out



Figure 2: It's important to have a machine that's reliable.

of balance. To avoid this detrimental situation, finding equipment you can rely on is essential. But, to find it, you need to know what to look out for and what to expect.

What to Look For

Warranties

Aside from parts that frequently require replacement during routine maintenance (such as nozzles, belts, filters, bulbs, etc.), all elements of your newly purchased SMT equipment should last for a long time. Most high-quality equipment suppliers will guarantee at least a year of running their machinery problem-free, and if anything happens, it should be covered under a standard warranty. This standard warranty should be included in the price of the machine, and should be good for a year or more, depending on the product being purchased. When it comes to used equipment, the warranty lengths vary. It is common to see a reduced warranty period for used machines, simply because they have experienced more wear and tear. Due to the lower up-front costs of pre-owned equipment, the trade-off of a shorter warranty period may be worth it to some customers. When looking at used equipment, make sure the supplier is reliable, not a dealer without the ability to run or train personnel on the machines being sold. If no warranty at all is offered at the time of purchase, or if the only warranty available is a big extra expense, this may be a red flag that the machinery in question is not reliable.

Good References

While looking for the best equipment for your business, you should choose a supplier that has good references. Honest reviews and feedback directly from real people who currently use the same machines can be an impactful resource for customers. If an equipment supplier is not willing to provide contact info for their referrals, you may want to look elsewhere. A good sign from a company is a long

list of customers willing to back up their claims of quality products.

Helpful Materials

Purchasing SMT machines from an unreliable dealer often leads to major issues with the materials that can be difficult to overcome—it may even make it impossible to use the equipment purchased. For instance, you may receive instruction manuals that are not written in English, making the machine unusable. From the product descriptions on the company's website, to the documents provided before the sale, to the instruction guides delivered with the machines, each element should be understandable and helpful. When deciding on a machine for your company, review the documents provided. If the information makes sense and is helpful, that will likely be a good indication of whether the machine itself will be reliable.

Reliable Support

Many SMT equipment suppliers offer little or no customer service. Without considering the level of support you may receive from a company; you may be faced with an offshore manufacturer who is unable to help with programming or troubleshooting issues. Your supplier should be easy to contact, helpful, and should understand their own products well. Rather than going through the hassle of making the switch to a more supportive supplier down the line, customers can instead find reliable support from the start by setting reasonable expectations.

What to Expect

A Great Buying Experience

Some key points that you should expect as a customer include clear communication, honest information, and high-quality products. These three aspects of the buying experience are important for showing that the products being purchased are ones you can feel confi-

dent about. If a company does not consistently remain in contact with customers, does not answer your questions or field your concerns, and does not provide helpful materials on the products for you to look over, they may not be an equipment supplier that should be trusted.

Some red flags to look out for during the buying process are false promises, misinformation, unclear product materials, and a lack of response from customer service.

Money Transfer

If possible, it is best to negotiate payment terms so that 100% of the cost is not due until after the machine has been delivered and inspected. Once you have ensured that the machine is in good working order, then is the time to pay in full.

Exceptional and Lasting After-Care

Once you have made your equipment purchase, the help should not stop there. A big area where many SMT suppliers fall short is in providing satisfactory after-care, and this can be a crucial element of production success versus failure.

The after-care process can be seen in two parts: services and materials.

Services that customers should expect to be available include:

- Remote diagnostics
- A variety of warranties
- Equipment installs and trainings
- Software updates and trainings
- A 24/7 customer service line

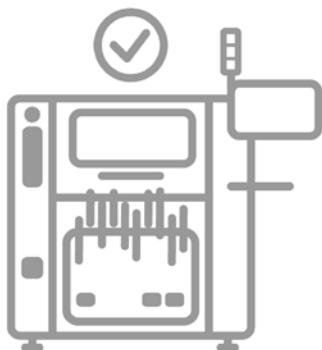


Figure 3: A machine line drawing.

Materials that customers should expect to be available include:

- BOM analyses
- Live equipment demos
- Helpful instruction manuals
- Custom floorplan layouts
- Informative blogs and videos

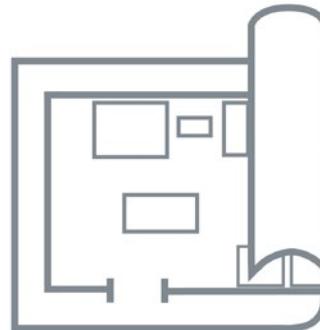
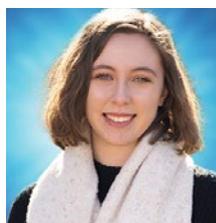


Figure 4: A materials line drawing.

Without these services and materials, a company bringing production in-house may struggle if/when they need training, repairs, or even simple advice.

A Final Word

Overall, customers can end up with reliable equipment and support by choosing a company that offers quality machines, thorough and honest communication, and a combination of helpful materials and services. If you are thinking about choosing an equipment supplier that does not offer the above—especially machines from equipment resellers with prices that seem too good to be true—it is best to proceed with caution. Finding a supplier that goes the extra mile, having that slightly more intangible trait of fostering lasting customer relationships, will be worth your time and effort in the long run. **SMT007**



Emmalee Gagnon writes about SMT-related topics and customer stories for Manncorp. To read past columns or contact Gagnon, [click here](#).



MilAero007 Highlights



EIPC Technical Snapshot Review: Microvia Reliability Issues ▶

Since the mid-1990s, when they were developed for mass production in the mobile phone industry, microvias have become principal enablers for high-density designs, and have evolved from single-level to complex stacked and staggered structures. They are fundamentally robust interconnects, although some aspects of their reliability are still under investigation.

Raytheon Technologies Working to Take the Heat Off a New Generation of Fighters ▶

The U.S. military has begun to define requirements for its future fighters. To conduct operations in advanced threat environments, next-gen fighters will need greater range provided by more powerful and fuel-efficient engines, better avionics, and advanced mission systems.

New I-007eBook Highlights System Analysis ▶

In this latest title from I-007eBooks, authored by Cadence Design Systems, readers will learn how system-level analysis of complex and high-speed electronic designs is critical to solve electromagnetic, electrothermal, and electromechanical simulation challenges and to ensure that the system works under wide-ranging operating conditions.

Germany Latest EU Country to Introduce Due Diligence Rules ▶

On 11 June 2021, the German Supply Chain Act was adopted by the German Parliament by

a large majority, introducing binding human rights and environmental due diligence obligations for companies.

Lockheed Martin Aeroshell Selected to Protect NASA's Next Mars Lander ▶

NASA's Jet Propulsion Laboratory awarded Lockheed Martin a contract to design and build the aeroshell for the Mars Sample Retrieval Lander.

Defense Speak Interpreted: POM—Explaining the Process for Defense Budgeting ▶

Anyone hanging around Defense programs will have surely heard of the term “POM.” Most of the connotations I have heard say that if you have a POM or will get “POM'd,” your program is “skating on solid ice.” That led me to infer that if you were in the POM, your program was established. But why and how?

Catching Up With Prototron's Kim O'Neil ▶

From his time of his two tours in Vietnam, to his time in our industry, Kim has always been a solid contributor wherever he has served.

International Space Station Astronauts Install Two Boeing Advanced Solar Arrays ▶

Two new, advanced solar arrays provided by Boeing have increased the International Space Station (ISS) power supply after European astronaut Thomas Pesquet and NASA astronaut Shane Kimbrough installed them during three spacewalks on June 16, 20 and 25.

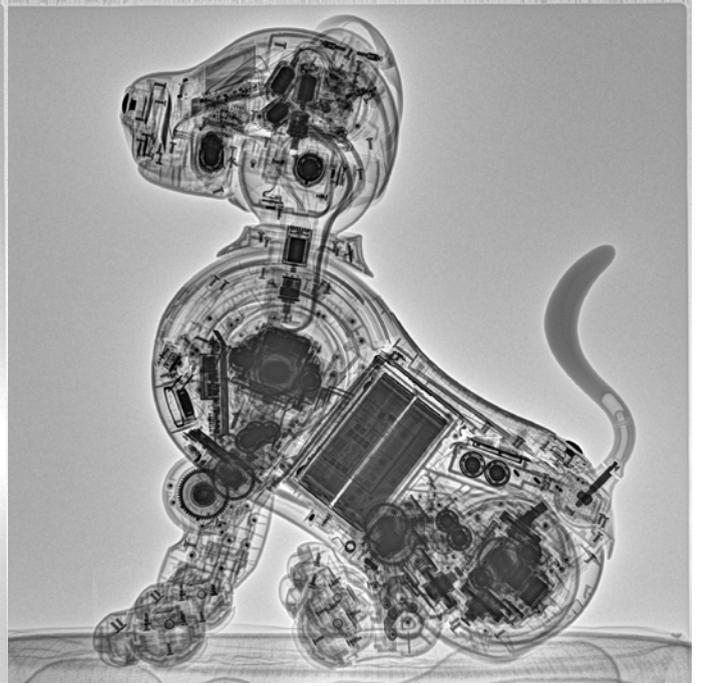
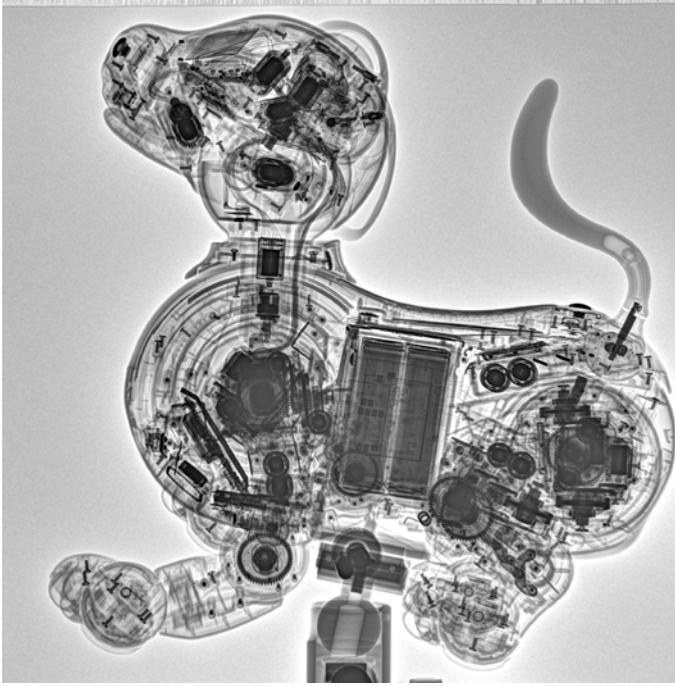


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Catching Up with the Latest at **Datest**

Interview by Nolan Johnson

I-CONNECT007

Nolan Johnson chats with Rob Boguski about the latest happenings at the Fremont, California testing and inspection service provider.

Nolan Johnson: This is our first chance to talk about Datest since last year's SMTAI. How has business been?

Rob Boguski: It has been a busy few months, particularly since January. Like everybody, we've emerged from our cocoon of the last year and life is certainly starting to accelerate the pace of business faster—the degree of involvement, the types of projects we're getting involved with, new customer activity is very vibrant right now. It seems like everybody is reinvigorated to some degree. Everyone in my immediate circle of colleagues is very busy right now. There's a high demand for different products that allow for many different levels, market sectors, and segments that are all starting to take off. We're the beneficiary to a

large extent, because these being in most cases electronic products, they've got to be tested in some form or another. On the backend, we're seeing increased demand for inspection and failure analysis services. More stuff breaks with increased volume. That's good for business.

Things are not working as reliably as they should, or they're being put under increased strain in the field due to this pent-up demand, and they're not lasting. Their design life is being truncated because they're being run flat out, and so things are being brought to us that don't work. That's what we do. We figure out why they don't work, and hopefully, we can help out our engineering clients that way. Just this morning, a company we previously hadn't done business with emailed me early, wanting to come in this very day to X-ray some valves that had failed in a hydraulic system. They wanted to isolate the source of the failure and it was a line down situation, so it really was imperative that they did that today.

Fortunately, we had a system available to accommodate, and I was on the phone with our operations manager, where he was describ-

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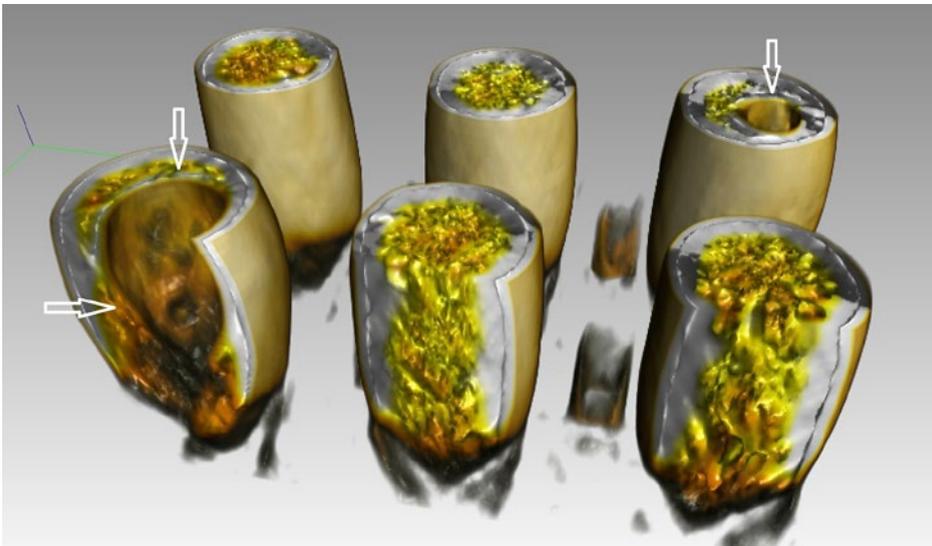
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ing to me what was going on, and we were CT scanning these products as we were speaking. Hopefully, by the end of the day, we're going to at least have some idea of what's going on and we can help this customer out and get them pointed in the direction of a solution.

Johnson: You mentioned pent-up demand. Is this a bunch of brand-new product starts, or are you seeing projects that were paused through the lockdowns?

Boguski: A lot of projects that were paused or put on the slow track, either due to financing or lack of availability of resources, supply chain problems—the things that we all read about, lack of components—are starting to come to fruition, getting the green light, and transitioning from prototyping into the production stage. Maybe they were being done at a slower pace surreptitiously for the 14 months previous and suddenly things have opened up and they need to move fast to make a market window. Almost everything we're hearing that is new is extremely urgent. I've taken on a handful of new customers in the past week and for every single new customer, the theme is the same: "I need something done right now. I need it in days, not in weeks. I need to obtain answers either to my problem or to get this

product tested and get it out the door by the end of the month."

Johnson: What's your take on this, Rob? Is this a board design/electronics design issue? For the products you're seeing, do they need to be designed for more stress or more capability than they have been previously?

Boguski: Yes. Or they were hastily designed with lit-

tle or no consideration for the manufacturing environment. Case in point, we're working on a project now, basically refereeing a dispute between a bare board fabricator and a contract manufacturer. A bunch of boards got built, shipped to the field, and started failing. The OEM started tearing into them, found pinholes in solder, which in some cases had metastasized into voids, and they claim these are the root cause of field failures. The OEM goes back to the assembly house, which points the finger at the fab house. The fab house returns fire, pointing a finger at the assembly house. Then we get the call: We're going to give you a random sampling of boards; tell us what you see.

We're now under contract to do a very thorough solder joint-level X-ray inspection of a small sampling of boards. No prior opinions, just report the results. Depending on the results, there's either a much larger lot of boards lying behind it with the same lot number that these were sampled from, and the results are that no trouble was found (for the most part), then certain things will happen; on the other hand, if we find lots of things, either assembly induced or fab level, then the repercussions could result in a much larger lot of boards showing up on our door sometime this month to do some form of screening good from bad.

Johnson: Often, if you go back to where the decision was made that created the situation, it was made in design; it happens in the CAD tool. Those are the issues you're diagnosing.

