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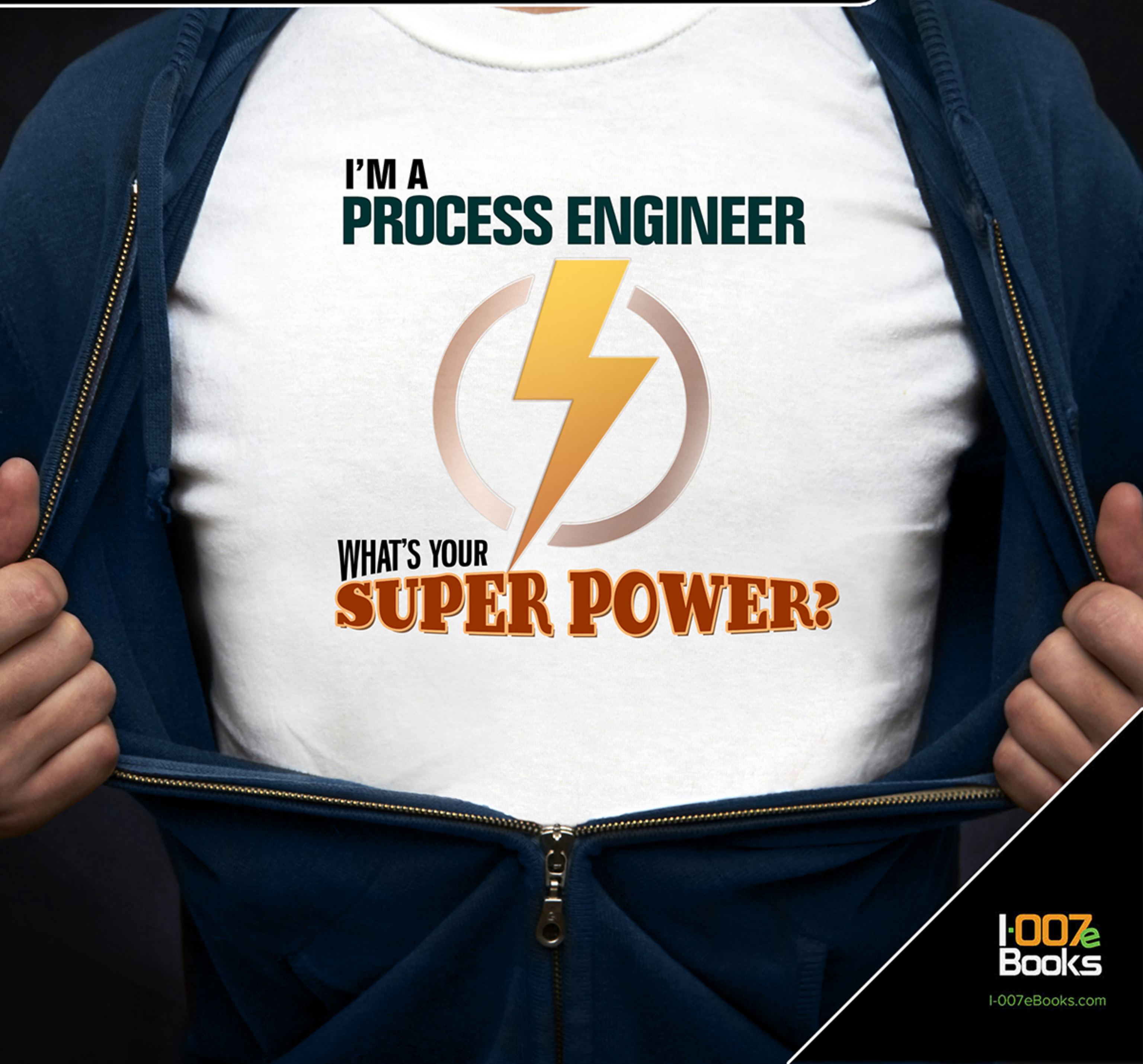
September 2017

the pcb magazine



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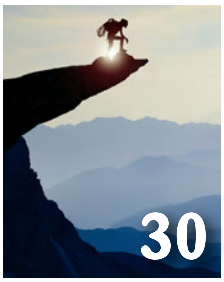

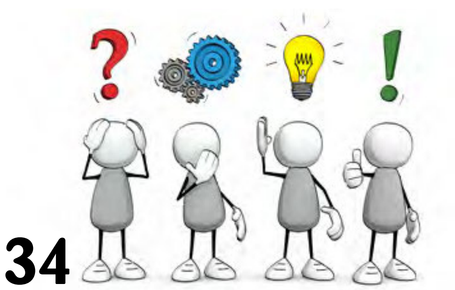

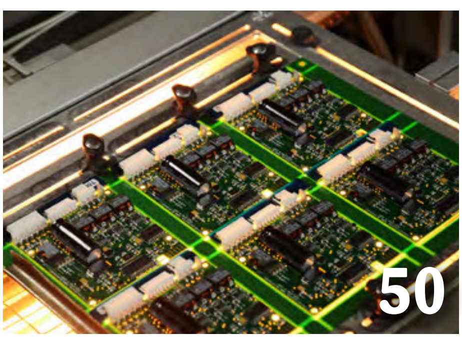

Process Engineering

This month, we're revisiting process engineering from the perspective of industry veterans with direct experience and who know what they're talking about. Read what it's all about, discover new techniques, gain fresh insights, and learn true appreciation for process engineeers, the backbone of PCB manufacturing.

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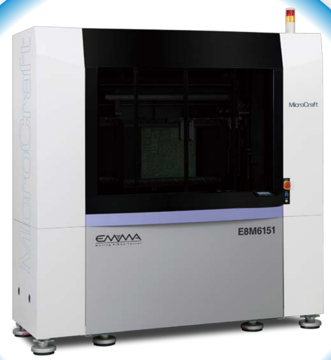

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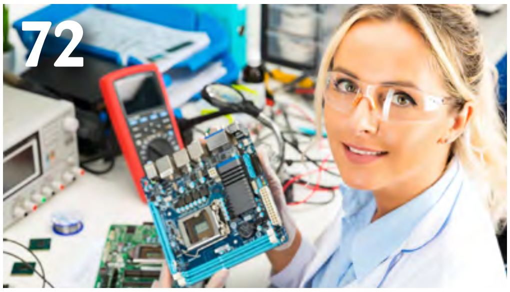

Correction:

In the June issue of *The PCB Magazine* on page 54, right-hand column, the units “mm” should be “mils.” The amended sentence should read:

“The imaging technology has improved and our product has improved to allow very miniature resistors like 50-micron (2 mils) wide resistors, 2 mils by 4 mils or 8 mils and holding a reasonable tolerance.”

This has been corrected in both the flip book and PDF versions. Please accept our apology for this error. Download the corrected version here and discard the previous PDF.

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The Fundamentals of Process Engineering

by Patty Goldman
I-CONNECT007

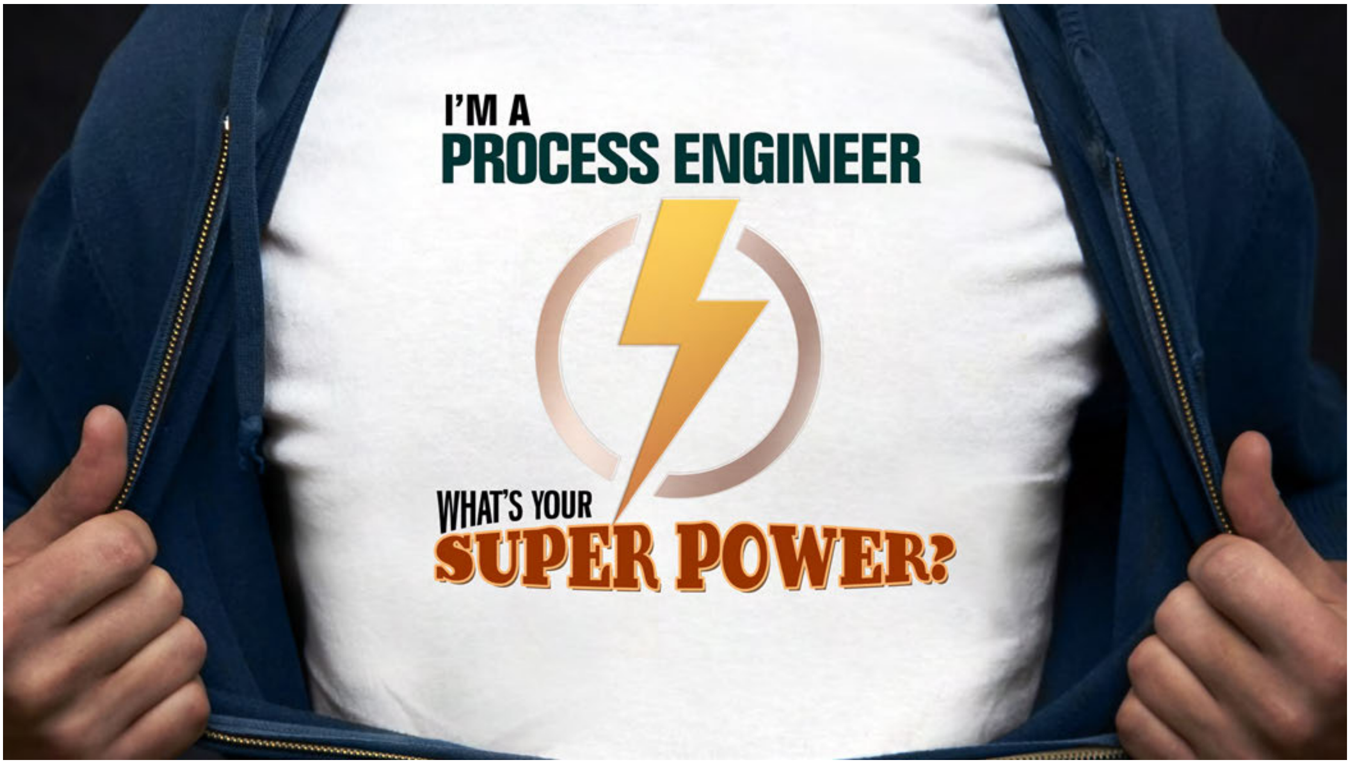
We've covered the subject of process engineering before in our magazines, so why are we doing it again? Well, do you really think that one issue can cover everything there is to know about process engineering? Of course not.

Having been there and done that as far as process engineering goes, I will expound only briefly on a point before getting to our line-up. It's what I call process evolution. I'm sure it's something that goes on in PCB shops all over the world: The original process is tweaked a little bit to run a certain PCB through, then tweaked again for another job, tweaked again because something isn't quite right, and…you get the picture. Pretty soon, that process has evolved (or devolved) into a process that is out of spec and no longer works—and then the engineer is called. (Step one: Reset back to the starting point.) I've seen that happen too many times to count.

At any rate, we do have a heck of a line-up this month with plenty of meat on its bones, I promise you.

As I mentioned, I've held the title of process engineer at times during my career, but rarely have I seen the position spelled out as clearly as George Milad (Uyemura) has in our intro article to this issue. George lays out the responsibilities of the role for us in clear, straightforward language. It's quite an involved job as any PE will tell you—and as their management should certainly recognize.

This made me think, "Wouldn't it be neat if there were a nice process engineering T-shirt out there? And if there is, shouldn't managers be providing one to their PEs?" Well, surprise,



of course there are such T-shirts online! I got a chuckle out of these:

- "Trust me, I'm a process engineer"
- "Being a process engineer is easy, it's like riding a bike, except the bike is on fire, you're on fire, everything is on fire and you're in hell"
- "Process Engineer: We solve problems you didn't know you had in ways you don't understand"
- "I'm a process engineer, not a magician"

Where were those when I needed one so many years ago!

But back to the magazine. There is no one more anxious to pass along his 40+ years of experience and knowledge of PCBs than Happy Holden, certainly one of the original process engineers in our industry. To that end, he distilled several conversations on the subject into an article that is full of useful info, great ideas and valuable advice worth heeding—and not just for the engineers, but for their management, suppliers (including designers) and customers.

Next, Steve Williams of The Right Approach Consulting delves into a specific task of process engineering, that of managing changes to a process—which can be endless. Follow his direction to prevent or at least control this process evolution, as I defined it above. Believe me, it does happen so pay attention to Steve as he explains how to manage a "temporary process change" program.

RBP Technology's Mike Carano is Mr. Troubleshooter and, true to form, he gives us a fine article on one of the process engineer's top priorities, which of course is troubleshooting—finding solutions (pun intended) to process problems and product defects. He illustrates his points using excerpts from the IPC-9121 troubleshooting guide (the subcommittee of which yours truly once chaired, a position now held by Mike).

Marc Ladle, Viking Test Ltd, provides a wonderful story that illustrates both the process change and troubleshooting columns just mentioned. Nothing like a real-life example to hammer these concepts home. You're paying attention, right?

Omni PCB's Tara Dunn uses a famous quote from a popular movie to illustrate the behind-the-scenes actions and decisions that make a fully assembled PCB magically come into being from a mere design file. She describes three examples of "magic" that, if these indeed seem to be like magic to you, perhaps a facility tour or two should be in your near future.

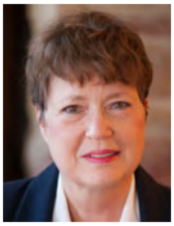
Straying somewhat from our process engineering theme, IPC's John Mitchell discusses automotive electronics and the importance of proper manufacturing standards. We all know autonomous vehicles are coming, but did you know that today's new cars already can have up to 80 electronic controllers on-board? Find out more inside (the magazine, that is).

Departing totally from the main topic, but in keeping with our standard modus operandi, we have a great technical article on printed electronics, and not just printed electronics—3D printed circuit structures. Maybe they're not ready to overtake our PCBs, but they do bring definite advantages for certain applications.

Finally, let's swing around to another subject and that is workplace safety. Yeah, we all have a safety program, but how do you get your employees to embrace it? Leave that to Barry Lee Cohen and Launch Communications to give you excellent recommendations to jazz up your safety program and get your employees—especially those younger ones—to not just buy in, but to carry it forward.

So, that's another chock-full month for you. Get busy, read, absorb, apply. Do it and your company will be better off for it.

Next month will be all about signal integrity and controlled impedance. What it takes to build these boards and what you need to know if you do. Get on board now by subscribing. And you managers out there, don't be surprised if your PEs come in sporting a new t-shirt—better yet, stock up on a few and motivate the heck out of them at the next monthly meeting. **PCB**



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

The Value of Process Engineering in PCB Manufacturing

by George Milad
Uyemura International Corporation

The PCB manufacturing cycle involves a series of interdependent processes starting from raw material and ending with the finished product. Successful PCB manufacturing shops coordinate, control and constantly upgrade their processes to meet the ever-changing market demands. Modification of existing processes for better efficiency in work flow, product quality, or cost savings is an ongoing activity designed for continuous improvement. As soon as processes are established, in comes sales with a new product beyond the capabilities of the present setup. Once it is established that this is a viable market for the shop, the addition of a new process is initiated.

The primary responsibility of maintaining, upgrading and initiating new processes falls to the process engineer (PE). Clearly, this is a tall order. Depending on the size of the operation, process engineering may be an individual or a series of engineers headed by an engineering manager. In the absence of process engineering the tasks are distributed to other departments. Mostly the burden rests with the manufacturing manager who is assisted by sales, vendors, maintenance, lab, and quality as well as upper management.

The PE establishes process control to ensure that the process remains consistent and that the quality of the product meets established criteria across three shifts, day to day and week to week. Engineering documents and charts the different variables using statistical control charts based on Lean Six Sigma (LSS) methodology.

Engineering sets up software systems like TrueChem. TrueChem defines and triggers activities based upon specific analysis, events, trends, tolerances, etc. It automatically logs and maintains important records. In addition, it ensures that required adds, corrective actions, sign-offs, etc., are performed in a timely manner. It also keeps track of who performed what activity, at what time, with what actions, and with what results for full accountability, traceability, and auditability. Engineering is constantly attempting to widen the operating window of the processes to ensure compliance.

All non-compliant parts are usually sorted out and documented by the quality and

inspection group. Resolving non-compliant issues is always the task of the process engineering team. Engineering categorizes the defect, gives it an assignable cause, and institutes corrective action. This activity becomes critical if any defective parts slip through final inspection and ends up at the customer. Assignable cause is documented and corrective action is instituted, to assure the customer that future parts will be compliant. It is an important part of doing business.

> **“Maintaining control of the process(es) for reproducibility, to ensure that the specified quality of the end product is met, remains the number one objective of the engineering department.”**

Maintaining control of the process(es) for reproducibility, to ensure that the specified quality of the end product is met, remains the number one objective of the engineering department. The PE is always aware of process cost. Engineering tracks the cost of setup time, down time and consumables in a continuous effort to eliminate waste. There is a constant effort to improve productivity without impacting the process cost. The PE generates a cost analysis any time there is a process change or a new process introduction.

Process engineering takes center stage when a new process or a process change is indicated. Engineering gets involved from the start in defining the process and selecting the supplier or vendor. Here the PE may create a test vehicle that would be sent to the respective suppliers, to demonstrate the capability of their process. Upon return, the PE assesses the quality of the product and calculates the cost of process. In addition, in-house testing of the process may be performed, or the PE may visit a facility using the process/equipment to evaluate it there. The PE then submits a report to management and purchasing for a final selection.

Engineering keeps track of the equipment manufacturer and scheduling. Eventually the equipment acceptance at the manufacturing site is done by engineering. Once the equipment/process is delivered, engineering has the major task of coordinating the role of the vendor and the maintenance department. The objective is to ensure that in house maintenance can take ownership of the maintenance of the tool.

A qualification plan is then put in place, to evaluate the tool capability and that it will meet its intended use. This includes the designing and manufacturing of a test vehicle that will yield information on the process capabilities and its operating window. Reproducibility, repeatability and maintainability are established and documented. Process capability is then communicated to management and sales.

Engineering then takes on training of all involved, this includes the manufacturing supervisor, and operators across all shifts as well as lab personnel. Vendors support during training is planned and coordinated by engineering. Training is a continuous process to ensure that the information has been properly communicated, also for any new personnel.

Process documentation may include preventative maintenance procedures, a reaction plan, and troubleshooting guides, etc. Once the process is set up, specified and is being measured, the process engineer’s job moves to reducing any variation that occurs in the process, the goal of which is to improve the process Cpk and become Six Sigma capable. Lastly, and over time, the process engineer’s job is to develop a failure mode and effects analysis (FMEA) for the process.

Engineering is well versed on industry specifications; they ensure that the product meets specification and are a resource for the shop when issues of specification interpretation arise.

Quoting Roxanne Hupp, engineering manager at Henkel, “The best skill for process engineers is one of systematic problem solving. I encourage new graduates to delve into Lean Six Sigma problem solving techniques. Process engineers should be flexible because projects seldom go as planned. Patience and perseverance are often required when facing setbacks and challenges. Excellent documentation and communication skills are essential to keep yourself organized in what is a fast -paced environment."

Julie Ahlstrom, manufacturing manager at Electrotek, enumerates the qualities of the process engineer: "Patience, deductive reasoning, both independent and team work, ability to prioritize, computer skills, writing skills and willingness to do the job alongside others."

The PE's communication abilities both verbal and written are critical. The PE interacts with a wide range of people inside and outside the company, such as suppliers, customers, quality engineering, production managers, peers, company GM or president, R&D personnel, shop floor operators, maintenance personnel, sales and procurement personnel.

The process engineer plays a complex, significant role in the board shop. Shops with good engineering support run a smoother operation and produce better quality products. Vendors appreciate the PE who takes ownership of the process, and works to resolve any issues that surface. **PCB**

George Milad is national accounts manager for technology with Uyemura International Corporation.

When Drones Fly Beneath the Radar

Drones offer many benefits, but unfortunately, they provide terrorists and criminals with new opportunities, so they need to be monitored. The Danish company Weibel Scientific A/S has now developed its first radar system for monitoring drones.

The expression 'flying beneath the radar' is used idiomatically so often that you almost forget the original meaning—but not at Weibel Scientific.

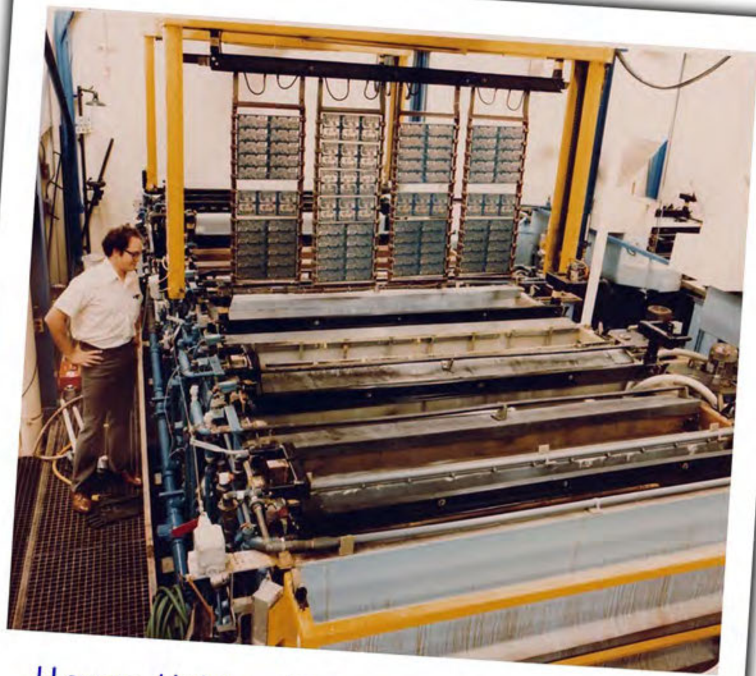
"A drone is capable of flying so low that it is not picked up by many traditional radar systems. At the same time, it is difficult to detect because of its small size," says Weibel CEO Peder R. Pedersen.

