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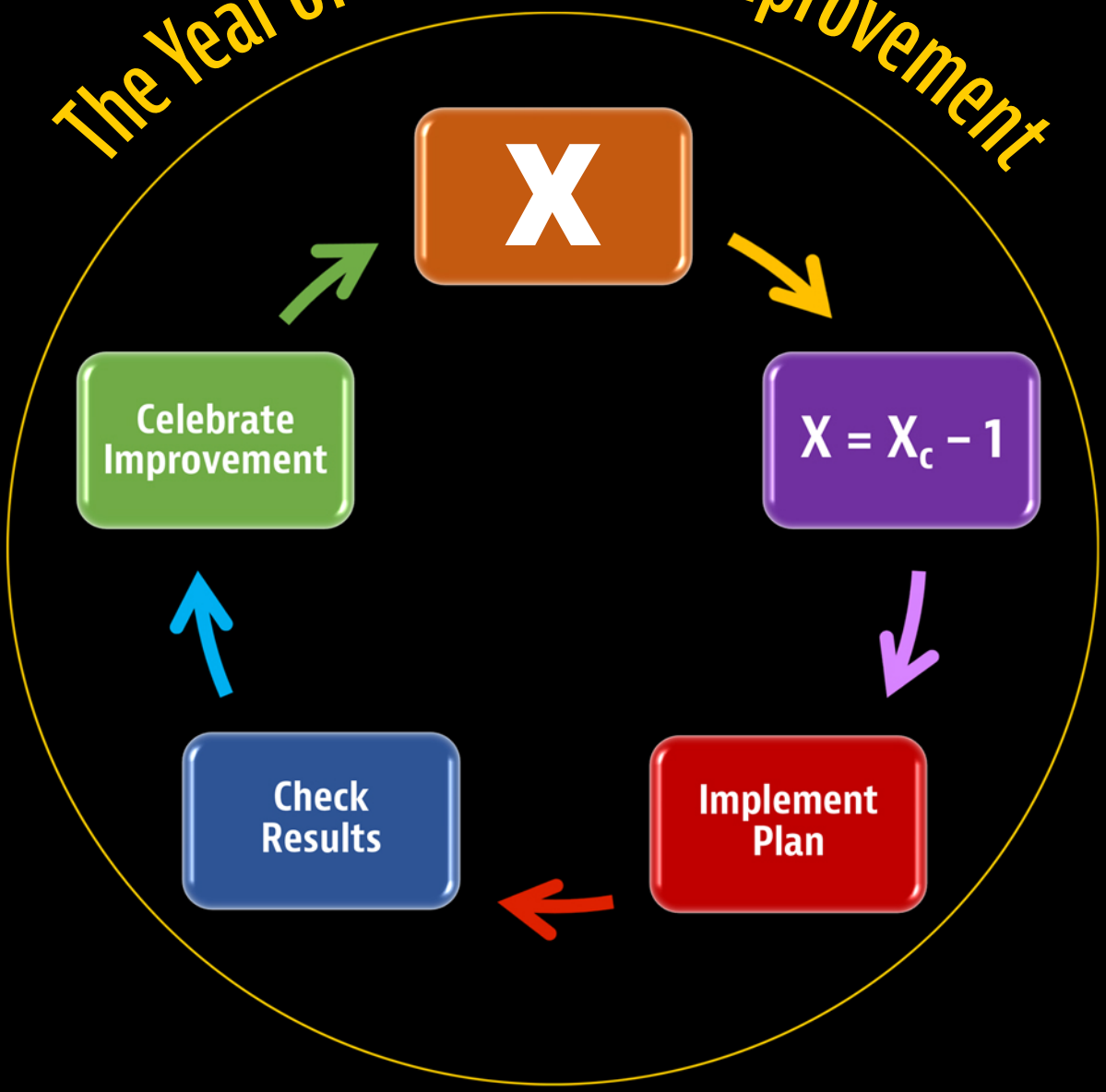
The Year of Continuous Improvement



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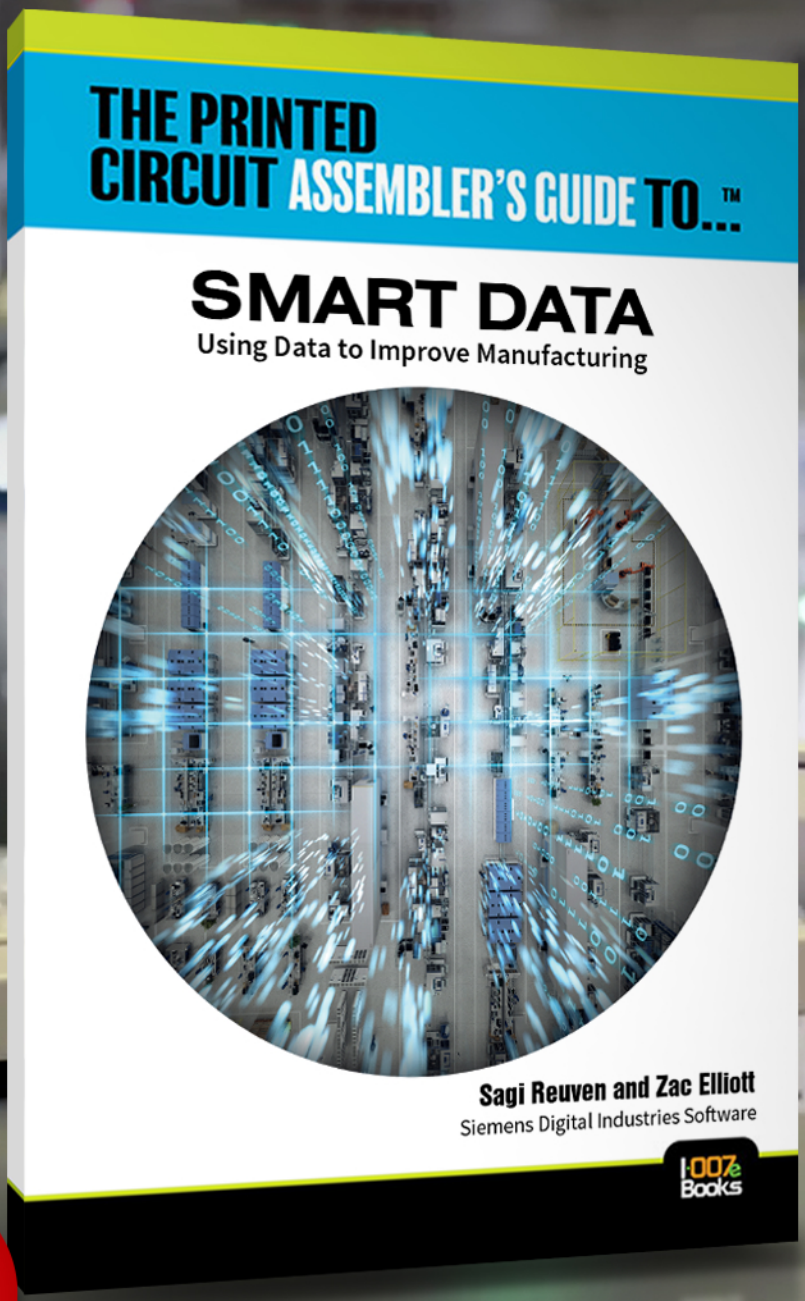

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$X = X_c - 1$

Continuous improvement not only can improve the targeted process, but often results in additional hidden benefits. Moreover, continuous improvement need not be a large project; numerous small improvements can snowball into large gains. In this issue, we launch our year exploring continuous improvement.

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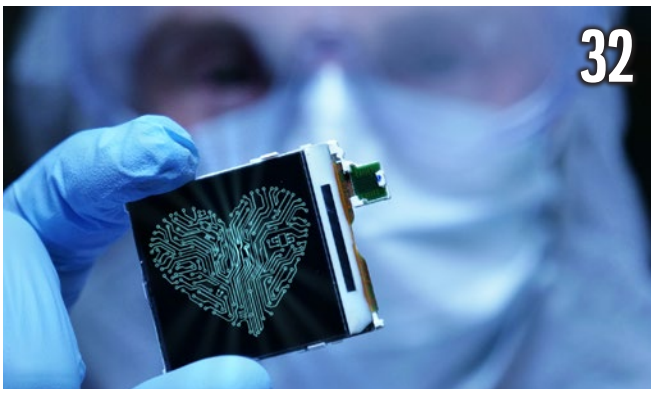

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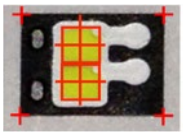

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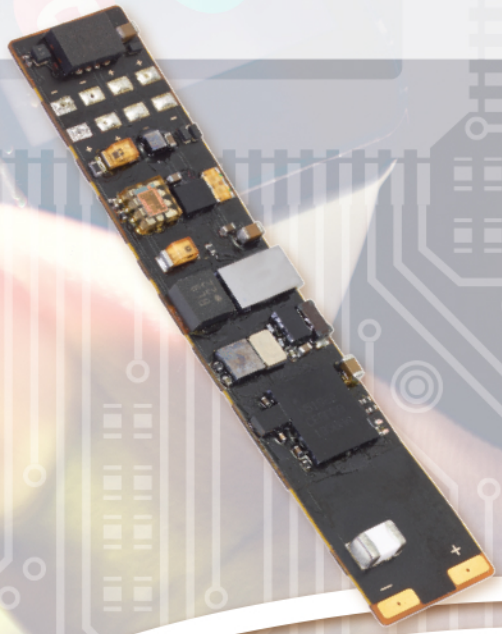