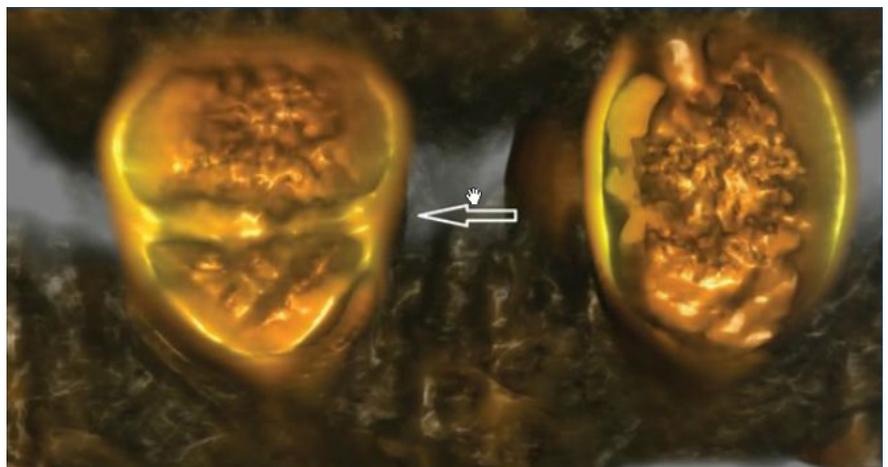
Boguski: It's true. The unfortunate reality is, by the time it reaches us, it's months, if not years away from the original design, and usually, that design has gone through many iterations and it's reached production level, so you can't go back and retroactively update the design. We'll point out certain things, and maybe we will actually talk to the designer. On that rare occasion that we do, their response invariably is, "I'm sorry, but it's a done deal. We've moved on. We're two product lines down the road from this, and you and the assemblers and everybody else associated with this, you're just going to have to live with it." It's rarely a coordinated effort, which is really a shame because there are great DFT tools available to screen CAD data on the front end and point out many of these problems in their infancy, before they become catastrophes.

But these tools are very expensive. A tier one or OEM might invest in them, but is a mom-and-pop shop, much less tier three, tier four, going to spend a hundred grand on a software suite? I doubt it, so they end up band-aiding it, making the best of it, and trying to pass accessibility standards at some minimal level with little or no consideration to long-term reliability. Okay. It ships, all is good. Electrons are flowing where they're designed to flow; ones and zeros transmit. When it goes out the door and they can certify that they've got the test data to prove it, Industry 4.0, up the stream, laterally, vertically, everything that the buzzword says. Even despite that, seven months from now, boom, it shuts down. Blackout. How do I know? Because that's when we get the call.

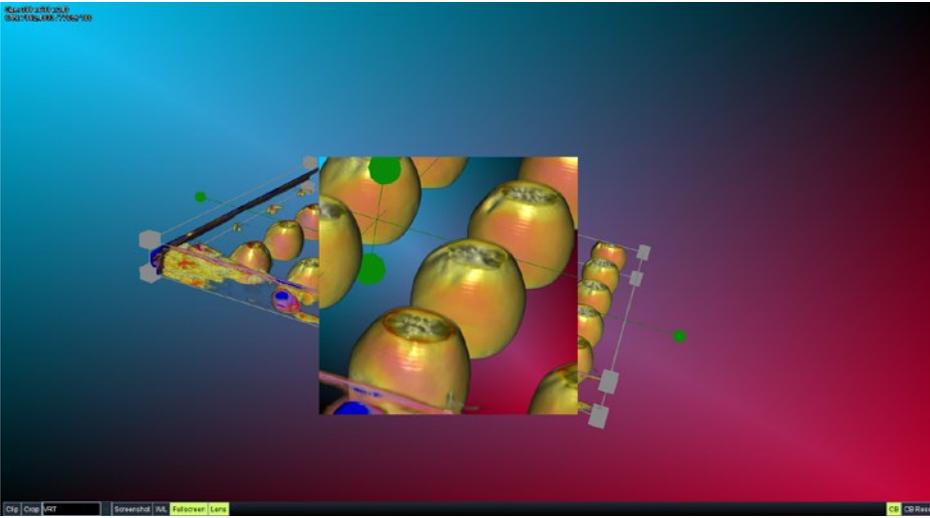
Johnson: What are some of the busiest areas in your shop? Which testing is the most in demand? I'm asking that question trying to get a feel for where the OEMs are potentially struggling the most.

Boguski: Number one, board-level failure analysis. We have a thriving X-ray business for board-level failure analysis. On any given day, a normal workload, we might have two or three jobs in the queue. When I got up this morning, we had 10 with four or five more emails from various customers saying, "I've got incoming for you," so those 10 could expand to 15 by the end of the week. Our poor X-ray technician who's responsible for that part of our shop is probably going to have his weekend ruined for the third consecutive week. That's area number one. Area number two, we also do industrial CT scanning as I described; the valve example is a good one. That's very busy. People send us other objects. We don't just do electronics. We do all other objects, medical products, mechanical products, castings, materials science/additive manufacturing applications, various things to ascertain what the failure mechanisms are.

Weld inspections, joint inspections, measurements of various kinds, void checks, porosity checks—we are very busy there for the same reasons. The third area that's really busy is flying probe testing. We operate SPEA



3D image of head-in-pillow defect.



3D multi-level view of BGA balls.

machines. We have two 4060s on our floor and they're both working flat out. We program by day, we test by night, and we test on weekends when we can't keep up with it during the week. Those machines are very, very busy right now. For one reason, we can create a test program, debug it, and be testing boards in days where using our old standby in-circuit testing takes weeks and sometimes months to do the same thing. With flying probe, you can achieve the same thing or most of the same thing that ICT does for a fraction of ICT's cost. Where ICT might cost you \$20,000 for a fixture in program, you might spend \$3,500 for a program for flying probes. It's implementable very quickly.

Johnson: It sounds like, while you're busy, you are doing everything you can to have as much capacity as possible for some very busy customers.

Boguski: Yes. We've added equipment. We acquired one of our two flying probe machines in the last year, and we're starting to give some thought to acquiring a third machine. It's that busy. We've added some personnel in a couple of areas just to give us some added flexibility. We run two shifts as it is. We're open from 6 a.m. to 10 p.m., Monday through Friday, but we've beefed up both of our shifts—day and swing—a little bit to make ourselves a little

more flexible, and handle some of the overflow that we're starting to see. The other thing we're getting, being who we are, we tend to use our machines in a much wider range of applications than most EMS companies do. Using flying probe as the example, we use all of the features in our machines where your basic tier three, tier two EMS company may not do so.

We have a slightly higher level of experience and expertise perhaps than they do. What often happens is some of our customers will prioritize their jobs and they'll keep in-house the simpler stuff, maybe the less expensive stuff, and they'll give us the tough stuff. They'll take the nine easy jobs and we'll get the one hard job. We're used to that. We charge accordingly. Takes longer to do it because it's the harder job, but we document our work and we can defend what we do, and if the customer really wants to meticulously go through what we've done (and actually understands it enough to ask challenging questions), we provide coverage reports of everything we do, and they can see. It's all on display. We have nothing to hide.

Johnson: Do you see this level of customer demand abating any time soon?

Boguski: Short-term, and I would define short term as perhaps the next six months? Correct. Beyond that, six months to a year looks pretty steady to me. Beyond that is anybody's guess, and there are lots of factors—political, macro-economic, weather, etc.—that are beyond our control. We're just going to have to see. One thing I'm watching very carefully is the so-called onshoring phenomenon. Is it real? Is it happening? We're getting a lot of inquiries from Mexico and Canada. Things that used



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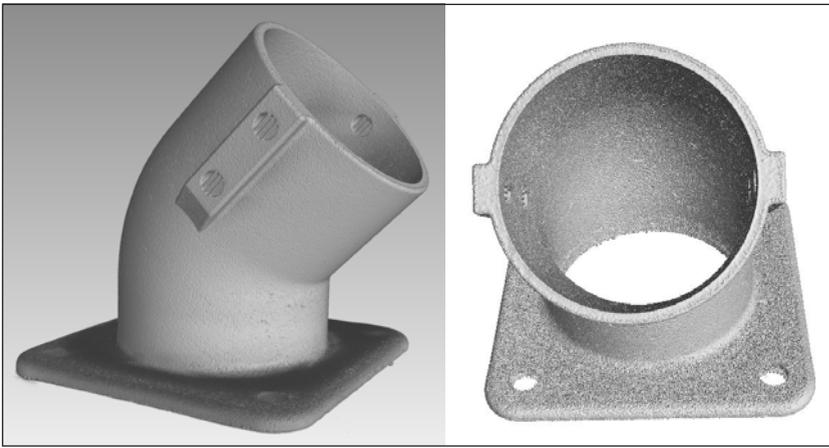
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to automatically go to China aren't necessarily going to China anymore. For all the things that we read about in the news, does that mean they're staying in Silicon Valley and being manufactured there? No, not really. Silicon Valley is R&D, and when it goes to any kind of appreciable volume, it's usually going somewhere else.

That somewhere else from where we sit seems to be Mexico right now. Some Southeast Asia, some Vietnam, some Thailand, some Malaysia, but I would say Mexico probably 60% of the time. We've seen an increasing level of failure analysis business coming from Mexico, which supports my hunch.

Johnson: The more business that's there, the more opportunities for you to see a failure. That makes sense. What's the biggest challenge for Datest right now, Rob?

Boguski: One, finding good people, and we're not waiting for them to drop from the sky. We're creating our own. Often, when you hear people lament the fact that they can't find qualified people, it simply means they don't have the desire to train them. We do have the desire to train them, so if someone of native intelligence and drive wants to work for us, then we'll make the exchange for your native intelligence and drive. We'll give you the tools. We'll give you the knowledge to operate this flying probe machine or to operate this CT scanning

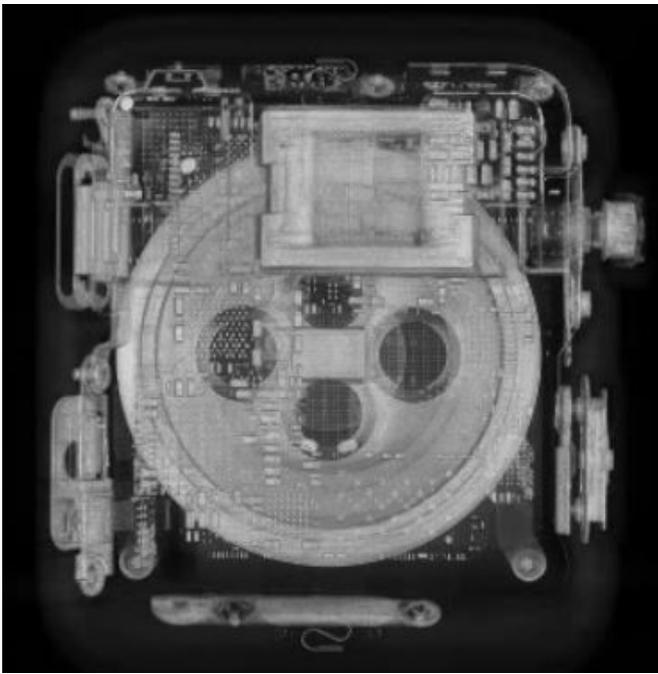
system. We'll train you up to that. We're finding them. We have to be discriminating in our search, but they are out there, though it still remains a challenge. The older test engineers are all retiring or getting close to retirement.

The folks that came up learning things like in-circuit testing, they're a rare breed and that's a dying methodology anyway. What do you do to replace them? In a small company like ours, we have to hire people who wear multiple

hats. If someone is knowledgeable about ICT and can also program a flying probe, that's a definite boon to us. Bonus points if you can also look at an X-ray and interpret the images, that's even better. That's usually how we work. We don't slot people into one slot, we move them around. Finding the right match there is important. The other biggest challenge right now is simply managing our time, being careful not to fall into the trap of working with a customer who's picking you for a lot of free engineering and who has no intention of doing business with you.

They'll take whatever you share with them, and then they march down the road to do the same thing for a better price. Part of my job is knowing the difference or determining the difference with each engagement and screening them out, so our guys and gals on the floor don't have to waste time with them. I'm the first line of defense in that regard, and that's a serious issue. We're a 13-person company, so if somebody gets taken offline doing research for somebody for a day or two, that's significant to us because it means they're not working on a revenue-generating activity elsewhere. We have to be rather abrupt sometimes, and it's not meant to be rude, it's meant so that we don't waste their time, and in turn, they don't waste our time.

Sometimes somebody will come to me saying, "I want X-Y-Z done. I want this kind of



DR Image of Apple Watch.

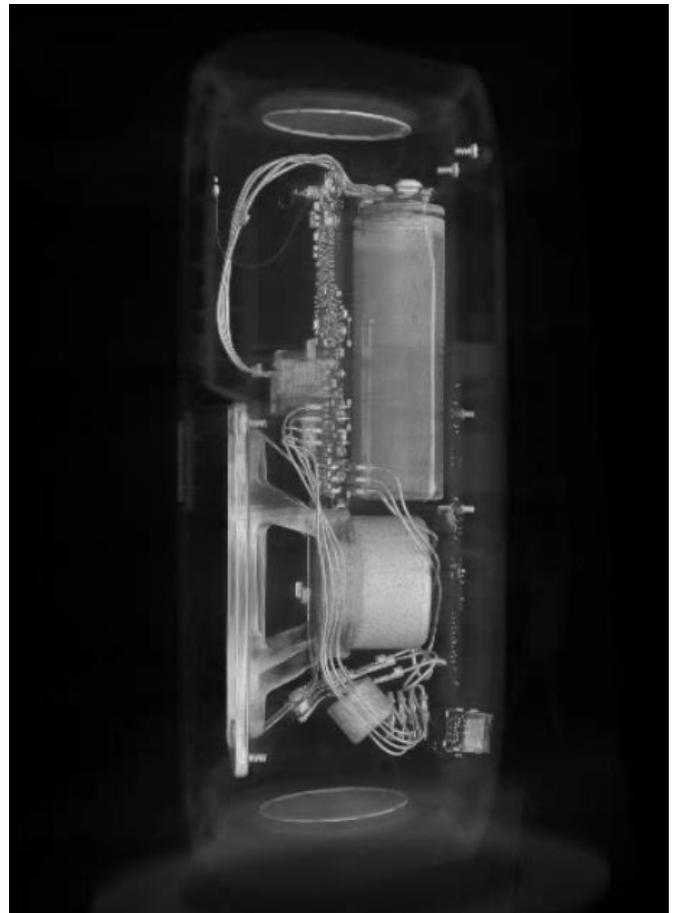
functional test done, or I want this kind of counterfeit screening done.” I’ll just cut to the chase and say, “If you’re not prepared to spend at least \$10,000, then let’s stop.” That separates them out. Nine times out of 10, that’s probably the end of the conversation. The one time where they are serious, they’ll say, “Yeah, I expected that. Now, tell me more. Let’s look at a detailed statement of work and let’s figure out how we can make this work,” and I say, “Okay, we’re in business here.”

Johnson: Triage is a component of your capacity. You get to the spot where you’re analyzing the intake, and you make the call, “Yes, we’ll take on the job,” or “No, we won’t.” That’s a throttle to your capacity.

Boguski: Yes. I don’t know if that’s an acquired skill, native-born, something you can learn in school, but the ability to read a customer and glean their intentions to cut behind the buzzwords, to cut behind the fluff and get to the heart of the matter of what you really want. What can we do for you? Maybe it’s because I’m getting old and impatient, and I just have very little tolerance for all the small talk and

niceties, but I tend to want to get there quickly and say, “Here’s what we offer. What would you like to do? I’m a big boy, so if you don’t want to do this on these terms, I’m fine. I can handle it. Just tell me. But if you do, here’s what we can do, and here’s what I think it’s going to cost,” and then move on.

Some of the testing projects we do just to develop a quote sometimes takes a month of pretty serious engineering, and you do that and you submit it in excruciating detail, a 10-page quote, then you don’t hear anything for several weeks and you have to go to them to find out what’s up with the quote, only to be told sheepishly, “Oh, well, we awarded it to someone else,” “We decided to keep it with our existing EMS company,” or, “The crude benchtop system that we have, that we wanted you to revamp as part of your quote, we decided the crude benchtop system is okay and we can duct tape it for a while longer.” It hurts when



DR Image of remote speaker.

that happens. You're never going to get that time back. It's a feeling that sticks with you. I'm sure you can identify.

Johnson: Parting thoughts, Rob?

Boguski: It's an interesting world right now, Nolan. At the beginning of the interview, I said I'm not sure what normal is any more. I think since we're all Zoom experts now, even though people can, once again, congregate, I think some degree of this video conferencing is going to continue. I find it very useful, to tell you the truth. Getting back to that wasting time analogy, I sometimes find a half-hour video conference with the customer is a lot more productive than setting aside half a day, sitting in my conference room, being bored to tears looking at a 37-slide PowerPoint. I can accomplish the same things in a short video conference, especially if that customer is not in my area—maybe they're in Arizona, for example—and we can get it done.