The company, located to the north of Copenhagen, was established on the basis of research originally carried out at DTU. In 1977, Erik Tingleff Larsen resigned from his position as an associate professor at DTU Electrical Engineering to form the company, which is now one of the world's leading suppliers of advanced radar systems. One of the first employees was Peder R. Pedersen, who did his DTU Master's project at Weibel in 1983. This led to a PhD project, followed by permanent employment, and then in 2002 he was appointed CEO.

When Peder Pedersen started working for Weibel, there were seven employees—now there are 100, of whom 35 are engineers. And the company needs more.

"We definitely expect to take on more engineers in future. There is a growing demand for radar systems, largely for tracking drones. We recently started to sell the first systems, but there is still a lot of R&D work to do. Drones represent a new type of threat, one which is very difficult to counter."

PCB Process Engineering: Details from One of the Originals



Happy Holden, 1974: Hewlett Packard, Palo Alto Automation Project

by Happy Holden

The main priority for process engineers is keeping things running. Meeting delivery times and customer satisfaction is always number one, and then behind that is the continuous improvement of whatever you're doing, whether it's less chemicals, simpler operations for people or eliminating the confusion or the complexity of what is happening. Then, implementing new customers and customers' new products and/or new processes is always important for expanding the business. As Figure 1 shows, implementing new technology is an S-shaped curve. Lastly, a process engineer supports a strategic plan that the owners or president has in terms of what the long-term goal is that you can constantly be working on.

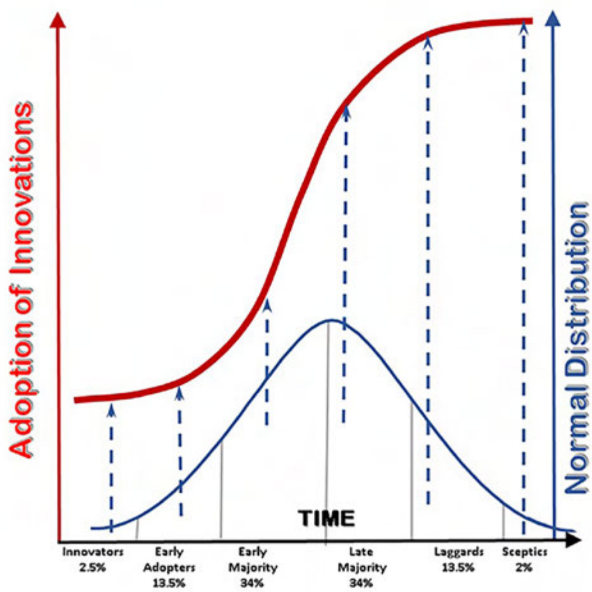


Figure 1: Adoption and innovation of new products and processes provide the opportunity for growth and rapid profit creation. The PCB contributes to this end.

My Background

I started out in process engineering 45 years ago as Hewlett-Packard's first chemical engineer, when their printed circuit manufacturing was run mainly by electrical engineers and mechanical engineers. I actually started in integrated circuit process engineering since that was my major. Hewlett-Packard made its own semiconductor devices and thin film and high-frequency devices.

I was at top of the hill in Palo Alto, and the PC shop was down the hill. They called me into the office one day and said, "We need you to go down the hill to help out our printed circuit

people." I was walking through this place with bubbling tanks and just about every manufacturing process seemingly known to man. They seemed to have everything America could build—machines for chemical processing, drilling/routing, etching, waste water treatment, chemical recovery, and image transfer. Boy, did they have a little bit of everything.

They also seemed to have a lot of problems. This was 1968, and we hadn't been that many years into plated through-hole processing work to develop all the troubleshooting techniques that people have today to refer to. I don't know what they magically expected me to do, since I didn't know anything about printed circuits, but I knew enough to say, "I had better read up on this." Well, they handed me the first edition of Clyde Coombs' Printed Circuit Handbook, which I read. As the next step, I called all the vendors of our chemicals and asked them about that. Lastly, I started asking, "What is our toughest problem for yields?" I went around with a clipboard asking the operators and the supervisors what they thought was causing the problem. Coupled with what Coombs had said in the book and what the vendors had recommended, I ended up with a Pareto chart of what everybody thought were the causes.

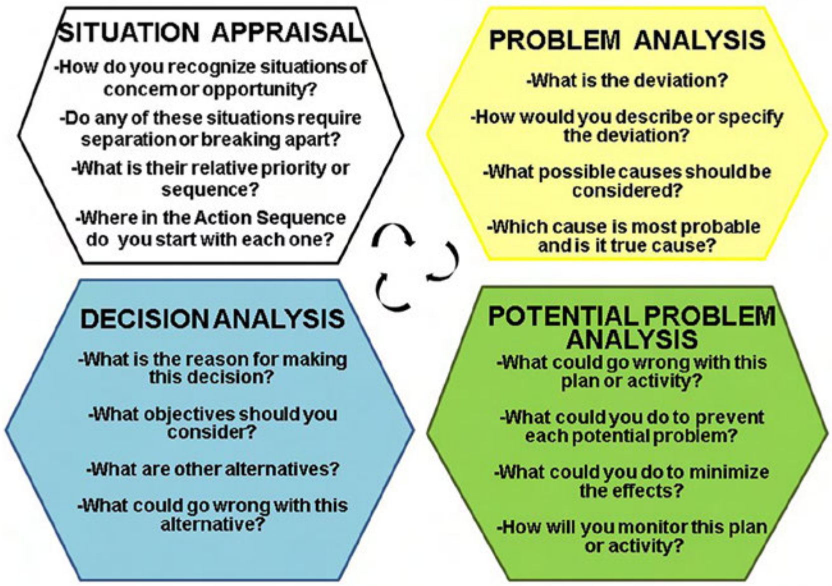


Figure 2: One of my favorite problem-solving methodologies is the Kepner-Tregoe method seen here in its four phases.

Fortunately for me, my university thought it was important that we chemical engineers learn a lot about engineering statistics. This is not the boring statistics you have in college or things like that for insurance companies or just mathematical formulae. This is the more practical methodologies and how to solve problems. In a matter of a few days using design of experiments, I had isolated the main causes, the interactions, and had corrected them.

Over the next several months, I went on to solve 10 to 15 other major problems that had been bugging them for months and months. Everybody thought it was a miracle or that I was a genius. Actually, I didn't know anything about printed circuits; I just used a problem-solving methodology that professors of mine thought was going to be very useful. Figure 2 shows one of those methodologies along with DOEs. Consequently, six months later, I got a stock award from the board of directors. First time ever a stock award was issued to somebody in manufacturing. Normally, it went to the PhD gurus who helped invent HP products.

Fortuitously, I started recruiting more engineers, and when I discovered that most of them had not had any formal engineering statistics training, we started a program on that to train all the engineers. For the most part, in the kind of work we're doing, we don't use a lot of our academic knowledge. Most of the time we're working with new equipment or new processes or just solving production problems. Basically, we need people who know how to think or know how to understand the qualitative variables like: day of the week, month of the year, where your water comes from, machine A versus machine B, or vendor A versus vendor B. These qualitative variables many times are the root cause of our production problems. It's not the quantitative variables, like grams per liter or centimeters per second or something in the data sheets the vendors give us that are causing our problems. Figure 3 outlines the three methods of experimentation that engineers have available. I was using the Design of Experiments–Factorial Designs.

Statistics is the Number One Skill

Statistics became to me the number one tool of a process engineer whose fundamental job is to make money for the company—which means you have to solve problems all the time or implement new equipment, new technology or new customers expediently with the highest yield possible. Over the years, as I managed the biggest printed circuit operation in the world, Foxconn (which had 32,000 employees, including 1700 engineers), I discovered that most of these Chinese engineers did not have the statistics background they needed to be effective process engineers for the seven big sites. Foxconn has about 30 million square feet of factory floor, making every kind of flex and multilayer, and chip-scale package you can imagine.

The problems in manufacturing printed circuits, even in large automated factories, are just as profound as they are in a quick-turn facility. So that's where I came up with the "25 Essential Skills"[1]. The first three chapters concern problem solving, statistics, and design of experiments, which I still consider the number one tool. And it doesn't require a college degree—only about eighth grade algebra for its background. So, it's something that any person calling himself/herself a process engineer could learn.

That's why I wrote about the $15,000 NIST/SEMATECH statistics package[2] that is available on the Internet from the U.S. government, free of charge. It's one of the best, and it's a self-paced tool. You don't want to print it out, as it's 3,800 pages, but it's all electronic and hypertext-linked. It helps you do your job because the eight sections are written for a working process engineer. It's not a statistics manual, but it's written by the best brains in statistics that are alive today.

And I'm still flabbergasted that so few seem to know about it. I'm really pleased that I-Connect007 is making it more visible. This is something you can download and keep at home.

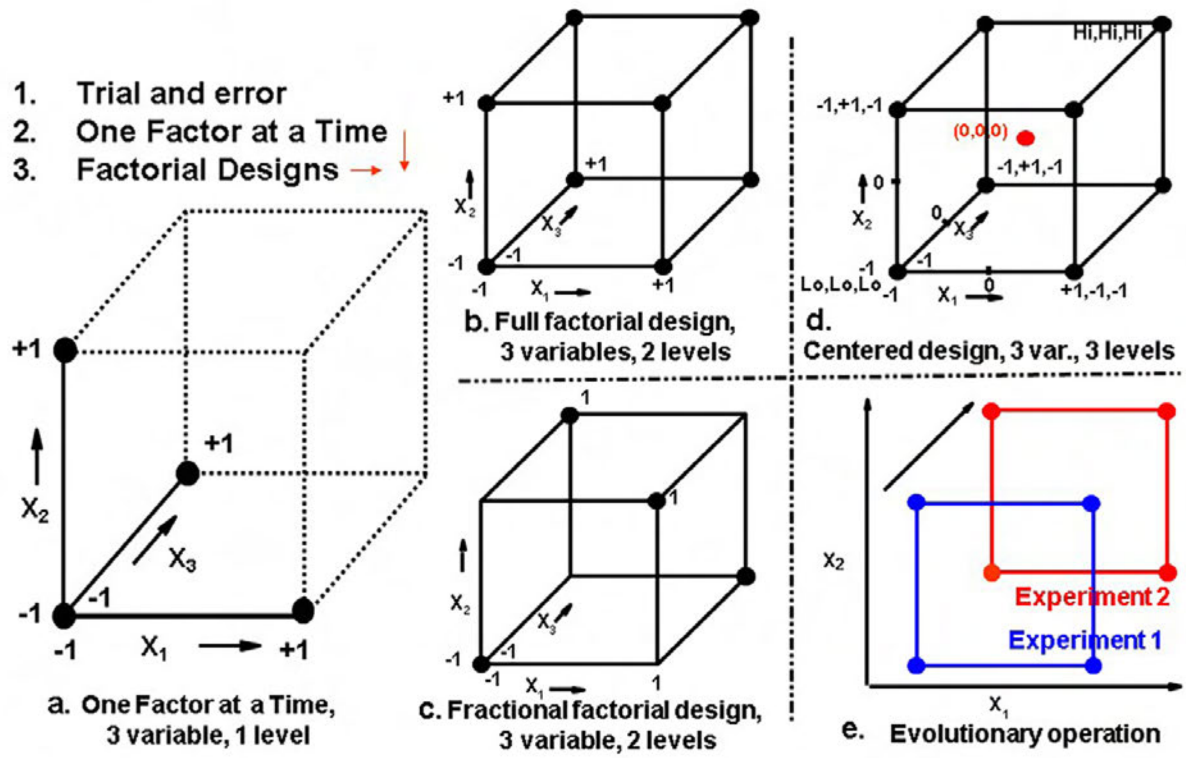


Figure 3: Of the three methods of experimentation available to process engineers, the complex environment of PCB fabrication favors the factorial design of DOE.

Even if your company has an expensive statistics package, duplicate the experiment's results on your own system because your next employer may not have it. Or if you start your own business, this will be your basis of solving problems and working on things.

Automating and Automation

Before you spend big money for automation, it's nice if you had a plan and knew exactly what automation meant. And it's not just necessarily buying equipment. It may also be streamlining the information or the accountability for the customers or traceability or something like that. Then we also have a chapter on automatic chemical control in a new mini e-book (not yet published), which you could implement yourself that's low cost or built by maintenance men. Because as things become more automated and happen faster, and you take the people out of it, you can use fewer chemicals. If you can automatically analyze and dose, your chemical inventory goes down and the swings in the bath go down. Figure 4 illustrates a very inexpensive but very sensitive specific gravity sensor that you can build for practically any aqueous process.

One of my hobbies is simple methods of automatic chemical control to go with the higher mechanization and the speed of throughput. Automation planning is just one along with the 25 essential skills that a process engineer needs to learn over their entire career. These are needed to get the bonuses, make the customers happy, make the boss happy, or get the important promotion. These are items that have taken me and my friends a long time to distill down into 25 topics. I'm not saying there aren't more than that; it's just the ones that have come to the top of my mind It will include long distance learning, in terms of how they can actually gain these skills if there's nobody around that happens to teach them, and make them available.

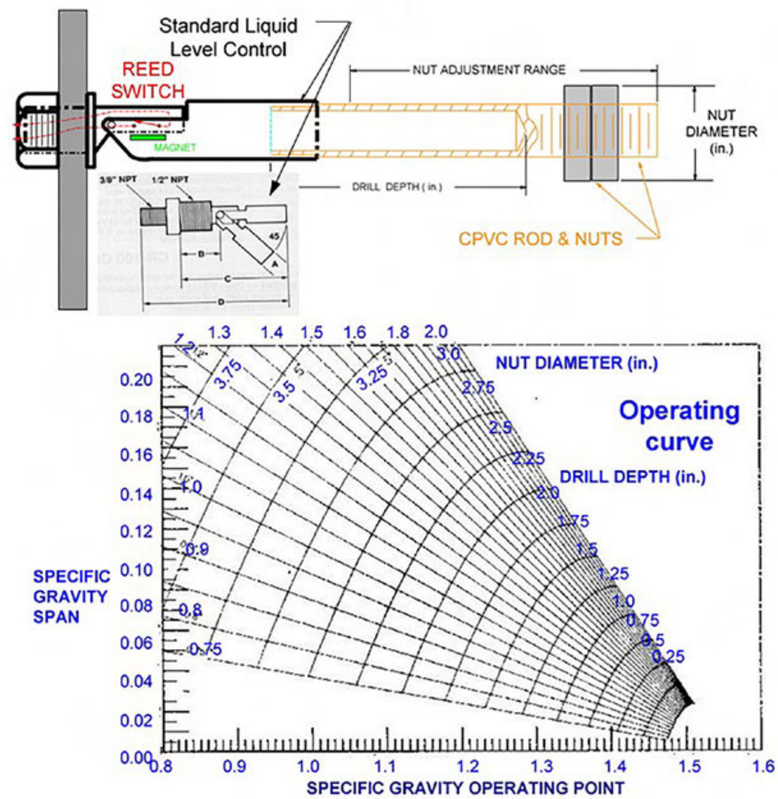


Figure 4: This specific gravity sensor is built from a simple plastic level switch where a threaded, drilled-out plastic rod and threaded nut have been attached.

PCB Design: Where the PE's Headaches Begin

Thinking back, one of the biggest headaches for a process engineer is something that they can't control, and that's the design of the product. Many times, the design of the product makes the process engineer's job rather difficult because it's somewhat unpredictable. What you have got to do as the process engineer is to go back and figure out how to improve the latitude of the processes because you can't afford to put another chemical into it. That's the wrong way to react to that type of crisis, by making things more complicated.

I still think that PC board designers feel their customer is the people paying the bill to have the board designed. But in a Six Sigma TQC, your customer is the next process step. So, the customer of the designer is the fabricator, the customer of the fabricator is the assembler and on down the line. Look at it that way.

I was in manufacturing, and as we improved quality and built quality

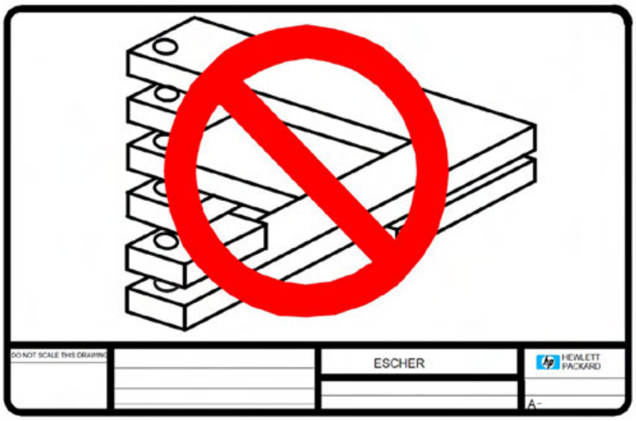


Figure 5: Even though your CAD system can describe a product, there is no guarantee that it can be manufactured.

in—instead of inspecting it in—we had to allocate all our resources to the front-end tooling because we were getting such variations in design. I complained to HP's vice president that manufacturing is building quality into the product but how come design can't design quality into the product. The designer says, "We don't need standardization. You guys just build what we design." Well, the vice president didn't like that reaction and fortunately he promoted me to be head of PC board design at HP.

I've always been aware of design rule checkers and things like that since at one time HP actually sold PC board design tools. One of HP's key successes in the IC business was having its own IC design tools that were highly automated. And the IC design tools were interesting; before you start designing the IC, you have to thoroughly characterize manufacturing or the IC design tool won't even let you start.

A printed circuit board design tool had the heritage that you could put in any numbers you want, just because it comes out of a computer and a CAD system, it's very easy for it to make things that are totally impossible to manufacture. So, the concept of quality/producability has been one of my soapboxes over the years talking about EDA design tools for PC board. There is no measure of producability or quality. Instead, everybody has to run something like the DRC. And then where do you get the numbers to put into the DRC is an interesting thing. Essentially, you're looking for errors. But errors are not really design for manufacturing as defined by the industry and two university professors that developed the technique. As Figure 5 shows humorously, just because a CAD system can describe a product does not necessarily mean it can be built.

When HP took a DFM/A license and put us all in school, we learned that DFM is "doing it right the first time." It's not designing it, tricking it out, building it and then going back and redesigning it, looping it around and around on re-spins. How do you figure out how it can be designed right the first time so it only takes a little tweaking and you're off and running a high-volume product with high yields and excellent quality?

Because DFM and DFX have been so misused I had to use the term "predictive engineering" in order to get people to understand what I'm talking about. But I'm talking about what we need is software systems that help us *do it right the first time*. I have a chapter on DFM/DFX, talking about the predictive engineering point of view[3], to explain the methodology and how that applies to PC board, IC, and surface mount assembly.

Predictive engineering works fundamentally by feeding back manufacturing data. So instead of being "over the wall," this is a true feedback loop where you look at how things actually were manufactured in their class, and their queue, their problems, and their quality. You feed that back into your predictive algorithms so the next time, you design it better. It's not just finding the mistakes from a design rule checker type of thing. The design rule checker helps, but what you'd potentially like to see is that these things are manufacturable and the design rule checker doesn't find anything. You can see in Figure 6 that the statistical process control of processes can lead to enlarged process latitudes and to enhanced design rule specifications.

And the high volume is the same as the prototype you made. All that time and wasted effort isn't there anymore. The EDA and the CAD venders are not particularly interested because they don't consider a PC shop a customer. They consider the person that buys the tool the customer. They have absolutely no visibility over what Six Sigma and total quality management

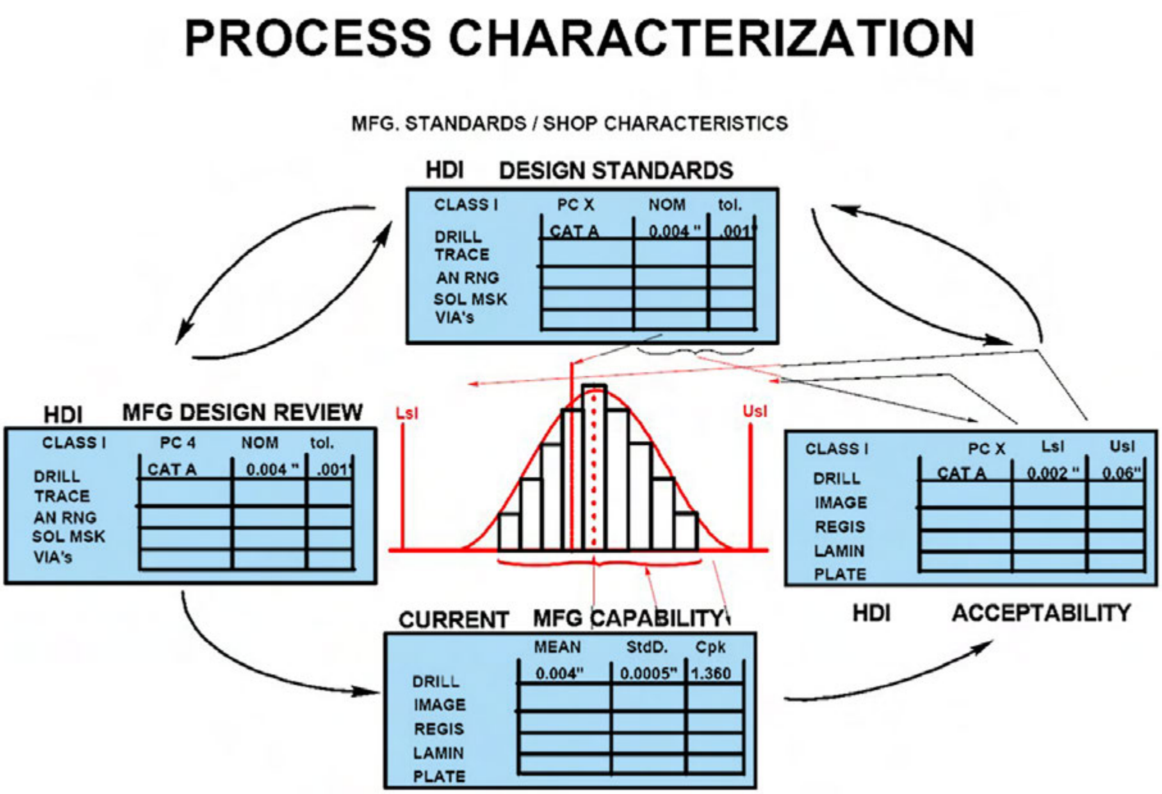


Figure 6: Statistical process control and Cp can lead to enhanced design rules and capability.

means. But everybody that buys their tools is going to be part of this supply chain where we each have to supply to the next stage in the Value Chain until it gets in the customer's hands.