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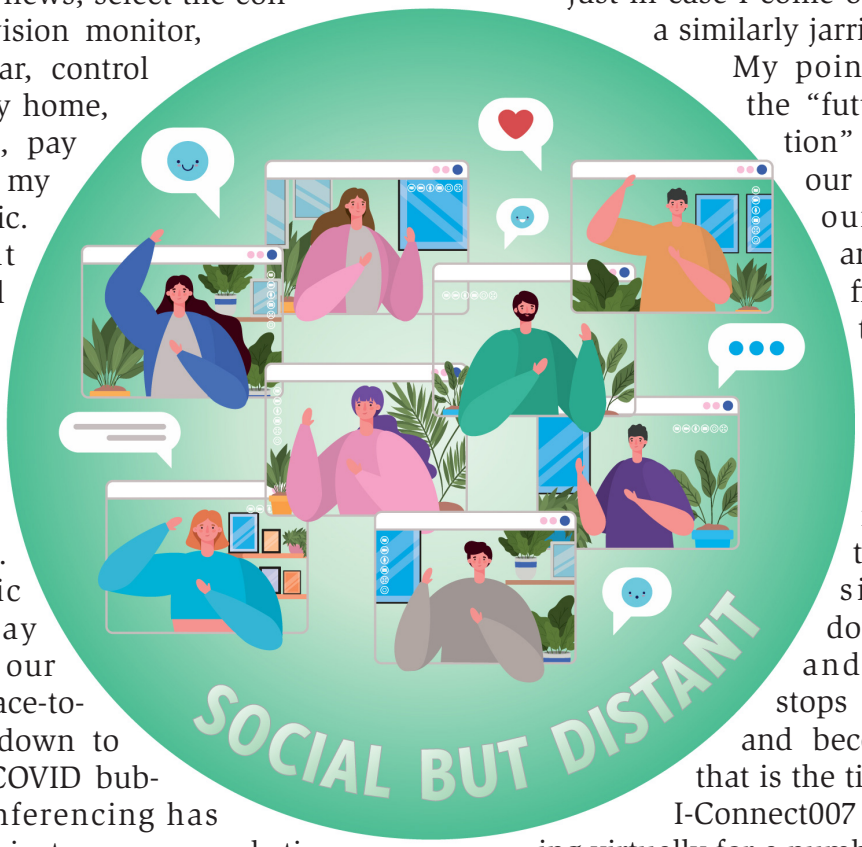
$X = X_c - 1$
A Year of Continuous Improvement

Nolan's Notes

by Nolan Johnson, I-CONNECT007

The conversation took place over a video teleconference, as do most conversations during 2020. I may not live in a Seattle Space Needle-shaped high rise, nor do I have my flying car of the future (yet), but there is plenty of "The Jetsons" in our lives these days, isn't there? My housecleaning robot may not look like Rosie (the Jetson's domestic automaton), but my Roomba has a name and responds to my voice commands; that's a close approximation. I talk to a popular home automation system to get the news, select the content on my television monitor, track my calendar, control the lighting in my home, do my shopping, pay my bills, and fill my home with music. So, what about the video call that I'm thinking about right now?

I would guess that video teleconferencing has changed your life during 2020. While pandemic restrictions may have restricted our ability to enjoy face-to-face interaction down to our respective "COVID bubbles," video conferencing has leapt into the mainstream as a substitute. To deliver their programs, tradeshows are moving to what amounts to massive video teleconferences. Professional groups, government agencies, clubs, friends and families are all turning to online videoconferencing. My mom, bless her heart, has become a video call expert. She's in her 80s (living under strict social distancing guidelines, as you might expect), and when she calls me, I know to double-check my background before I accept her video call. One time, I accidentally had the sun over my shoulder as I answered, surprising her with a screen full of camera glare. Now, when the call connects, she squints a little to protect her eyes, just in case I come onto the screen in a similarly jarring manner.



My point is that, when the "future of digitalization" becomes part of our daily lives; when our grandparents are using science fiction technology to maintain (or cultivate) closer relationships with their grandchildren who might be across the continent or simply in lockdown across town; and when digital stops being a novelty and becomes automatic, that is the tipping point.

I-Connect007 has been working virtually for a number of years, making use of video teleconference technology at the center of our corporate culture. Even still, our team tended to leave cameras turned off—

that is, until a few weeks into the first U.S. lockdown in March. At some point, organically, cameras started lighting up, and faces became a part of our meeting, adding body language to the conversation as well.

And that was the environment in which this video call I first mentioned took place. Our I-Connect007 editorial team was discussing process improvement. As a theme in our current market, process improvement seems to automatically trigger visions of automation and smart factories.

If you're a Star Wars fan, how many times has a movie included a scene in which one of our heroes finds themselves on a moving conveyor belt, sweeping along through a life-threatening series of automated robots manufacturing big iron? Our hero ducks, dodges and shimmies through the gauntlet of swinging robot arms, laser welders and massive die stampers, emerging unscathed at the end. Thankfully, we were not discussing that sort of automated factory. Instead, we were hashing out the implications of digital twin and process control.

The question was asked from someone in one of the multiple little squares of video feed on my screen, "If you could reduce a PCB design project by just one spin, how much would you save?" "Twelve million dollars," replied someone, almost immediately, from a different square, continuing "that's the number I've heard from someone at a large international firm. For their big projects, the total cost, direct and indirect, for one design spin is $12 million. If they can reduce the design cycle by one, it's worth that much to them."

"Not everyone will save that kind of money," said someone in another square. True. Many design teams are working on much smaller scales than this particular company, but it's reasonable to assume that, while the raw dollar amounts aren't the same, the percentage of the design budget is likely to be consistent.

"You know, reducing a spin in a design process has nothing to do with smart factories. It has everything to do with working smart, with using smart processes," piped up another person from their video square.

And that got us on our way. Here at I-Connect007, we wholeheartedly agree that factory and process control automation have a crucial place in our industry. But we also posit that simply automating is insufficient. If you automate inefficient and wasteful processes, you only solidify and perpetuate those inefficiencies in your business, thereby throttling down your company's ability to grow in the digital age. Smart factories are only partially about digitalization; at the core, smart factories are about smart processes—efficient and flexible processes. We even tagged this idea with "$X = X_c - 1$" wherein X_c is your current process, and X is your new, incrementally optimized process to replace X_c.

The video call in which this conversation took place was a clear example of digitalizing how our team functions, removing the overhead of commuting and travel. Our work team has made changes to how we hold our meetings online. Sure, we've done this type of group meeting for years, but the dramatic increase in use of videoconferencing has caused the whole team to look hard at how to be more efficient with our meetings. It's a process of continual improvement: Make your processes smart, then make them smarter still.

In this issue of *SMT007 Magazine,* we kick off our continuous improvement coverage throughout 2021. We'll explore smarter processes, smarter equipment, automation, and operational efficiencies. We will consider "$X = X_c - 1$" from all angles. This month, we begin by establishing why continuous improvement is so critical to our industry; why does this matter?

As always, we value talking to our readers. If you have a story of your own related to "$X = X_c - 1$" to share, we'd love to hear it. Reach us at editorial@iconnect007.com. **SMT007**

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

Continuous Improvement: As Simple as $X = X_c - 1$

Feature Interview by the I-Connect007 Editorial Team

$X = X_c - 1$ is a conceptual equation for continuous improvement. You define X and work to reduce it by a factor of 1. This could be one work hour, one process step, one day less in a cycle, and so on. We recently met with Dr. Ron Lasky to discuss the concept of $X = X_c - 1$ and get his advice on generating enthusiasm among readers and the next generation about continuous improvement. As this discussion illustrates, many process improvements are small in scale, not yearlong, major efforts.

Nolan Johnson: Continuous improvement is not a new idea, but we would like to shine a light on the idea of "$X = X_c - 1$." To do this, first, you define what X is, and then you make an action plan to reduce it by one. It could be reducing your design spins, the number of steps in your process, or the number of gates in manufacturing. It could be any approach where you can incrementally improve, take something out, and get it done with fewer steps and iterations.

Happy Holden: It's the concept of solid base hits rather than going for the home run all the time.

Ron Lasky: It's sort of a formulaic approach, but maybe that's better. Continuous improvement is the essence of Lean Six Sigma. There is a term in Lean Six Sigma called DMAIC (define, measure, analyze, improve, and control), assuming you want to improve something. You define what it is that you want to improve (D). You measure where you are (M). You collect some data and analyze it (A). Then, you improve it (I), usually with a designed experiment. Once that's all set up, you must develop a plan to control it (C). That's statistical process control.