It will be me, the customer and our rep in that area. We can accomplish a great deal without having to travel, and I think that's going to impact what we do. We still cherish face to face for some things like trade shows and some technical conferences and that's going to continue, but at the same time, people are rethinking that a company's time can be better utilized using some of these new resources. Now that we all have these new-found skills, to one degree or another, why not use them, and make really efficient use of our time? The other thing that's really interesting is nobody seems to care what working hours are anymore. I don't know about you, but I get emails at 2 or 4 a.m.

I'm an early riser. I tend to get up about 4 a.m. normally, and I'm generally working by



Rob Boguski

4:30 a.m. It's not uncommon for me to be trading emails with some engineer in some part of the country at that time, going over a problem: "My board has failed. These are the symptoms. What can you do? What will it cost? When can you do it?" By dawn's early light at 6:30 a.m., I've got a new customer, boom, and we're off and running, which is actually cool. I like that. But the point is, there are no boundaries anymore. I think, like it or

not, that's the world we live in.

Johnson: Are we going to see Datest at SMTAI 2021?

Boguski: We are. I will be there because I'm on the board and I have board-related things I have to do. As to whether we will exhibit, we have to make that decision probably in the next couple of weeks.

Johnson: Gotcha. I do look forward to running into you and having a chance to catch up on the show floor.

Boguski: Me too. You'll see me there for that, that's for sure. Whether we have a booth, that remains to be seen.

Johnson: Great. Rob, thanks so much for taking the time to update us on Datest.

Boguski: Thanks, Nolan. Appreciate the invite.
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Factors Affecting Quality of Solder Joints in Multi-Busbar Interconnection

Article by Narahari S. Pujari
MACDERMID ALPHA ELECTRONICS SOLUTIONS

Introduction

Tabbing and stringing is the dominant method in the market for making crystalline silicon (c-Si) solar cell modules. Soldering ribbons are used as an interconnection medium in this process on the four or five busbars of the front- and back-side metallization. The process is well established and proven reliable ^[1]. However, there are still challenges to obtain high efficiency, cost-effective solar electricity. These challenges include ^[1,2]:

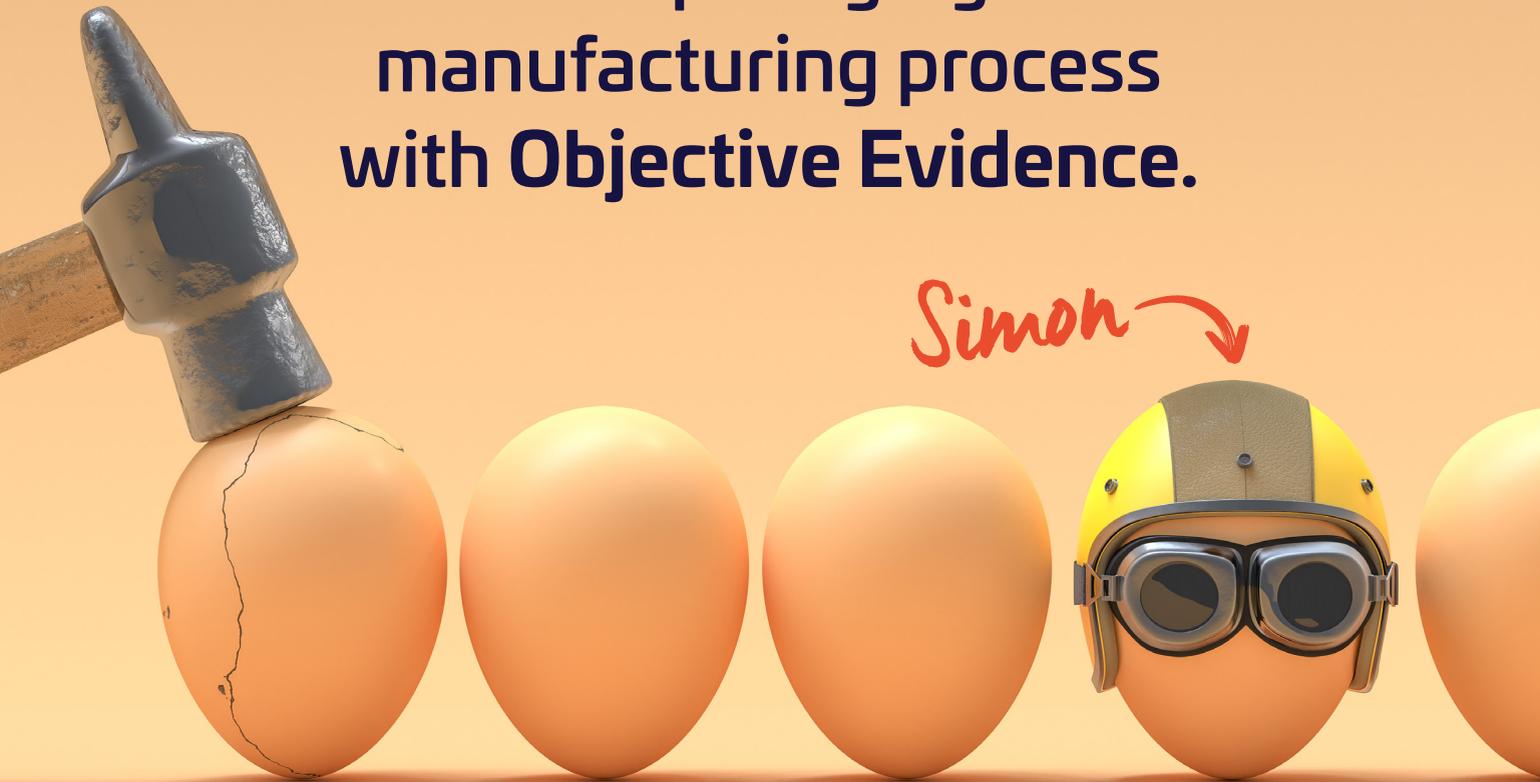
1. Low-cost manufacture with higher power output.
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3. Achieve current redundancy.
4. Introduction of fine gridline print in front metallization to reduce electrical and optical losses.

5. Implementation of simple and low-cost processing along with advanced cell architectures to achieve higher efficiencies (>20%) in the field.

Amongst several new interconnection technologies, multi busbar (MBB) interconnection promises to alleviate some of the above problems. The technology was first introduced in 2006 ^[3] and over a period of time several approaches to achieve MBB interconnection have been emerged. Soldering ^[2], low temperature alloy lamination (Smart wire) ^[3,4], woven fabrics assisted soldering ^[5], and the prefabricated interconnected grid method (Merlin) ^[6], etc. to name few. The MBB technology of soldering is the closest to the traditional cell interconnection technology. The current module equipment can be upgraded to assemble MBB modules.

Schmid company was the first one to develop a special stringer machine for MBB modules. Now, several Chinese equipment manufactur-

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ers are developing this kind of machine. Typically, MBB cells are interconnected by seven to 15 solder coated copper wires with circular cross-section (diameter between 200 and 450 μm) on each side of the solar cell. The wires are soldered by infrared soldering on silver pads printed on the front and back of the cells.

MBB offers a number of advantages [2]:

1. MBB modules use copper wires instead of ribbons for interconnection. This allows one to use narrower or no busbars on the cells and, therefore, results in reduced silver paste consumption.
2. Reduced current per finger enables small finger width, and shorter effective current paths in fingers enables an increased homogeneous series resistance distribution.
3. The round shape of the wires generates additional reflection gains from the air/glass interface to the cell which brings on improved light absorption and improved generated current.
4. The large number of wires reduces the requirement for lateral transport which results in lower series resistance.
5. A more homogenous busbar design of the cell leads to higher tolerance to cracks.
6. The large number of homogeneously distributed solder joints leads to an electrical redundancy. A failure in solder joints only affects a smaller area of the solar cell and a finger failure is disconnecting a shorter finger length.
7. Technology gives lower optical interconnector shading and higher power on module level.

Like standard tabbing and stringing process, the main challenge for the MBB technology remains soldering. The MBB approach requires the realization and reliability of over 100 solder joints on the front side and a similar large number of solder joints on the back side of each solar cell. From the mechanical point of

view this represents a major difference to the continuous soldering of a standard four busbar H-pattern design. Defects caused by thermo-mechanical stress after temperature cycling according to DIN EN 61215 (-40°C to 85°C, 50 cycles) have been reported [7,8]. Mechanical stress-induced delamination of the metallization paste, or adhesive fracture between solder and silver paste, is also known. In some cases, combinations of the different defect mechanisms can be found. Wire crippling and pulling the wire through the grippers as well as excessive flux pollution are also associated defects in MBB soldering.

At elevated temperatures, the weaker MBB solder joint connection area subjected to the thermal stress can develop micro-cracks. Previous studies show that the cracks are developed mainly in the contact surface of the strip interconnection and the contact condition can adversely affect the performance of the whole module in terms of power output [9]. The crack developed induces contact resistivity between the Cu ribbon interconnection and cell, resulting in cell-to-module (CTM) loss, hot spot, and eventually the disconnection of the bus bar line which consequently results in DC arc [9, 10]. This article reviews factors affecting MBB soldering and interconnection, and also suggests the ways to obviate the same for optimum soldering results.

Experimental

Soldering

All the cells were $156.75 \times 156.75 \text{ mm}^2$ 12BB mono PERC solar cells (Runergy) with a thickness of $200 \mu\text{m} \pm 20 \mu\text{m}$. For the MBB front grid, each busbar contains 11 silver pads with $1100 \mu\text{m}$ (length) \times $700 \mu\text{m}$ (width) which were designed to enhance the quality of contact between the wires and fingers. Each processed cell had 20.4% efficiency.

The first phase in a photovoltaic module manufacturing line is joining the solar cells, which is done by a solar tabber and stringer.

Table 1: Processing parameter details.

Process Parameters	Details
Machine	Automated tabbing & stringing (Lead Xi Automated machine)
Fluxing method	Through sponge
Soldering method	IR soldering
Pre-heat temperature	70°C–180 °C
Soldering temperature	230–270°C
Soldering time:	1–3 sec
Cell	12 BB cell (Make: Runergy)
Interconnection strip	0.4mm tin60lead40 (Sn60Pb40) alloy coated on copper (Cu) wire
Flux	PV-21
Soldering side	Front and back

The cells are joined to each other by wire to form the typical strings that then go to form the photovoltaic module. An automated tabbing and stringing machine (Lead Xi Automated machine) was used for soldering. This comes with contactless IR soldering so that stress is not generated in the cell. The infrared soldering system focuses the light beams on the wire lines for a constant welding process. The motorized ribbon unwinding system and the new stretching system permit positioning of the wire on bus bars avoiding bowing and possible misalignment. The process parameters are described in Table 1.

Stringed cells were cut in between to get single cells and then bus ribbons were soldered by hand soldering. Some cells were used to do functional characterization like peel strength analysis, microscopic analysis etc. and some cells were laminated at 140°C using standard ethyl vinyl acetate (EVA) laminating materials. Single cell panels were then used for various electrical and reliability studies.

Characterization

Digital Microscope

A Keyence microscope (VHX-5000 and VHX-2000) was used to get higher magnified

images. MBB cells were analyzed closely for surface smoothness and topology using higher magnified microscope. From the topology, surface variation was estimated.

The nature of soldering characteristics was evaluated by scanning electron microscopy. Samples were cut and cold mounted. The metallographic preparation of these cross-sections included grinding and polishing using SiC (silicon carbide) abrasive pads to flatten the sections and remove damage from cutting. An argon ion polisher (Hitachi made) was

use in its flat milling mode. A field emission scanning electron microscope (FESEM) from JEOL (model 7800F PRIME) was used for imaging, whereas the qualitative identification of the IMC (intermetallic compound) composition was done using energy dispersive spectroscopy (EDS) analysis.

Peel test

The mechanical strength of the soldered joints was assessed by a peel test according to DIN EN 50461^[11]. Tests were done at 180°C using an Imada force measurement unit. All cells were peeled at a speed of 50 mm/min. The force is recorded over the interconnected distance and normalized to the width of the interconnection. A peel strength of 1 N/mm is deemed necessary according to DIN EN 50461, explicitly for soldered interconnections. All force data was exported into Excel. Approximately 204 data points were collected for a 156.75 mm cell on both sides. Fractured cell surface and ribbon was analysed after peel test to see the solder joint nature and adhesion using the Keyence microscope.

Wetting

Wetting was measured by wetting balance (Rheska) test as per JIS Z 3198 standard. Stan-

standardized specimens were used along with a set of specified test variables. In this test, fluxed standardized copper specimens are dipped into the molten bath of alloy (Sn-Pb) while time and force required for the solder to wet the surface was measured and plotted.

Raman Spectroscopy

Raman spectrum is a distinct chemical fingerprint for a particular molecule or material that can be used to very quickly identify the material or distinguish it from others. The LabRAM HR Evolution Raman microscope (Horiba Scientific) with ultra-fast confocal imaging and high spectral and spatial resolutions was used to identify any oxides present on the wire surface.

X-Ray Analysis

The phoenix micromex is a 180 kV micro-focus X-ray inspection system used for real time inspection of solder joints and voiding analysis.

Reliability

Reliability of modules was investigated by performing thermal cycling (TC) and damp heat (DH) testing as per IEC61215. In this process, modules were subject to climatic testing with defined temperatures and humidity conditions while the change in module performance after testing was the key parameter to be evaluated.

Conditions for damp heat were:

- Test temperature: 85°C ±2°C
- Relative humidity: 85% ±5%
- Test duration: 1000 hours
- Conditions for thermocycling were:
 - Test temperature: 40°C to 90°C
 - [30 min minimum dwell times,
 - <100°C/min. transition] for 200 cycles.

An electroluminescence system was used to inspect the modules for any kind of cracks and other defects. Electrical performance was determined by I-V curve measurement.

I-V Curve Measurement

Modified Sinton Instrument FMT-0038 was used to measure electrical properties of mini panels. I-V curve was derived from which efficiency, power output, fill factor, etc., parameters were obtained.

Results and Discussion

The Multi-Busbar (MBB) technology appears to be another novel cell interconnection technology to increase the module power. Figure 1 shows 12 BB and silver pad design. The interconnection was processed with the help of the Lead Xi machine. The interconnected cells were laminated with a glass and EVA. We identified four factors that affect the solder joints. They are:

1. Cell metallization
2. Solder wire
3. Flux
4. Process condition

We will discuss on each in detail in ensuing sections.

Cell Metallization

MBB cells were analyzed closely for surface smoothness and topology using higher magnified microscope (Figure 1).

Screen printing metallization is cost-competitive and robust technology used in the production. The technology has attracted considerable attention due to significant improvement in printing medium and simplicity of the process. The new generation solder pastes provide better aspect ratio (the ratio of line height to line width) which helps in improving the current-carrying capacity of the contacts, as the shadow loss and the series resistance decreases. However, if the right screen parameters such as mesh count, wire dimension, and emulsion thickness are not chosen, the final outcome suffers from issues like adhesion, glass on the surface, printing smoothness, etc., of the metallization surface will impact the soldering adhesion.

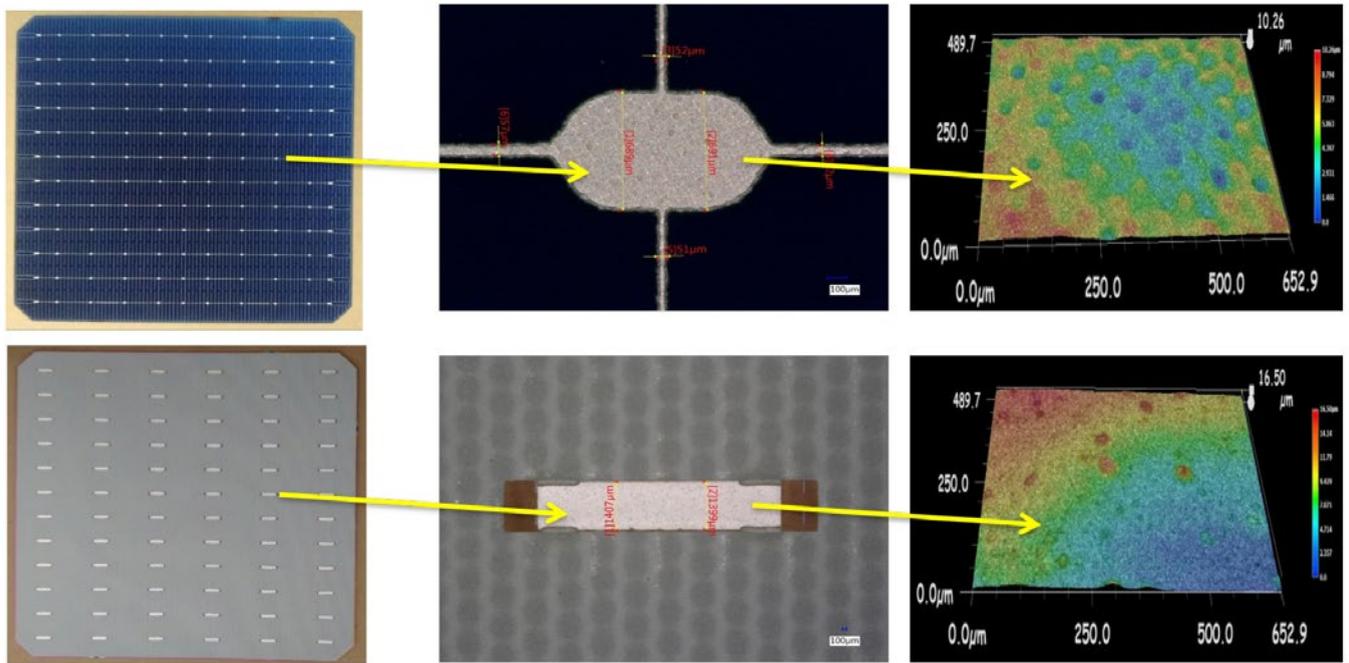


Figure 1: Surface topology of MBB cells.