What designers really need is feedback from manufacturers, fabricators that can recognize the design-related interactions with many factoring processes, so that they can feed back to the designers. "When you come to this branch in your design, go this way and not this way because this way is going cost you less and you're going to deliver the better product, cheaper, faster. But these other two branches, although they look attractive, are going to lead you down a path that's going to make this thing very difficult to manufacture." And it's typically not as simple as "we can't make it." It's that we're going to have a 3% yield loss or a 7% yield loss, not a 95% yield loss.

It's all these subtleties that process engineers spend their days working on. Because this is such a complicated manufacturing process that has so many variables in it, but the biggest variable, which we can't quantify, is the variable of the design itself. That's why I created a new parameter called, "The Complexity Index," so I could rank designs by how complicated they were. That's given me an independent variable to look at important factors in manufacturing. Otherwise, you're looking at just the number of holes, hole diameter, number of layers, type of material, size of the panel, size of the board, etc. You end up working with one independent variable to look at all the significant results, instead of ten independent variables; it's pretty difficult to relate how that many affect manufacturing. Figure 7 shows how the Complexity Index is used to model first-pass yield in the manufacturing process.

One of the "25 Essential Skills" is a thing called dimensional analysis[4], which refers to the dimensionless parameters used in engineering as pseudo-independent variables, like the Reynolds number or the Mach number. I figure that we have as much right to invent these as anybody else.

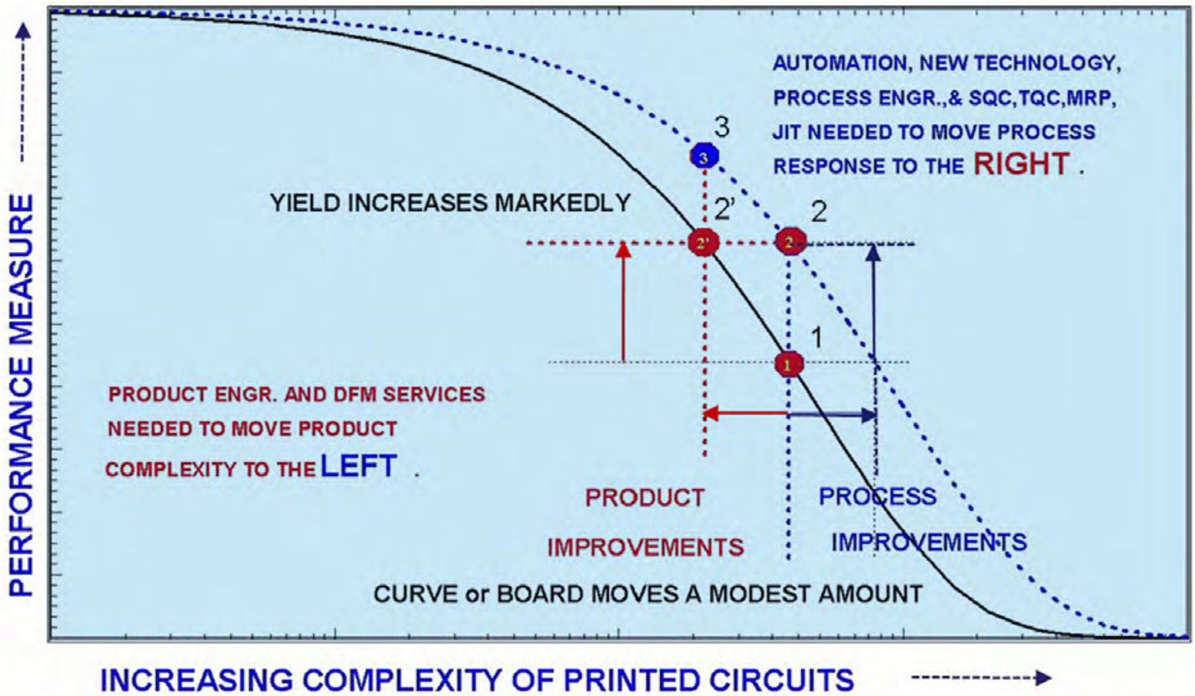


Figure 7: The first-pass yield (FPY) on fabrication of complex HDI and multilayers can be characterized from design characteristics, realizing improved yields if the design can be simplified (2 to 2') or the process improved (1 to 2) resulting in lower cost (1 to 3).

The Lost Connection

It was a sad day when the big OEMs started outsourcing and were no longer making their own circuit boards in their internal circuit board facilities, like I was doing at Hewlett-Packard. One of our main missions was to build the prototypes, the production of the innovations the company needed to be successful and dominate the field. The fact that it couldn't be done was only the first sentence of the negotiation. Sitting down with the team to figure out how best can we accomplish this. A lot of important developments came out of that, which then later—as they moved on with other new innovations—trickled down to the merchant market. Some adventurous PCB shops were the recipients of one of our first headaches where the IC guys developed their first 32-bit computer on a chip and we found out the chip wouldn't work on conventional circuit boards. We eventually ended up with six-layered Teflon® multilayers with metal core and laser-drilled micro-vias (Figure 8). This was 1982. Ah, the old days!

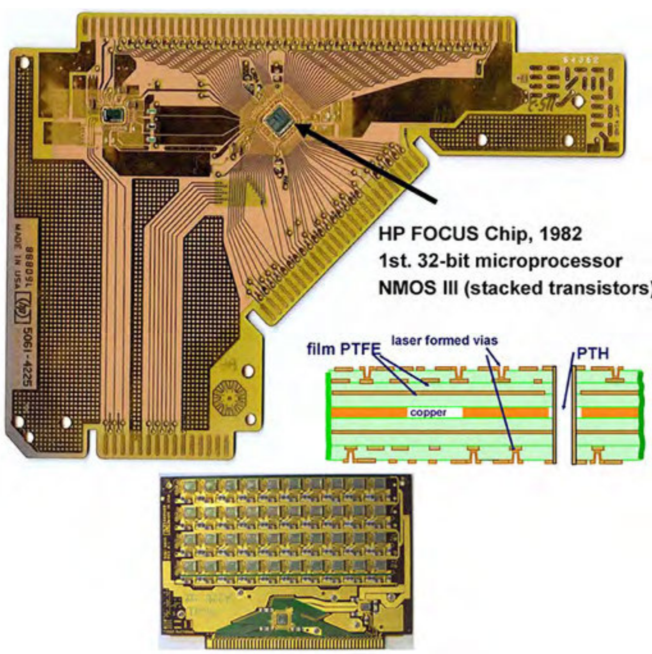


Figure 8: The HP Finstrate technology of laser-drilled microvias, metal-core and PTFE dielectrics permitted the use of HP's first 32-bit single-chip microprocessor.[5]

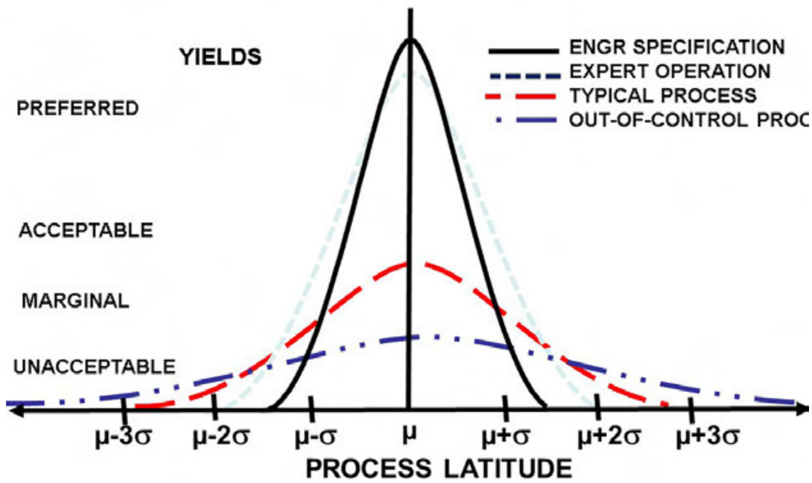
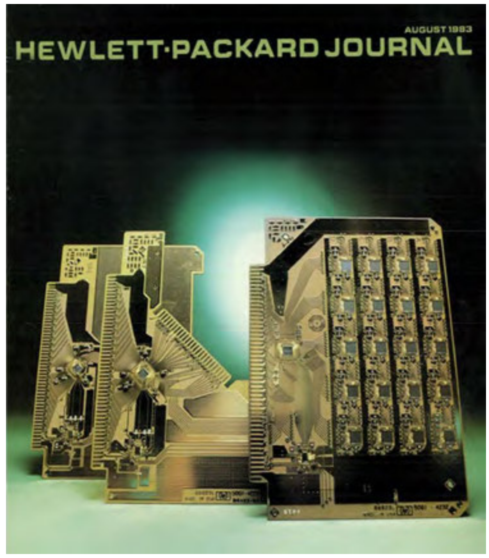


Figure 9: The better the process latitude then the better the yield responds to varying design running through a process. What is wanted is the "expert" process that is much better than a "typical" process and certainly not the "out-of-control" process.



Process Improvement

When you set out to improve a process, what should your goal be? You always want greater efficiency and higher yield, but you also want latitude and safety. You want to set up parameters and operating conditions so that you can make a multitude of different PCB designs and not have to worry about it. The same is true for the chemical variations, or if it's mainly run time variations, such that the output is not going to be affected by these variations. If you have a very "exacting" process, then it's easy to fall off the peak. This is illustrated in Figure 9 with various process latitudes.

Conclusion

Process engineering is an exciting vocation, and for printed circuits, a necessary one. The electronics industry is the world's largest industry and shows no signs of slowing down or maturing. Components will always need a platform, and currently that is the rigid or flex printed circuit. It has been exciting for me for 45 years and will continue to be for at least another 45 years. The only constant we can depend on is change! **PCB**

I-Connect007 will be publishing e-books on automation and automation planning for the process engineer. Look for these to be coming soon to the I-Connect007 website!

References

1. Happy's Essential Skills: the Need for Total Quality Control (Six Sigma and Statistical Tools): Part 1.

2. Happy's Essential Skills: Tip of the Month—The NIST/SEMETECH e-Handbook of Statistical Methods.

3. Happy's Essential Skills: Understanding Predictive Engineering.

4. Happy's Essential Skills: Metrics and Dimensional Analysis.

5. Hewlett-Packard Journal, August, 1983, pp. 3-25.

Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa/Westwood, Merix, Foxconn and Gentex. He is currently a contributing editor with I-Connect007. To read past columns or to contact Holden, click here.

Supply Lines
Highlights

A Conversation with New Isola Chief Revenue Officer Michael White

In a recent conference call with Isola's new Chief Revenue Officer Michael White, I-Connect007 Publisher Barry Matties, and Managing Editor Patty Goldman gained a deeper understanding of the internal reorganization happening right now with Isola and Mike's plans for Isola's marketing team.

The Speed of Nouya: Interview with Bao Xinyang of Shanghai Nanya

The theme of the June issue of PCB007 China Magazine is "High-Speed Materials." As is becoming more widely understood, domestic material supply is the only way for China's high-frequency, high-speed circuit board industry to grow.

Summit Interconnect Orange Chooses atg A7a for High-speed Electrical Test and Automation

Summit Interconnect has installed an atg A7a, an eight-head, double-sided, high-speed auto-load/unload system that provides true "lights-out" operation, at its Orange, California facility. Board sizes of 24" x 21" or larger with small pad/fine-pitch technology can be tested quickly and easily.

High-Frequency, High-Speed: an Opportunity for China CCLs to Lead

As a leading Chinese CCL manufacturer, Shengyi Technology has invested 250 million RMB in 2016, for the new Jiangsu Shengyi Special PCB Co. Ltd. facility, which will make high-frequency, high-speed CCL product. We invited Lin Xia, senior marketing director of Guangdong Shengyi Technology Co. Ltd., and assistant general manager of Suzhou Shengyi Sci-Tech Co. Ltd.

I-Connect007 Launches 'The Printed Circuit Designer's Guide to... Signal Integrity by Example' Micro eBook

The latest title in our new line of eBooks, "The Printed Circuit Designer's Guide to…Signal Integrity by Example," is authored by Fadi Deek of Mentor, a Siemens business. This free micro eBook details the importance of eliminating signal integrity challenges. The chapters explore four possible signal integrity problems using an understanding of essential signal integrity principles.

Sun Chemical and Camtek Ltd. Form Strategic Partnership

Sun Chemical has formed a strategic partnership with Camtek Ltd, a market leader in digital and optical solutions for printed circuit boards and inspection solutions for the semiconductor industries.

ITEQ Announces Launch of Halogen-free IT-88GMW

ITEQ Corporation announced today the introduction of its new halogen free IT-88GMW product for use in automotive radar, millimeter wave and emerging 5G applications. The product has a nominal dielectric constant of 2.98 and a dissipation factor of 0.0012 at 10 GHz, making it the lowest loss product in this category of thermoset products.

IMPACT Interview: Tony Revier, Uyemura

One of the best parts of IMPACT for me is meeting and getting to know people in our industry that I haven't met before. While hors d'oeuvres were coming around before the Tuesday evening awards dinner, I found a quiet corner to talk with Uyemura USA President and CEO Tony Revier.

TUC Gains IPC-4101E Validation Services QPL Certification

Taiwan Union Technology Corporation (TUC) is pleased to announce that TUC has gained certification to IPC-4101E validation services for three more products. TU-933, TU-933D and TU-933E are now listed on the IPC website under QPL Specification Sheet 102 in addition to TU-933+ which was the first product so listed.

Rogers Appoints Jeff Owens to Board of Directors

Rogers Corporation's Board of Directors has appointed Jeffrey J. Owens to serve as a member of the Company's Board.

Navigating Process Change? TPC is the Key

by Steve Williams
THE RIGHT APPROACH CONSULTING

Introduction

Change is a given. While this adage may be quite true and normally a good thing, it can wreak process engineering havoc in a printed circuit operation. Change is good, but the operative word is controlled change relative to the complex processes involved in manufacturing a printed circuit board. The key to successfully navigating process change is to develop a robust Temporary Process Change (TPC) program.

Process Engineering: 75% Science, 20% Black Magic and 5% Luck

My process engineer friends will certainly take exception to this statement, however, no matter how talented our process gurus are, I believe I could make a compelling argument with them over a couple of beers. It is incontrovertible that two plus two will always equal four, no matter who is doing the math. If printed circuit process engineering was 100% science, then what works in one shop would work just as well in every other shop, period. We all know that is about as true as the statement that "politicians never lie." That is why it is so important, once the process recipe has been engineered to be highly repeatable, to have a controlled method to continue to tweak and improve it.

Even in the most controlled manufacturing environment, internal audits, rework and yield issues can oftentimes be traced back to an unauthorized minor process change. Changing a bath temperature or time, skipping a traveler step, or changing the supplier for a consumable may seem like a good idea at the time—until everyone is scratching their heads over a spike in scrap. Operators, leads and supervisors have their hearts in the right place when they want to try an idea to improve a process. More times than not they simply lack experience with the DoE (design of experiment) or other controlled change methodology.

Process Overview

When crafting the program, the first thing that needs to be fleshed out is what function will serve as the watchdog of the system, which is the first mission-critical decision of a TPC program. Employee engagement and creativity must certainly be fostered while at the same

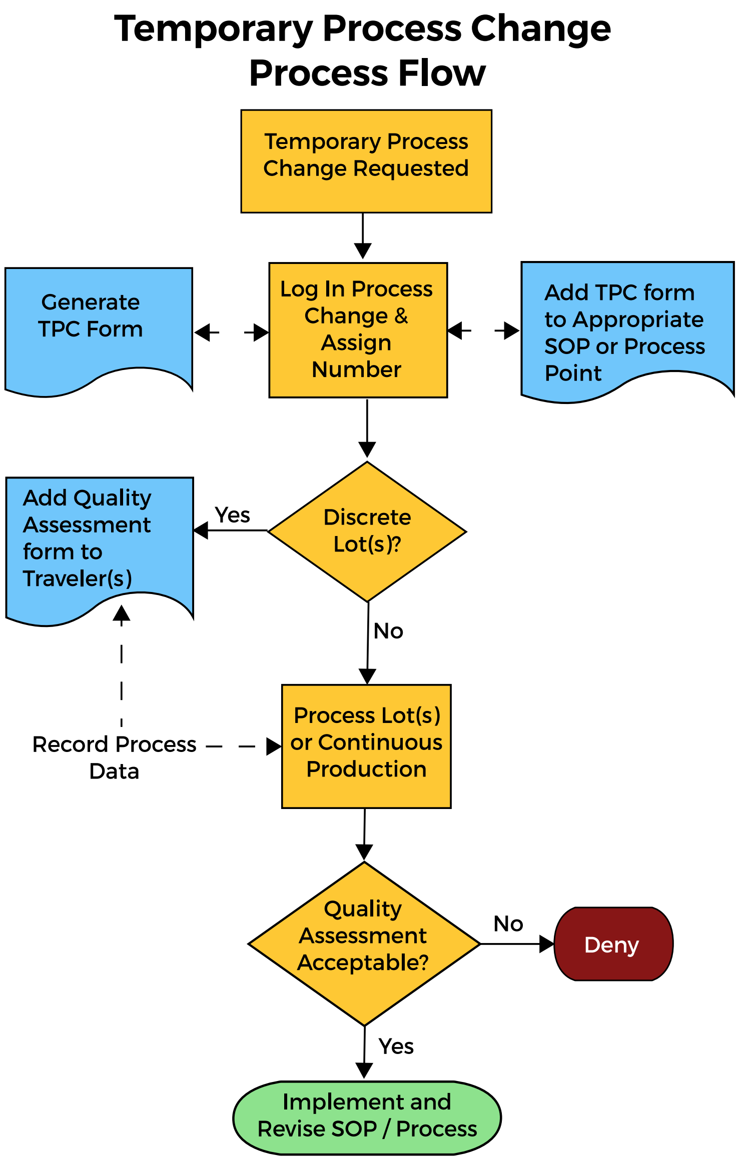


Figure 1: Process flow for a temporary process change program.

time guarding against changes that could have detrimental effect on the process. Redundant TPCs must also be avoided as there is no need to expend resources on a method that has been proven unsuccessful in the past. Obviously, process engineering, engineering or whatever function owns the shop's processes, should manage this. Each shop is different; however, my only caveat would be to have a single entity overseeing the process. I would also highly recommend making this a stand-alone procedure/work instruction.

There are three main components of a solid system, the temporary process change form, the temporary process change log, and the quality assessment phase. My position affords me the unique opportunity to evaluate the best and brightest in the PCB world, but on the other hand I also get to observe the opposite end of the evolutionary scale. It continues to amaze me, ISO notwithstanding, how many times I run across controlled procedures that have things crossed off and/or changed, or processes that only the operator knows has been "unofficially" changed. A few companies have even accounted for this by including in their document control procedure that handwritten changes are allowed! Although this loophole may satisfy a Barney Fife ISO auditor, that would require banishment to the "not ready for prime time" file in my book. Figure 1 details the process flow for a TPC program.

TPC Form

A simple form should be developed—either electronic or paper will work fine—that provides the basic information needed to implement and track the change. It should include sections that describe the change, any chemical changes, the reason for the change, and the results (implemented or denied). A TPC can be defined as "Any process change that deviates from a standard operating procedure (SOP) for a short period of time." The change could be procedural, raw material, or supplier/brand-related, and the "short period of time" must be defined. Anyone should be allowed to submit a TPC for review and approval, however utilizing the organization's various Improvement Teams for this activity increases buy-in and can be an effective filter for unworthy ideas. If the change is global for the process, it should be attached to the appropriate procedure (either paper or electronic). If the change is limited to a specific lot(s), it should be attached to the appropriate process travelers. In either case, all appropriate operators should be notified of the change, again improvement teams are a perfect media for this communication.

TPC Log

A method for managing TPCs needs to be developed, and a simple spreadsheet log is the most effective. Building a level of intelligence into the TPC numbering system (such as embedding the procedure or department number) will allow historical analysis of successful and unsuccessful TPCs for any process. Regular review of open TPCs and status is critical to a successful program.

Quality Assessment Phase

The second mission-critical aspect of a TPC program is the quality assessment phase, where a decision will be made to either permanently incorporate the change into the process or deny it. This decision needs to have the cross-functional approval from the department/improvement team, engineering, operations and quality at a minimum. This decision needs to be documented (TPC form) and as data driven as possible, i.e., yield & rework, material/labor cost reductions, etc., over the TPC period. If a discrete lot(s) is being evaluated, the quality assessment form can be attached to the process traveler(s) to gather the appropriate data as mentioned above. Global TPC's affecting continuous production will require a systemic tracking method over the course of the time period.

Closure

This should be easily accomplished, but getting to the decision point is where many often stumble. As mentioned earlier, setting a defined time frame for the TPC evaluation is critical. In most cases, 30, 60, or 90 days are sufficient to execute a meaningful evaluation of a process change. It is a strongly recommended best practice to close out as many of the open TPCs as possible prior to a major customer or registrar audit. Closure also means revising the appropriate SOP to include any successful TPCs, and retraining operators when required. Don't be concerned with having a history of frequent TPCs; if the quality system is operating correctly this activity should be encouraged. In the quest for continuous improvement, change is good.

I'll end this column with a quote about change that seems appropriate in the volatile world of printed circuit board manufacturing. It is from my good friend and quality guru W. Edwards Deming, who said, "If you can't describe what you are doing as a process, you don't know what you're doing." **PCB**

Steve Williams is the president of The Right Approach Consulting LLC. To read past columns, or to contact Williams, click here.

Drones Relay RFID Signals for Inventory Control

Radio frequency ID tags were supposed to revolutionize supply chain management. The dirt-cheap, battery-free tags, which receive power wirelessly from scanners and broadcast identifying numbers, enable warehouse managers to log inventory more efficiently than by reading box numbers and recording them manually.