For example, let's say a small mom-and-pop shop collected the data for the year 2020, and they found that at the end of the line before repair, they had 2% fallout: 2% of the boards had to be repaired. They collected the data in a Pareto chart. If they made 100,000 boards, they had about 2,000 boards that were defective, and they found that the primary defect was shorts. That was 1,200, and then the second defect was a missing component and on down

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Ronald Lasky, Ph.D., PE, Sr. Technologist, Indium Corp.
Professor of Engineering, Dartmouth College

the list. Usually, you would want to attack the most significant defect mode. That was shorts. They started to look at what typically causes shorts. Two-thirds of end-of-line defects can be attributed to stencil printing, so that is good place to start.

This mom-and-pop shop may hire a local college student as an intern, who has a Lean Six Sigma Green Belt, and they teach the intern about electronic assembly. The company may also have pictures of all 2,000 defects. They analyze those images and decide that the main reason they had too many shorts is that there's too much solder paste on the pads. When the component is placed, excess solder paste spills over the pad that occasionally, when it melts, creates a solder bridge to an adjacent pad. They do some more work and decide that maybe they should make all of their stencil apertures a little tighter, or maybe they should get a different solder paste. They call their current solder paste vendor and discuss some of these issues.

Often, you have to do some designed experiments, which would be the improved part of the DMAIC process, and then the control part would be where you'd measure the volume of the stencil printed brick of solder paste for statistical process control. That's a simple example of continuous improvement. There could be others that weren't so directly related to just improving quality.

You could have issues where you look at the amount of time it takes from the receipt of the order until you start the job on the line because you've been losing customers who say, "Geez, we like the quality of your stuff, but you're two weeks longer than our other suppliers." Then, you would do a mapping of the process of when the order comes in. What happens to it? You go through all of those steps and find there's a lot of dead time. There is one that's not related to something like solder paste stencil printing quality but is related to the process itself. There's a common expression in Lean called "mapping the process." The comical thing about all this is when you really think about it, it's common sense, but common sense is not so common.

Barry Matties: Often, until the process is visible or mapped, the process inefficiencies remain invisible because it's "just the way you've always done it."

Lasky: Yes. We had a student at Dartmouth that was getting a Master of Engineering Management (MEM) degree where we taught Lean processes. He had a summer internship with a company, and they had about seven buildings. This wasn't making electronics; this was making valves. At the time, in 2015, the company had existed since 1890. It started with one building, and they continued adding until they had seven. Because technology changed, it was now a 30-step process where they would do different steps in different buildings. It was just the way it grew.

However, they never thought to streamline it, and the student pointed out that they could reduce their costs by at least 10% because of the transportation between buildings. Whenever you transport something, you're going to break some of them. These are basic principles that people should consider in continuous

improvement. But it's important to start with a brainstorming session about what people think they need to improve. And that's something that they have to determine themselves.

Matties: That's really where the $X = X_c - 1$ is. They define X; plan, do, check, and act; and define, measure, analyze, improve, and control their operations. You have to help people look for X and understand where's the best place to start. A lot of times, people will start with these grandiose plans that will take a year or more to accomplish. In continuous improvement, it's better to start with small tasks in short windows. Then, your team starts to feel the victories.

Lasky: I like to call that incremental success, and people will be excited to do it. Here's another example of something that may sound a little bit counterintuitive, but it has happened in my life a couple of times. I worked for IBM in an era when it was probably the best company in the world to work for. But the managers, especially if they were younger, were so hyped up that they wanted everybody to work on many things at once. At that time, my wife worked there, and one of her managers said, "You have five top priorities." She replied, "I can only have one top priority," but they insisted on five.

Then, they had a consultant come in. Afterward, the new executives said, "What we learned from the consultant is fantastic. We will not do another project until we finish one because if you have five people working on five number one projects, nothing ever gets finished." That's because you must have your engineers focused, and even if they come up with clever ideas that may be great, that will be the next thing we work on, but you have to finish your top priority first. We all start things but never finish them.

Matties: In an environment of continuous improvement, one of the things that we look to reduce is stress and frustration with people's work. That's often overlooked in the improvement process.

Lasky: Absolutely. You have to understand the human factors in anything you do. You just can't assume that people are superhuman. That can be a big mistake. That was one of the issues I mentioned with the manager who wanted people to be working on five top priorities. People get burned out, and they'll end up even quitting if that's the case. Especially today, stress is a super important factor.

Matties: Stress or frustration is usually an indicator that there's a process that needs to be improved.

Lasky: I was asked to work with some young medical professors at a large metropolitan hospital. They said, "Our main issue is that we have 20,000 patients in our database, and most of them are poor. Every day when we go home, we're 200 prescription refills behind. Could you help us?" We mapped the process out and stayed with it. It took less than a day for about five people to do it, but they argued with each other about the best way to do it. People that were involved in the process were each doing it differently.

After we finally got it all mapped out, what we found was the reason they were 200 prescription refills behind was that about 30% of the time, the prescription was kicked back by the pharmacy because the doctors who were residents didn't fill out the paperwork right. The person who asked us for help was the boss of the residents, and he told them, "If you have more than three of these in a month, you're out of the program." Overnight, they went from being 200 behind a day to zero. That's powerful, and it wasn't difficult; it was just about looking at your process and understanding where it was and why.

Matties: The important thing that you keyed in on earlier is there's a process for looking at your process. And if you follow that process, you're going to find what needs to happen. There's a discipline to mapping processes. But when you run into an area where people are each doing it a different way, then you have to find agreement and have the discipline to fol-

low the agreed-upon process. It's one thing to have a map and to say, "Here's our process." But if you're not disciplined with the process, then you have too much variation for real continuous improvement.

Lasky: We talked about DMAIC earlier. Control is the last phase of it, and keeping it in control is the hardest because people will slip back into old habits. You have to have a "champion" who is responsible for control and ensure that the old habits don't return.

Matties: It's easy for people to circumvent a process and think that it will be better to take that shortcut because they're behind schedule or whatever the case may be. That's when the discipline to stick to the process is the most important.

Holden: One of the things about a process is that you have to define the metrics. With respect to this equation, what if your X is nothing but opinion? It's not always easy to get a measurable metric that is the right measure of performance. With "figure of merit," you use expert opinions and a methodology to come up with data. That's your X. Everybody understands continuous improvement when they see $X = X_c - 1$. But what if you measure the wrong thing, or you don't know how to measure it, or you can't define it?

Lasky: The most important thing is deciding what you want to improve. We all know people who spend a lot of time doing something well, but it's the wrong thing or not what should be worked that hard on.

Matties: You have to staff a continuous improvement effort, meaning you may have to have somebody whose job title is "continuous improvement facilitator" to facilitate the process.

Lasky: If there isn't a champion of something, it will die. There has to be a champion. I completely agree.

Matties: If you hire somebody to be your continuous improvement facilitator, that return on investment will be astronomical if you bring in the right person.

Lasky: Philip B. Crosby has a great quote: "Quality is free. It's not a gift, but it's free." What he meant by that is exactly what you're saying. You're going to have to put some investment in it, and it should save you much more than the investment, but if you're not willing to do that, you're not going to get anything.

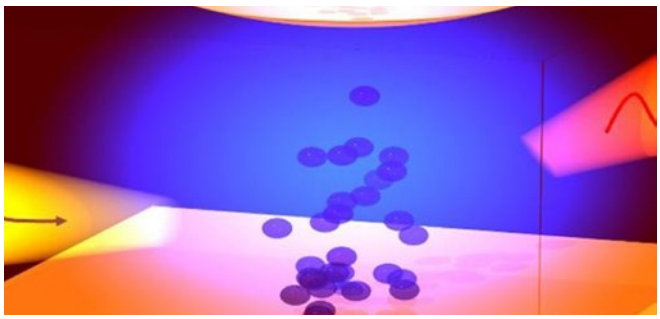
Matties: It's always a pleasure. Thank you so much.

Lasky: Thank you. SMT007

Squeezing Light Inside Memory Devices Could Help Improve Performance

The ability to understand how structural changes characterize the function of materials which are used for low-power, ultra-responsive devices called memristors, is important to improve their performance. However, looking inside the 3D nanoscale devices is difficult using traditional techniques.

The team used the technique to investigate the materials used in random access memories, while in operation. The results will allow detailed study of these materials, which are used in memory devices.



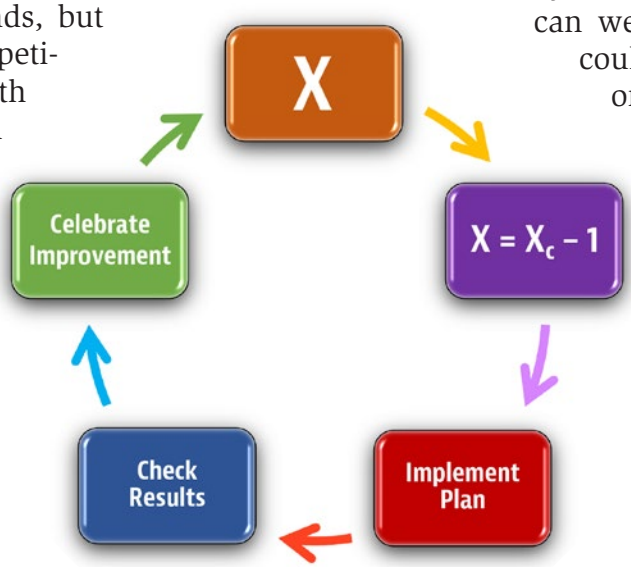
To solve this issue, the researchers had to reliably construct cavities only a few billionths of a metre across–small enough to trap light within the device. They used the tiny gap between a gold nanoparticle and a mirror and observed how the light was modified when the device was functioning correctly or breaking down.