It is reported that cells having a smooth surface on front as well as on the back side form reliable joints. [12]. Surface topology of cell metallization is shown in Figure 1. As mentioned in the introduction, the technology used to make MBB cells can save silver paste. In our cells, the silver paste consumption of MBB cells was reduced by 20 mg (16.7%) compared to that of 4BB cells. As seen in Figure 1, only hexagonal pads are printed on the front side of the MBB cells. Moreover, the height of the silver deposition is also about 8-11 micron, significantly lower than conventional 4BB solar cells. This also means that less surface area is available and there is the probability of silver leaching during soldering. It has been shown that [12] the smoother the metallization, the better is the peel strength. This may happen because the difference between the highest (edge) and the lowest point in the middle of the busbar in some places more than $>10 \mu\text{m}$. The peaks at the edges will keep the ribbon off from the major part of the surface [12]. The consequence is an increase in thermal contact resistance between the busbar and the wire. In the case of “low quality” cells where the variations are high and paste is not printed smoothly, the

impact is significant and this is the main reason for the failure mode. To evaluate the effect of metallization further, some cells were oxidized and soldered under similar conditions. In all those cases non-wetting or very low peel strength was observed.

Solder wire

Tin-lead (Sn-Pb) alloy is coated onto copper wire to form PV soldering wire. During the coating process, reactions occur between solder and copper wire and IMCs, which may nucleate and grow at the solder/copper interface, are formed (Figure 2). The presence of these IMCs is an indication of good metallurgical bonding, and a thin and continuous layer is an essential requirement for good wetting and bonding [13]. As can be seen in Figure 2, our copper wire has uniform solder coating and continuous IMC layer is formed at the Cu-solder interphase.

Raman shifts are typically reported in wavenumbers, which have units of inverse length, as this value is directly related to energy. Raman spectral analysis is performed to determine the surface oxides. Results indicate the absence of tin oxide on the ribbon surface. The Tin oxide

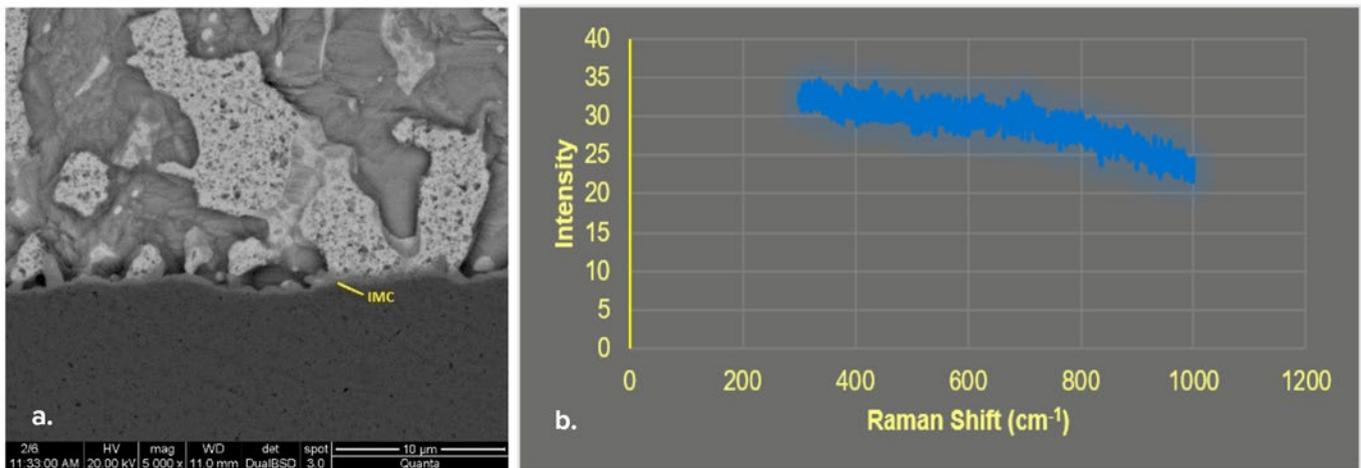


Figure 2: a) Cross-sectional analysis of solder wire; b) Raman spectrum of wire surface.

raman shift peak typically appears at around 525 cm⁻¹. It is known that limiting the oxygen level in the wire improves wettability and thus contact with metallization paste [13].

The MBB interconnection has one unresolved design/manufacture challenge: the problem associated with the non-homogeneity of solder coating that is produced around the Cu-wire which can result in weaker solder joints [14]. Simulation modeling of the non-homogenous solder coating on round wire used in multi-busbar (MBB) strip interconnection of solar PV module may lead to form micro-crack initiation at high temperatures. Rendler, et al. [8, 15] have investigated the deformation of cell and thermomechanical stress in both cell and interconnecting wire of MBB PV modules. They found by using lower diameter of wires and by reducing the Young's modulus or the yield strength of the copper, the thermo-mechanical stress in a solar cell is decreased. They also recognized that the maximum stress in the wires occurs at the edge of the outermost contact pads on both sides of the solar cell and interconnections.

Another challenge is to produce low yield strength wire, which is difficult to process and even make. Changing the shape of copper-based wire potentially leads to a significant change of its mechanical properties. To reshape a wire, a method that enables the production of wave-shaped wires with adjustable

periods and amplitudes has been developed [16]. The authors proposed wave-shaped wire with a diameter of 300 µm, a constant period of 3.1 mm, and various amplitudes for MBB. Another way to improve better contact between the pad and wire is to use thicker solder-coated Cu wires [17]. The authors have reported that increasing solder thickness could help in increasing the efficiency of the panel. This approach, however, requires thicker EVA and it may induce cracks during the lamination. We propose to use wire with periodic solder bumps as shown in Figure 3. Our experiments show that that this design (Figure 3) provides better contact with the silver pad and produces reliable soldering results. The influence of solder joint failures in one interconnector can be mitigated by the neighboring interconnectors, as 12BB MBB provides current redundancy.

Flux

Fluxes are typically liquid and consist of a chemical activator package, additives, a solvent system and, optionally, rosin or synthetic resin. The solar industry is traditionally using alcohol-based flux formulations. For an efficient soldering, the fluxing mechanism requires the right chemistry coupled with a proper initial heat cycle to remove the oxide and surface contamination.

Acid number and wetting of a flux are two important characteristics to determine the

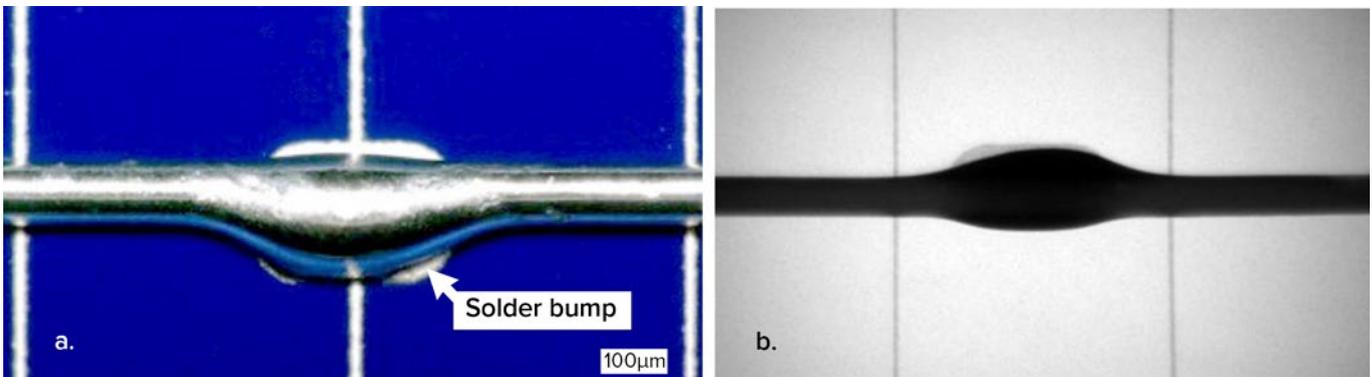


Figure 3: a) Image and b) X-ray image showing copper wire with solder bump. No voids are seen in X-ray image.

activity of a flux. The wetting results of Alpha's PV-21 are given below in Figure 4. The equilibrium wetting force figure shows, that the flux has wetting time of 0.43 sec and wetting force of 7 gF. This means PV-21 and similar fluxes can be used in a high throughput environment as they can be activated in a shorter time. The equilibrium wetting force is a function of both the solid-liquid and the solid-vapor interface. Both interfaces may depend on the presence of the flux. The solid-vapor interface will be influenced by the presence of the flux. In addition, different fluxes will remove surface oxides from the solid with different efficiencies. Usually, the rate of wetting increases as the acid content of the flux increases. The rate of wetting is dependent on the degree of oxide removal, which is a function of acid concentration and temperature. This indicates that the flux with better wetting time effectively removes surface oxides within the first [18,19]. However, fluxes with classification L are preferred as higher acid number or halogenated may cause corrosion issues [19].

Shelf life of flux is another important factor. Typically, fluxes are stable for six months. In today's environment, longer shelf-life fluxes are preferred. A good flux should have [19]:

- Excellent wetting and spread
- Higher acid number (15-21 mg/g of KOH)
- Longer shelf life
- No harmful or corrosive residues
- Rapid oxide removal characteristics

- Reliability as evidenced by Cu mirror and corrosion test per IPC standard
- No interaction with EVA
- Class "L" classification and excellent wettability

In addition, since most of the MBB tabbing and stringing operation is done by dip coating method, higher solid content (1.6-3 %) flux is preferred. Jae Hun Kim et al [17] have reported that flux including high solid material can affect to solder behavior on Ag electrode in MBB interconnection. Solder tends to migrate towards the edge of the wire during soldering, thus leading to lower growth of IMC layer. This thin and uniform IMC layer helps in increasing fill factor. They proved that in a soldering process, the amount of solid material in flux and the solder thickness, determines characteristics of solder bond. The right balance of these along with contamination-free operation is a key to achieve high throughput manufacturing as well as reliable solder joints.

Process Conditions

Effect of solder time and temperature

The MBB soldering operation is preferably done at higher temperature for better thermal contact and achieving high throughput. This has one downside, due to the different thermal expansion of the copper and the silicon elements; solder joints can form microcracks, which might not be detected during the man-

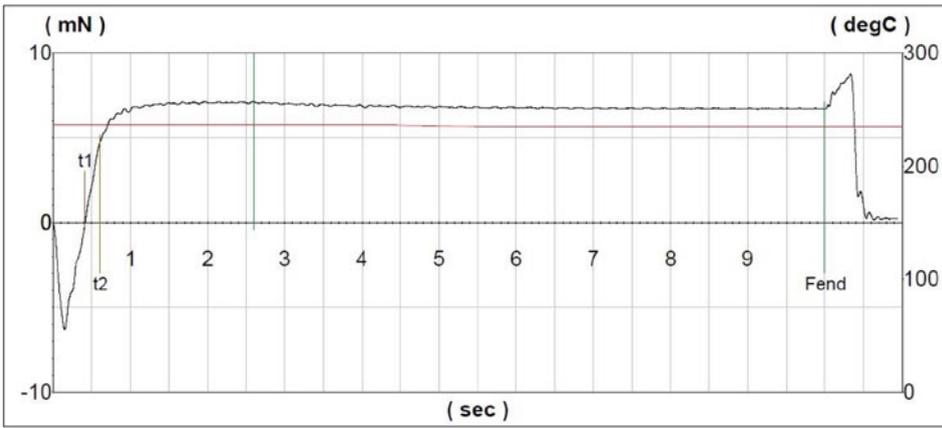


Figure 4: Wetting curve of PV-21 flux.

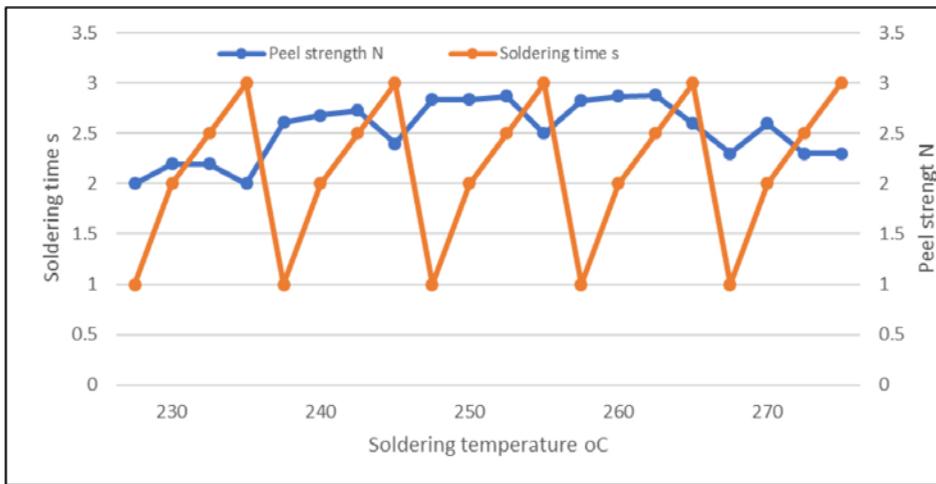


Figure 5: Effect of soldering temperature and time on peel strength. Average of 10 strings each.

ufacturing process. Undetected micro-cracks could result in a less than expected field lifespan [18]. The effect of soldering time and temperature is investigated (Figure 5). In this study, soldering temperature was varied from 230° to 270°C and soldering time was varied in between 1 and 3 seconds. As can be seen from Figure 5, the higher peel strength was obtained at 250-260°C. It was also observed that higher temperature or longer soldering time does not necessarily yield higher peel strength. In fact, silver leaching and crystal damage, and elimination of the silver bus bar from the surface of the silicon, may be observed in the case of excessive soldering time and temperature [20]. Precise control of time and temperature reduce the possibility of forming micro-

cracks in the substrate is necessary.

Solder joint thickness should have adequate capacity to transfer generated current with minimal residual stresses in the joint. In addition, the solder joint should have enough thickness to properly function as a mechanical support as well as a thermal conduit. Proper soldering will result in an intermetallic layer that is within 0.5-1.5 μm . Soldered cells were cross-sectioned and analyzed with FESEM for solder joint adhesion and IMC formation at the interconnecting area. For properly processed samples, SEM analysis indicates that there is excellent solder adhesion with distinct continuous IMC layer formation in the interconnecting area (Figure 6).

Intermetallic compounds (alloys) form whenever two different metals are soldered together

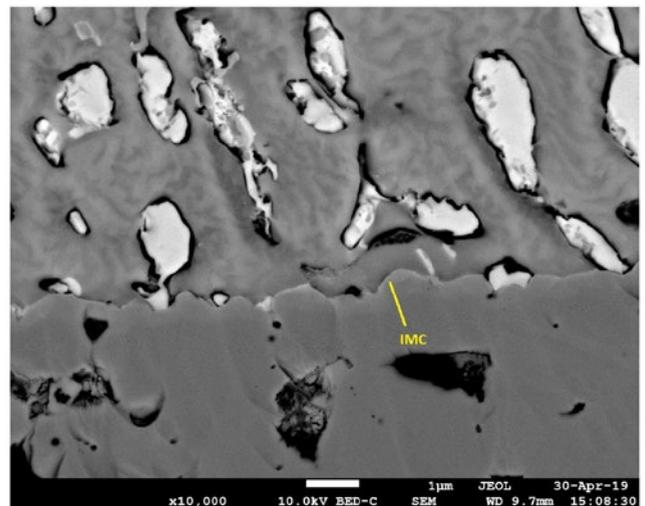


Figure 6: IMC formation in MBB solder joint.