But the scale of modern retail operations makes even radio frequency ID (RFID) scanning inefficient. Walmart, for instance, reported that in 2013 it lost $3 billion in revenue because of mismatches between its inventory records and its stock. Even with RFID technology, it can take a single large retail store three months to perform a complete inventory review, which means that mismatches often go undiscovered until exposed by a customer request.

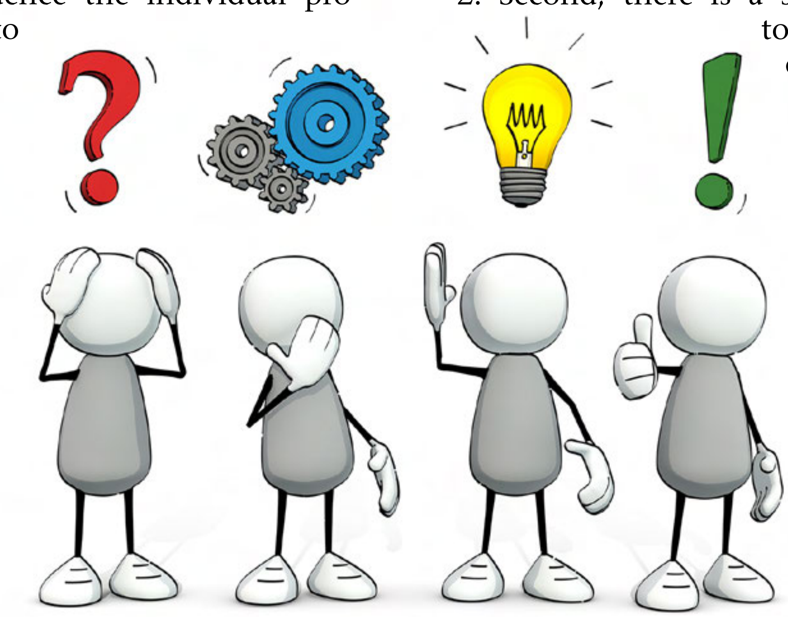
MIT researchers have now developed a system that enables small, safe, aerial drones to read RFID tags from tens of meters away while identifying the tags' locations with an average error of about 19 centimeters. The system could be used in large warehouses for both continuous monitoring, preventing inventory mismatches, and locating individual items, to meet customer requests.

PROCESS ENGINEERING & DEFECT PREVENTION

by Michael Carano
RBP TECHNOLOGY

As of this writing, I have explored many topics related to specific defects that plague printed circuit board fabricators. A key underlying theme of these writings underscores the critical need of the skilled troubleshooter to get to the underlying cause or causes of the defects. Defects may "manifest" or be detected in or after a specific operation within the printed circuit board manufacturing process, but the underlying root cause may have occurred earlier (perhaps much earlier) in the process. As I have written in prior columns, I chose to present the anomaly or defect where it is most likely to be detected, then subsequently presented the most likely root causes wherever they might have been introduced. It should be noted that these examples are presented as likely starting places for the investigation of anomalies or defects presented, or the kinds of causes that might be investigated.

The troubleshooter's task is complicated by the fact that there are many possible ways to combine or sequence the individual process steps available to achieve the desired end structure. As an example, a simple, single-lamination multilayer printed wiring board may involve 30 to 50 process steps, while a complex, multiple lamination (sequential lamination) printed wiring board, with pre- and post-machining and other mechanical operations, and selective plating processes, could involve several hundred process steps. In an ideal world, each step could be verified correct immediately during or after the process, but in practice the effect of many processes cannot be readily evaluated until the completion of many subsequent steps make latent errors visible. Much effort is and has been expended in attempts to improve this, with limited success. Thus, it remains a troublesome issue. The concern then is the defect may not manifest itself until several downstream process steps. One may refer to this as the latent defect. The impact of these latent defects is four-fold:



1. First, the detection and verification of the defect may require real time and the diversion of skilled resources—already in short supply in most lean-running modern operations.
2. Second, there is a schedule impact in today's just-in-time operating mode, both of the process flow disruption inherent in the detection and in the verification of the defect. Far more

important is the double impact of the wasted process time and effort invested to the point of detection, and the necessity of repeating that processing. The combined schedule disruption will cascade through the producer, the immediate customer, all the way to end-customer's delivery/implementation commitments.

3. Third, the cost impact of the lost labor and materials, possibly compounded by expediting costs (overtime and raw material rush replacement premiums).

4. Fourth, lost opportunities for other valuable or urgent work that cannot be accomplished while resources and materials are diverted to the recovery effort.

More complex printed circuit board structures may require multiple "loops" through the process from multilayer layup through tin strip, and selective plating increases the number of loops through the imaging and plating sequences. These have the obvious effect of increasing the required process time, but also the less-obvious effect of increased risk of yield loss. The message here: Process engineering adjustments and close attention to detail are needed.

Various simulation models of cumulative effect of process complexity on yield have been put forward (including some which pessimistically predict that no printed board of sufficient complexity can (mathematically) ever be successfully produced). While the picture is not quite that bleak, it is clear that complexity adds to cost, build time, and risk of loss (with the resultant schedule impact). To the extent possible, additional early effort expended in simplifying a design, or its build process will yield benefits in the long run.

Process Design and Control

With increasing circuit board complexity comes the greater possibility of defects. A surprisingly common underlying cause of defects, particularly in high-mix/low-volume operations (characteristically, quick-turn, prototype, specialty production, etc.), where frequent changeovers between products produced is experienced, is incorrect (or sub-optimal) conversion of the incoming data and requirements into the working process sequence and/or test and measurement requirements. The wide variety of work types and configurations processed in such operations may delay recognition that an error has, in fact, occurred until it is too late to salvage the product.

Common errors include (in no order of criticality):

- Omission or transposition of selective plating or etching mask areas from data package to production working phototools
- Skipped, or mis-ordered process steps
- Data collection instructions omitted for a specific process step not readily retrieved later, or necessary test vehicles (coupons) not added to the initial panelization scheme
- Premature removal of electroplating buss-bars (electrical tie-in), in-process test points, or of etch-resist metallization
- Transposed (or just incorrect) dimensions incorporated into mechanical operation programming (drilling, milling), especially when manual or override is required by the data supplied.

Process control excursions (or process breakdowns) that are undetected until after an operation remain as hurdles to high-yield, flexible-response manufacturing. Scrap (or suspect product) containment is a major focus at high-speed, high-volume processes, particularly continuous (reel-to-reel, automotive, or cellular production, for example) processes. Automatic monitoring and shutdown (or at least alarm) of key process parameters is becoming the norm. Process control and process monitoring are key levers that one can pull to insure process repeatability and performance consistency. However, process engineering improvements often overlook process conditions such as rinse water temperature and cleanliness, pH controls, rectifier issues that reduce electroplating quality, malfunctioning temperature controllers, etc. These are just a few of the potential process engineering issues that if not corrected, will contribute to printed board defects and loss of revenue. Learning that some very expensive printed circuit boards are found to fail in the field due to lack of process engineering or lack of simple controls is

both devastating financially as well as compromising confidence of the customer. Let's look at some real-world examples where several different root cause issues lead to the "observed defect" or non-conformance.

Etching

Most process problems that appear during the etching stage of printed circuit production can be traced to one of two general areas. The most obvious causes (though not necessarily the most common) of etching problems occur in the etching equipment itself, either through equipment failure or mis-adjustment or chemistry outside normal operating parameters. As is often the case in printed circuit processing, anomalies detected during or after the etching step may trace back to technical issues induced during prior processing steps but not detected until the boards are processed through the etcher. An example would be resist scum left on the board during the stripping of a plating resist, which can cause uneven etching to occur, although blocked nozzles, "tracking" from rollers, uneven distribution (top to bottom, or across the machine) of spray pressure can all mimic the effects of incomplete resist removal under some circumstances.

Figure 1 shows what appears as unetched copper. The excess remaining copper will lead to either a short or at the very least violate the spacing requirements. The possible causes for this defect as well as likely solutions are listed in the Table 1.

Figure 2 depicts a circuit trace that has been etched out and is very close to having an open created. It would be easiest to point the finger at the etching operation. However, the skilled troubleshooter will not fall into that trap.

The engineer should note that the defect is not widespread. The issue is isolated to a few spots. While it would be easiest to blame the etching operation, experienced process engineers would look elsewhere first. A few of the most likely causes and solutions are shown in Table 2.

While there are many more possible defects related or at least attributable to etching, this column is not meant to address them all. In addition, one needs to review defects that manifest themselves in the plated through-hole (i.e., electroplating).

Electroplating

Electroplating in the manufacture of printed wiring is used to deposit a metallic pattern,

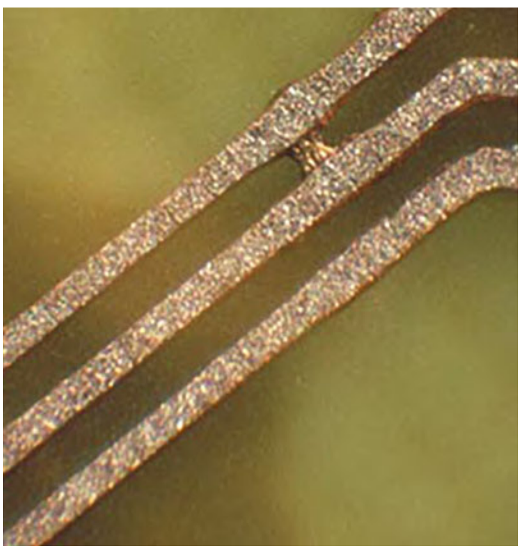


Figure 1: Excess or unetched copper. (Source: IPC photo archive, Bannockburn, Illinois)

Potential Cause
1. Photoresist residual (exposure or developer process defect). 2. Inadvertent plating (resist lift). 3. If more generally distributed, under-etch (etch process conditions).
Potential Solution
1. Categorize photo-process defect (repetitive, single-instance, frequency. Repetitive is likely phototool/expose, random/scattered could be resist lamination, or developer "scumming." Review and correct source process as needed. 2. Frequency and distribution may help point to photoresist lamination (incl. pre-clean) process or too-aggressive pre-plate clean (for example). Review and correct source process as needed. 3. Widely-distributed, large, under-etched areas point more towards etch process (chemistry, including temperature, conveyor speed, etc.). Review and correct source process as needed.

Table 1: Possible causes and solutions for unetched or excess copper. (Excerpted from IPC-9121 "Troubleshooting for Board Fabrication Processes," Section 10.1 Etching)

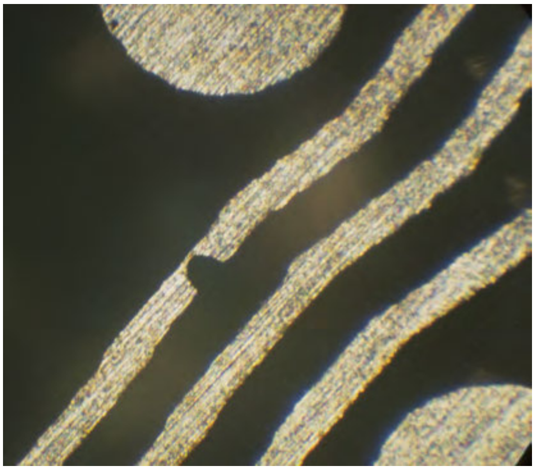


Figure 2: Nearly etched-out circuit trace. (Source: RBP Chemical Technology)

Potential Cause
1. Resist lifting—Poor resist conformity to copper-possible glass weave issue. Improper surface preparation prior to resist lamination. 2. Over developing. 3. If more generally distributed, over-etching is possible (etch process conditions).
Potential Solution
1. Review cleaning procedures. Adjust lamination pressure and time. 2. Reduce time and pH in developer solution. Adjust breakpoint. 3. Widely-distributed, several over-etched areas point more towards etch process (chemistry, incl. temperature, or conveyor speed, etc.). Review and correct source process as needed.

Table 2: Possible causes and solutions for over-etched/ missing copper. (Excerpted from IPC-9121 "Trouble Shooting for Board Fabrication Processes," Section 10.2 Etching)

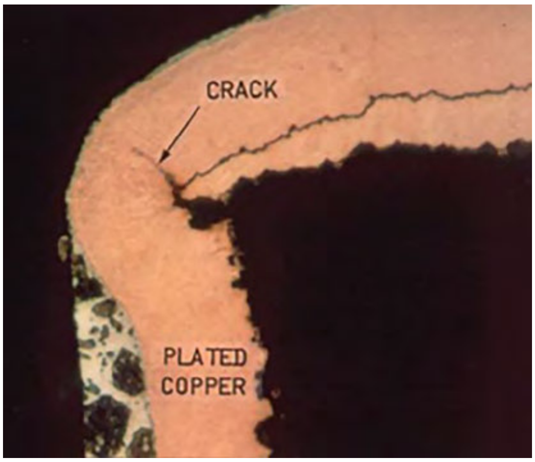


Figure 3: Electroplated copper cracks after thermal excursion. (Source: RBP Chemical Technology)

Table 3: Possible causes and solutions for copper cracking in barrel of hole. (Excerpted from IPC-9121 Section 7.4 Hole Preparation and Protection)

Potential Cause
Insufficient resistance to thermal stresses due to: a) Insufficient copper thickness b) Improper metallurgical characteristics of deposited copper c) Excessive (beyond anticipated) thermal stress d) Localized voids or inclusions e) Excessive organic contamination of plating solution f) Inappropriate choice or condition of laminate (dielectric) material resulting in excessive "Z" axis stress
Potential Solution
a) Review plating parameters (duration, current density, chemistry) and correct as needed. b) Verify plating chemistry (analysis, CVS) and performance of deposited samples (Hull cell, CVS, etc.) and correct as needed c) Review contractual and engineering requirements with customer and/or assembly operation. Revise requirements, assembly process, or both as needed. d) Review bath filtration system, carbon treat process, and chemical analyses, and correct as needed. e) Carbon treat plating solution. Monitor carbon with TOC-total organic carbon analysis f) Review laminate material properties. Laminate undercured, resulting in excessive Z-axis expansion-possible lamination cycle did not allow for proper cross-linking of the resin materials

generally on copper-clad substrates. Plating acceptability is judged by plating thickness, adhesion, ductility and uniformity (the presence of inclusions, nodules, voids or cracks). Factors that affect these criteria are board surface preparation, board racking and handling, control of chemical parameters, and physical parameters of the plating operation (solution filtration, distribution, anode/cathode placement and geometry, etc.).

Some of these variables are capable of "immediate" control by the operator (adjustment of plating chemistry, temperatures, etc.) and others can be changed only slightly, or with difficulty such as varying the geometry of anode/cathode placement. This adjustment is limited by the geometry of the plating line and individual tanks as installed.

One of the very troublesome defects is corner cracking in the electroplated copper within the PTH (Figure 3). The potential root causes and solutions are listed in Table 3.

This real-life example underscores the need to have a deep understanding of how variations in one or more processes may cause the defect several steps removed. One can surmise that the processes or processes need improved controls as well as more sophisticated analytical methods. In addition, regular tensile and elongation measurements will serve as a leading indicator for possible copper cracking.

Finally, in Figure 4, the classic innerplane separation is observed. At first glance, it may be easy to determine that the root cause of the separation is that the electroless copper deposit separated from the innerlayer post. That is certainly a logical conclusion. And one is viewing the section after solder excursion and without etching the specimen (which is correct procedure up to this point). However, further study is required.

Is that separation due to some resin smear remaining on the post? Thus, preventing the adhesion of the electroless copper to the post? And whether the separation is due to resin smear or simply the copper separating, it is nonetheless a separation and a non-conforming defect. Regardless, the unetched specimen shows a separation. However, where does one go from here to troubleshoot the problem? Clearly there is no evidence of any etchback so it is possible there is drill smear remaining. It is somewhat difficult at this point to detect smear without SEM/EDAX. The skilled troubleshooter will now accept the challenge of reviewing whether this defect is more widespread or an isolated case. Table 4 lists several possible causes for the defect seen in Figure 4.

Figure 4: Separation of plated copper from the innerlayer post. (Source: IPC photo archive, Bannockburn, Illinois)

Potential Cause
Drill/desmear related 1. Drill parameters/process inappropriately chosen or controlled for material/geometry of hole 2. Desmear process insufficient/incorrect for drill conditions or dielectric material 3. Pre-plate cleaning incorrect 4. Evaluate electroless copper process-look for excessive deposition rates, over catalyzation, excessively thick deposit
Potential Solution
1. Verify drilling parameters (feeds, speeds, drill-hit-count-limits, tool geometry) correct for this dielectric material, hole geometry (diameter/aspect ratio). Correct as necessary. 2. Verify process parameters/control for desmear process correct and sufficient for this dielectric material. Correct as necessary. 3. Verify pre-plate cleaning process (cleaner concentration/condition/depletion, all rinses, microetch activity and duration, pre-dip concentration/contamination, etc.). Correct any and all as needed. 4. Check and verify all electroless copper parameters including rate panels, catalyzation times, rinse water cleanliness

Table 4: Possible causes and solutions for innerplane separation (excerpted from IPC-9121 Section 7.2 Hole Preparation and Protection)

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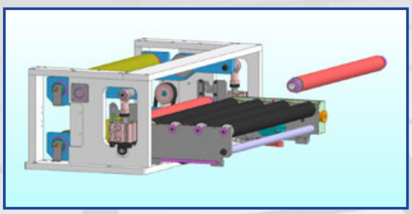
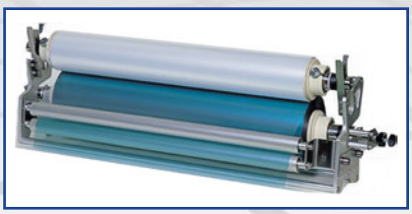
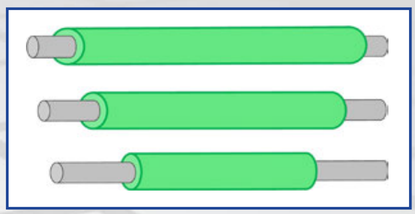


Change Rolls in Seconds

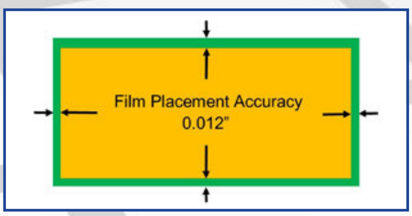


Cassette Film Load Off-line



Rubber to Match Panel Sizes

Ease of Use and Training



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Troubleshooting defects and process issues starts first with optimizing the processes for highest yields possible. However, even the best engineering does not guarantee the total elimination of defects in the process-intense PCB manufacturing process.

Thus, the good troubleshooter enhances the problem-solving exercise using various Six Sigma techniques. The one used here by the author and illustrated throughout this article is the DMAIC method:

- Define the problem and goal, identify the customers served by the process, and define customer requirements
- Measure—refine the problem statement, decide what to measure, and begin the search for root causes
- Analyze the data looking for trends, patterns, etc.
- Improve—develop innovative new processes
- Control—institute controls to insure improvements remain. Document all activities for future usage/training

There was quite a lot of subject matter here. However, it should be recognized that nothing can substitute for a methodical approach to problem solving utilizing all the tools and knowledge available to the troubleshooter. **PCB**

Michael Carano is VP of technology and business development for RBP Chemical Technology. To reach Carano, or read past columns, click here.

Custom Robots in a Matter of Minutes

Even as robots become increasingly common, they remain incredibly difficult to make. From designing and modeling to fabricating and testing, the process is slow and costly: even one small change can mean days or weeks of rethinking and revising important hardware.

But what if there were a way to let non-experts craft different robotic designs, in one sitting?

Researchers from MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) are getting closer to doing exactly that. In a new paper, they present a system called "Interactive Robogami" that lets you design a robot in minutes, and then 3D print and assemble it in as little as four hours.

One of the key features of the system is that it allows designers to determine both the robot's movement (gait) and shape (geometry), a capability that's often separated in design systems.

"Designing robots usually requires expertise that only mechanical engineers and roboticists have," says PhD student and co-lead author Adriana Schulz. "What's exciting here is that we've created a tool that allows a casual user to design their own robot by giving them this expert knowledge."

The paper, which is being published in the new issue of the International Journal of Robotics Research, was co-led by PhD graduate Cynthia Sung (now an assistant professor at the University of Pennsylvania) alongside MIT professors Wojciech Matusik and Daniela Rus.

The other co-authors include PhD student Andrew Spielberg, former master's student Wei Zhao, former undergraduate Robin Cheng, and Columbia University Professor Eitan Grinspun.

Electronics Industry News
Market Highlights

The Internet of Things and Machines: Linking Machines to Machines

Linking industrial machinery, robots, and systems together holds considerable potential. However, it also requires a high level of security to avoid both breakdowns and break-ins.

Before, it was 3D Printing: Now Additive Manufacturing is the New Black

"Additive Manufacturing is a hot topic in the manufacturing industry worldwide at the moment. Companies are looking for ways in which they can produce products and prototypes fast and in more cost-efficient ways," says Guido Tosello, associate professor at DTU Mechanical Engineering, at the innovation conference.

3D Printing Market Worth $23.79 Billion by 2025

The global 3D printing (3DP) market is estimated to reach USD 23.79 billion by 2025, according to the new report conducted by Grand View Research Inc. Also called additive manufacturing (AM), this technology is referred to as a procedure that produces parts through the successive addition of layers of materials in various 2D shapes.

Fighting Dehydration with Wearables and Big Data

Dehydration is one of the most common causes of death among young children in the developing world—particularly during the hot summer months. ETH Professor Walter Karlen and his team of researchers have developed an inexpensive mobile device that could be used by laypeople to more effectively treat dehydration.

Heat-Conducting Plastic Could Lead to Lighter Electronics, Cars

Advanced plastics could usher in lighter, cheaper, more energy-efficient product components, including those used in vehicles, LEDs and computers—if only they were better at dissipating heat.