(University of Cambridge)

Your Greatest Competition is Yourself

by Barry Matties
I-CONNECT007

It really doesn't matter who you think your external competitors are, because the only competitor that really matters is yourself. Of course, you will look externally to stay on top of latest trends, but when it comes to competition, just competing with yourself is a win. When you look at yourself as your greatest competitor you will start with a huge advantage: you already have great intel on how "your competition" thinks. Ask yourself, "What can I do to displace my 'competitor' and create something much better?"



Process efficiency: The first area in which to compete is process efficiency. If you can perform your processes in a more efficient way, you will begin to add capacity, increase employee happiness, enjoy higher productivity, and find greater customer satisfaction. This will lead to more sales and ultimately higher profits.

And when we talk about process efficiency this includes all processes: how you answer phones, make sales, process orders, manufacture your products, do your accounting, shipping, filling out paperwork and every other process step in your business. When doing these tasks in your business, think differently. Think in terms of crushing the competition.

Albert Einstein said: "We cannot solve our problems with the *same thinking* we used when we created them." So, if you are busy chasing your so-called external competition, you will miss the greatest opportunity sitting right in front of you—the opportunity to think differently and compete with yourself.

Use the formula: As we start the new year—what we are calling the year of continuous improvement—it's a good time to start with the simple process improvement formula: $X = X_c - 1$. When you look at any current process (X_c), the question you want to ask (and have your coworkers ask) is, "How can we reduce (X_c) by (1)?" It could be one day, one hour, one minute, one less piece of material, one less percent of scrap, one less form to fill out, or it could even be lowering a risk factor or other even less tangible things. By reducing (X_c) by (1) we now have a new (X) and the process starts over.

The tricky part can be deciding what to choose for your first (X). In the early phases of process improvement, the common advice is to start with small improvement projects and grow from there. By doing so, you and your team will be able to feel and celebrate the success and benefits gained.

$X = X_c - 1$ is perhaps a new way of thinking for some. In any case, $X = X_c - 1$ focuses you and your team to really compete with your greatest competitor—yourself. **SMT007**

5 Keys to Smart Process Success

Feature by Steve Williams
THE RIGHT APPROACH CONSULTING

Introduction

It can be challenging to stay current with the vernacular of our industry; terms like IoT, M2M, Industry 4.0 and smart processes appear in just about every publication we see. Buzzwords aside, the substance behind these technologies is here to stay and driving this fourth-generation industrial revolution.

Next Gen Manufacturing

If we accept that Industry 3.0 is defined as the computerization and automation of factory floor processes to make them "smart," then I suggest that Industry 4.0 is defined as the expansion of this idea to include all the support processes required to manufacture a quality product. By connecting factory-floor computers with all the logistic-based computers throughout the supply chain, Industry 4.0 will revolutionize how companies make stuff. Adding in smart algorithms, machine learning and customer connectivity will transform our current linear/sequential processing into the next generation of "smart processes." For this to occur, the five characteristics below are critical for a successful transition.

1. IIoT

Smart factories require the core underlying processes to be connected and "talking" to generate the data necessary to make real-time process decisions, that is, the IIoT (Industrial Internet of Things). In a truly connected factory, an ongoing continuous dialog between machines, business processes, suppliers and customers is happening in the background. This dialog is not only interactive, but proactive, as a constant stream of real-time data is tweaking and adjusting processes to drive improvement. It also provides time-critical information on how processes are operating, supply chain pipeline, and delivery status updates—all based on data. When starting this journey, it is important to utilize the right technology, data, and analytics infrastructure for your business model. You will need to re-imagine your processes from end-to-end for software interoperability, data

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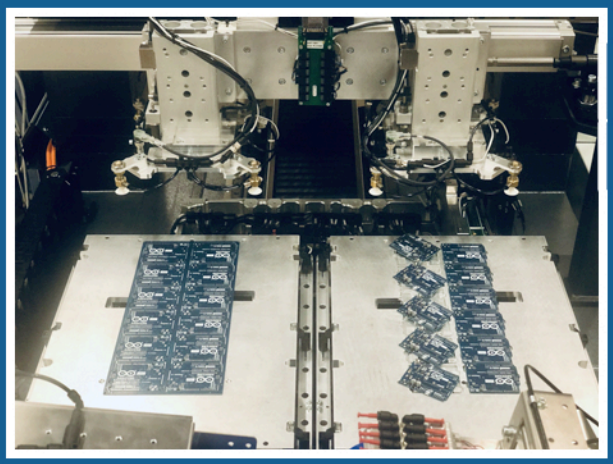

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2. Cyber Physical Systems

Cyber physical systems are the integration of computers, networking and physical processes. Computers and networks monitor and control physical processes with feedback loops; the physical system reacts; the system uses software to interpret actions and tracks results. This system is based on embedded computers and software in devices, not for traditional data computation, but rather as a loop of action and machine learning. The smart factory is a flexible system enhanced by augmented intelligence that can self-optimize performance across a broader network. A cyber physical system can self-adapt to and learn from new conditions in real or near-real time, and autonomously run entire production processes.

The traditional manual methodology for process optimization consisted of four tasks:

a) Gain process understanding.
b) Create process model.
c) Recognize constraints and optimization parameters.
d) Optimize the process model.

Enabled by the previous connectivity characteristic and "machine learning," the smart process adapts and makes process tweaks on-the-fly based on what is working and what isn't. How does this work? The process "learns" from the data through connectivity and data exchange between the equipment, software and process KPIs. Based on this information, the process model can then decide which system configuration delivers the best performance, and which does not. The integration of cyber and physical components provides both new opportunities and challenges. The benefits include new functionality in traditional physical systems, such as brakes and engines in vehicles, intelligent control systems for biochemical processes, and wearable devices. On the other hand, the integration of cyber components adds new layers of complexity, from both a design and process standpoint.

Data Infrastructure

"The data-driven world will be always on, always tracking, always monitoring, always listening and always watching—because it will be always learning." [1]

A data infrastructure refers to the hardware, firmware and software required to collect, interpret, and analyze the immense amount of data generated by an organization. Big data is defined as a collection of data from traditional and digital sources inside and outside an organization that provides a source for ongoing discovery and analysis. In today's business environment, data is collected everywhere, from systems and sensors to mobile devices. The challenge is that the industry is still developing methods to best collect, interpret, and analyze the data. With the vast amount of data being acquired, having a robust data infrastructure to manage these tasks is mission-critical to Industry 4.0 and smart processes.

Fun Facts on Big Data [1]

- By 2025, the world's data will grow to 175 zettabytes
  - One zettabyte is equivalent to a trillion gigabytes
  - It would take 1.8 billion years to download 175ZB at the average current internet connection speed
- On average, office workers each receive 110 to 120 emails per day, equaling approximately 124 billion emails on any given day
- Amazon records $283,000 in sales per minute
- 49% of the world's stored data will reside in public cloud environments by 2025
- Manufacturing and financial services are the leading industries in terms of Data Readiness Condition (DATCON) maturity
- More than 150 billion devices will be connected globally by 2025

4. Digital Supply Network

Digital technology is disrupting traditional operations, from quoting to shipping, and every business is now a digital business. The impact on supply chain management is particularly great. Businesses cannot unlock the full potential of digital without reinventing their supply chain strategy. A digital supply network is simply a supply chain managed via automated systems and web or cloud-based solutions. The supply chain is morphing rapidly from a linear material flow to one that includes an increasing number of emerging technologies and digital connectivity. It's no secret that robotics, physical systems and other innovations are creating new, previously unthinkable capabilities in modern supply chains such as 24/7 connectivity, enhanced visibility, and efficiency. Supply chain professionals are drawing on digital innovations from other areas of the business to create a three-phase closed loop supply chain digital transformation (Figure 1):

- **Physical-to-digital:** Capturing information from the physical world to create a digital record of the supply chain and what's happening in it. Examples of these innovations include sensors, controls, GPS, wearables, and 3D scanning.
- **Digital-to-digital:** Harnessing the power of advanced algorithms and machine-to-machine communication to enable advanced analytics of real-time data from multiple sources. Examples include predictive analytics, artificial intelligence, and machine learning.
- **Digital-to-physical:** Using automation and other technologies to translate decisions and actions from the digital realm into physical outcomes in the supply chain. Examples include autonomous robots and control systems, real-time geospatial visualizations, autonomous vehicles, drones, remote maintenance, and 3D printing.