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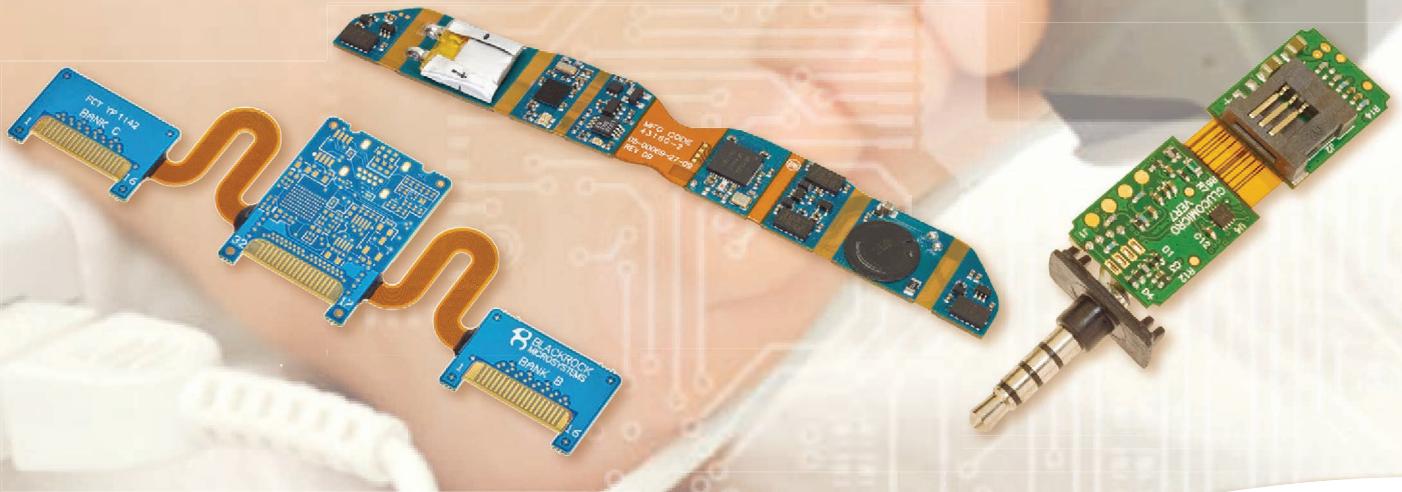
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and grow as solid phases during the solidifying of solders on the interface between the solder alloy and its bonding pads [21]. This ensures reliable bond strength.

Effect of wire misalignment

Since both, wire diameter and Ag pad width (in front side of the cell) are minimum, even a slight misalignment will affect the peel strength values [19]. Peel strength of each of the Ag pads on the front and back side was noted and plotted. Corresponding microscopic images were taken to see the correlation between wire alignment on Ag pad and peel strength. The graphical representation of peel strength on front and back side is illustrated in Figure 7. When there

is wire misalignment over the Ag pad, peel strength value decreases drastically (1.0 to 1.5 N). In the case of proper wire alignment, peel strength values were high (3.0-3.5 N). Thus, wire misalignment has a direct impact on peel strength.

The peel strength data of the back side of the cell was less affected and relatively constant due to wider silver pads (Figure 8).

Other Factors—Cold and Dry Solder Joints

Cold or dry joints are weak joints and characterized by the absence of bond formation between the wire and pad. Both terms can be interchanged but there is a slight difference. Weak joints are joints having peel strength <1

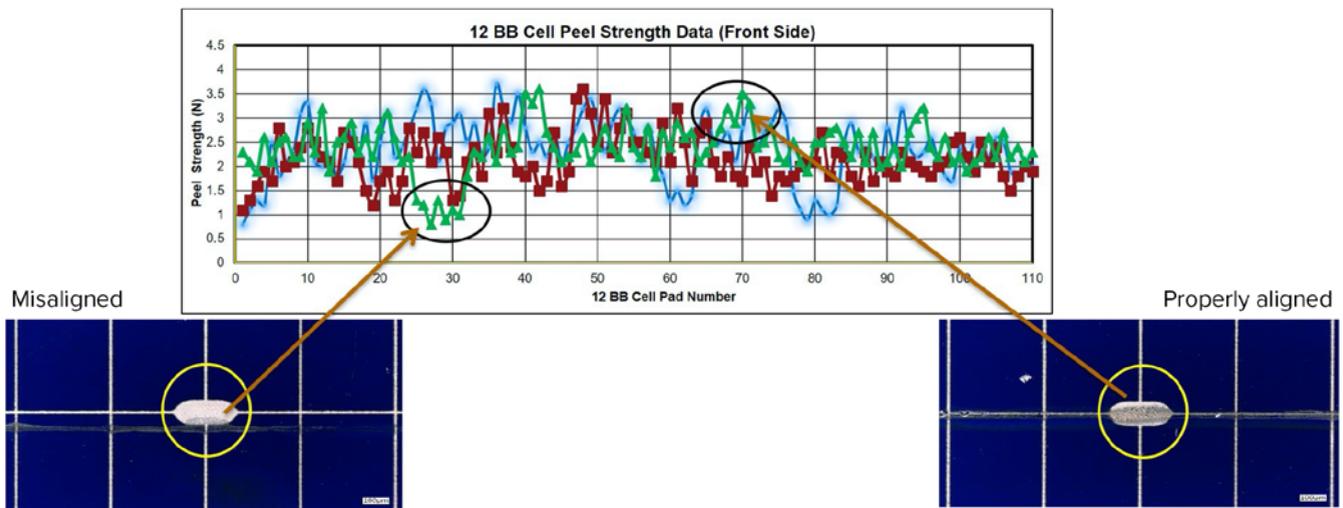


Figure 7: Peel strength of individual silver pads on the front and effect of wire misalignment.

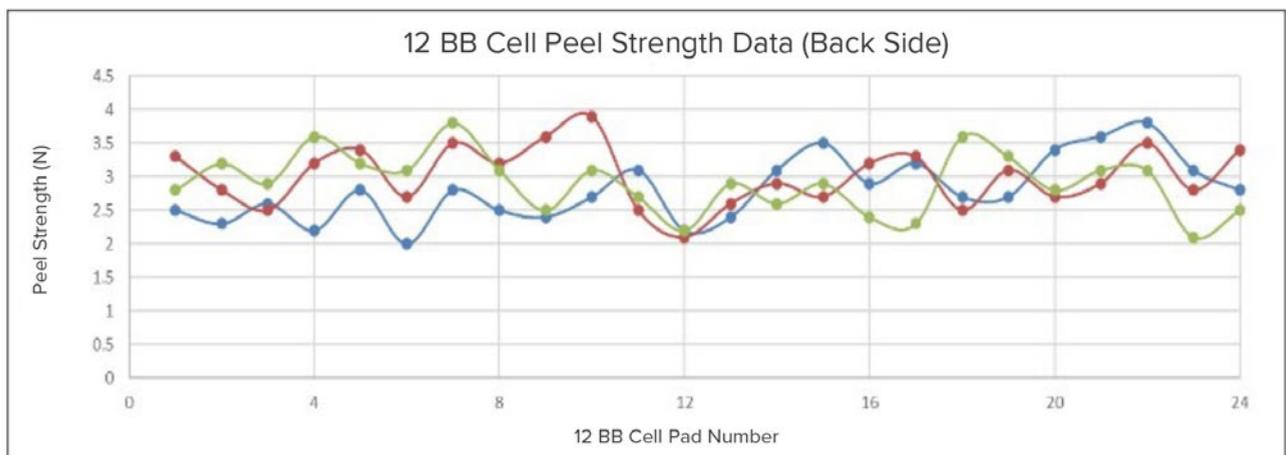


Figure 8: Peel strength of individual silver pads on the back side of the cell.

Table 2: Factors contributing to cold and dry solder joints.	
Factor	Cause of defect
Environment	The temperature difference between day and nighttime
	Failing to bring the solar cells and ribbon at the soldering temperature
Process	Partial melting of solder
	Process is too fast to melt the solder
	Flux burn-out due to high temperature
	Soldering/preheating temperature is too low or too high
Flux	No/insufficient flux due to clogging or pollution
	Flux residue underneath the ribbon
	Insufficient wetting of flux
Wire	No/partial contact between wire and pad
	Wire bowing/crippling

N/mm. A cold joint is one where the solder does not melt completely. It is often characterized by a drastic reduction in peel strength value. Cold joints are unreliable. The solder bond will be poor and, often, power degradation could be seen over a period of time. This defect occurs due to either soldering temperature is too low or soldering time is too short. Less heat transfer and inadequate capillary action leads to the cold soldering. In this case, there is no alloying (joint) between silver pad and wire [20]. Dry joint is a result of inadequate flux or flux burn-out at high temperature. It mostly underlines the flux's inability to remove oxide from the pad

and wire surface. Factors contributing to these defects are given in Table 2.

From the table, it is clear that various factors may have adverse effects on the quality of solder joints. It is, therefore, important to consider the optimized parameters and try to minimize external factors.

Reliability Test Results

Thermal cycle and damp heat test were performed as per IEC standard 61215. IV curve data (of before and after test) was measured using Sinton Instruments IV curve tester. The results are tabulated in Figure 9.

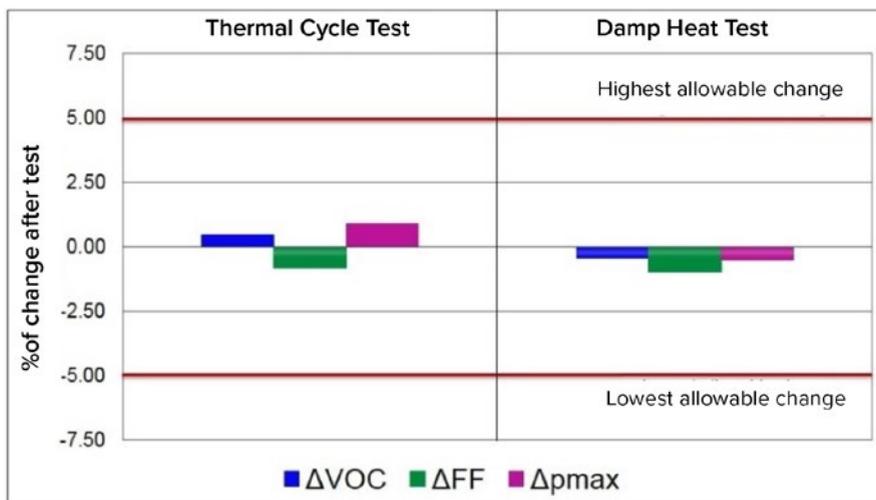


Figure 9: Accelerated aging test results of 100 thermal cycling test and 1000 h damp heat test as per IEC61215.

I-V curve data of before and after testing (for both thermal cycle test and damp heat test) are within the specification limit ($\pm 5\%$). The breakage of cell ribbons or wires is a critical failure mode concerning solar modules. The loss of a ribbon/wire does influence the serial resistance of the module and therewith leads to power degradation. To compare the resulting degradation of a solar module due to ribbon/wire breakage 1-cell-laminates have been deliberately damaged. Similar work was done by Dethlefsen et al ^[22]. Our observations also confirm the higher redundancy of the MBB technology compared to the 5BB cell. The fill factor was reduced by 10% when the crack propagation was 2 bb long. Generally, the MBB technique proves to be by far more robust with respect to interconnection breakage, than the 5BB standard interconnection with 5BB cells. This is easily understandable, as the current transport is much better distributed in the MBB technique.

Conclusion

Factors affecting quality of solder joints in MBB technology are discussed. The soldering challenges arise due to change in technology, process, material, and reliability requirements. It was observed that metallization, solder wire and flux play an important role in determining solder joint strength. Various process parameters including wire alignment have additional effect on solder joint peel strength. Higher solder volume and flux with excellent wetting characteristics found to yield reliable solder joints. When all process testing parameters are optimized peel strength of over 3N with continuous uniform IMC formation observed. MBB panels in such conditions pass reliability testing as per IEC61215 requirement. **SMT007**

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Narahari Pujari is global technology manager-PV at MacDermid Alpha Electronics Solutions.

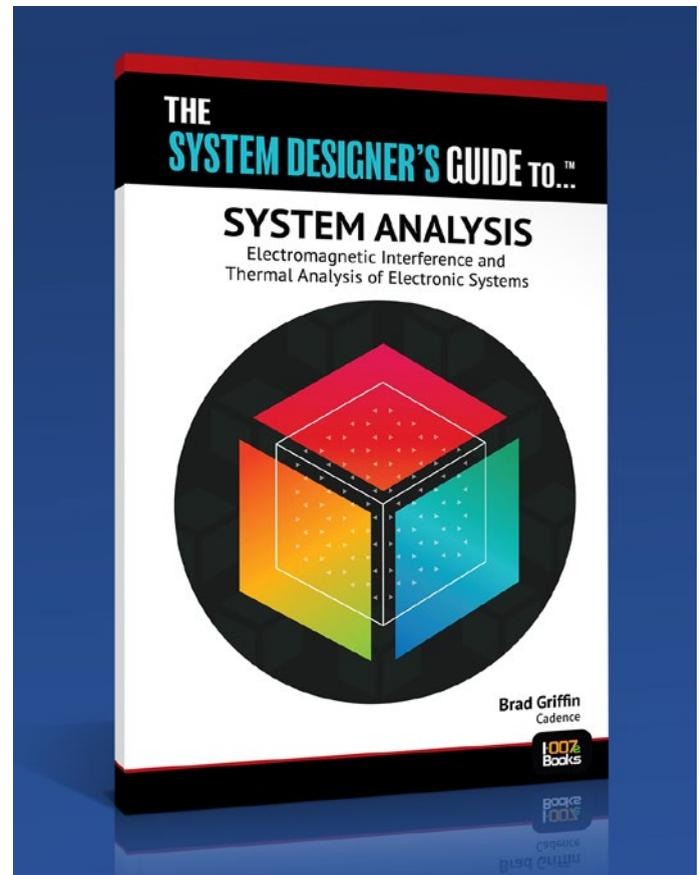
New I-007 eBook Highlights System Analysis

In this latest title from I-007eBooks, readers will learn how system-level analysis of complex and high-speed electronic designs is critical to solve electromagnetic, electrothermal, and electromechanical simulation challenges and to ensure that the system works under wide-ranging operating conditions.

According to signal integrity expert Lee Ritchey, founder and president of Speeding Edge and author of *Right the First Time: A Practical Handbook on High-Speed PCB and System Design*: “Author Brad Griffin offers readers a very good explanation of system-level analysis of complex and high-speed electronic designs. I highly recommend this book for those who are getting started with the design of PCBs and systems that are used in data centers.”

Download your free copy today!

You can also view other titles in our *full library*. *The System Designer’s Guide to...* series is specifically dedicated to educating the printed circuit and systems design sectors and serves as a valuable resource for people seeking the most relevant information available.





Supplier Highlights



AOI Ensures Defect-free PCB Assemblies at BSU ▶

BSU, Inc. incorporates advanced Automated Optical Inspection (AOI) into build process for each and every printed circuit board assembly (PCBA) at its manufacturing facility.

Europlacer Expands Existing Reseller Relationship with Aegis Software ▶

Aegis Software, a global provider of Manufacturing Operations Software (MOM/MES), announced that Europlacer has expanded its 20+ year reseller relationship, for Aegis' FactoryLogix® Digital Manufacturing Engineering software module, to now include China.

Yamaha Motor Releases YRi-V 3D Hybrid AOI System ▶

Yamaha Motor Europe announced that it has launched the YRi-V 3D hybrid automated optical inspection system, which achieves both high speed and high precision in operation, for high-end factories mounting electronic components.

Laserssel Introduces rLSR Mini LED Rework System ▶

Laserssel Co., LTD, a leading provider of laser selective soldering technology, is pleased to introduce its rLSR Mini LED Rework System.

Whizz Systems Installs Crest Ultrasonics' Powersonic ▶

Whizz Systems, Inc., the award-winning premier provider of electronics product design, development, and manufacturing services located in the heart of the Silicon Valley,

announced the addition of a Powersonic™ Benchtop Ultrasonic Cleaner from Crest Ultrasonics.

Murray Percival Co. Offers Automated Soldering Solutions from Apollo Seiko ▶

The Murray Percival Company, the leading supplier to the Midwest's electronics industry, offers automated point soldering systems from Apollo Seiko, including desktop solder robots, in-line soldering robots, and laser soldering robots.