Global Market for Smart Manufacturing Solutions to Top $320 Billion by 2020

Industry 4.0 is a concept that has attracted a lot of attention in the global marketplace since its emergence in 2012. Following this conceptual framework, manufacturing companies in various industries have embarked on a mission to transform their operations by deploying smart technologies.

Foxconn, Keyssa, and Samsung Introduce Disruptive 'Connected World' Smartphone Ecosystem

A group of leading technology companies and Keyssa investors announced a 'Connected World' initiative focused on extremely high-speed data transfer between mobile devices and the increasing number of connected devices.

Gartner Releases 'Hype Cycle for the Digital Workplace, 2017'

Digital business execution is requiring more frequent and complex decision making, continuous problem solving and rapid pattern recognition, all of which require workforce digital dexterity. In most organizations, however, responsibility for helping employees develop the desire and ability to exploit a wide range of transformative technologies—highlighted in the Gartner Inc. "Hype Cycle for Digital Workplace, 2017"—does not have to rest with any group or individual.

Wearable Devices' Expansion to Industrial Sector Thrives with Addition of Advanced Sensors and Software

The emergence of the Internet of Things (IoT) and workers' need for real-time data, monitoring and tracking are boosting the development of wearable technologies for the industrial sector. With the technology crossing the concept phase, stakeholders in manufacturing, logistics and warehousing, construction, mining, oil & gas, retail and healthcare industries are eager to incorporate it into their portfolios.

China Still Leading the Global Smart Meter Market with 68% of Tracked Installations

A new report from Navigant Research analyzes the state of the global utility electric smart meter market, tracking data related to customer endpoints, meter manufacturers, advanced metering infrastructure (AMI) communications vendors, systems integrators, and meter data management (MDM) vendors.

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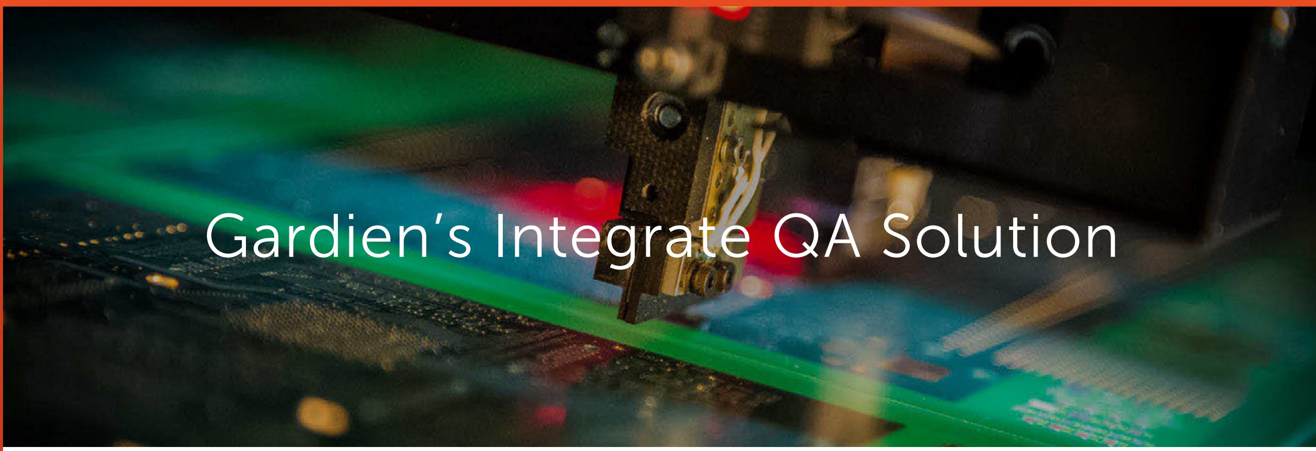

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by Marc Ladle
VIKING TEST LTD.

Many companies in the printed circuit industry are based in a single factory. When everything is going well, this can really help to get the best out of people and machinery. The main drawback is that seeing the same issues day after day, it can be easy to accept your manufacturing problems as being normal.

I installed an AOI machine for a customer in a small factory which employs around 10 people in the manufacturing area. I would describe everyone who works there as multi-skilled. Processes would run only as they were required and the factory was busy and reasonably efficient for the type of work that was being completed. Most of the equipment had been in place for quite a few years, but generally everything looked well maintained.

Installing inspection or test equipment is a great opportunity for an outsider to get an idea of the range of typical faults that are occurring in the manufacturing processes. In this case we were inspecting panels after outer layer etch. Training was going well and we were picking out the types of faults that the customer was interested in catching.

We saw quite a few examples that I thought looked like the dry film had lifted either before or during the electroplating process, resulting in excess copper between tracks. Because the factory was small and production was not a constant flow, I suggested we look back through the preceding processes when we ran out of panels to inspect.

The idea was sound enough. I thought it would be a good opportunity to see if we could find an underlying cause for the poor dry film adhesion which would account for the faults we detected on the AOI. As I was intending to be

onsite for a couple of days, I thought we may be able to see an improvement before I left.

We started at drilling and worked our way through the production process as far as the carbon through-hole line. We could see some cleanliness issues with residues on the rollers, which were far from ideal. We discussed the machine cleaning regime and the customer admitted that things may slowly have slipped with the care of this process.

There were still no further panels to AOI, so we carried on with what had turned into a very low-key process audit. By this time, most of the production had wound down for the day and the factory was rather quiet. We had become a group of four—myself and three of the more senior production staff in the factory. We were getting on quite well and it was a good opportunity to look at each stage of the production process.

We had reached the pattern plating line and I was looking down the tanks from the loading end. It was a small transporter line using stick jigs, and the last few panels for the day were on their way through the final stages.

Small batch production is always difficult to load to this type of jig arrangement. The last few panels often must be run in a compromised arrangement on the jigs to fill the space. But looking down the line I could see that the anodes were in different positions in each of the plating tanks. I asked the question: Have you moved the anodes to help get a better distribution when you have a small area loaded to the flight bar? I could tell from the puzzled expression that the arrangement was not due to any special technical intent.

After a few questions about the panel sizes and the way that the panels were loaded to the jigs, I realised that the edges of the panels were probably always over-plated, as some of the anodes were well outside the plating window they were using.

Now, here was the surprise for me. My suggestion to move the anodes was met with quite a degree of skepticism. There was a detectable change in atmosphere and I could tell that all was not well in the world of informal audits! I like to think that I have a gentle "lineside manner" and I tried again suggesting that at least the arrangement in each of the plating cells should match each other to ensure a consistent result.

After an amount of discussion, a few pencil drawings and a cup of coffee, I left the guys from the factory to their thoughts. I retreated to the local bed & breakfast to consider what I could have done better. Production issues can be delicate subjects. In this case I have an idea that the plating operator may not have been the easiest guy to deal with and at least some of the problem would be the drawing of straws to see who got the job of telling him that his setup was not perfect.

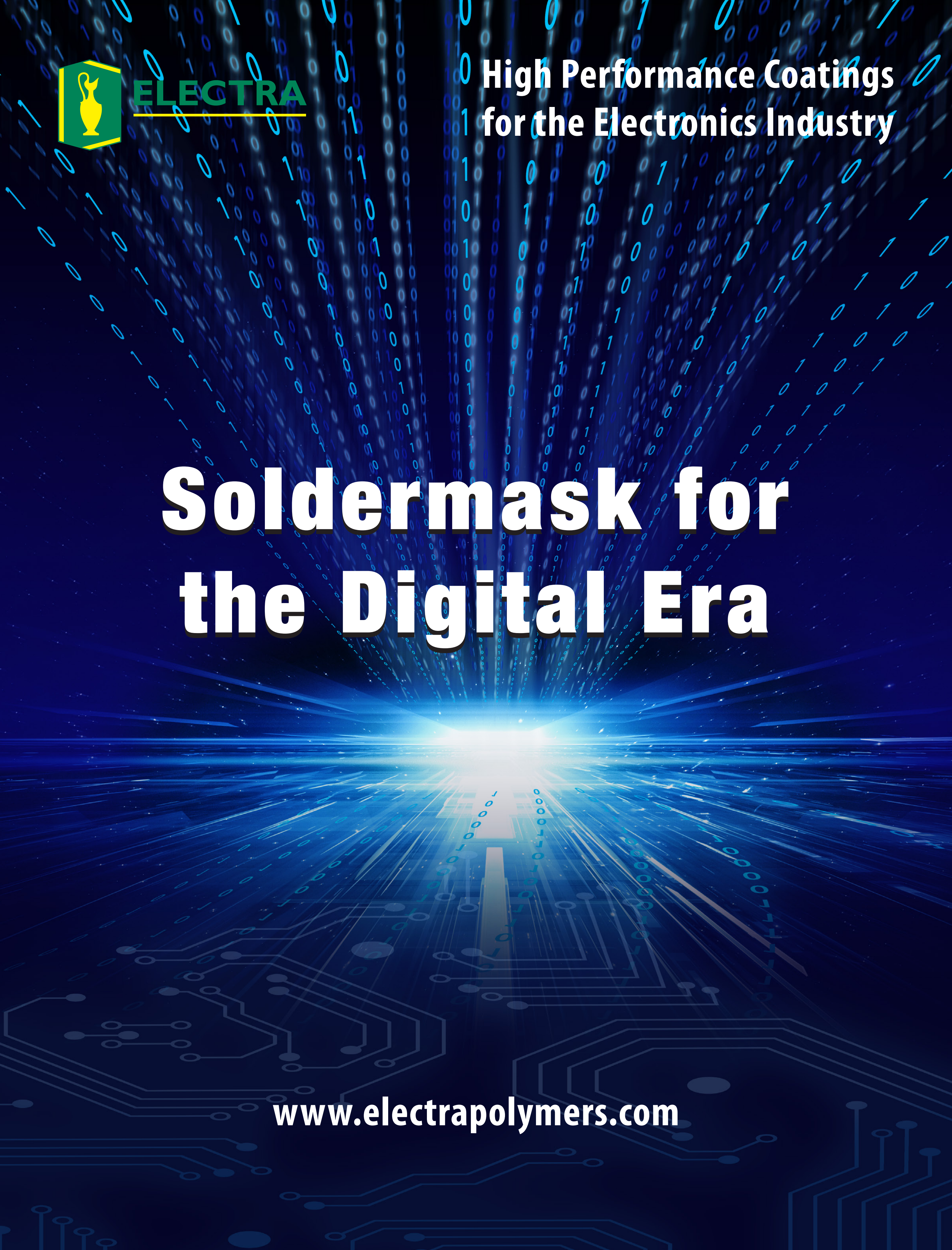
Twelve hours can be a long time in circuits and the following morning, when I arrived at the factory, I was met by a delegation rushing out of the factory door. Any worries were only momentary as I could tell by the smiles that things were OK this morning.

The guys had stayed for quite a while after I left and tried making the changes we had discussed together. The results were a significant improvement in copper distribution. We saw some tenable benefit from the time we had taken to look at the processes. The improvement in this process would have many benefits for the quality of the parts being manufactured so it made our efforts very worthwhile.

There was no huge expense involved—my time was free for the agreed duration of the AOI installation and the guys at the factory were salaried staff. The real benefit was a renewed enthusiasm to question if best practice was being followed throughout the factory.

For me, the main advantage was the added kudos with the customer. It certainly adds some gravity to your advice if you can show some practical benefit. If I am 100% truthful, I really enjoy the problem-solving aspect of process engineering and when a customer allows me to be involved in this way, it is therapeutic time for me. Happy days! **PCB**

Marc Ladle is director at Viking Test Ltd. To contact Ladle, or to read past columns, click here.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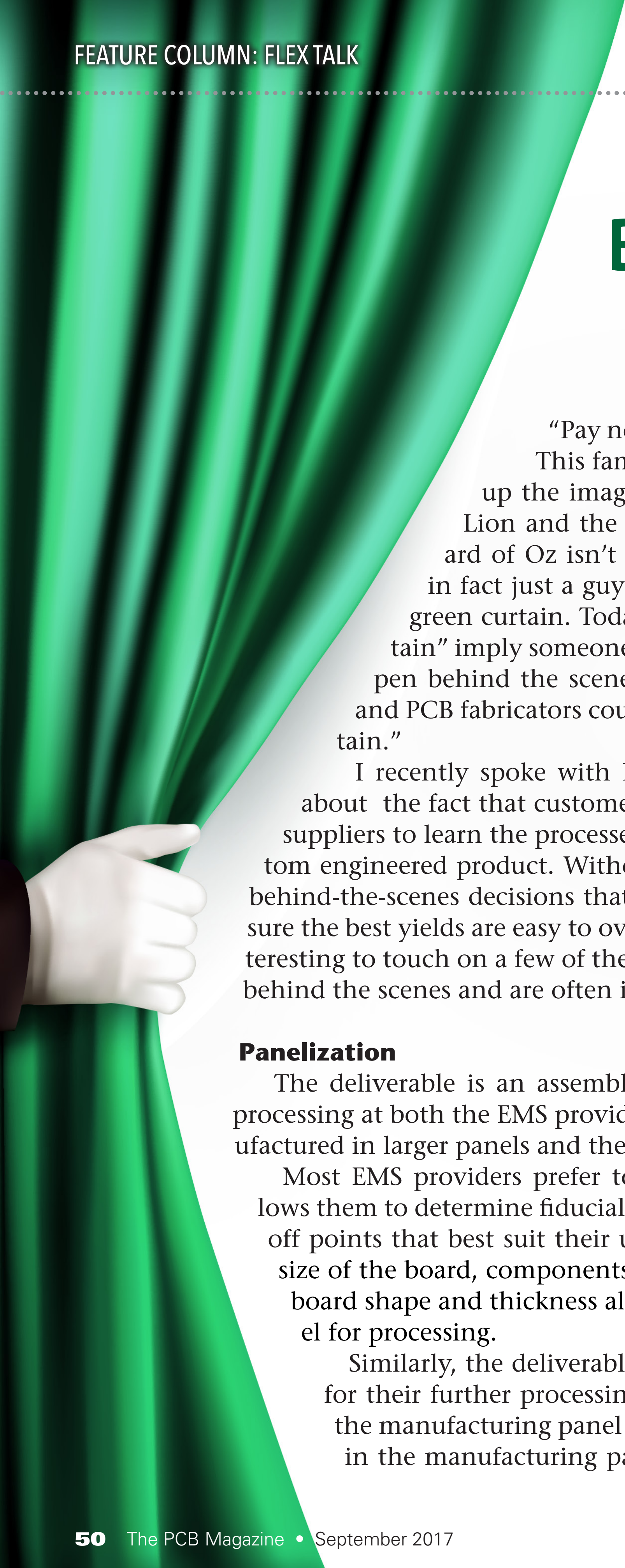


The Man Behind the Curtain

by Tara Dunn
OMNI PCB

"Pay no attention to the man behind the curtain." This famous quote from *The Wizard of Oz* conjures up the image of Dorothy, the Tin Man, the Cowardly Lion and the Scarecrow discovering that the great Wizard of Oz isn't as grand or as magical as he seems. He is in fact just a guy operating a bunch of controls behind the green curtain. Today, references to "the man behind the curtain" imply someone making decisions and making things happen behind the scenes. Process engineering at EMS companies and PCB fabricators could be considered "the man behind the curtain."

I recently spoke with Holly Olsen from Electronic Systems Inc. about the fact that customers rarely tour their PCB fabricators or EMS suppliers to learn the processes and challenges behind building this custom engineered product. Without these visits, knowledge of some of the behind-the-scenes decisions that are made day in and day out to help ensure the best yields are easy to overlook. Holly and I thought it would be interesting to touch on a few of the key processes and decisions that are made behind the scenes and are often invisible to the customer.

Panelization

The deliverable is an assembled printed circuit board. But throughout processing at both the EMS provider and the PCB fabricator, product is manufactured in larger panels and then broken down to the final product.

Most EMS providers prefer to specify their own panelization. This allows them to determine fiducial size and location, tooling holes and break-off points that best suit their unique process and equipment needs. The size of the board, components that overhang the edge of the board, and board shape and thickness all play a part in the design of the ideal panel for processing.

Similarly, the deliverable to the EMS company is an array of parts for their further processing. During the PCB fab process, the size of the manufacturing panel and the placement of parts, or arrays within the manufacturing panel is one factor that is adjusted depend-

ing on technology of the design. A typical fabrication panel will be 18″ x 24″ or 21″ x 24″. As technology requirements increase, the panel size used will decrease. Panel size is typically reduced to 12″ x 18″ when tight features are required or when the process requires tighter registration than standard processing is expected to meet. With the smaller panel size, there is less impact from standard material movement. When processing on a 12″ x 18″ panel does not yield the anticipated results due to material movement, process engineering may suggest using the center or "sweet spot" on the panel to minimize that impact even further.

Processing Thin Materials

Again, this is an area that both fabrication and EMS work their magic behind the curtain. From the EMS perspective, PCBs that are less than 0.031″ thick or flex materials require additional support for processing. Thin materials will flex and move during component placement and reflow. A common method to stabilize the array is to create a SMT pallet. Pallets will cycle through and be reused in the process. The number of pallets needed is determined by the manufacturing lot size and SMT cycle time to ensure proper manufacturing flow is maintained.

SMT pallets must be made to withstand high temperatures and cannot conduct heat allowing them to go through the reflow process. CDM Durapol ESD is a commonly used composite material that can withstand the high temperatures and includes static dissipative characteristics. Tension pins are designed into the pallet to align with the tooling holes on the PCB panel, securing the board in place through processing.

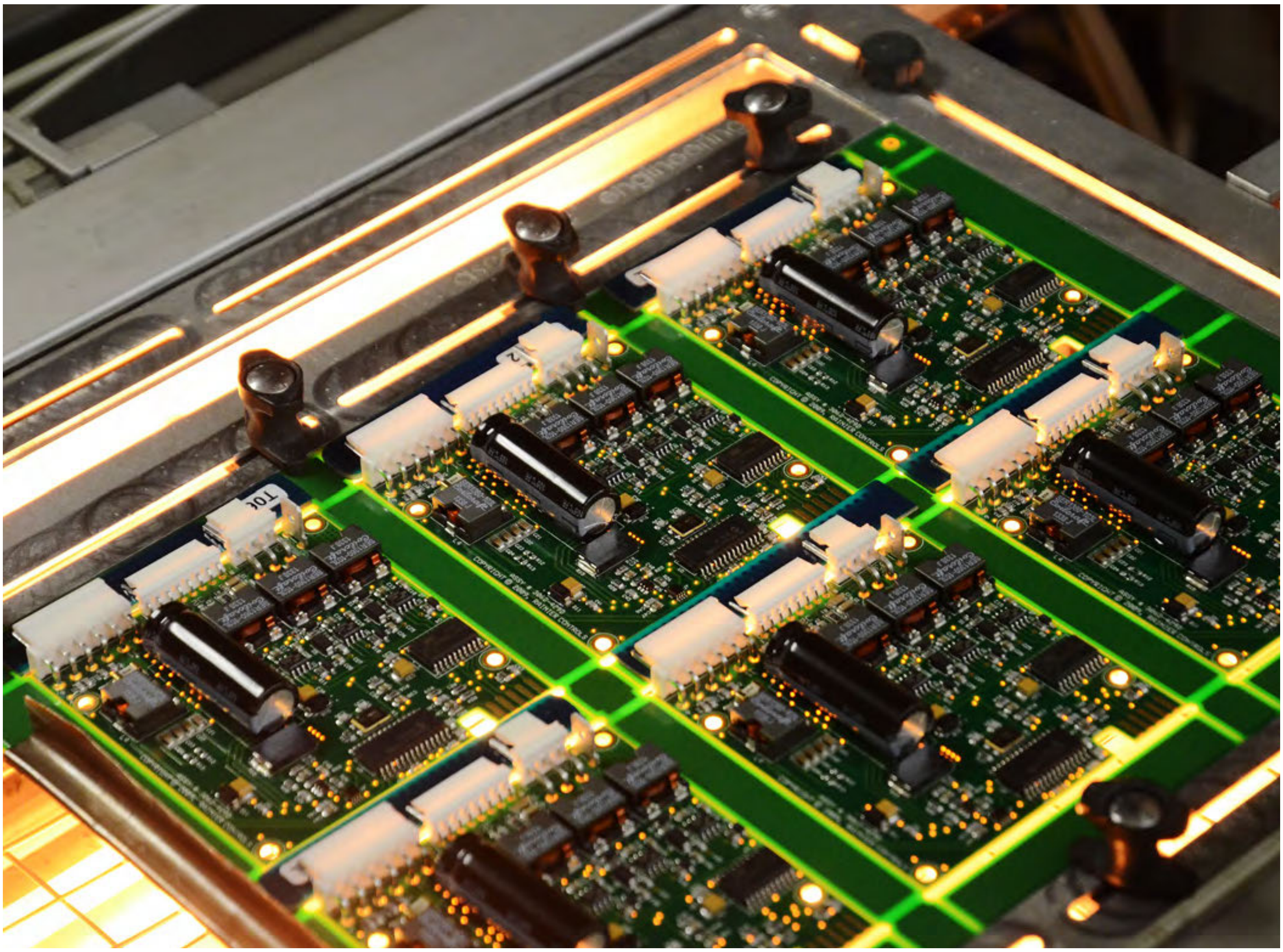


Figure 1: PCB panel design aids in manufacturing processes throughout the factory.

Similarly, fabricators take special precautions with thin materials. Often special carrier panels are used to transport the product from location to location and operators are trained to handle materials—picking up from opposing corners to eliminate flex in the material. Any dents or dings in the copper will have a high probability of creating scrap as the circuit pattern is created. Because automated equipment is often not specifically designed for thin materials, leader panels are often taped to the manufacturing panel to provide additional support moving through automated equipment.