To fully realize the digital supply network, however, manufacturers will need to embrace the new way of working and expand supply chain management in three areas:

- Horizontal integration through the myriad operational systems that power the organization
- Vertical integration through connected manufacturing systems
- End-to-end, holistic integration through the entire value chain

5. Intelligent Automation

For years, organizations have been working toward an automated future that frees people from time-consuming, manual work. Today, automation has moved from the factory floor into every facet of the organization to support better ways of working that fuel business growth. Intelligent automation thrives

Figure 1: All businesses are now digital businesses.

Figure 2: Be sure to take full advantage of the benefits of the digital world.

when it is paired with people to drive better outcomes. Let me repeat that: To succeed with intelligent automation, it is vital to put people first and evolve their skills and roles to really take full advantage of its benefits. As with any push toward automation, the perpetual fear is that people will no longer be needed. The fact is nothing could be further from the truth (Figure 2).

People and automated processes must collaborate in the overall workflow to complement each other and compensate for each other's shortcomings. While the skill set and job title may be vastly different than before, people are an irreplaceable piece of Industry 4.0 and smart processes. An effectively designed process should not only utilize the power of technology to process large volumes of data or perform repetitive tasks with high accuracy, but also recognize the qualities people add for decision making, improvising, and innovating. One of the most widely used intelligent automation tools are "smart algorithms." Smart algorithms are on the verge of pervading all aspects of business and our daily lives. Have you ever done an online "chat" while trying to get technical support and a chatbot would try to answer your question or narrow down your issue before connecting you with a live person? How about saying "Hey Siri" or "Alexa, play country music?" Those are prime examples of smart algorithms. Most initial efforts focused on the "low hanging fruit," such as replacing awkward text interfaces with natural language processing interaction, performing pattern recognition in huge data sets, or automating repetitive or highly regulated processes requiring low human intelligence. Current developments in smart algorithms are looking to automate higher value-added tasks.

Industry 5.0?

It's incredibly exciting to be on the front lines as our companies transform from the integration of computerization and automation that Industry 3.0 brought us to the connectivity, machine learning and smart processes of Industry 4.0. As we scramble to embrace the incredible benefits of this technology, I know someone, somewhere, is already thinking about the things that will become Industry 5.0. **SMT007**

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Steve Williams is the president of The Right Approach Consulting. Read Steve's column, *The Right Approach,* on PCB007.com. A no-nonsense view of manufacturing and management strategies.

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2021: The Year of $X = X_c - 1$

Feature by Nolan Johnson
I-CONNECT007

Throughout 2021, I-Connect007 will focus on our theme, "$X = X_c - 1$," in which we will explore continuous improvement in a practical way. Get talking about continuous improvement as a business method and the conversation often hinges around large programs and grand transformations. "Company culture" and "corporate transformation" are terms that often appear in these conversations. Often, it seems, continuous improvement is simply a huge undertaking.

The good news is that not everyone sees continuous improvement in this light. Continuous improvement methods can be scaled down; smaller, more manageable goals can be set. Continuous improvement can be implemented at a departmental level, team level, even an individual level. In their paper "How Continuous Improvement Can Build a Competitive Edge," McKinsey & Company authors Carolyn Dewar, Reed Doucette and Blair Epstein write, "Continuous improvement is an ongoing effort to improve all elements of an organization—processes, tools, products, services, etc. Sometimes those improvements are big, often they are small. But what's most important is they're frequent." [1]

Maggie Millard writes in her blog, "Improvements are based on small changes, not only on major paradigm shifts or new inventions… By approaching change in small, incremental steps, the continuous improvement model reduces the fear factor and increases speed to improvement." [2]

Jon Terry writes, "Sacrificing quality can rarely be justified by the ability to do something faster or cheaper. To maintain quality standards while cutting time and cost, companies turn to Lean ways of working, including continuous improvement." [3]

In fact, if your company is pursuing ISO9001 certification, continuous improvement is one of the eight key principles for ISO9001.

Continuous improvement "is all about 'doing' but it isn't something that you do. It's how a company operates. Continuously improving means creating a culture that pro-

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moted improvement. As odd as it may sound, employees might be more aware of company processes than the management. Hence, it's important to take everyone on board when it comes to improvement. The concept is simple, the process should include employees." [4]

In fact, Dewar, Doucette and Epstein point out, "Companies that excel at continuous improvement start with the belief that success comes from:

- Innovating "how" they do what they do (big and small)
- Engaging all employees in sharing knowledge and generating improvement ideas
- Exploring better ways to deliver to customers and respond to changes in the external environment." [5]

Here at I-Connect007, we've tagged this concept "$X = X_c - 1$." We're presenting the idea that incremental improvements can happen at any level and can be of any size. We posit that a significant number of small, easy-to-implement, no- or low-cost incremental improvements can add up to a significant increase in operational efficiencies, improved quality, and profitability. The "X" could be anything: steps between repetitive work tasks on the shop floor; the number of design respins needed to get a working prototype of a new product; or maybe a routine process in the accounting department. Further, this kind of incremental improvement need not necessarily require top-down company mandates to change company culture.

How Can We Recognize it?

The "$X = X_c - 1$" dynamic may already be in place in your company. In a blog post, Daedalus Howell writes, "In its essence, continuous improvement is the practice of honing every aspect of your company's processes in a manner that enhances your offering's value to your customer while diminishing any activity that proves wasteful along the way." [6]

What if continuous improvement is being employed within your company organically, at the individual or team level? Does that count? Millard thinks it does. She wrote, "Continuous improvement can be viewed as a formal practice or an informal set of guidelines."

One way to sniff out organic continuous improvement is to listen for complaints and watch to see how those complaints are resolved. Millard advises us to "embrace them [complaints] as opportunities for improvement. If a team member notices something amiss and says something about it, that's a good thing. That's the beginning of the improvement cycle." [7]

Do You Suffer from Performance Transparency?

Once a complaint about an inefficiency in the process has been identified, and then monitored to learn how the complaint was resolved (or was it?), you also get a sense for the performance transparency in your organization. Was the inefficiency identified? Was a root cause determined? Was the root cause then addressed? And was the resolution communicated to others?

Millard says, "Constant feedback is an important aspect of the continuous improvement model. Open communication during every phase of executing an improvement is critical to both the final results of the improvement and to the maintenance of employee engagement." [8]

With respect to feedback, Dewar, Doucette and Epstein add, "Making goals public and cascading those goals (typically a balanced mix of financial and operational metrics) in a way that is tailored to individuals at all levels of the organization. Progress toward goals must be transparently tracked to give the frontline and management clear visibility into what is working and what needs work." [9] This is entirely reasonable when attacking continuous improvement on a larger scale. But does this work on a smaller scale?

For example, how does one achieve transparency when working alone, or when optimizing one's individual contributions to the overall flow of a team? To whom do you hold yourself accountable?

These methods can, and do, scale down. Inspiration can be found in Millard's comment that "to achieve real improvement, the impact of change must be measured. This makes it possible to determine if the change can be applied successfully to other problems." [10] Perhaps it is enough to be accountable to oneself? Measure the improvement by posting metrics at your workspace, or on the machinery, where others might notice. Regardless of the scale, Millard counsels, "Proving positive ROI also helps keep the organization aligned around improvement."

Do You Share Knowledge?

At this point, problems are being identified and measurement of baseline and attempted improvements are in process. Sharing results more widely is the next step toward continuous improvement. When tackling continuous improvement on a larger scale, Dewar, Doucette and Epstein share that it is "critical to scale best practices across (and up and down) organizations." They point out, "One of our clients became adept at deploying small cross-functional teams against any problem to break down the organizational silos that had previously prevented knowledge sharing."

Remember, the change need not be dramatic. Small improvements in highly repetitive work tasks accumulate into significant gains over time.

This is a key point: to get knowledge sharing to be effective, create teams with representatives from all affected departments. It's the involvement of the upstream, downstream, and administrative teams as well that help make a change effective and improve the permanence of the solution.

Do You Have Employee Involvement?

Employee involvement is a key factor. The stories are that Deming required his continuous improvement training to start at the top and be taught down the organizational chart by the managers themselves. This method certainly assures that the methods being taught come with an automatic approval from higher up. Yet it's the staff at the "action end" of the organizational chart who can be expected to have the most practical insight. In fact, Dewar and team disclose, "Frontline employees are closest to the work, and thus typically have the richest insights on how their work can be done better. Capturing their perspectives is critical."

Millard concurs, "The continuous improvement model relies greatly on employees, not only top management, to identify opportunities for improvement. This bottom-up improvement is effective because employees are closest to the problems, and thus better equipped to solve them."

And then, Millard rings the "$X = X_c - 1$" bell by suggesting, "Ask people what improvement they could make that would save them 5 minutes a day. Then empower them to implement that improvement, and spread it to everyone else in the organization doing the same process. In this way, you can take a small idea that anyone could come up with and drive a big impact."

Benefits

Techniques for implementing continuous improvement strategies are well documented elsewhere; expect that we will visit some of these sources throughout the year. In the meantime, "$X = X_c - 1$" opportunities come at all levels of the organization and fall into some common categories. Continuous improvement benefits can be categorized as follows.