Mycronic Receives Order for Prexision Lite 8 Evo ▶

Mycronic AB has received an order for a Prexision Lite 8 Evo, for deployment in Asia. The order value is in the range of USD \$6-9 million. Delivery of the system is planned for the second quarter of 2023.

CyberOptics Adds New Regional Sales Manager to SMT Americas Team ▶

CyberOptics is pleased to introduce Quintin Armstrong as a new member of the SMT Americas sales team. Quintin will be taking on the role of regional sales manager for the southern USA territories.

Takaya Launches APT-1600FD-SL Dual-Sided Flying Probe Tester ▶

Takaya's APT-1600FD-SL dual-sided flying probe test system for assembled PCBAs delivers both high speed and a larger testing area designed to accommodate large PCBAs for the emerging markets of 5G communications and battery management system applications.



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What is Your Uptime?

Maggie Benson's Journey

by Dr. Ronald C. Lasky, INDIUM CORPORATION

Editor's note: This series of columns is about a fictional character and her electronics company, BE, to demonstrate continuous improvement and education in SMT assembly.

Maggie was never interested in things like makeup and dresses. Instead, she preferred to spend her time playing sports like basketball, baseball, football, and especially golf. Needless to say, Maggie was thrilled when her mother and John's mother agreed to take the lead on planning Maggie and John's wedding. She was also thrilled that her parents approved of John as a future son-in-law, and John's parents approved of her as a future daughter-in-law. While thinking these pleasant thoughts in her office at BE, she remembered she had a meeting coming up in just a few minutes.

After Frank Emory's measurement that line uptime was only 15%, Maggie and John decided that increasing uptime was now an emergency. They chatted with BE's lead technician, Chuck Tower. Chuck was 6 feet 5 inches tall and all of his co-workers called him "The Tower." Chuck had worked for BE for years and seemed to Maggie and John to just be "with it." Maggie set up a meeting for the three of them.

"Chuck, you did the best on the SMT 101 test: nine out of 10. Nice work!" John exclaimed.

"Thanks, Mr. Jennings," Chuck responded.

"It's John," John replied. "Remember, we are a team."

As they began their discussion, Maggie explained that uptime was simply the percent of time that the lines were running.

"Chuck, what do you think our line uptime is?" Maggie asked.

"I'd like to think it was really high, but I'm assuming it must be low since you are asking. Is it about 50%?" Chuck asked.

"Frank gets about 15%," John said.

Chuck turned pale. "That's embarrassing," Chuck groaned. "But how about we try to measure it as precisely as possible?"

"How do you propose doing that?" Maggie asked.

"The junior techs and I will monitor the lines every half hour," Chuck explained. "If the line



Illustration: Sophie Morvan

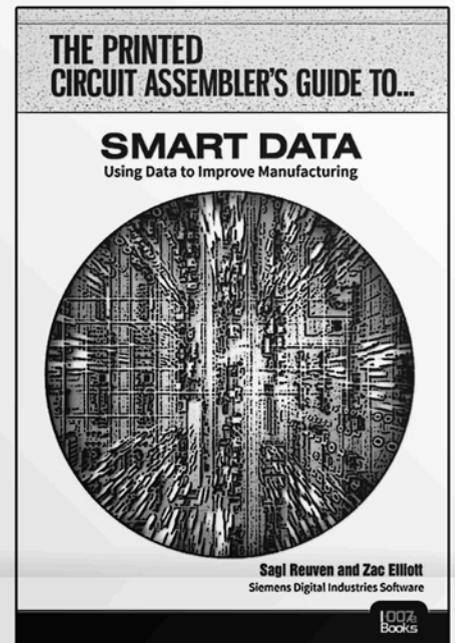
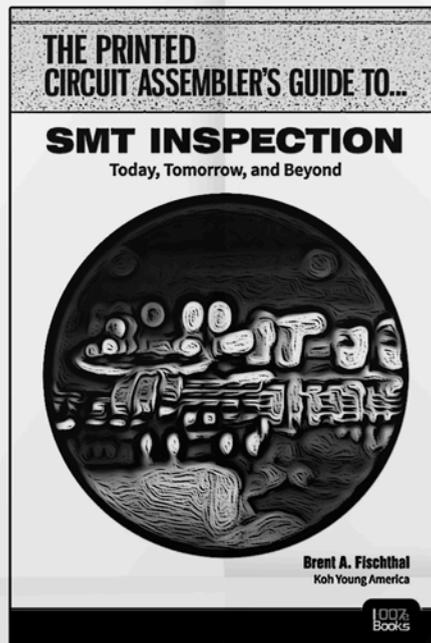
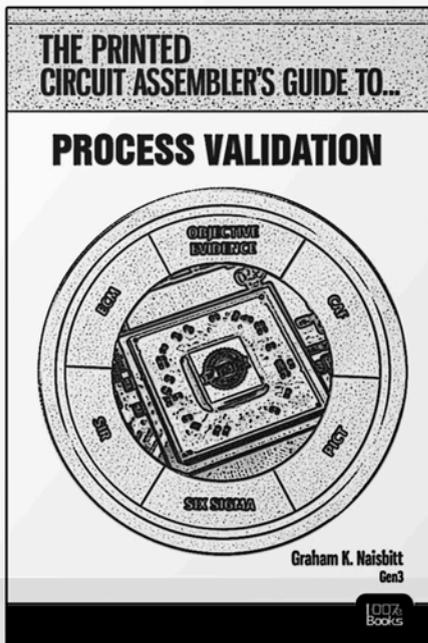
E-BOK*



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STEP 2

STEP 3



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*Some assemblers required

is running, we will put a '1' in an Excel spreadsheet cell; if the line is not running, we will put enter a '0.' Let's do it for two weeks and see what we get."

Maggie and John were impressed. They then discussed with Chuck how BE did changeovers. Handling changeovers was important as BE was a high-mix business, and some of their product runs were less than 100 PCBs. The following points were made:

Strengths

1. Each line had three white boards on which the operators would write the status of preparation for the components, stencil, solder paste, etc., for the next three jobs on the line.

Opportunities for Improvement (OFI)

1. Feeder racks, though available, were not used. They were in storage, and there was never time to learn how to use them.
2. Even with the white boards, there was usually "shopping time" required to locate a needed component or a stencil.
3. There was not a sense of urgency regarding replenishing solder paste or components on feeders. Often when these actions were needed, the operators would use this time to take a break, hence stopping the line.
4. The lines were shut down for the 30-minute lunch hour, but the actual

time the line was down was much more than 30 minutes.

After discussing all of this, Chuck was despondent.

"I'm embarrassed that I thought the uptime might be in the 50% range," Chuck lamented. "Clearly, with all of these OFIs, Frank's number is probably more accurate."

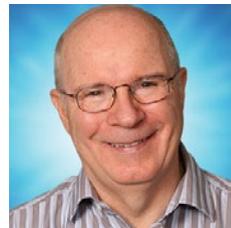
"Don't feel too bad, Chuck," Maggie said, sympathetically. "Professor Coleman has told us that most people think their line uptime is high; sometimes they think it is 95%, when it is actually only 10%."

"When you think about it, the line running is the only thing that makes us money. If our uptime is poor, we are losing our shirt, money-wise," Chuck noted.

With that statement, Maggie and John knew that Chuck Tower would be a key person in the drive for continuous improvement.

Stay tuned to see what BE's uptime is.

What is your uptime? **SMT007**



Ronald C. Lasky is an instructional professor of engineering for the Thayer School of Engineering at Dartmouth College, and senior technologist at Indium Corporation.

To read past columns, or contact Lasky, [click here](#).

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Editor's Picks from SMT007.com

1 X-Rayted Files: Tales from the Files of Lithium-ion Batteries ▶

Lithium-ion batteries have, in part, enabled the continued miniaturization of the devices we love. They have also played an important role in making practical electric cars a reality. But like other approaches high density energy storage, they do present risks.



Bill Cardoso

2 A Framework for Large-Scale AI-Assisted Quality Inspection Implementation in Manufacturing Using Edge Computing ▶

This paper discusses in detail the challenges in large-scale deployment of AI models for quality inspection operation and introduces a framework for large-scale AI-assisted quality inspection in manufacturing environment using edge computing architecture. The framework focuses on IT architectural deci-

sions to fulfill the OT requirement, including user experience in the quality inspection ecosystem.

3 SMTA Offers New Membership Structure ▶

SMTA membership is being revamped for Jan. 1, 2022. This interview details those changes with SMTA President Martin Anselm and Membership Vice President Rob Boguski.



Martin Anselm

4 Her Voice: Advice From a Trailblazer ▶

We all have people we look up to—our heroes—but it's not often that we get to meet them and learn from them. But that's what happened to columnist Christine Davis when she met Bonnie Fena, a true trailblazer in EMS.



Christine Davis

5 Cleanliness Behind Many Assembly Challenges ▶

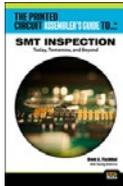
Eric Camden says nobody knows your board like you do, so it's time for assemblers to start doing their own cleanliness testing and due diligence, and stop relying on outside organizations to determine how clean their boards need to be.



Eric Camden

6 Excerpt: The Printed Circuit Assembler's Guide to... SMT Inspection: Today, Tomorrow, and Beyond, Chapter 5 ▶

Reliable AOI methods have become powerful, economical complements to traditional test strategies. AOI can be used successfully as a process monitoring tool for measuring printing, placement, and reflow performance. Yet, a single inspection system has limitations, especially when there is limited or no communication with the balance of the line. In this setup, it simply cannot optimize a printed circuit board assembly process.

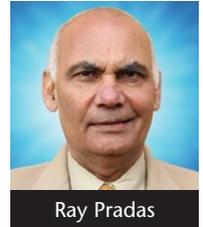


7 Smart Factory Insights: Hands-off Manufacturing ▶

The use of automation has not eliminated causes of unreliability, nor defects, which ironically continue to drive the need for humans to be hands-on, even as part of SMT operations. There is clearly something missing, so cue our digital twin.

8 SMT Solver: Optimizing Your Manufacturing Operations ▶

If you take a 50,000-foot view of the subject, we should ask: What is the focus of manufacturing operations? The way columnist Ray Prasad sees it, there are only two things: quality and delivery. This is essentially the focus on the factory floor. Why? Because the customer cares about getting a quality product and getting it on time.



Ray Prasad

9 State of the Coating Industry ▶

Several trends have really stood out as the first half of 2021 comes to a close. First, 150°C appears to have become the “new normal” for the maximum required operating temperature of conformal coatings for automotive use. This is an increase from 85°C or 120°C on the last generation of products.



Phil Kinner

10 ACDi Acquires Enhanced Manufacturing Solutions ▶

ACDi, a leading provider of electronics manufacturing services, announced it has acquired Enhanced Manufacturing Solutions, LLC to expand its geographical footprint, increase manufacturing capacity, and complement service and product offerings.



For the latest news and information, visit [SMT007.com](https://www.smt007.com). Subscribe to our newsletters or premium content at [my I-Connect007](https://www.myI-Connect007.com).

Career Opportunities



Is your team growing?

Find industry-experienced candidates at I-Connect007.

For just \$750, your 200-word, full-column ad will appear in the "career opportunities" section of all three of our monthly magazines, reaching circuit board designers, fabricators, assemblers, OEMs, and suppliers.

In addition, your ad will be featured in at least one of our newsletters, and your posting will appear on our jobConnect007.com board, which is also promoted in every newsletter.

Potential candidates can click on your ad and submit a resume directly to the email address you provide or be directed to the URL of your choice. If you wish to continue beyond the first month, the price is the same per month.

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Career Opportunities



PCB Field Engineer— North America Operations

ICAPE Group is a European leader for printed circuits boards and custom-made electro-mechanical parts. Headquartered in Paris, France, we have over 500 employees located in more than 70 countries serving our +2500 customers.

To support our growth in the American market, we are looking for a PCB Field Engineer.

You will work in our North America technical center, including our U.S. technical laboratory, and will be responsible for providing technical and quality support to our American sales team.

You will have direct customer contact during all phases of the sales process and provide follow-on support as required.

RESPONSIBILITIES INCLUDE

- Feasibility recommendations
- Fabricator questions and liaison
- Quality resolutions
- Technical explanation (for the customer) of proposals, laboratory analysis or technology challenges

REQUIREMENTS

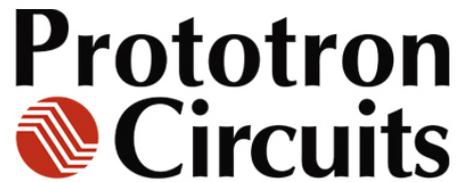
- Engineering degree or equivalent industry experience
- 5 years' experience with PCB manufacturing (including CAM)
- Excellent technical understanding of PCBs
- Experience with quality tools (FAI, PPAP and 8-D)
- Good communication skills (written and oral)

Communication skills are essential to assist the customer with navigation of the complex process of matching the PCB to the application.

SALARY

Competitive, based on profile and experience. Position is full time in Indianapolis, Ind.

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Prototron Circuits, a market-leading, quick-turn PCB shop, is looking for sales representatives for all territories.

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or email to

danbbeaulieu@aol.com

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Career Opportunities



Rewarding Careers

Take advantage of the opportunities we are offering for careers with a growing test engineering firm. We currently have several openings at every stage of our operation.

The Test Connection, Inc. is a test engineering firm. We are family owned and operated with solid growth goals and strategies. We have an established workforce with seasoned professionals who are committed to meeting the demands of high-quality, low-cost and fast delivery.

TTCI is an Equal Opportunity Employer. We offer careers that include skills-based compensation. We are always looking for talented, experienced test engineers, test technicians, quote technicians, electronics interns, and front office staff to further our customer-oriented mission.

Associate Electronics Technician/Engineer (ATE-MD)

TTCI is adding electronics technician/engineer to our team for production test support.

- Candidates would operate the test systems and inspect circuit card assemblies (CCA) and will work under the direction of engineering staff, following established procedures to accomplish assigned tasks.
- Test, troubleshoot, repair, and modify developmental and production electronics.
- Working knowledge of theories of electronics, electrical circuitry, engineering mathematics, electronic and electrical testing desired.
- Advancement opportunities available.
- Must be a US citizen or resident.

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Test Engineer (TE-MD)

In this role, you will specialize in the development of in-circuit test (ICT) sets for Keysight 3070 (formerly HP) and/or Teradyne (formerly GenRad) TestStation/228X test systems.

- Candidates must have at least three years of experience with in-circuit test equipment. A candidate would develop and debug our test systems and install in-circuit test sets remotely online or at customer's manufactur-

ing locations nationwide.

- Candidates would also help support production testing and implement Engineering Change Orders and program enhancements, library model generation, perform testing and failure analysis of assembled boards, and other related tasks.
- Some travel required and these positions are available in the Hunt Valley, Md., office.

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Sr. Test Engineer (STE-MD)

- Candidate would specialize in the development of in-circuit test (ICT) sets for Keysight 3070 (formerly Agilent & HP), Teradyne/GenRad, and Flying Probe test systems.
- Strong candidates will have more than five years of experience with in-circuit test equipment. Some experience with flying probe test equipment is preferred. A candidate would develop, and debug on our test systems and install in-circuit test sets remotely online or at customer's manufacturing locations nationwide.
- Proficient working knowledge of Flash/ISP programming, MAC Address and Boundary Scan required. The candidate would also help support production testing implementing Engineering Change Orders and program enhancements, library model generation, perform testing and failure analysis of assembled boards, and other related tasks. An understanding of stand-alone boundary scan and flying probe desired.
- Some travel required. Positions are available in the Hunt Valley, Md., office.

Contact us today to learn about the rewarding careers we are offering. Please email resumes with a short message describing your relevant experience and any questions to careers@ttci.com. Please, no phone calls.

We proudly serve customers nationwide and around the world.

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Career Opportunities



Arlon EMD, located in Rancho Cucamonga, California, is currently interviewing candidates for open positions in:

- **Engineering**
- **Quality**
- **Various Manufacturing**

All interested candidates should contact Arlon's HR department at 909-987-9533 or email resumes to careers.ranch@arlonemd.com.

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

Our facility employs state of the art production equipment engineered to provide cost-effective and flexible manufacturing capacity allowing us to respond quickly to customer requirements while meeting the most stringent quality and tolerance demands. Our manufacturing site is ISO 9001: 2015 registered, and through rigorous quality control practices and commitment to continual improvement, we are dedicated to meeting and exceeding our customers' requirements.