Stencil Design

"The screen printing process is one of the most critical steps in the SMT process," says Kevin Buffington, manufacturing engineer for Electronic Systems. "The combination of a good stencil and solder paste inspection is vital to the outcome of placement and reflow." The screen printing process begins with a well-designed SMT stencil. Proper volume and placement of solder paste is crucial to the reduction or elimination of solder defects such as insufficient solder, shorts, and solder balls. This is achieved by choosing the right foil thickness and aperture size for the mix of components on the printed circuit board. Stencil design parameters are developed based on aspect ratio and area ratios of components. These ratios are a calculation of the size of the stencil opening and the stencil thickness that allows the solder paste to release. While not preferred, in limited cases where some very large components are included on a design with very small, fine-pitch components, step stencils may also be used to ensure that enough solder paste is deposited for the larger components. Step stencils, as the name suggests, step up the stencil thickness in a specific area to place a greater amount of solder paste.

Framed stencils can either be fixed frame or universal frame. Stencils will typically range from 15" x 15" to 23" x 23" and use either a solid or hollow aluminum frame. As the name suggests, the fixed stencil is permanently fixed to the frame. With the universal frame, the stencil is held within the frame which makes it possible to make changes as they are needed.

While IPC specifies best practices for component spacing in design, today's designers are expected to do more with less space and more often need to push the envelope of standard processing. Fabricators and EMS providers are continually refining their processes to manufacture tighter pitch trace and space and assemble tighter pitch components. Involving your PCB fabricator and EMS provider early in the design helps to ensure that manufacturability is designed into the product. Even better, plan a facility tour and gain a little insight into what goes on behind the curtain when manufacturing PCBs and PCBAs! **PCB**

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

Highly Flexible, Wearable Displays

A research team led by Professor Kyung Cheol Choi at the School of Electrical Engineering presented wearable displays for applications including fashion, IT, and healthcare. Integrating OLED (organic light-emitting diode) into fabrics, the team has developed some of the most highly flexible and reliable technology for wearable displays in the world.

Recently, information displays have become increasingly important as engineers construct the external part of smart devices for the next generation. As world trends are focusing on the Internet of Things (IoTs) and wearable technology, Choi's team has made great progress towards commercializing clothing-shaped 'wearable displays.'

The Future of Electronics in the Automotive Industry

by John Mitchell
IPC–ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

Automotive electronics is not a new topic. While there is a trend for both performance and luxury electronics, many of the recent conversations tend to focus on self-driving/autonomous vehicles. While the technology is exciting, it is just the tip of the iceberg. Did you know that your car is most likely the most technologically advanced device you own? It seems weird to refer to a car as a device, but modern automobiles have more chips and circuit boards than your average home Internet appliance.

In fact, high-tech systems in cars has been around since the 1980s. And we aren't just talking about for GPS, computerized screens, or entertainment. Electronically controlled ignition and fuel injection systems allow automotive designers to meet standard requirements for fuel economy, while lowering emissions. With these systems, cars can still maintain high levels of performance and convenience for drivers. Today's automobiles are comprised of many processors. Printed circuit boards play a vital role in the performance and reliability of everything from engine, fuel injection, ignition systems, and throttle control. And that's just a start. Most of today's cars have between 30 and 80 separate electronic controllers.

Furthering the importance of proper standards for manufacturing, Volvo recently announced that all their manufactured vehicle models will be electric or hybrid by 2019. This decision marks Volvo as the first traditional automaker to work toward phasing out cars powered by only internal combustion engines. This means more electronics, which means more effort needs to be placed on ensuring these vehicles can handle the rigorous thermal cycles present in a vehicles day-to-day usage.

In conjunction with that, France has announced that as part of their plan to be carbon neutral by 2050, they are rolling out a plan to eliminate gas powered vehicles by 2040. IPC will continue to work hard to drive the proper manufacturing required to ensure electric vehicles are produced to correct standards.

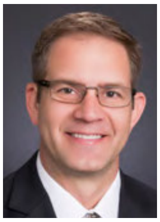
In the coming weeks, we will have a certification program available for IPC-6012DA: Automotive Applications Addendum to IPC-6012D, Qualification and Performance Specification for Rigid Printed Boards, which provides documentation/drawings for rigid printed boards that must survive the vibration and thermal cycling environments of electronic interconnects within the automotive industry.

And, as of last year, IPC began the development of a press-fit standard for automotive requirements[1]. This standard, which was requested by the European automotive electronics industry, intends to cover the qualifications and acceptance requirements for press-fit pin technology that includes the reliability needs for automotive and other industries, such as aerospace.

For more information on IPC's standards development initiatives including those for the automotive industry, visit our standards website[2]. PCB

References

1. IPC Announces Development of a Press-fit Pin Standard for Automotive Requirements
2. IPC.org/Standards

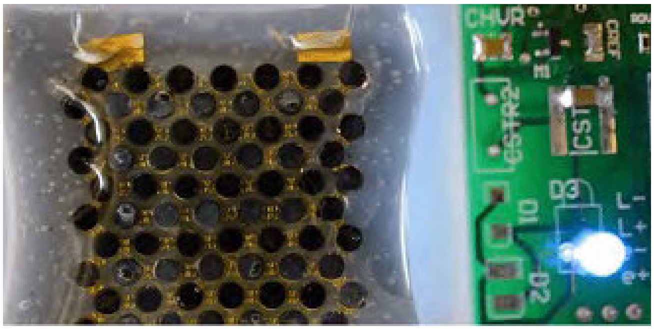


John Mitchell is president and CEO of IPC—Association Connecting Electronics Industries. To read past columns or to contact Mitchell, click here.

Stretchable Biofuel Cells Extract Energy from Sweat to Power Wearable Devices

A team of engineers has developed stretchable fuel cells that extract energy from sweat and are capable of powering electronics, such as LEDs and Bluetooth radios. The biofuel cells generate 10 times more power per surface area than any existing wearable biofuel cells. The devices could be used to power a range of wearable devices.

The epidermal biofuel cells are a major breakthrough in the field, which has been struggling with making the devices that are stretchable enough and powerful enough. Engineers from the University of California San Diego were able to achieve this breakthrough thanks to a combination of clever chemistry, advanced materials and electronic interfaces. This allowed them to build a stretchable electronic foundation by using lithography and screen-printing to make 3D carbon nanotube-based cathode and anode arrays. The biofuel cells contain an enzyme that oxidizes the lactic acid present in human sweat to generate current. This turns the sweat into a source of power.



Engineers report their results in the June issue of Energy & Environmental Science. In the paper, they describe how they connected the biofuel cells to a custom-made circuit board and demonstrated that the device powered an LED while a person wearing it was exercising on a stationary bike.

Professor Joseph Wang, who directs the Center for Wearable Sensors at UC San Diego, led the research, in collaboration with Patrick Mercier, electrical engineering professor and center co-director, and Sheng Xu, professor of nano-engineering.

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Wisdom Wednesday — **Webinar**
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September 16–21
IPC Fall Committee Meetings — **Meeting**
held in conjunction with SMTA International
Rosemont, IL, USA

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IPC & WHMA Wire Harness Manufacturing Conference — **Conference**
Paris, France

October 3–4
IPC Technical Education — **Workshop**
Paris, France

October 9–10
IMPACT Europe — **Meeting**
Brussels, Belgium

October 11
Wisdom Wednesday — **Webinar**
Members Only

October 17–18
IPC Flexible Circuits-HDI Forum — **Conference**
Tutorials and Technical Conference
Minneapolis, MN, USA

November 8
IPC Technical Education — **Workshop**
held in conjunction with PCB Carolina
Raleigh, NC, USA

November 8
Wisdom Wednesday — **Webinar**
Members Only

November 14–17
IPC Committee Meetings — **Meeting**
held in conjunction with productronica
Munich, Germany

November 14–17
IPC Hand Soldering Championship — **Competition**
held in conjunction with productronica
Munich, Germany

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

December 13
Wisdom Wednesday — **Webinar**
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- Printed Board Design Technology
- Printed Electronics
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- Product Reliability
- Rigid Printed Boards
- Testing

For more information, visit www.ipc.org/fall-meetings.

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MilAero007 Highlights

Performance Evaluation of Thin-Film Embedded Resistors

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

It's Only Common Sense: Finally, the DoD Gets It!

Last week a friend of mine sent me this excerpt from the Congressional Record. Yes, that congressional record. If this doesn't set your hair on fire, then nothing will.

Prototron Circuits Achieves AS9100 Rev D

Prototron Circuits announced recently that their Tucson, Arizona facility has achieved AS 9100 Rev D qualification.

Mil/Aero Markets: Defense Budget Analysis—Patience is a Virtue

Patience may be the most necessary watchword for proponents of significant growth in the budget for the U.S. military. The historic increases in defense spending promised by President Trump on the campaign trail won't come immediately, but it is likely that Congress will find ways to provide solid increases to the Pentagon's budget, particularly in 2019 and beyond.

Eltek Receives an Order for up to $3 Million from a Governmental Authority

Eltek Ltd. has received an order from a governmental authority for a project that includes, among other things, manufacturing and procurement in an amount of up to approximately US$3 million.

IPC Welcomes Exec Order on Strengthening the U.S. Defense Industrial Base

According to Nextgov, Peter Navarro, Deputy Assistant to the President and Director of the White House Office of Trade and Manufacturing Policy (OTMP), said the order will determine whether there are enough U.S. manufacturers to supply "everything from submarine propeller blades to circuit boards and military-grade semiconductors," and whether there are enough skilled workers to work in the field.

IMPACT Interview: Anaya Vardya, American Standard Circuits

I-Connect007's Patty Goldman spoke with Anaya Vardya, president and CEO of American Standard Circuits, a few days after the conclusion of IMPACT, especially wanted his views as a first-timer there.

Trilogy Circuits: Mil/Aero Demands Technological, Regulatory Expertise

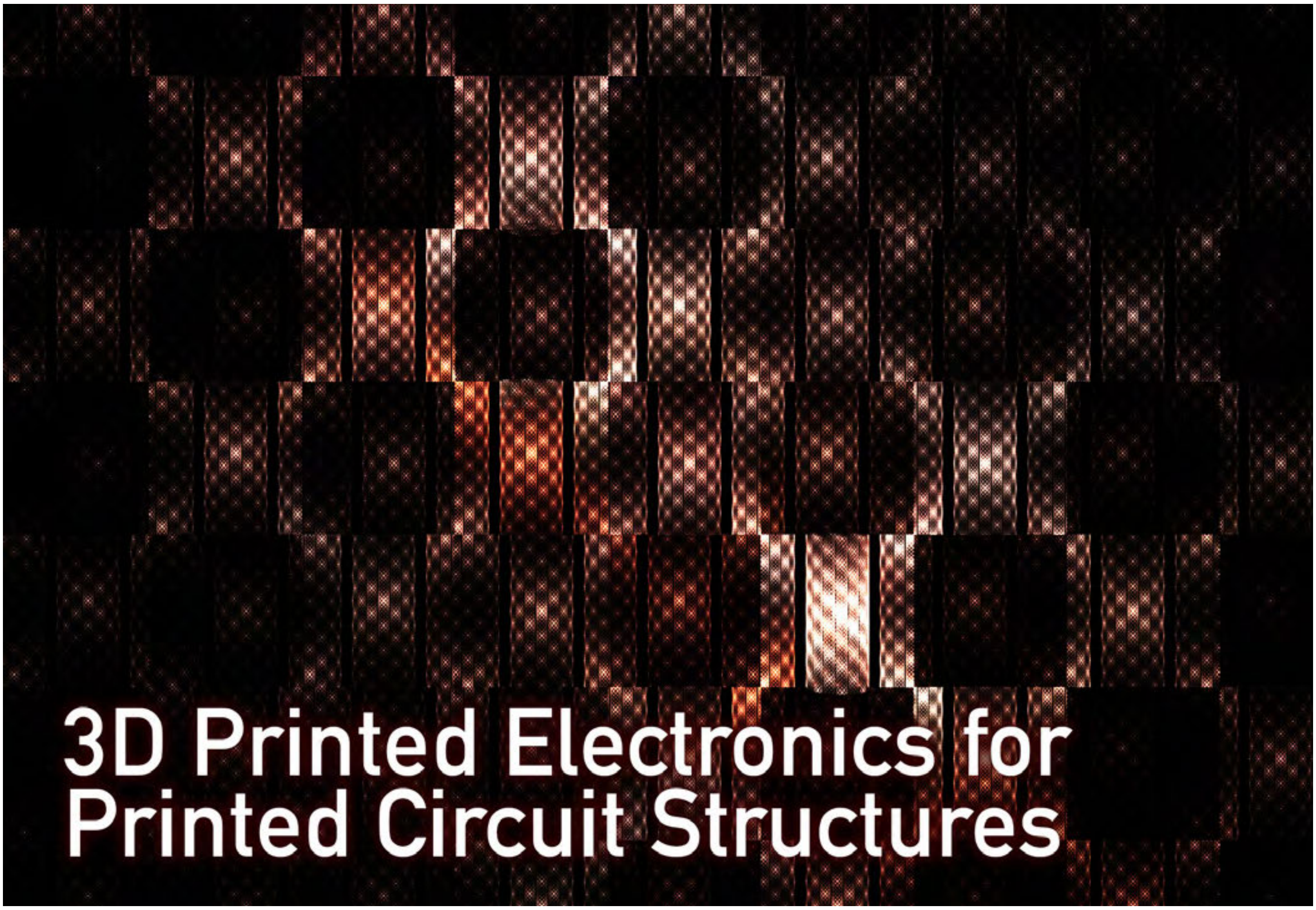
In the 16 years since its founding, Trilogy Circuits has become one of the go-to companies for mil/aero PCB design and manufacturing. I spoke with Charlie Capers, president and founder of the Richardson, Texas firm, about how he keeps ahead of the game. As he explains, succeeding with mil/aero PCB work requires not only mastery of the technological side, but of the regulations and certifications as well.

Strategies for Compliance with DoD Regulations Including ITAR and DFARS

ITAR is usually the topic when compliance with DoD regulations is discussed. But what about DFARS? This article will examine strategies one can implement to ensure that one is compliant with all DoD regulations, by analyzing internal and external factors in relation to procurement and compliance, and by asking the vital questions: what, how, where and to whom?

Strategic Technology Office Outlines Vision for "Mosaic Warfare"

STO seeks to turn complexity into a powerful new asymmetric weapon via rapidly composable networks of low-cost sensors, multi-domain command and control nodes, and cooperative manned and unmanned systems.



3D Printed Electronics for Printed Circuit Structures

Samuel LeBlanc, Paul Deffenbaugh, Jacob Denkins, and Kenneth Church
nSCRYPT INC.

Abstract

Printed electronics is a familiar term that is taking on more meaning as the technology matures. Flexible electronics is sometimes referred to as a subset of this and the printing approach is one of the enabling factors for roll-to-roll processes. Printed electronics is improving in performance and has many applications that compete directly with printed circuit boards. The advantage of roll-to-roll is the speed of manufacturing, the large areas possible, and a reduction in costs.

As this technology continues to mature, it is also merging with the high-profile 3D printing. 3D printing is becoming more than just a rapid prototyping tool and more than just printing small plastic toys. Companies are embracing 3D printing as a manufacturing approach to fabricate complex parts that cannot be done using traditional manufacturing techniques. The combination of 3D printing and printed electronics has the potential to make novel products and, more specifically, to make objects electrically functional. Electrically functional objects have the advantage of competing with printed circuit boards.

Printed circuit structures will be a new approach to electronic packaging. It is the desire of many companies to reduce assembly processes, decrease the size of the electronics, and do this at a reduced cost. This is challenging, but the potential of printing the structure and the electronics as a single monolithic unit has many advantages. This will reduce the human touch in assembly, as the electronics and the object are printed. This will increase the ruggedness of the product, as it is a monolithic device. This will eliminate wires, solder, and connectors, making the device smaller. This has the potential to be the future of printed circuit boards and microelectronic packaging. This article will show working demonstrations of printed circuit structures, the obstacles, and the potential future of 3D printed electronics.

Introduction

While 3D printing, as stereolithography (SLA), has been around since the early 1980s, it is has evolved considerably into many forms. For the purposes of this paper, fused filament deposition (FFD), also known as fused deposition modeling (FDM), will be considered. Only recently has FDM printing been joined by electronic printing to create 3D printed electronics. With this evolution in 3D printing, printed circuit structures (PCSs) can possess distinct advantages over printed circuit boards (PCBs). Many components that are present on a PCB can be integrated into a PCS. It has been shown that PCSs can contain fully embedded circuity such as antennas[1,2], lumped components[3], and even connectors[4]. Instead of creating a PCB to attach to an object, it would be possible to print the object with the circuitry as an integrated part of it.

This printing method is made possible using a direct digital manufacturing (DDM) machine that combines the use of multiple tool heads including a micro-dispensing pump, a heated extrusion head, a pick-and-place head, and a micro-milling, drilling, and polishing head. While PCBs require the use of many machines and require masking, PCSs can be completely automated, as total fabrication is done in-situ on a single machine[5,6]. Although PCSs do have advantages, there are still several obstacles to overcome, namely speed of fabrication and strength of final parts.

Fabrication Speeds

FDM-style 3D printing is notorious for being slow. This is mainly due to the low volumetric extrusion rates of conventional desktop 3D printers. There are many factors that determine extrusion rate. Some of these include nozzle diameter, nozzle temperature, bed temperature, X-Y movement speed, material, and even the extrusion motor. While these have an effect on the total amount of filament being extruded, the nozzle diameter is the main determiner of extrusion rate. Layer height, extrusion widths, and print speeds are all based on the nozzle diameter, therefore this is the facet of the printing process that stands to generate the most benefits from improving.

The standard printing nozzle has a 0.4 mm inside diameter. This allows for print speeds of up to 80–100 mm/s, depending on machine and desired print quality. Nozzle size can be increased, however, while this can shorten the overall print time, a decrease in quality will be seen. These decreases in quality can be things such as a rougher surface finish, rounded corners, and incorrect dimensions. Larger diameter nozzles are also limited when printing small objects as the small features can be problematic. While the quality-related downsides of selecting a large diameter nozzle are not attractive, they can be dealt with.

A method of printing called "spaghetti" printing was developed to greatly increase extrusion rates and decrease print times. This pro-

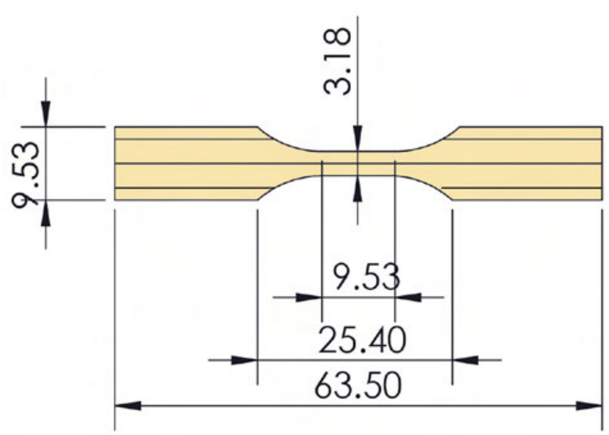


Figure 1: ASTM D638 Type V tensile specimen, 0° infill.

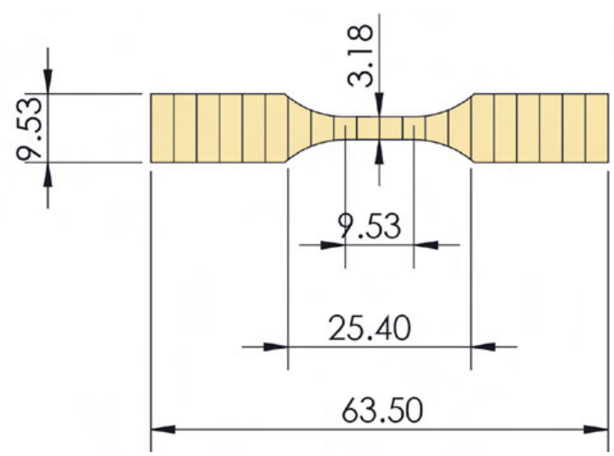


Figure 2: ASTM D638 Type V tensile specimen, 90° infill.

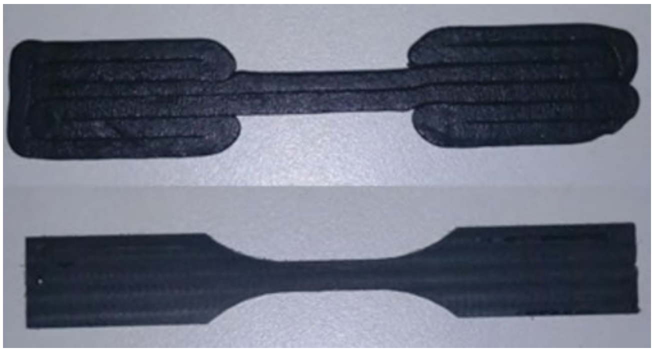


Figure 3: Spaghetti-printed tensile specimen before and after milling.

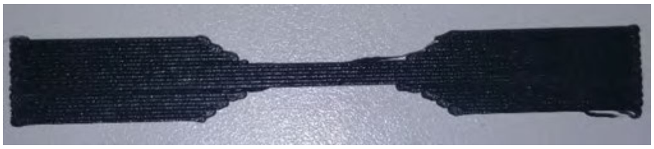


Figure 4: 0° printed tensile specimen using 0.4 mm nozzle.

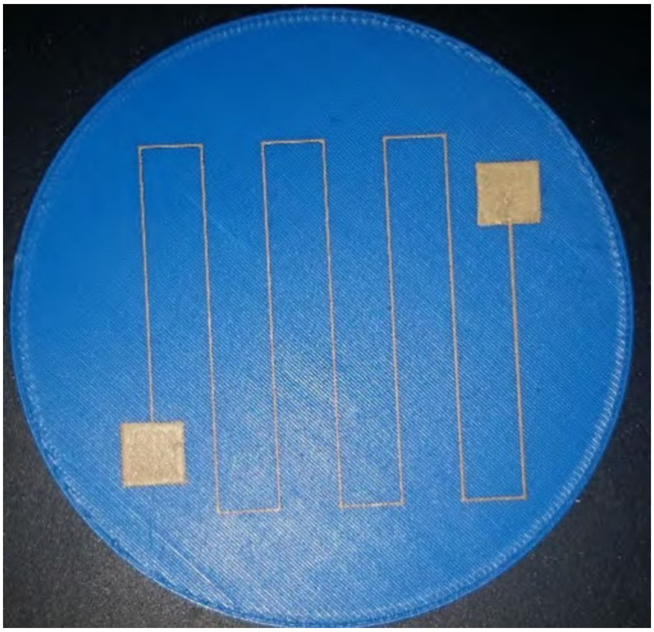


Figure 5: Micro-dispensed conductive paste on 3D printed substrate.

cess involves printing filament out of a specially designed 1.75 mm nozzle and then utilizing a milling head to give a high-quality surface finish where required as well as bringing the print into dimension. A speed experiment was set up comparing the printing speed of an ASTM D638 Type V tensile specimen printed using a 0.4 mm nozzle and the "spaghetti" printing approach. Two types of tensile specimens were printed; one with a 0° infill and one with a 90° infill from the horizontal. These samples were printed with no perimeters as this would throw off tensile testing.