Streamline Workflows

"Working to constantly improve is the number one way in which many businesses reduce operating overhead," writes Jon Terry. "For example, projects that involve shifting deadlines, changing priorities and other complexities are usually filled with opportunities to improve. It's just that no one has acted on that opportunity. The gateway to streamlined workflows is frontline worker involvement.

Millard points out that changing habits is a difficult thing to do, adding, "Know what makes it easier? Rolling out changes that originated from the front lines. When people come up with the ideas to improve their own work, they intrinsically see the value of the changes. Knowing that improvements come from their peers inspires faith in the necessity of the changes much more so than does a decree from senior leadership."

Reduce Costs

Labor is a significant expense, and easy to lose track of, especially at the microtask level.

"For this reason," notes Terry, "most project management offices benefit from knowing the amount of time it takes to get certain types of work done." Labor waste, therefore, is a natural area to practice continuous improvement.

It doesn't take extensive studies and consultants to analyze whether a job function can reduce the number of repetitive walking steps an operator must take, or whether solder paste pot time can be optimized to increase material utilization as well as labor time loading in fresh solder paste. Frontline employees, in fact, are ideal sources for this type of optimization. Millard says, "Employees tend to focus on small changes that can be accomplished without a lot of expense. In fact, many ideas from employees involve eliminating processes, rather than adding them."

But frontline involvement is not always limited to small changes. I-Connect007 has recently shared customer stories in which management was planning to buy a new line to increase capacity, only to have frontline workers present a study showing that the existing line still had more than enough capacity to run the extra work, provided that the company make some changes to their material flow processes. Small changes (relative to purchasing and installing an entire line) were made, and the needed capacity was achieved. This, of course, leads to increased profits.

More Profits

Most often, reduced costs (and increased capacity for sale) translate directly to improved margins and more profit. Whether the company keeps this profit or returns it to the customer in the form of reduced prices, is up to the company. Just keep in mind that, as the team at Rever Inc. says, "The purpose of every small change is to make the business more profitable."

Employee Morale

It is a general truth that we all just want to make a difference in our world. On this topic, Jane Goodall has often been quoted as saying, "What you do makes a difference, and you have to decide what kind of a difference you want to make."

When employees are encouraged to point out process problems, effect change, and then not only have the successes from those changes shared across the company, but perhaps also see the monetary value of that change to the

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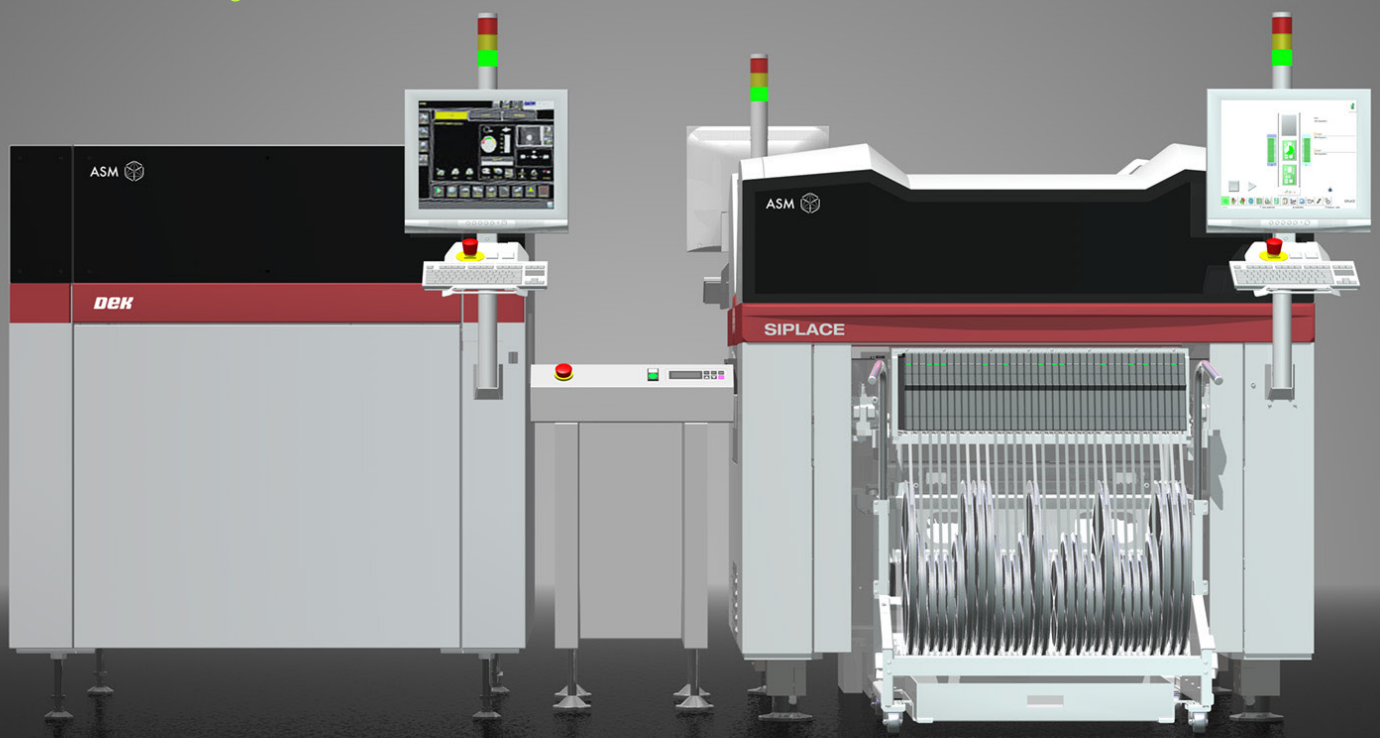

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organization, there is little more management can do to demonstrate an employee's worth. Henry Ford understood this. The anecdote goes that when a consultant, upon seeing one of Ford's employees sitting with his feet up on his desk, asked Ford why he paid that man $50,000 a year, Ford replied, "Because a few years ago, that man came up with something that saved me $2 million. And when he had that idea, his feet were exactly where they are now."

Greater Agility

Continuous improvement future-proofs your business. Incremental changes to adapt and optimize are at the core of creating an agile company. There is a close relationship between continuous improvement and company evolution that requires the presence of human observation.

In a recent conversation on the topic of smart versus automated processes, Calumet Electronics' Dr. Meredith Labeau said: "You're not going to get there if you completely remove the humans who are watching and learning the process, understanding how to iterate through that process, and then understanding that process control enough to say, 'I can move it this way and get this result.' And, 'Hey, that result, while it was out of process, is next-generation technology.' We fundamentally believe that humans are the future, coupled with some really great machinery."

Grow the Business

All these benefits contribute to growing the business. By doing more with fewer resources, and doing it more efficiently, small changes add up incrementally to big results. The knowledge that comes from consistently analyzing, improving and measuring processes contributes directly, allowing the business to grow.

The Rever team states, "A lack of visibility will prevent you from reaching your goals. Remember that no business can grow without realizing what's causing it to stop growing."

Conclusion

As quaint as it may sound, continuous improvement is never-ending; it's continuous. Change is continuous, too. A recent example from the U.S. entertainment industry helps make this point. Blockbuster was a video rental company (it technically still is, with one remaining Blockbuster retail outlet in Bend, Oregon). Sources say that, at its peak, Blockbuster had 9,000+ stores and employed 58,000+ people worldwide. Blockbuster had a good business model and dominated the video rental industry. No surprise, then, that Blockbuster management was reluctant to change even as the market changed around them.

Enter companies like Netflix and, a bit later, Redbox. Netflix began in 1997 as a DVD movie rental service, operating through mail-order and a website instead of a storefront. The Netflix subscription model—a flat monthly fee with unlimited rentals and no late charges—changed how its customers consumed the content they rented. The convenience of having a DVD show up in the mail, ready to watch, without rental restrictions, created deep customer loyalty to which Blockbuster did not adequately respond. When Netflix further evolved in 2007, introducing the streaming option, Blockbuster's unchanged business model was simply unable to compete. In contrast, Netflix intentionally innovated new distribution methods that were not only less expensive, but

The last Blockbuster store on the planet is located in Bend, Oregon.

also more convenient for customers. Netflix improved continuously into a market leadership position, toppling an industry giant in the process. Ironically, in the early days of Netflix, Blockbuster had a chance to buy the company for $50 million, and passed. Today, Netflix's reported annual income is more than $20 billion.

But there is another lesson in the Blockbuster/Netflix story. Netflix not only adapted business operations to be more competitive and nimbler, but they also adopted innovations in electronic distribution. Netflix went digital; that changed everything. Netflix was able to grow as it did because the company had already improved upon its business practices continuously, so that when they went digital, the efficiencies scaled.

The electronics manufacturing industry is embarking on a transition to Industry 4.0, a transition for us that is not unlike the Netflix transition. To fully utilize their investment in smart factory equipment, real-time data for process control, and the benefits of the digital twin, manufacturers must first ensure they are automating optimized processes, then continuously improve them.