For additional information please visit our website at www.arlonemd.com

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Logistics Assistant

Koh Young America is looking for a Logistics Assistant to assist and oversee our supply chain operations. Working alongside a Logistics Specialist, you will coordinate processes to ensure smooth operations using a variety of channels to maximize efficiency. You must be an excellent communicator and negotiator well-versed in supply chain management principles and practices. Also, you should be meticulous with a focus on customer satisfaction. These attributes are ideally complemented by a Bachelor's in Supply Chain Management or equivalent professional experience in the manufacturing industry.

This position is in our Duluth, Georgia, headquarters, where we serve our customers within North and South America. We offer health, dental, vision, and life insurance with no employee premiums, including dependent coverage. Additionally, we provide a 401K retirement plan with company matching, plus a generous PTO policy with paid holidays.

Koh Young Technology, founded in 2002 in Seoul, South Korea, is the world leader in 3D measurement and inspection technology used in the production of microelectronics assemblies. Using patented 3D technology, Koh Young provides best-in-class products in Solder Paste Inspection (SPI) and Automated Optical Inspection (AOI) for electronics manufacturers worldwide.

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Career Opportunities



MANUFACTURERS OF QUALITY PRINTED CIRCUIT BOARDS

Maintenance Technician

Inspects work-related conditions to determine compliance with prescribed operating and safety standards. Operates power-driven machinery and uses equipment and tools commonly used to maintain facilities and equipment. Replace filters, belts, and additional parts for repairs and preventive maintenance. Moves objects weighing up to 150 lbs. using a hand truck or pulley. Cleans work area and equipment. Works with cleaning fluids, agents, chemicals, and paints using protective gear. Works at elevations greater than ten feet, climbing ladders, while repairing or maintaining building structures and equipment. Assists skilled maintenance technicians/workers in more complex tasks and possible after-hours emergency repairs. Must meet scheduling and attendance requirements.

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Plating Operator

Plating operator for printed circuit boards. No experience necessary, will train. Must be able to work with chemicals, lift up to 50 pounds, and have good math skills. Minimum high school/GED or equivalent. All shifts (1st, 2nd, 3rd), 8 hours per day minimum, Monday thru Friday. Saturday and Sunday work is common allowing for steady overtime pay.

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MANUFACTURERS OF QUALITY PRINTED CIRCUIT BOARDS

Water Treatment Operator

Responsible for operating waste treatment plant, our operation that converts wastewater in drains and sewers into a form that's metal free to release into the environment.

Control equipment and monitor processes that remove metals from wastewater. Run tests to make sure that the processes are working correctly. Keep records of water quality and pH. Operate and maintain the pumps and motors that move water and wastewater through filtration systems. Read meters and gauges to make sure plant equipment is working properly. Take samples and run tests to determine the quality of the water being produced. Adjust the amount of chemicals being added to the water and keep records that document compliance.

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Drilling Operator

Drilling operator for printed circuit boards. Minimum 2 years of experience. Minimum high school/GED or equivalent.

All Shifts (1st, 2nd, 3rd), 8 hours per day minimum, Monday thru Friday. Saturday and Sunday work is common allowing for overtime pay.

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Career Opportunities



Technical Writer (Full-time, Remote)

SEO company seeking a technical writer in the area of PCB design & manufacturing. We provide Search Engine Optimization and Thought Leadership services for well-managed, ethical companies. Our team produces high-level content for companies who are leaders in their industry. We are seeking writers who are well-rounded researchers with a particular interest in electrical engineering and impeccable writing skills.

Ideal candidates are seasoned writers with practical experience in electronic systems development in one or more of the following areas:

- Circuit simulation
- Schematic capture
- PCB layout
- Design analysis
- PCB fabrication
- PCB assembly
- PCB testing

Qualifications:

- Technical writing experience with a proven track record of independent research and content development. Experience in data sheet, report, or white-paper writing preferred.
- Electronic technician or engineering degree, ideally in electrical engineering, computer science, or mechanical engineering.
- Industry experience in PCB design, testing, or manufacturing.
- Punctuality, professionalism, and excellent time management skills.
- A reliable internet connection and computer

Salary & Benefits:

This is a full-time telecommuting position with a starting salary range of \$62,000 to \$68,000 annually. Benefits PTO, sick time, 401K, health and dental coverage, and more!

To see the full job description and apply, please click the link below.

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Marketing Coordinator/Writing Strategist: Embedded Software

Location: Portland, Oregon or USA (remote)

Job Number: 242982

Seeking a technology communications change maker! Siemens Digital Industries Software is looking for a content creator for its embedded software group. The ideal candidate for the Brand Marketing coordinator/writing strategist position will work closely with engineers and managers to write, edit and produce compelling technology marketing content (magazine articles, blogs, technology papers, multi-media, customer success stories and promotional materials). Do you possess creative energy and enjoy storytelling with an energetic team?

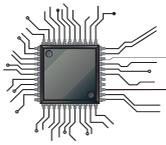
Requirements:

- Strong writing and editing skills
- Education and/or experience in technology, science, journalism and/or English
- A technical background or experience (such as a BS or an associate's degree in engineering or computer science) is preferred
- 1-3 years of experience in writing about technology solutions
- Basic knowledge of online publications, digital platforms and social media is useful to meet project specifications in a fast-paced environment
- Ability to research and collect data, repurpose existing materials, collaborate with subject matter experts, and translate technical information into compelling marketing communications content that engage audiences

Creative materials will be used globally, in a high-energy environment, supporting the world's leading industrial software company.

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Career Opportunities



MivaTek

Global

Product Manager

MivaTek Global is preparing for a major market and product offering expansion. Miva's new NG3 and DART technologies have been released to expand the capabilities of Miva's industry-leading LED DMD direct write systems in PCB and Microelectronics. MivaTek Global is looking for a technology leader that can be involved guiding this major development.

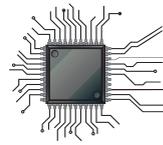
The product manager role will serve as liaison between the external market and the internal design team. Leadership level involvement in the direction of new and existing products will require a diverse skill set. Key role functions include:

- **Sales Support:** Recommend customer solutions through adaptations to Miva products
- **Design:** Be the voice of the customer for new product development
- **Quality:** Verify and standardize product performance testing and implementation
- **Training:** Conduct virtual and on-site training
- **Travel:** Product testing at customer and factory locations

Use your 8 plus years of experience in either the PCB or Microelectronic industry to make a difference with the leader in LED DMD direct imaging technology. Direct imaging, CAM, AOI, or drilling experience is a plus but not required.

For consideration, send your resume to N.Hogan@MivaTek.Global. For more information on the company see www.MivaTek.Global or www.Mivatec.com.

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MivaTek

Global

Field Service Technician

MivaTek Global is focused on providing a quality customer service experience to our current and future customers in the printed circuit board and microelectronic industries. We are looking for bright and talented people who share that mindset and are energized by hard work who are looking to be part of our continued growth.

Do you enjoy diagnosing machines and processes to determine how to solve our customers' challenges? Your 5 years working with direct imaging machinery, capital equipment, or PCBs will be leveraged as you support our customers in the field and from your home office. Each day is different, you may be:

- Installing a direct imaging machine
- Diagnosing customer issues from both your home office and customer site
- Upgrading a used machine
- Performing preventive maintenance
- Providing virtual and on-site training
- Updating documentation

Do you have 3 years' experience working with direct imaging or capital equipment? Enjoy travel? Want to make a difference to our customers? Send your resume to N.Hogan@MivaTek.Global for consideration.

More About Us

MivaTek Global is a distributor of Miva Technologies' imaging systems. We currently have 55 installations in the Americas and have machine installations in China, Singapore, Korea, and India.

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Career Opportunities



A Flex Company

Sheldahl, a leading provider of flexible interconnect products and electronic materials, is seeking candidates to join their diverse and skilled team.

We are looking for people who demonstrate:

- Intense collaboration
- Passionate customer focus
- Thoughtful, fast, disciplined execution
- Tenacious commitment to continuous improvement
- Relentless drive to win

Positions in America include:

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Candidate will provide timely cost estimation and project budget definition, be responsible for maintaining customer relations, participate in meetings, etc.

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Program Manager – Specialty Films

Candidate will work with our Specialty Films in the Aerospace, Medical, and Commercial Aviation markets providing timely cost estimation and project budget definition, maintaining customer relations, participate in meetings, etc.

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Business Development Manager – North America

Candidate will provide leadership in the planning, design and implementation of customers' specific business plans and will provide vision, penetration strategies and tactics to executive managers in order to develop and drive external and internal senior-level relationships.

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A Flex Company

Sheldahl, a leading provider of flexible interconnect products and electronic materials, is seeking candidates to join their diverse and skilled team.

We are looking for people who demonstrate:

- Intense collaboration
- Passionate customer focus
- Thoughtful, fast, disciplined execution
- Tenacious commitment to continuous improvement
- Relentless drive to win

Positions in Europe include:

Business Development Manager – France

Seeking out-of-the-box thinkers to help us take the ordinary to the extraordinary by cultivating current customer relationships and developing new business opportunities with our European team, based in France.

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Business Development Manager – Germany

Seeking out-of-the-box thinkers to help us take the ordinary to the extraordinary by cultivating current customer relationships and developing new business opportunities with our European team, based in Germany.

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Career Opportunities



ventec
INTERNATIONAL GROUP
騰輝電子

Technical Support/ Sales Engineer, UK

We are looking to expand our UK technical & sales support team. As a technical support/sales engineer (home office/Leamington Spa) you will assist potential and current customers in appreciating the benefits of using--and optimizing the use of--Ventec materials in their printed circuit board manufacturing processes, and so enhance customer loyalty and satisfaction, spread the use of Ventec materials, and grow sales. You will provide a two-way channel of technical communication between Ventec's production facilities and UK/European customers.

Skills and abilities required for the role

- HNC, HND, degree or equivalent in a technical/scientific discipline
- Sales experience/negotiating skills
- Printed circuit board industry experience an advantage
- Good written & verbal communications skills
- Ability to work in an organized, proactive and enthusiastic way
- Ability to work well both in a team and independently
- Good user knowledge of common Microsoft Office programs
- Full driving license essential

What's on Offer

- Excellent salary and benefits commensurate with experience

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

Please forward your resume to
anthony.jackson@ventec-europe.com

[apply now](#)



U.S. CIRCUIT

Plating Supervisor

Escondido, California-based PCB fabricator U.S. Circuit is now hiring for the position of plating supervisor. Candidate must have a minimum of five years' experience working in a wet process environment. Must have good communication skills, bilingual is a plus. Must have working knowledge of a plating lab and hands-on experience running an electrolytic plating line. Responsibilities include, but are not limited to, scheduling work, enforcing safety rules, scheduling/maintaining equipment and maintenance of records.

Competitive benefits package. Pay will be commensurate with experience.

Mail to:
mfariba@uscircuit.com

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Career Opportunities

SIEMENS

Siemens EDA Sr. Applications Engineer

Support consultative sales efforts at world's leading semiconductor and electronic equipment manufacturers. You will be responsible for securing EM Analysis & Simulation technical wins with the industry-leading HyperLynx Analysis product family as part of the Xpedition Enterprise design flow.

Will deliver technical presentations, conduct product demonstrations and benchmarks, and participate in the development of account sales strategies leading to market share gains.

- PCB design competency required
- BEE, MSEE preferred
- Prior experience with Signal Integrity, Power Integrity, EM & SPICE circuit analysis tools
- Experience with HyperLynx, Ansys, Keysight and/or Sigrity
- A minimum of 5 years' hands-on experience with EM Analysis & Simulation, printed circuit board design, engineering technology or similar field
- Moderate domestic travel required
- Possess passion to learn and perform at the cutting edge of technology
- Desire to broaden exposure to the business aspects of the technical design world
- Possess a demonstrated ability to build strong rapport and credibility with customer organizations while maintaining an internal network of contacts
- Enjoy contributing to the success of a phenomenal team

***Qualified applicants will not require employer-sponsored work authorization now or in the future for employment in the United States. Qualified Applicants must be legally authorized for employment in the United States.*

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American Standard Circuits

Creative Innovations In Flex, Digital & Microwave Circuits

CAD/CAM Engineer

Summary of Functions

The CAD/CAM engineer is responsible for reviewing customer supplied data and drawings, performing design rule checks and creating manufacturing data, programs, and tools required for the manufacture of PCB.

Essential Duties and Responsibilities

- Import customer data into various CAM systems.
- Perform design rule checks and edit data to comply with manufacturing guidelines.
- Create array configurations, route, and test programs, penalization and output data for production use.
- Work with process engineers to evaluate and provide strategy for advanced processing as needed.
- Itemize and correspond to design issues with customers.
- Other duties as assigned.

Organizational Relationship

Reports to the engineering manager. Coordinates activities with all departments, especially manufacturing.

Qualifications

- A college degree or 5 years' experience is required. Good communication skills and the ability to work well with people is essential.
- Printed circuit board manufacturing knowledge.
- Experience using CAM tooling software, Orbotech GenFlex®.

Physical Demands

Ability to communicate verbally with management and coworkers is crucial. Regular use of the telephone and e-mail for communication is essential. Sitting for extended periods is common. Hearing and vision within normal ranges is helpful for normal conversations, to receive ordinary information and to prepare documents.

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Career Opportunities

Now Hiring

Director of Process Engineering

A successful and growing printed circuit board manufacturer in Orange County, CA, has an opening for a director of process engineering.

Job Summary:

The director of process engineering leads all engineering activities to produce quality products and meet cost objectives. Responsible for the overall management, direction, and coordination of the engineering processes within the plant.

Duties and Responsibilities:

- Ensures that process engineering meets the business needs of the company as they relate to capabilities, processes, technologies, and capacity.
- Stays current with related manufacturing trends. Develops and enforces a culture of strong engineering discipline, including robust process definition, testing prior to production implementation, change management processes, clear manufacturing instructions, statistical process monitoring and control, proactive error proofing, etc.
- Provides guidance to process engineers in the development of process control plans and the application of advanced quality tools.
- Ensures metrics are in place to monitor performance against the goals and takes appropriate corrective actions as required. Ensures that structured problem-solving techniques are used and that adequate validation is performed for any issues being address or changes being made. Develops and validates new processes prior to incorporating them into the manufacturing operations.
- Strong communication skills to establish priorities, work schedules, allocate resources, complete required information to customers, support quality system, enforce company policies and procedures, and utilize resources to provide the greatest efficiency to meet production objectives.

Education and Experience:

- Master's degree in chemical engineering or engineering is preferred.
- 10+ years process engineering experience in an electronics manufacturing environment, including 5 years in the PCB or similar manufacturing environment.
- 7+ years of process engineering management experience, including 5 years of experience with direct responsibility for meeting production throughput and quality goals.

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Now Hiring

Process Engineering Manager

A successful and growing printed circuit board manufacturer in Orange County, CA, has an opening for a process engineering manager.

Job Summary:

The process engineering manager coordinates all engineering activities to produce quality products and meet cost objectives. Responsible for the overall management, direction, and coordination of the engineering team and leading this team to meet product requirements in support of the production plan.

Duties and Responsibilities:

- Ensures that process engineering meets the business needs of the company as they relate to capabilities, processes, technologies, and capacity.
- Stays current with related manufacturing trends. Develops and enforces a culture of strong engineering discipline, including robust process definition, testing prior to production implementation, change management processes, clear manufacturing instructions, statistical process monitoring and control, proactive error proofing, etc.
- Ensures metrics are in place to monitor performance against the goals and takes appropriate corrective actions as required. Ensures that structured problem-solving techniques are used and that adequate validation is performed for any issues being address or changes being made. Develops and validates new processes prior to incorporating into the manufacturing operations

Education and Experience:

- Bachelor's degree in chemical engineering or engineering is preferred.
- 7+ years process engineering experience in an electronics manufacturing environment, including 3 years in the PCB or similar manufacturing environment.
- 5+ years of process engineering management experience, including 3 years of experience with direct responsibility for meeting production throughput and quality goals.

apply now

Career Opportunities



Sales Account Manager

Sales Account Management at Lenthor Engineering is a direct sales position responsible for creating and growing a base of customers that purchase flexible and rigid flexible printed circuits. The account manager is in charge of finding customers, qualifying the customer to Lenthor Engineering and promoting Lenthor Engineering's capabilities to the customer. Leads are sometimes referred to the account manager from marketing resources including trade shows, advertising, industry referrals and website hits. Experience with military printed circuit boards (PCBs) is a definite plus.