Both of these sample types are 1.0 mm and were printed with a nozzle temperature of 235°C and a bed temperature of 50°C. The perimeters seen in Figure 1 and Figure 2 are used to show dimensions.

When printed with the 0.4 mm nozzle, each tensile specimen completed printing in four minutes and 24 seconds. When done with the spaghetti method, each tensile specimen averaged one minute and 58 seconds total time with the actual 3D printing portion only taking 32 seconds. This experiment was repeated 25 times. Not only did the spaghetti method complete the object more than twice as fast, the final surface finish from milling was far superior to that of the conventionally printed specimen.

This benefits PCS greatly as printing the electronics portions requires a smooth surface for conductive material to be dispensed. Normally, for a conductive print to be successful, the FDM substrate layer needs to be printed with a nozzle as small as 100 microns to provide a smooth surface for the conductive material to be printed accurately and true to design. Although surface mapping is available, which enables contour printing, a smooth surface is preferred. This also provides an ideal surface when printing multiple thermoplastics onto one another.

Creating PCS incorporates multiple processes and materials, though everything is done on one system. Take, for example, Figure 6. This small demo shows the steps to create an embedded USB device. First, a base to hold the USB chip was printed out of ABS plastic, one of the most common 3D printing materials. To accommodate the printing of the circuitry, which will extend the pads of the USB chip to the edge of the device, a smooth surface was desired. The milling head was selected to accomplish this task. With around one micron of runout, the milling head is able to selectively smooth and flatten a

Figure 6: Steps of a printed USB device.

surface to well within the requirements of dispensing circuitry. Once done, the USB chip was precisely positioned on the smooth surface using a pick-and-place head.

Next, a conductive material was dispensed beginning at the pads of the USB chip and finishing at the end of the tab on the printed base. Again, the smooth surface here benefits the dispensing process by creating a uniform height across the entire area. This allows for higher consistency when dispensing materials as this process requires a constant "Z-gap" or distance between nozzle and substrate. A polycarbonate shell was then printed around the perimeter of the circular portion to create a barrier used to hold a dispensed epoxy. Once the epoxy cured, the milling head was brought back in to give a nice, smooth finished surface. This is a small demonstration of multi-material, multi-process in-situ PCS fabrication.

Strength of Printed Parts

Printable fused filaments range from somewhat durable materials such as acrylonitrile butadiene styrene (ABS) to flexible thermoplastic elastomers (TPE) and even FST-rated thermoplastic polyetherimide (PEI) resins. These materials have their own strengths and weaknesses. Whether it is the high impact strength of ABS or the chemical and temperature stability of thermoplastic polyetherimide (PEI) resins, choosing the right material for a particular application can determine whether or not it is successful. However, FDM printed parts fall well short of the strengths of other fabrication methods such as injection molding[7]. This is due to the fact that the strength of 3D printed parts relies on layer-to-layer surface adhesion, adhesion of side-by-side printed lines, and print direction as well as the mechanical properties of the material itself. Another aspect of 3D printing that decreases overall strength of printed parts compared to bulk material properties is the presence of voids that are introduced into the part during the printing process.

In both of these examples shown in Figures 7 and 8, voids can be observed wherever there is an overlap of side-by-side lines. This is due to the fact that the edges of printed lines are rounded. To combat voids, an overlap factor

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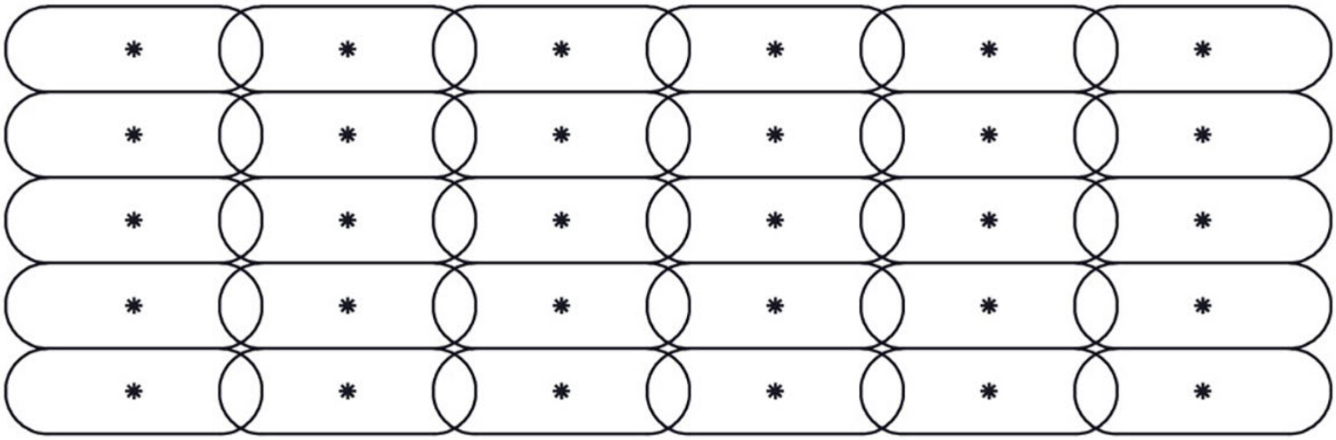

Figure 7: Cross-section view of printed layers with a 0.4 mm nozzle.

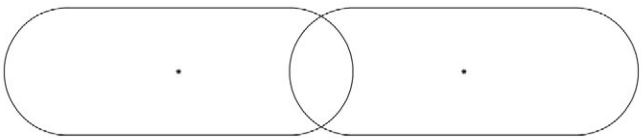

Figure 8: Cross-section view of spaghetti-printed layers.

can be input into the generation of the print path of the object. This will squeeze the lines closer together, minimizing voids, to an extent. When a high overlap factor is specified, the material being squeezed together must go somewhere and thus it is displaced upwards. This will create a rough surface finish if on the top layer, and could throw off overall height dimensions if allowed to compound throughout the print. When printed with the 0.4 mm nozzle, many, albeit smaller, voids are introduced into the object. While the few voids that are present with the spaghetti-printed layer are larger, the total void area of the parts printed with the 0.4 mm nozzle is greater. These voids contribute to the ~10% difference in ultimate tensile strength for the printed specimens (Figure 9).

The print direction plays a major role in the strength of printed parts[7,8]. It is common practice when printing structural parts to have layers printed in the direction of force that the final part will experience. To exemplify why printing in the direction of force is important,

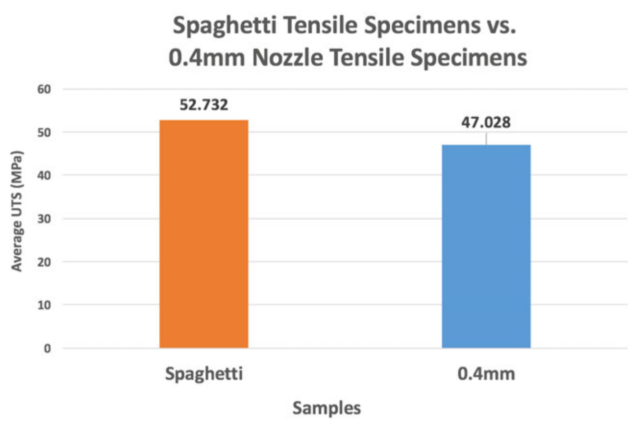

Figure 9: UTS comparison of spaghetti and 0.4 mm nozzle tensile specimens.

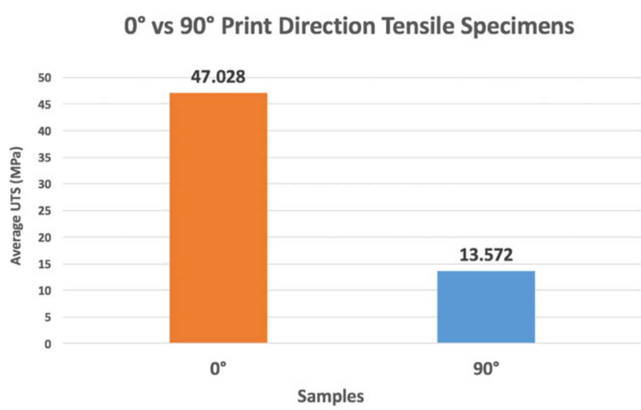

Figure 10: UTS of 0° and 90° tensile specimens.

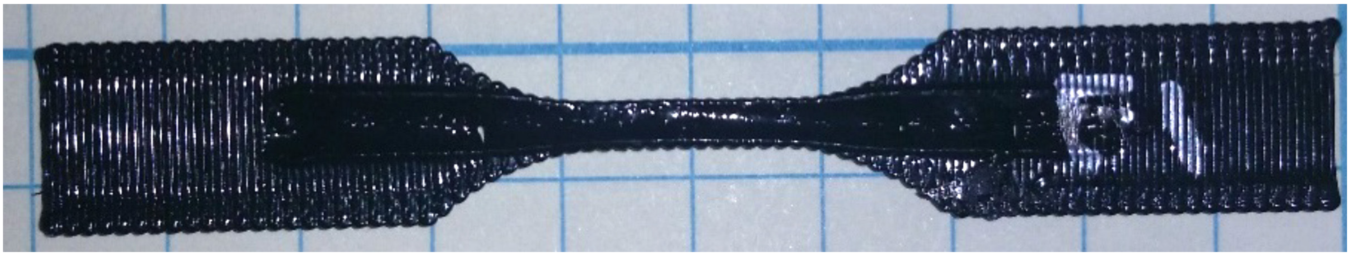

Figure 11: Laser "reflowed" tensile part.

tensile specimens were printed in the direction of force (0° specimens) and perpendicular to the direction of force (90° specimens). The 0° specimens failed at an average of 47.028 MPa UTS while the 90° specimens failed at a much lower force of 13.572 MPa, a ~72% loss of strength. The difference in observed UTS is drastic and shows the effect that print direction has on strength. This difference is again due to the fact that, since the direction of force is perpendicular to the 90° specimen's print direction, the adhesion between lines is the only thing providing resistance rather than the material itself.

Ideally, there would be strength in every direction as there can be multiple directions of force in certain applications. It is common in 3D printing to not print 0° or 90° infills, but rather to print 45° as this would provide strength in multiple directions[7,8]. However, this is a compromise as this decreases the overall tensile strength when compared to printing solely in the direction of force. Furthermore, if the direction of force is in the Z-direction, the same problem arises because layer adhesion is the predominant factor in determining how much force a part can be subjected to before failure. Since layer and side-by-side line adhesion are aspects of 3D printing, there needs to be a way to increase the force they can sustain. To do this, a "reflow" experiment was performed. The approach was to use a temperature-controlled laser to heat and essentially "reflow" the already-printed plastic. A 30W laser was mounted on the machine and was placed just above the 90° tensile part. Using a non-contact thermometer, the temperature of the plastic part was elevated and held to 120°C while the laser traveled across the surface of the specimen. The laser completed three passes over the middle section

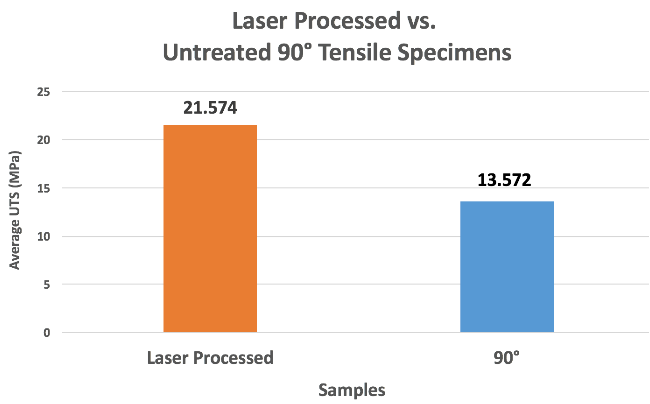

Figure 12: Average UTS of reflowed and untreated 90° tensile parts.

of the part, reflowing the plastic and increasing the adhesion between layers.

Tensile testing these "reflowed" samples yielded an average 21.574 MPa UTS compared to the untreated samples' average 13.572 MPa UTS, a 58% increase.

While the strength increase is much improved, it is still below the UTS of parts with infill printed in the direction of force. This is important because it can enable the printing of stronger parts that exhibit force in multiple directions. While this was performed to essentially increase side-by-side line adhesion, it could also be applied to layer adhesion. By placing the laser in front of the printing head, the previous layer of deposited material would be reheated while simultaneously being printed on top of, creating a more solid part. This will increase layer adhesion with the added benefit of possibly removing voids, resulting in a stronger overall part; this is for future work.

Conclusion

PCBs today are optimized and ubiquitous. They can be mass produced, created relatively quickly, and are a proven, reliable product. They do have their limitations, though. They are process-intensive, one-offs are not necessarily economical, and they produce a lot of waste, which creates extra expense to manufacture in the U.S. Printed circuit structures are the evolution of the PCB and 3D printing industries. They have several distinct advantages over PCBs in that they greatly reduce process steps, one-offs and customization are easy because of the DDM process, and since they are primarily additive, there is very little waste.

However, there are still some obstacles present. PCS as it is today would struggle with large volumes because the speeds are not yet there. Strength of fabricated parts is another obstacle in the way of PCS. 3D printed parts are not as strong as bulk properties, so consideration must be taken into the design of the PCS. Using the methods described in this paper, these two issues were addressed and improvements have been made. A more than 2x speed increase was realized through the use of spaghetti printing which also yielded a stronger, smoother part. Another method of increasing strength utilized a laser to reflow already printed plastic creating better line-by-line and layer adhesion. Combining these methods, stronger, more durable printed circuit structures can be fabricated much faster. **PCB**

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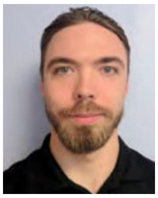

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Myths about Millennials: Workplace Safety Matters

by Barry Lee Cohen

Today, more than one in three American workers are millennials, and they represent the largest share of the American workforce[1]. As baby boomers increasingly enter the ranks of retirement, companies are embracing the differences of this younger generation to foster a safe workplace, while increasing employee productivity and engagement.

Defined as those who were born between 1980 and 2000 (give or take a year), millennials are sometimes unfairly maligned as self-absorbed. Given this perceived obsession with "me, me, me," you might assume this generation exhibits a lack of interest and motivation to participate in workplace safety programs.

In fact, millennials place a higher value on safety[2], and most especially workplace safety—more than any other generation. This may surprise you, but stop and think about it. This generation grew up in what continues to be some of the most turbulent times. Such tragedies as the Oklahoma City bombing, the World Trade Center attacks, and conflicts across the globe have ingrained the importance of safety in the minds of millennials since childhood.

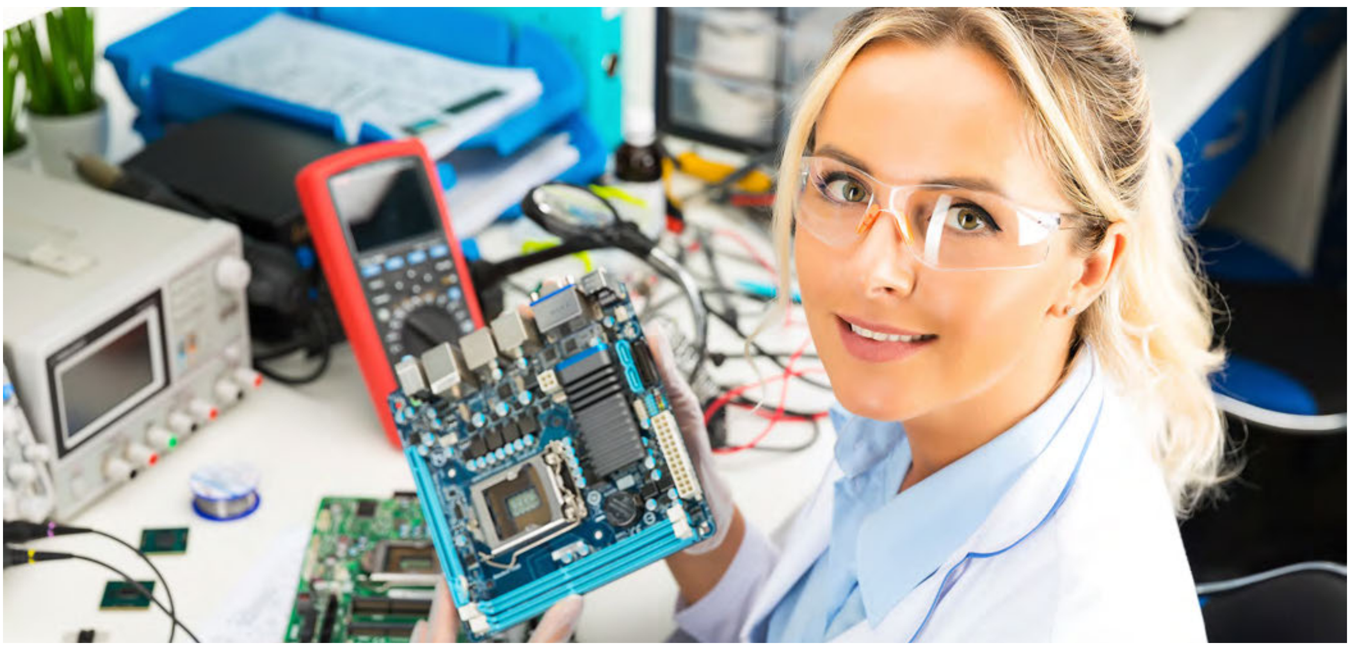
That said, millennials are indeed unique when compared with prior generations. And that's a good thing! Savvy companies have seized upon these differences to re-evaluate and refresh their workplace safety training and their corporate communications strategy overall. This change has benefitted all employees.

Consider the following employee engagement strategies to turn millennials into key contributors to your workplace safety team.

Sound Bites vs. Big Bites

Given the vast array of media options today, rolling out the traditional safety training video or an endless PowerPoint presentation can be as interesting as watching paint dry. Millennials are often blamed for having short attention spans, but the fact is, everyone does.

Texting and Twitter have short-circuited all our communication. YouTube has forever changed the way we think of videos. On-



line learning has adapted to these changes by serving up short, interactive modules. E-learning offers 24/7 accessibility that enables all employees the flexibility to "self-serve" and learn at their own pace. Classroom instruction still has its place. Just be sure to divide safety training into several sessions vs. hours-long marathons. Publish safety tips on your company's electronic display boards to reinforce safety sound bites. Comprehending the information is more important than testing one's mental endurance.

Release Your Millennials!

You know the line, "Teach a man (or woman) to fish…" The same holds true for workplace safety training. Serve up those sound bites and then release your millennials to investigate and report back on ways to improve hazard spotting, accident prevention, off the job safety and other office safety topics. Make it a competition! Break up into teams that are comprised of all generations to uncover safety dos and don'ts. Videotape each team's ongoing exploration, along with the informative (and often humorous) strategy sessions and publish them on your intranet or digital signage for all employees to see and share.

> "Be sure to publicly acknowledge all participants and ask for feedback during and post-competition."

Be sure to publicly acknowledge all participants and ask for feedback during and post-competition. If making a game of it is not a viable option, allow employees to complete workplace safety programs within a more flexible, yet defined timeframe. Provide links to your company's intranet or an industry association. You're paying corporate dues to these organizations. Empower your employees by using the valuable resources that these associations generate on your behalf.

Social Makes Safety Sense

Social media gives everyone the power to speak up, influence, and join the conversation. To millennials, this is second nature. Put these powers to good use! Create a Twitter safety poll to obtain insights into beliefs and training priorities. Have some fun and ask folks to comment on the latest safety goggles and lab apparel posted on your Instagram account. Start a company page on Facebook and invite your employees (and their families) to safety summits using the "Create Event" tool. These suggestions are just a few ways to extend workplace safety from your corporate headquarters to the home and community. Regardless of what social media channels you use, regularly post safety updates and training opportunities to keep safety top of mind for all employees.

Summarize Safety with Infographics

It's not just millennials that prefer visual[3] communication. Infographics have become a very popular way to communicate complex subjects in a simple, digestible way. Corporate communications departments have added them to their arsenal for sharing important information with employees. Infographics[4] can be used to summarize job safety programs, highlight workplace safety tips and include statistics on accident prevention and healthy living. They are perfect for sharing on social media and are often reproduced in print and posted on employee bulletin boards, or displayed on electronic display boards. Infographics can drive important safety training essentials both on-the-job and at home.

Millennial Mentorship

Often stereotyped as superheroes ready to leap to their next employer in a single bound, millennials arguably get bored more quickly than prior generations. Therefore, keeping these multi-taskers engaged through mentoring and coaching[5], giving direct feedback, and providing opportunities to learn new technical skills are some keys to retaining this safety-conscious generation.

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Temporary assignments, such as working in logistics to observe warehouse safety or enlisting their help to conduct third-party safety audits for other departments, foster teamwork across the company. Furthermore, completing OSHA workplace health and safety training, being part of a successful ISO audit, or earning Six Sigma certification should be worthy of any company's employee recognition program. Recognition improves employee morale and increases productivity, while also demonstrating the company's commitment to developing and investing in the future of its people.

Let them lead!