With the tagline "$X = X_c - 1$," we're representing the idea that incremental improvements can happen at any level and need not be large. I-Connect007 will devote regular attention in 2021 to the ideas of continuous improvement—both incremental and large-scale. SMT007

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The Eight Principles of ISO9001:

1. Customer focus: Organizations can establish this focus by trying to understand and meet their customers' current and future requirements and expectations.

2. Leadership: Organizations succeed when leaders establish and maintain the internal environment in which employees can become fully involved in achieving the organization's unified objectives.

3. Involvement of people: Organizations succeed by retaining competent employees, encouraging continuous enhancement of their knowledge and skills, and empowering them, encouraging engagement, and recognizing achievements.

4. Process approach: Organizations enhance their performance when leaders manage and control their processes, as well as the inputs and outputs that tie these processes together.

5. Systematic approach to management: Organizations sustain success when processes are managed as one coherent quality management system.

6. Continuous improvement: Organizations will maintain current levels of performance, respond to changing conditions, and identify, create and exploit new opportunities when they establish and sustain an ongoing focus on improvement.

7. Factual approach to decision making: Organizations succeed when they have established an evidence-based decision-making process that entails gathering input from multiple sources, identifying facts, objectively analyzing data, examining cause/effect, and considering potential consequences.

8. Mutually beneficial supplier relationships: Organizations that carefully manage their relationships with suppliers and partners can nurture positive and productive involvement, support, and feedback from those entities.

Electronics Industry News and Market Highlights

Artificial Intelligence Technology Solutions Receives Wally HSO Order ▶

Artificial Intelligence Technology Solutions, Inc. announced that its wholly owned subsidiary Robotic Assistance Devices (RAD) has received an order from a global top 20 medical devices company with over 50,000 employees for what RAD expects as the first of several Wally HSO (Health Screening Option) units to be deployed at one of the client's manufacturing facilities.

Vishay Aluminum Capacitors Increase Design Flexibility, Save Board Space ▶

Vishay Intertechnology, Inc. introduced a new series of low impedance, automotive grade miniature aluminum electrolytic capacitors that combine high ripple currents up to 3.36 A with high temperature operation to +125°C and very long useful life of 6,000 h at 125°C.

Qualcomm IoT Services Suite Aimed to Enable Digital Transformation of Smart Cities ▶

Qualcomm Technologies, Inc. has announced the Qualcomm® IoT Services Suite, which delivers comprehensive, end-to-end IoT as a Service (IoTaaS) solutions to enable the digital transformation of smart cities and smart connected spaces globally.

Keysight Collaborates with NTU Singapore on Hybrid Vehicle to Everything Communications ▶

Keysight Technologies, Inc., a leading technology company that helps enterprises, service providers and governments accelerate innovation to connect and secure the world, announced a collaboration with Nanyang Technological University, Singapore (NTU Singapore) to develop a transceiver test bench for a hybrid vehicle-to-everything (V2X) communication system.

NVIDIA, Ampere Computing Raise Arm 26x in Supercomputing ▶

In the past 18 months, researchers have witnessed a whopping 25.5X performance boost for Arm-based platforms in high performance computing, thanks to the combined efforts of the Arm and NVIDIA ecosystems.

Xilinx, Texas Instruments to Develop Energy Efficient 5G Radio Solutions ▶

Xilinx, Inc. announced a collaboration with Texas Instruments to develop scalable and adaptable digital front-end solutions to increase energy efficiency of lower antenna count radios.

Swissbit Announces Long-term Availability for SD, CompactFlash Cards S-250 and C-350 ▶

Swissbit announces that it has extended the availability of its SLC-based SD memory cards, microSD memory cards and CompactFlash™ cards. The new product series S-250(u) and C-350 deploy the same product architecture as the previous S-200(u) and C-300 products.

HD Vision Systems is the VISION Start-up of 2020 ▶

On November 11, 2020, six candidates competed live in an exciting digital pitch session. HD Vision Systems GmbH made the best impression with the topic of "Light Field and Deep Learning-based Machine Vision" and was chosen as the winner with 39% of the votes cast.

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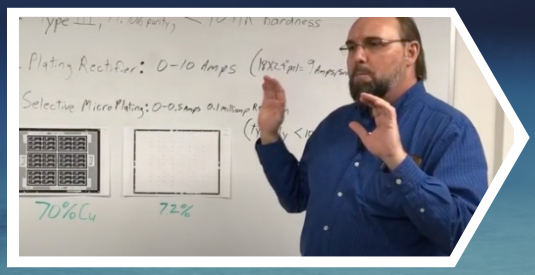
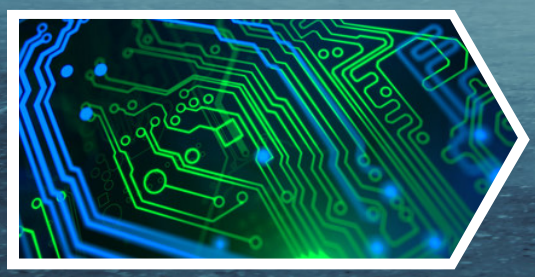


EXPERTS BLOG

The ASC Experts help you learn more about advanced PCB technologies



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Is U.S. Production Ready for Advanced Medical Devices?

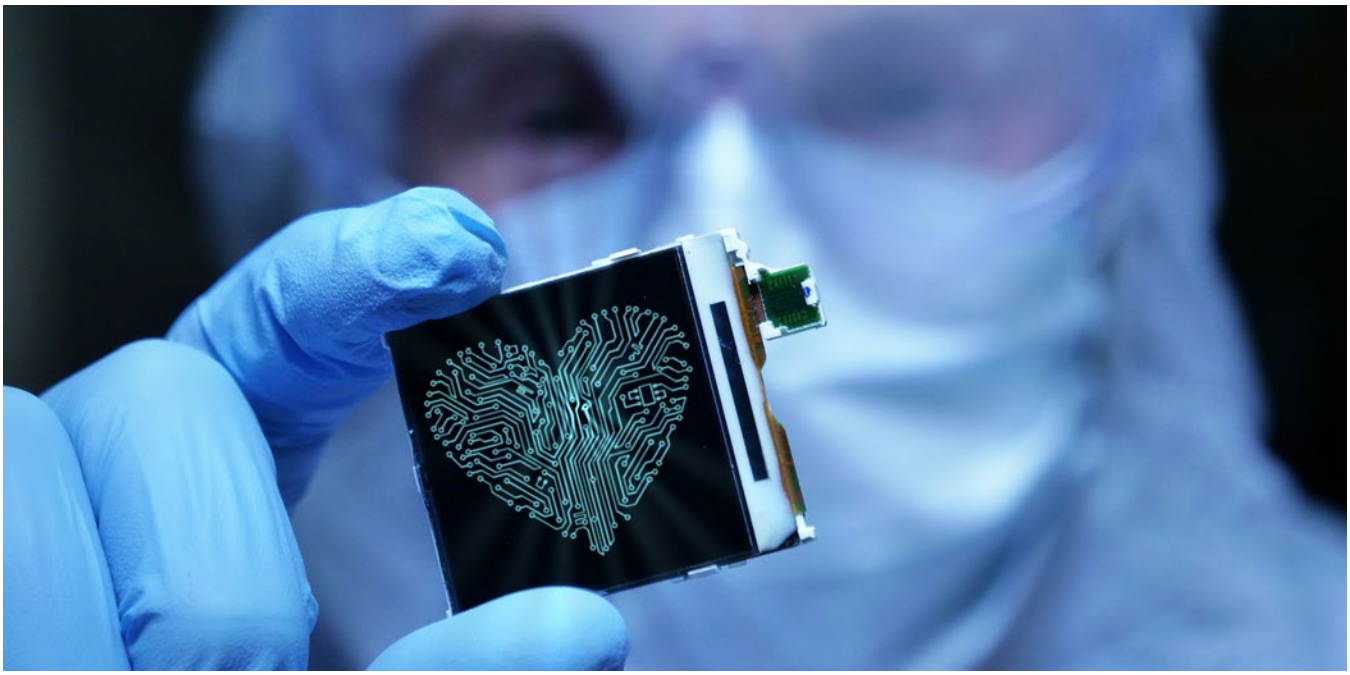
Zulki's PCB Nuggets
by Zulki Khan, NEXLOGIC TECHNOLOGIES

The outlook appears promising in 2021 for electronics OEMs to bring some or most of their manufacturing back to the U.S. In particular, medical electronics OEMs may be able to move forward with their prototypes into pilot, medium, and high runs right here on American soil. And it may be sooner than later due in large part to the advances in PCB microelectronics assembly and perhaps a helping hand from the U. S. Government.

Let's take a look at what is driving those advances in microelectronics and what is now possible. There is an abundance of news reporting on such advanced medical devices as wearables, portables, and insertable and ingestible products in the planning and development stages. Those types of new products require technologies associated with PCB microelectronics assembly, such as wire bonding, chip on board (CoB), flip chip, and die attach, among others.