Responsibilities

- Marketing research to identify target customers
- Identifying the person(s) responsible for purchasing flexible circuits
- Exploring the customer's needs that fit our capabilities in terms of:
 - Market and product
 - Circuit types used
 - Competitive influences
 - Philosophies and finance
 - Quoting and closing orders
 - Providing ongoing service to the customer
 - Develop long-term customer strategies to increase business

Qualifications

- 5-10 years of proven work experience
- Excellent technical skills

Salary negotiable and dependent on experience. Full range of benefits.

Lenthor Engineering, Inc. is a leader in flex and rigid-flex PWB design, fabrication and assembly with over 30 years of experience meeting and exceeding our customers' expectations.

Contact Oscar Akbar at: hr@lenthor.com

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Senior Process Engineer

Job Description

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

Position Duties

- Senior process engineer's role is to monitor process performance through tracking and enhance through continuous improvement initiatives. Process engineer implements continuous improvement programs to drive up yields.
- Participate in the evaluation of processes, new equipment, facility improvements and procedures.
- Improve process capability, yields, costs and production volume while maintaining safety and improving quality standards.
- Work with customers in developing cost-effective production processes.
- Engage suppliers in quality improvements and process control issues as required.
- Generate process control plan for manufacturing processes, and identify opportunities for capability or process improvement.
- Participate in FMEA activities as required.
- Create detailed plans for IQ, OQ, PQ and maintain validated status as required.
- Participate in existing change control mechanisms such as ECOs and PCRs.
- Perform defect reduction analysis and activities.

Qualifications

- BS degree in engineering
- 5-10 years of proven work experience
- Excellent technical skills

Salary negotiable and dependent on experience. Full range of benefits.

Lenthor Engineering, Inc. is the leader in Flex and Rigid-Flex PWB design, fabrication and assembly with over 30 years of experience meeting and exceeding our customers' expectations.

Contact Oscar Akbar at: hr@lenthor.com

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Career Opportunities



SMT Field Technician Hatboro, PA

Manncorp, a leader in the electronics assembly industry, is looking for an additional SMT Field Technician to join our existing East Coast team and install and support our wide array of SMT equipment.

Duties and Responsibilities:

- Manage on-site equipment installation and customer training
- Provide post-installation service and support, including troubleshooting and diagnosing technical problems by phone, email, or on-site visit
- Assist with demonstrations of equipment to potential customers
- Build and maintain positive relationships with customers
- Participate in the ongoing development and improvement of both our machines and the customer experience we offer

Requirements and Qualifications:

- Prior experience with SMT equipment, or equivalent technical degree
- Proven strong mechanical and electrical troubleshooting skills
- Proficiency in reading and verifying electrical, pneumatic, and mechanical schematics/drawings
- Travel and overnight stays
- Ability to arrange and schedule service trips

We Offer:

- Competitive Pay
- Health and dental insurance
- Retirement fund matching
- Continuing training as the industry develops

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SMT Operator Hatboro, PA

Manncorp, a leader in the electronics assembly industry, is looking for a **surface-mount technology (SMT) operator** to join their growing team in Hatboro, PA!

The **SMT operator** will be part of a collaborative team and operate the latest Manncorp equipment in our brand-new demonstration center.

Duties and Responsibilities:

- Set up and operate automated SMT assembly equipment
- Prepare component kits for manufacturing
- Perform visual inspection of SMT assembly
- Participate in directing the expansion and further development of our SMT capabilities
- Some mechanical assembly of lighting fixtures
- Assist Manncorp sales with customer demos

Requirements and Qualifications:

- Prior experience with SMT equipment or equivalent technical degree preferred; will consider recent graduates or those new to the industry
- Windows computer knowledge required
- Strong mechanical and electrical troubleshooting skills
- Experience programming machinery or demonstrated willingness to learn
- Positive self-starter attitude with a good work ethic
- Ability to work with minimal supervision
- Ability to lift up to 50 lbs. repetitively

We Offer:

- Competitive pay
- Medical and dental insurance
- Retirement fund matching
- Continued training as the industry develops

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Career Opportunities

INSULECTRO



Are You Our Next Superstar?!

Insulectro, the largest national distributor of printed circuit board materials, is looking to add superstars to our dynamic technical and sales teams. We are always looking for good talent to enhance our service level to our customers and drive our purpose to enable our customers build better boards faster. Our nationwide network provides many opportunities for a rewarding career within our company.

We are looking for talent with solid background in the PCB or PE industry and proven sales experience with a drive and attitude that match our company culture. This is a great opportunity to join an industry leader in the PCB and PE world and work with a terrific team driven to be vital in the design and manufacture of future circuits.

View our opportunities at
Insulectro Careers ([jobvite.com](https://www.jobvite.com))

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Multiple Positions

Innovative Circuits, a quick-turn, high mix, low-volume PCB manufacturer located in Alpharetta, Georgia, is growing and looking for talented individuals to join the team.

Front End Engineering Manager

Oversee CAM, programming/production engineering and quoting departments. Ideal candidates will have 15 years' experience working in a printed circuit board front-end department with flex and rigid flex circuit board construction.

Process Engineer

Responsible for the implementation and maintenance of chemical and/or mechanical processes used to produce flex circuits, rigid flex and rigid printed circuit boards.

Third Shift Production Manager

Oversee third shift productions workers, product schedule and reporting.

Wet Lab Tech

Perform all lab analysis using burettes, pipettes, pH/ion meters, atomic absorption spectrophotometer, laboratory balance, hydrometers, hull cells, CVS, and all other lab-related equipment.

CAM Operator

Inspect, modify, and contribute to the initial development of producing flex circuits, rigid flex and rigid printed circuit boards based upon customer requirements and data files.

Quality Inspector

Responsible for verifying that the product meets customer requirements prior to shipping.

Wastewater Technician

Operate, monitor, maintain and troubleshoot the wastewater treatment facility and its processes.

Production Worker

Machine operator and light chemistry in a PCB manufacturing environment.

Please visit the link below to view our opportunities and apply.

[apply now](#)

Career Opportunities



BLACKFOX

Premier Training & Certification

IPC Instructor

Longmont, CO; Phoenix, AZ;
U.S.-based remote

*Independent contractor,
possible full-time employment*

Job Description

This position is responsible for delivering effective electronics manufacturing training, including IPC Certification, to students from the electronics manufacturing industry. IPC instructors primarily train and certify operators, inspectors, engineers, and other trainers to one of six IPC Certification Programs: IPC-A-600, IPC-A-610, IPC/WHMA-A-620, IPC J-STD-001, IPC 7711/7721, and IPC-6012.

IPC instructors will conduct training at one of our public training centers or will travel directly to the customer's facility. A candidate's close proximity to Longmont, CO, or Phoenix, AZ, is a plus. Several IPC Certification Courses can be taught remotely and require no travel.

Qualifications

Candidates must have a minimum of five years of electronics manufacturing experience. This experience can include printed circuit board fabrication, circuit board assembly, and/or wire and cable harness assembly. Soldering experience of through-hole and/or surface-mount components is highly preferred.

Candidate must have IPC training experience, either currently or in the past. A current and valid certified IPC trainer certificate holder is highly preferred.

Applicants must have the ability to work with little to no supervision and make appropriate and professional decisions.

Send resumes to Sharon Montana-Beard at
sharonm@blackfox.com.

apply now



APCT

Passion | Commitment | Trust

APCT, Printed Circuit Board Solutions: Opportunities Await

APCT, a leading manufacturer of printed circuit boards, has experienced rapid growth over the past year and has multiple opportunities for highly skilled individuals looking to join a progressive and growing company. APCT is always eager to speak with professionals who understand the value of hard work, quality craftsmanship, and being part of a culture that not only serves the customer but one another.

APCT currently has opportunities in Santa Clara, CA; Orange County, CA; Anaheim, CA; Wallingford, CT; and Austin, TX. Positions available range from manufacturing to quality control, sales, and finance.

We invite you to read about APCT at APCT.com and encourage you to understand our core values of passion, commitment, and trust. If you can embrace these principles and what they entail, then you may be a great match to join our team! Peruse the opportunities by clicking the link below.

Thank you, and we look forward to hearing from you soon.

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Career Opportunities



MANUFACTURERS OF QUALITY PRINTED CIRCUIT BOARDS

Pre-CAM Engineer

Illinois-based PCB fabricator Eagle Electronics is seeking a pre-CAM engineer specific to the printed circuit board manufacturing industry. The pre-CAM Engineer will facilitate creation of the job shop travelers used in the manufacturing process. Candidate will have a minimum of two years of pre-CAM experience and have a minimum education level of an associate degree. This is a first-shift position at our Schaumburg, Illinois, facility. This is not a remote or offsite position.

If interested, please submit your resume to HR@eagle-elec.com indicating 'Pre-CAM Engineer' in the subject line.

apply now

Process Engineer

We are also seeking a process engineer with experience specific to the printed circuit board manufacturing industry. The process engineer will be assigned to specific processes within the manufacturing plant and be given ownership of those processes. The expectation is to make improvements, track and quantify process data, and add new capabilities where applicable. The right candidate will have a minimum of two years of process engineering experience, and a minimum education of bachelor's degree in an engineering field (chemical engineering preferred but not required). This is a first shift position at our Schaumburg, Illinois, facility. This is not a remote or offsite position.

If interested, please submit your resume to HR@eagle-elec.com indicating 'Process Engineer' in the subject line.

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eptac

TRAIN. WORK SMARTER. SUCCEED.

Become a Certified IPC Master Instructor

Opportunities are available in Canada, New England, California, and Chicago. If you love teaching people, choosing the classes and times you want to work, and basically being your own boss, this may be the career for you. EPTAC Corporation is the leading provider of electronics training and IPC certification and we are looking for instructors that have a passion for working with people to develop their skills and knowledge. If you have a background in electronics manufacturing and enthusiasm for education, drop us a line or send us your resume. We would love to chat with you. Ability to travel required. IPC-7711/7721 or IPC-A-620 CIT certification a big plus.

Qualifications and skills

- A love of teaching and enthusiasm to help others learn
- Background in electronics manufacturing
- Soldering and/or electronics/cable assembly experience
- IPC certification a plus, but will certify the right candidate

Benefits

- Ability to operate from home. No required in-office schedule
- Flexible schedule. Control your own schedule
- IRA retirement matching contributions after one year of service
- Training and certifications provided and maintained by EPTAC

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Career Opportunities



JOHNS HOPKINS

CAM / Process Engineer

The JHU/APL PCB Fabrication team is seeking a Computer Aided Manufacturing Engineer to support front-end data processing of APL manufactured hardware. You will directly contribute to hardware fabrication in support of National Security, Military Readiness, Space Exploration, National Health, and Research related to fundamental scientific advancement. This position includes a variable mix of core CAM work scope with additional opportunities for hands-on support such as bare board electrical testing, laser drilling, and mechanical CNC drilling and routing.

Responsibilities:

1. Computer Aided Manufacturing for rigid PCB, rigid-flex, and flexible circuits
 - a) Perform design checks, panel layout, coupon generation, file generation, stackups
 - b) Support manufacturability reviews with internal APL engineers (customers)
 - c) Generate work travelers
 - d) Communicate status to supervisors and internal customers
2. Support transition of software tools (Genesis 2000 to InCAM Pro)
 - a) Edit design rules checks and generate automation scripts
 - b) Develop new ideas to further the technical progress of our product
 - c) Develop CAM area through continuous improvement initiatives
3. Interface and inform APL Engineers on PCB design for manufacturing guidelines
4. Operate bare board electrical tester
5. Backup operator for CNC drilling, routing, laser drilling (on-site training)

For more details and to apply:

<http://www.jhuapl.edu/careers> and search for CAM.

apply now



U.S. CIRCUIT

Sales Representatives (Specific Territories)

Escondido-based printed circuit fabricator U.S. Circuit is looking to hire sales representatives in the following territories:

- Florida
- Denver
- Washington
- Los Angeles

Experience:

- Candidates must have previous PCB sales experience.

Compensation:

- 7% commission

Contact Mike Fariba for more information.

mfariba@uscircuit.com

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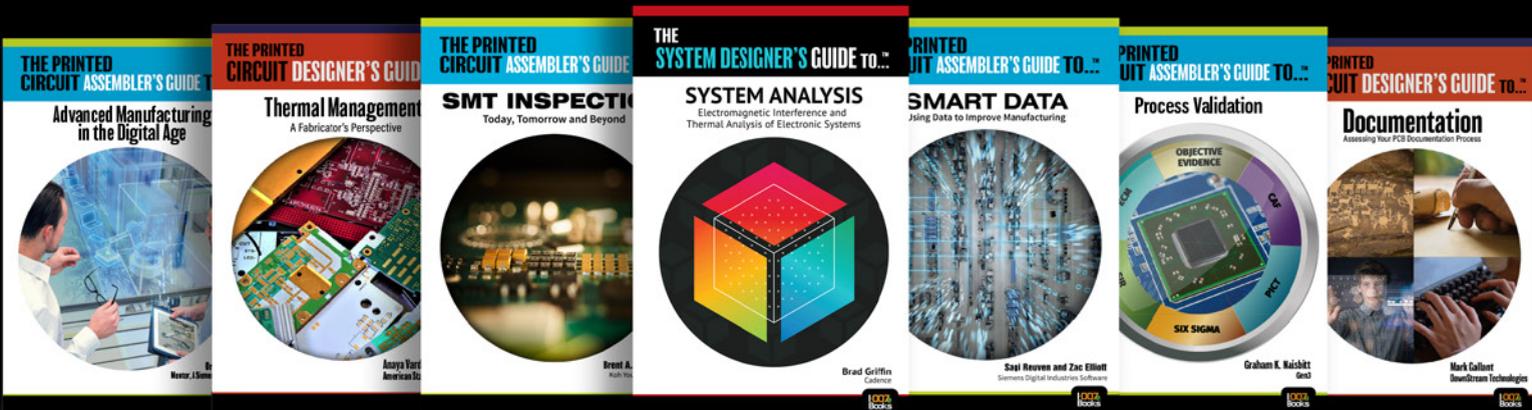
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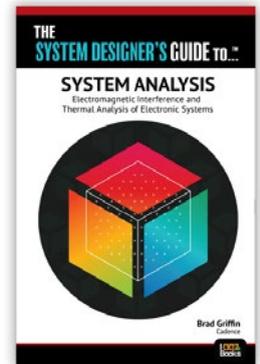
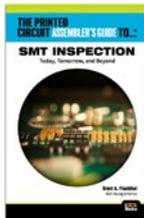
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Introducing:***The System Designer's Guide to... System Analysis****Electromagnetic Interference and Thermal Analysis of Electronic Systems*

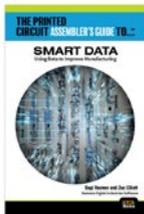
By Brad Griffin, Cadence

In this latest title from I-007eBooks, readers will learn how system-level analysis of complex and high-speed electronic designs is critical to solve electromagnetic, electrothermal, and electromechanical simulation challenges and to ensure that the system works under wide-ranging operating conditions. **Get your copy now!**

**The Printed Circuit Assembler's Guide to...*****SMT Inspection: Today, Tomorrow, and Beyond***

by Brent Fischthal, Koh Young America

An in-depth insight into new and exciting true 3D inspection technology is provided in this book, along with a look into the future of leveraging big data management and autonomous manufacturing for a smarter factory.

***Smart Data: Using Data to Improve Manufacturing***

by Sagi Reuven and Zac Elliott, Siemens Digital Industries Software

Manufacturers need to ensure their factory operations work properly, but analyzing data is simply not enough. Companies must take efficiency and waste-reduction efforts to the next phase using big data and advanced analytics to diagnose and correct process flaws.

***Process Validation***

by Graham K. Naisbitt, Gen3

This book explores how establishing acceptable electrochemical reliability can be achieved by using both CAF and SIR testing. This is a must-read for those in the industry who are concerned about ECM and want to adopt a better and more rigorous approach to ensuring electrochemical reliability.

***Advanced Manufacturing in the Digital Age***

by Oren Manor, Siemens Digital Industries Software

A must-read for anyone looking for a holistic, systematic approach to leverage new and emerging technologies. The benefits are clear: fewer machine failures, reduced scrap and downtime issues, and improved throughput and productivity.

Our library is open 24/7/365. Visit us at: I-007eBooks.com

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SMT007

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...We Answered!



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TO SEEK OUT LAND PATTERNS...
AND NEW BASE MATERIALS.
TO BOLDLY GO WHERE NO PCB DESIGNERS
HAVE GONE BEFORE!

DESIGN007 MAGAZINE

A glowing, fiery question mark.

SMT007 MAGAZINE

X = Xc - 1

A LEGO forklift with a minifigure driver.

SMT007 MAGAZINE

A person rappelling down a rock face.

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