Not only do millennials value being mentored, but they also wish to share their skills with other employees. Reverse mentoring[5] enables older workers to learn from millennials. Whether it's adopting new software, training on effective use of collaboration tools or adding a social component to a workplace safety initiative, millennials can share their knowledge to help co-create new solutions. Invite millennials to take the lead on specific corporate communication initiatives involving safety in the workplace. Put them in charge of updating safety tips on digital signage throughout your company's facility.

Finally, although this article focuses on millennials, it's important to state that intergenerational teams[6] bring out the best in all employees. They allow many views to be heard and can generate unique approaches to workplace safety throughout the company. Not only does it facilitate collaboration across generations, it's critical to defining an inclusive and dynamic high-performance culture. **PCB**

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5. Mentoring Millennials, Meister and Willyerd, Harvard Business Review.

6. Bringing Out the Best from Each Generation, Sodexo Insights.

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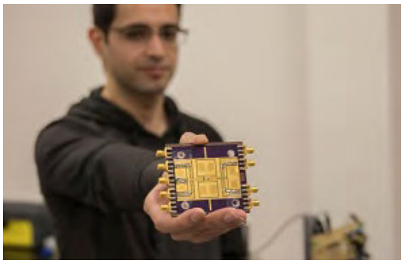
Barry Lee Cohen is president and managing director of Launch Communications. To read past columns or to contact Cohen, click here.

High-Frequency Chip Brings Researchers Closer to Next Generation Technology

A novel, high-frequency electronic chip potentially capable of transmitting tens of gigabits of data per second—a rate that is orders of magnitude above the fastest internet speeds available today—has been developed by engineers at the University of California, Davis.



Omeed Momeni, an assistant professor of electrical and computer engineering at UC Davis, and doctoral student Hossein Jalili, designed the chip using a phased array antenna system. Phased array systems funnel the energy from multiple sources into a single beam that can be narrowly steered and directed to a specific location.

MEIKO

Leading PCB Manufacturer Seeks Account Manager

Meiko Electronics, a global leader in PCB interconnect solutions for Tier I and II electronics companies, has expanded its global manufacturing footprint to include two campuses in China and two in Vietnam.

We are looking for a full-time account manager to introduce the company and our outstanding capabilities to new customers, primarily in the automotive space.

Key Responsibilities:

- Work directly with PCB sourcing teams to generate interest in our company
- Manage all customer relations, including scheduling onsite customer meetings with sourcing team decision makers, factory audit and qualification visits resulting in AVL status attainment
- Manage quality/engineering/logistics issues pertaining to key accounts

Qualifications:

- 3 years' professional experience in PCB sales or similar electrical component experience
- Excellent communication and relationship building skills
- Organizational skills, with a strong attention to detail
- Knowledge of Japanese or Mandarin languages a plus

Location:

The ideal candidate will have some initial prospective customers located nearby in the Midwest region and the ability to travel as needed to our Asia-based manufacturing locations.

Competitive compensation and benefits package, including competitive base salary, generous bonus/commission plan, medical/dental/vision and life insurance, matching 401k, PTO.

apply now

American Standard Circuits

Creative Innovations In Flex, Digital & Microwave Circuits

CAM Operator

American Standard Circuits is seeking a candidate to join its team in the position of CAM operator. Applicants will need experience in using Valor/Genesis (GenFlex) CAD/CAM software with printed circuit board process knowledge to edit electronic data in support of customer and production needs. Other requirements include:

- 5+ years of experience in PCB manufacturing
- Process DRC/DFMs and distinguish valid design and manufacturing concerns
- Modify customer supplied data files and interface with customers and engineers
- Release manufacturing tooling to the production floor
- Prepare NC tooling for machine drilling, routing, imaging, soldermask, silkscreen
- Netlist test, optical inspection
- Work with production on needed changes
- Suggest continual improvements for engineering and processing
- Read, write and communicate in English
- Understand prints' specifications
- Must be U.S. citizen or permanent resident (ITAR)
- High school graduate or equivalent

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ventec
INTERNATIONAL GROUP
騰輝電子

Ventec Seeking U.S. Product Manager for tec-speed

Want to work for a globally successful and growing company and help drive that success? As a U.S.-based member of the product and sales team, your focus will be on Ventec's signal integrity materials, tec-speed, one of the most comprehensive range of products in high-speed/low-loss PCB material technology for high reliability and high-speed computing and storage applications. Combining your strong technical PCB manufacturing and design knowledge with commercial acumen, you will offer North American customers (OEMs, buyers, designers, reliability engineers and the people that liaise directly with the PCB manufacturers) advice and solutions for optimum performance, quality and cost.

Skills and abilities required:

- Technical background in PCB manufacturing/design
- Solid understanding of signal integrity solutions
- Direct sales knowledge and skills
- Excellent oral and written communication skills in English
- Experience in making compelling presentations to small and large audiences
- Proven relationship building skills with partners and virtual teams

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

Please forward your resume to jpattie@ventec-usa.com and mention "U.S. Sales Manager—tec-speed" in the subject line.

www.venteclaminates.com

apply now

ZENTECH

Experienced PCB/ Assembly Professionals Needed

Find a rewarding career and become a successful leader with Zentech Manufacturing. With locations in Baltimore, Maryland, and Fredericksburg, Virginia, Zentech is rapidly growing and seeking experienced professionals in all areas:

- Operations leadership
- Engineering
- Manufacturing engineering
- Program management
- Testing
- Quality assurance

Zentech offers an excellent benefits package, including an employer-matched 401(k) program.

Established in 1998, Zentech holds an ultimate set of certifications relating to the manufacture of mission-critical printed circuit card assemblies, including ISO:9001, AS9100, DD2345, ISO 13485, J-STD 001 with space certification, and is ITAR registered. Zentech was also the first in the U.S. to re-certify for IPC 610 trusted source QML status.

apply now

Altium

Application Engineer

The application engineer is the first contact for our customers who have technical questions or issues with our product. We value our customers and wish to provide them with highest quality of technical support.

Key Responsibilities:
- Support customer base through a variety of mediums
- Log, troubleshoot, and provide overall escalation management and technical solutions
- Create various types of topic based content, such as online help, online user guides, video tutorials, knowledge base articles, quick start guides and more
- Distill complex technical information into actionable knowledge that users can understand and apply
- Continually develop and maintain product knowledge

Requirements:
- Understanding of EDA electronic design software, schematic capture and PCB layout software
- Bachelor's degree in electronics engineering or equivalent experience
- Sales engineering and/or support engineering experience
- Circuit simulation and/or signal integrity experience
- Understanding of ECAD/ MCAD market segments
- Understanding of micro controllers, SoC architecture and embedded systems market
- Database experience preferred (i.e., MySQL, PostgreSQL, Microsoft Access, SQL, Server, FileMaker, Oracle, Sybase, dBASE, Clipper, FoxPro) etc.
- Experience with PLM/PDM/MRP/ERP software (Program Lifecycle Management) preferred
- Salesforce experience a plus

Salary based upon experience. Comprehensive benefits package and 401k plan. Openings in USA, UK, and Germany.

For more information, contact Altium.

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esi®

Designed for Brilliance. Engineered for Production.

Embedded Engineer—
Portland Oregon

ESI, a pioneer and leading supplier of world-class production laser systems that help microtechnology customers achieve compelling yield and productivity gains, is looking for an embedded engineer.

As a software engineer, you are designing and delivering the embedded software that drives ESI's leading-edge manufacturing systems. The successful candidate will join a multi-disciplinary team focused on developing cutting edge technology in a fast-paced and technically challenging environment. Primary responsibilities will include embedded real-time system development, low-level machine control, system-level troubleshooting, and some supporting application level development.

Desired experience includes:
- Highly proficient in C/C++ programming
- Proficient in working with and programming DSPs or microcontrollers
- Experience designing software for embedded systems with constrained resources
- Knowledge of different embedded runtime environments (Linux, bare metal, RTOS)
- International travel to support ESI system installations (<10%)
- Engineering degree with to 5–7 years of related experience, or equivalent combination of education and experience
- Fundamental engineering knowledge (basic physics, calculus, problem solving)

Interested? Please apply below.

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MacDermid
PERFORMANCE SOLUTIONS

Do you have what it takes?

MacDermid Performance Solutions, a Platform Specialty Products Company, and daughter companies manufacture a broad range of specialty chemicals and materials which are used in multi-step technological processes that enhance the products people use every day. Our innovative materials and processes are creating more opportunities and efficiencies for companies across key industries – including electronics, graphic arts, metal & plastic plating, and offshore oil production. Driving sustainable success for companies around the world, and at every step of the supply chain, takes talent. Strategic thinking. Collaboration. Execution.

The people of MacDermid Performance Solutions stand united by a guiding principle: That if it doesn't add value, don't do it. This belief inspires a unique culture where each team member has opportunities to imagine, create, hone and optimize. Do you have what it takes? Join our growing team of over 4,000 professionals across more than 50 countries with openings in research, finance, customer service, production and more.

MacDermid Performance Solutions and its affiliates are Equal Opportunity/ Affirmative Action Employers.

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eptac
TRAIN. WORK SMARTER. SUCCEED.

Become a Certified IPC Master Instructor

We are growing! EPTAC, a leading provider in the electronics training industry is looking for some great people to join our team. If you love teaching, choosing the classes and times you want to work, and being your own boss, this may be the career for you. We are looking for instructors who have a passion for working with people to develop skills and knowledge. If you have a background in electronics manufacturing and an enthusiasm for education, drop us a line or send us your resume. We would love to chat with you. Opportunities available across U.S. and Canada, especially in our growing markets of California, Florida and New England. Some travel involved. IPC-7711/7721 or IPC-A-620 CIT certification a big plus.

apply now

MivaTek
Global

Application/Sales Engineers

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

Service Technicians

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

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

apply now

NCAB GROUP
Integrated PCB Production

Outside Sales/ Key Account Managers

NCAB Group USA is adding to our existing outside sales team in various U.S. locations:

- Ontario, California
- Itasca, Illinois
- Irving, Texas
- Vancouver, Washington

This is a sales position that requires the ability to convert those cold calls into high-value customer meetings. What we are looking for:

- A "hunter" mentality
- The ability to create solid customer relationships
- A desire to excel and not settle for mediocrity
- 5+ years of experience in the PCB or semiconductor industry
- An excellent ability to present a product and do the "deep dive" during customer visits by asking open ended questions and identifying customer pain points
- The energy to move from prospecting to cold calls to getting the win
- Knowledge of "SPIN" selling
- A college degree
- Willingness to travel, domestically and globally
- U.S. citizens with a valid U.S. passport

Interested? Send your resume.

apply now

Visit us at www.NCABGroup.com

ACE
ACCURATE
CIRCUIT
ENGINEERING

PCB Process Planner

Accurate Circuit Engineering (ACE) is an ISO 9001:2000 certified manufacturer of high-quality PCB prototypes and low-volume production for companies who demand the highest quality in the shortest time possible. ACE is seeking a skilled individual to join our team as a PCB process planner.

Responsibilities will include:

- Planning job travelers based on job release, customer purchasing order, drawings and data files and file upon completion
- Contacting customer for any discrepancies found in data during planning and CAM stage
- Consulting with director of engineering regarding technical difficulties raised by particular jobs
- Informing production manager of special material requirements and quick-turn scheduling
- Generating job material requirement slip and verify with shear clerk materials availability
- Maintaining and updating customer revisions of specifications, drawings, etc.
- Acting as point of contact for customer technical inquiries

Candidate should have knowledge of PCB specifications and fabrication techniques. They should also possess good communication and interpersonal skills for interfacing with customers. Math and technical skills are a must as well as the ability to use office equipment including computers, printers, scanners, etc.

This position requires 3 years of experience in PCB planning and a high school level or higher education.

apply now

TECHNICA, U.S.A.
Fulfilling Manufacturing Needs
Throughout the Electronics Industry

Southern California Territory Sales Engineer

Technica, USA, a Western regional manufacturer's representative/distributor, has an open sales position for our Southern California territory. The position will be responsible for selling and servicing our entire product line within the specified territory to the PCB manufacturing industry.

This position requires a highly self-motivated, hands on, confident individual of the highest integrity.

Required Skills:

- BA/BS degree-desired, in a technical area is preferred
- Two years of outside/inside sales or manufacturing experience in the PCB manufacturing environment is desired
- Self-motivated self-starter with the ability to initiate and drive business with little supervision
- Independent worker with a strong commitment to customer satisfaction
- Understanding of consumable sales process
- Ability to organize activities and handle multiple projects simultaneously with effective and timely follow-up
- Ability to solve problems and make decisions for which there are no precedents or guidelines and be resourceful in nature
- Positive attitude while operating under pressure and be an independent problem-solver
- Computer skills in Windows, Outlook, Excel, Word and PowerPoint
- Must have a valid driver's license with good driving record

Please send resume.

apply now

TECHNICA, U.S.A.
Fulfilling Manufacturing Needs
Throughout the Electronics Industry

Western Regional Equipment Service Technician

Technica, USA, a Western regional manufacturer's representative/distributor has an opening for an equipment service technician covering the Western USA, including but not limited to, California, Oregon, Washington, Utah, Colorado, and Arizona. The position will be responsible for servicing our PCB fabrication equipment product line, including installation, troubleshooting, repair service, rebuild service, etc. This position requires a highly self-motivated, hands on, confident individual of the highest integrity.

Key responsibilities are to install and service equipment, conduct equipment audit, and provide technical service when appropriate to solve problems.

Required Skills:

- 2+ years of experience in a PCB manufacturing environment or similar
- Willing to travel
- Positive "whatever it takes" attitude while operating under pressure
- Self-motivated self-starter with the ability to initiate action plans
- Ability to work independently with a strong commitment to customer satisfaction
- Excellent communication and interpersonal skills
- Strong ability to use all resources available to find solutions
- Computer skills with ability to write detailed service and equipment reports in Word
- Understanding of electrical schematics
- Able to work in and around equipment, chemical, and environmental conditions within a PCB manufacturing facility

Please send resume.

apply now

BLACKFOX
Premier Training & Certification

IPC Master Instructor

This position is responsible for IPC and skill-based instruction and certification at the training center as well as training events as assigned by company's sales/operations VP. This position may be part-time, full-time, and/or an independent contractor, depending upon the demand and the individual's situation. Must have the ability to work with little or no supervision and make appropriate and professional decisions. Candidate must have the ability to collaborate with the client managers to continually enhance the training program. Position is responsible for validating the program value and its overall success. Candidate will be trained/certified and recognized by IPC as a Master Instructor. Position requires the input and management of the training records. Will require some travel to client's facilities and other training centers.

For more information, click below.

apply now

CHEMCUT
BOUNDLESS INNOVATION | UNBEATABLE PRECISION

Field Service Technician

Chemcut is looking for a field service technician who is willing to travel worldwide. Previous experience with industrial machine controls (including PLC systems), mechanical components such as conveyors and pumps, plastic piping and fabrication are desirable.

To learn more about Chemcut and apply for this position, please apply to Mike Burke below, or call 814-272-2800.

apply now

Prototron Circuits

Experienced PCB Sales Professional

With more than 30 years of experience, Prototron Circuits is an industry leader in the fabrication of high-technology, quick-turn printed circuits boards. Prototron of Redmond, Washington, and Tucson, Arizona are looking for an experienced sales professional to handle their upper Midwest Region. This is a direct position replacing the current salesperson who is retiring after spending ten years with the company establishing this territory.

The right person will be responsible for all sales efforts in this territory including prospecting, lead generation, acquiring new customers, retention, and growth of current customers.

This is an excellent opportunity for the right candidate. Very competitive compensation and benefits package available.

For more information, please contact Russ Adams at 425-823-7000, or email your resume.

apply now

Process Engineer (Redmond, Washington)

With more than 30 years of experience, Prototron Circuits is an industry leader in the fabrication of high-technology, quick-turn printed circuits boards. We are looking for an experienced PCB process engineer to join the team in our Redmond, Washington facility. Our current customer base is made up of forward-thinking companies that are making products that will change the world, and we need the right person to help us make a difference and bring these products to life. If you are passionate about technology and the future and believe you have the skills to fulfill this position, please contact Kirk Williams at 425-823-7000 or email your resume.

apply now

Recent Highlights from PCB007

1 Victory Giant Technology: The Qualified Forerunner of PCB Smart Factories

The topic of the July issue of PCB007's China Online Magazine is "Automatic PCB Factories," focusing on the pressures of cost, delivery time and process, and the irreversible trend toward automated PCB factories. Centering on this theme, we interviewed Andy Zhou, COO of Victory Giant Technology (HuiZhou) Co. Ltd.

2 Catching up with American Standard Circuits' Joe Nickerson

Dan Beaulieu had the chance recently to sit down with Camtech Technologies founder and President Joe Nickerson, now the newly appointed American Standard Circuits' VP of sales, to discuss Camtech Technologies and his new role with American Standard Circuits. It was an interesting talk.

3 EPTE Newsletter: M-Tech 2017

Tokyo Big Sight hosted the Mechanical Component & Materials Technology Expo (M-Tech) on June 21. The three-day show included the 21st Design Engineering & Manufacturing Solutions Expo (DMS), the 25th 3D Virtual Reality Expo (IVR) and the Medical Device Development Expo (MEDIX).

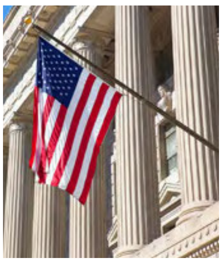
4 Punching Out! Mid-2017 Report on the State of the N.A. PCB M&A Market

One of the most popular questions we receive concerns the market for M&A. Here is our take on the current market for PCB shops in North America. In general, the PCB market in North America is not growing, which means that to grow, shops either must take market share from others, or grow through acquisitions.

5 It's Only Common Sense: Getting to No

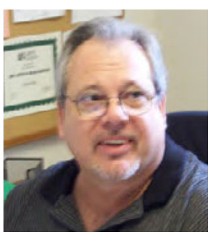
Does this sound familiar to you? There is a potential customer you have been chasing for a long time. Now, this guy seems to be a pretty good guy because he is always willing to see you, always happy to have a cup of joe with you, and more than happy to go out to lunch with you, especially if you go to his favorite sushi place.

6 IPC: Department of Labor Releases RFI to Seek Information on Overtime Regulations



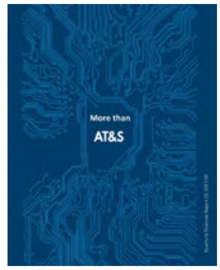
This week, the Department of Labor (DOL) released a request for information (RFI) to gather additional feedback from the public on the overtime regulations, which define and delimit exemptions from the Fair Labor Standards Act's minimum wage and overtime requirements for certain executive, administrative, professional, outside sales and other employees.

7 Catching up with Prototron Circuits' Tucson GM Kim O'Neil



This has been an exciting year for Prototron, which has achieved Mil-PRF-31032 and gone into the flex business. Most recently, Prototron received word that they had achieved their AS9100 Rev D, which made me want to check in with Kim O'Neil and find out more.

8 AT&S Concludes Q1 2017/18 with Significant Revenue Growth and Improved Earnings

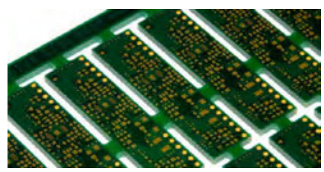


After more than one year of production at the plants in Chongqing, China, which initially had a significant influence on the profitability of AT&S, a clear upward trend is showing and, consequently, a positive development of revenue and earnings compared with the previous year.

9 TTM Technologies to Exhibit at the Electric & Hybrid Vehicle Technology Expo

TTM Technologies, Inc. will be exhibiting at the Electric & Hybrid Vehicle Technology Expo North America 2017 at Booth 1013. The expo runs September 12–14. Technical experts will be available at the booth to answer printed circuit board design, manufacturing, and assembly-related questions.

10 IPC Reports Strong PCB Order Growth in June



IPC—Association Connecting Electronics Industries has posted the June 2017 findings from its monthly North American PCB statistical program. Strong PCB order growth moved the book-to-bill ratio up to 1.08 in June, while sales remained sluggish.

For the latest PCB news and information, visit: PCB007.com

Events

For IPC Calendar of Events, click here.

For the SMTA Calendar of Events, click here.

For the iNEMI Calendar of Events, click here.

For the complete PCB007 Calendar of Events, click here.

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productronica India
September 14–16, 2017
Pragati Maidan, New Delhi, India

24th FED Conference
September 15–16, 2017
Bonn, Germany

SMTA International 2017 Conference and Exhibition
(IPC Fall Committee meetings held in conjunction with SMTAI)
September 17–21, 2017
Rosemont, Illinois, USA

IPC Fall Standards Development Meetings
September 16–21, 2017
Rosemont, Illinois, USA

IMPACT Europe
October 9–10, 2017
Brussels, Belgium

electronicAsia
October 13–16, 2017
Hong Kong

IPC Flexible Circuits: HDI Forum
October 17–19, 2017
Minneapolis, Minnesota, USA

TPCA Show 2017
October 25–27, 2017
Taipei, Taiwan

productronica 2017
(IPC Committee meetings held in conjunction with productronica)
November 14–17, 2017
Munich, Germany

HKPCA/IPC International Printed Circuit & South China Fair
December 6–8, 2017
Shenzhen, China

47th NEPCON JAPAN
January 17–19, 2018
Tokyo Big Sight, Japan

DesignCon 2017
January 30–February 1, 2018
Santa Clara, California, USA

EIPC 2018 Winter Conference
February 1–2, 2018
Lyon, France

IPC APEX EXPO 2018 Conference and Exhibition
February 27–March 1, 2018
San Diego, California, USA

China International PCB and Assembly Show (CPCA)
March 20–22, 2018
Shanghai, China

KPCA Show 2018
April 24–26, 2018
Kintex, South Korea

Medical Electronics Symposium 2018
May 16–18, 2018
Dallas, Texas, USA

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the pcb magazine

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OCTOBER:
Signal Integrity and Controlled Impedance
Why these elements are critical to PCB manufacturers.

NOVEMBER:
HDI
Today, tomorrow and the future.

DECEMBER:
Thermal Management
Keeping off the hot seat.