Therefore, the stage is now set for prototype quantities as proof of concept to move on to pilot, medium, and high runs so that the intellectual property (IP) of these state-of-the-art medical devices is safe and staying here in the U.S. Pilot runs deal with a few hundred to a few thousand units; depending on the product, medium runs could be a few thousand to tens of thousands of units; and high runs involve hundreds of thousands in quantity.

Let's go through these assembly and manufacturing stages and check out PCB microelectronics assembly challenges and what is possible (may lay in store) for medical OEMs. Or put another way, what is involved in transitioning medical electronics PCBs from small prototype quantities into volume production?



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Get in the Right Mindset

Proof of concept at the outset of prototyping isn't so much focused on ease of production and testability. Instead, the emphasis is more toward process development to find a workable solution and a fully functioning product. This process typically can extend into two to three iterations, either in traditional SMT manufacturing or in PCB microelectronics labs.

This is especially true for microelectronics assembly that has a cleanroom environment with extra sensitive material and special equipment for assembling medical insertable and ingestible devices. So, at the earliest prototype stages, the PCB assembly mindset must change. That means focusing on ease of production and testability rather than on process development. This would be difficult to practically implement, as proof of concept is the desired outcome rather than product maturity and process development. The next best thing would be to make the process mature and stable at the tail end of the prototype development.

Although it may sound confusing, there must be assurances that the process is solid when transitioning from prototype to pilot runs. Dies, for example, need to be in a specific format for pick-and-place machines to pick these up in the cleanroom. For example, when performing prototypes, there may or may not be a preference for the way dies are picked up. But for production, a well-defined process is absolutely necessary with even the minutest detail worked out.

A diced wafer can be pulled through vacuum and placed on an interposer, substrate, or PCB. That is acceptable for five, 10, 15 or even 100 units. But when it comes to production, there are several aspects that need to be considered and incorporated into production runs for the pick-and-place stages for pick and place details along with fiducial marks on dies and substrates.

Number one, dispensing material needs to be fully automated, regardless whether epoxies or other materials are being dispensed on the board, substrate, or underneath the dies. This requires carefully dialing the dispensing parameters and making sure these substances are not under or over dispensed.

Number two, especially when it comes to PCB microelectronics, an infrastructure combining machines and capabilities is critical to automatically pick up dies for production runs. These are dies that should be picked up from a common carrier, like waffle or gel pack rather than diced dies from a wafer. Also, there needs to be a pick-and-place high-speed die attach machine, as well as high-speed wire bonding equipment, to make sure production run speeds are properly maintained.

Also, having the microelectronics assembly process conveyorized or in-line like in traditional SMT manufacturing makes it production friendly. In a conveyorized microelectronics assembly, you can have a dispenser, pick-and-place machine, and wire bonder. Everything is conveyorized and in-line so that one function after another can be performed without physical human intervention. This makes the whole process optimized, fast, efficient, and reliable. But, still, there are other things needed to make these production stages happen smoothly, efficiently, and optimally.

Jigs, tools, and fixtures are needed to make the flow of different processes in multiple formats go through easily. You might have a fixture, jig, or tool that can do one product or placement at a time when dealing with small prototype quantities of 10 to 20 to 30 units. However, when you're talking about a few hundred to a few thousand units, specialized tools and fixtures that take multiple products need to be produced to make the production optimized. We also have to look at the PCB—whether it's a flex board for ingestible or insertable devices, bio-degradable material for ingestible devices, or rigid-flex—to make sure they are manufactured in optimized panels, rather than one-up.

Also consider that these are very tiny circuit boards, and they are processed in panel form. Ten or so are on a panel that undergoes dispensing, pick and place, and wire bonding. Compared to traditional assembly, in this instance 10 boards are undergoing this assembly step versus one assembly at a time.

The same process is repeated one time in a one-up setup versus the same process repeated

for a panelized 10-unit product, essentially saving time and money. Therefore, special tools, jigs, and fixtures need to be created to be able to make the transition at the same time from prototype to pilot, medium, and production runs.

Further, it's important to utilize automated tools and robotics as much as possible. Robotics, with its vision system in particular, makes the process a lot easier for placement accuracy. Those assembly systems measure with a laser beam to keep accuracy intact, which is especially critical for microelectronics involving CoB, flip chip, and wire bonding.

We are talking about accuracies in sub-mils and in some cases, microns. Sometimes, one- or two-micron accuracies are needed to make those portable and wearable devices. Robotics and automated equipment would make it a lot easier for making the transition from prototype to production.

At the same time, we must make sure that we have batch modules for testing the devices after the whole assembly is performed as part of the final quality assurance process.

When production units are completed, sample size for testing must be defined. This involves how testing small-to-medium run products can be tested in a short period of time. In some cases, test fixtures and test programs must be made, which can test and measure different units at the same time. This allows production to run efficiently and in a very small period.

Keeping IP in the U.S.

In summary, our industry has made significant headway toward production units for advanced medical products such as wearable, portable, ingestible, and insertable devices. We've got the knowhow and equipment for the necessary PCB microelectronics assembly and manufacturing. But even more CAPEX is necessary to assure production stays in this country, and can be performed conveniently and as easily as possible.

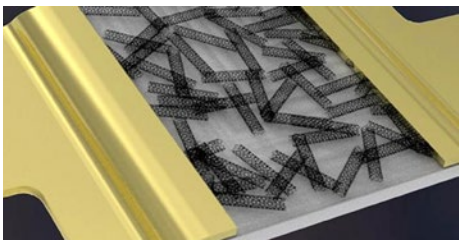
Keeping these products in the U.S. protects the medical OEM's IP since there is virtually no theft when it comes to manufacturing within the U.S. due to stringent laws. These are strong safeguards that are available to OEMs. Plus, the other major benefit is that logistics and supply chains are here in the U.S. OEM personnel can eliminate costly and time-consuming travel back and forth between the U.S. and offshore countries where production has been located. **SMT007**

Zulki Khan is the president and founder of NexLogic Technologies Inc. To read past columns or contact Khan, click here.

Easy-to-Make, Ultra-Low-Power Electronics Could Charge Out of Thin Air

Printed electronics are inexpensive and pave the way for low-cost electronic devices on unconventional substrates–such as clothes, plastic wrap, or paper.

However, these devices need to operate with low energy and power consumption to be useful for real-world applications. Researchers from the University of Cambridge, working with collaborators from China and Saudi Arabia, have developed an approach for printed electronics that makes low-cost devices that recharge out of thin air. Even the ambient radio signals that surround us would be enough to power them.



The technology is based on thin-film transistors which are "ambipolar" using only one semiconducting material to transport both negative and positive electric charges. If electronic circuits made of these devices were to be powered by a standard AA battery, the researchers say they could run for millions of years uninterrupted.

The work paves the way for a new generation of self-powered electronics for biomedical applications, smart homes, and infrastructure monitoring.

(University of Cambridge)

The Skilled Worker

Feature by Leo Lambert
EPTAC CORP.

"Knowledge has to be improved, challenged, and increased constantly, or it vanishes."
—Peter Drucker [1]

Why do we train and educate our employees? Here, I will share my perspective based on what is happening in facilities trying to outsource their products, as I see that many companies are losing the tribal knowledge of how things are manufactured and the basic skills necessary to physically build a product.

The ability to make good decisions is crucial for your employees making your products. They must use decisions in knowing which tool to use, how to use that particular tool, how to read the print to remove and replace a component, and how to make necessary changes so your product works. Regardless of where you are working, there are many decisions to be made and each employee should have enough knowledge about their job to make those decisions—no matter how minor the task may seem.

In this article, I will explore some fundamental ideas underlying the overarching question, "Why do we train our employees?" Clarifying these key strategies will lead to more effective training and a proper focus on the actual training needs.

What Resources Do You Need to Make This Happen?

Skill training will require learning new technologies and skills to manufacture new products. Companies need to be aware of what is coming so they can prepare the tools to manufacture the product. There may be some new techniques or equipment which may be necessary to learn as well as provide the ability to make these new products with minimal rework or rejects.

Who Are the Skilled Workers?

Skilled workers know what they are doing and have the skills to do the job. Don't forget the formula "Ability = Knowledge + Skills." [2] The skilled worker needs to know what to do and what their responsibilities are. Skilled workers

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must be trained to certain proficiency levels. In manufacturing, they apply their skills to the respective products, as they are the last line of defense before the product goes to the customer. It's necessary to have someone who is capable, has the incentive, and is happy doing the work. This makes a skilled worker.

Therefore, companies must pay attention to their employees who physically make the products. When they are proficient, have the proper tools to manufacture the product, and are noted as major contributors to the end product, their value increases.

What Are the Goals and Objectives?

When a company addresses its business goals, it can certify these goals will complement the following manufacturing goals or objectives:

- Improve product quality
- Improve yields
- Reduce scrap
- Improve throughput
- Improve morale and employee retention
- Remain competitive and current
- Increase customer base

Ask yourself:

- "How has my product changed over the years?"
- "How has it evolved or how has the company grown?"

For example, look at how smartphones (Apple's iPhones, for example) have evolved. EMS companies are successful when they adapt to the changes and make the necessary modifications within the organization to make it happen.

What Are Your Manufacturing Goals?

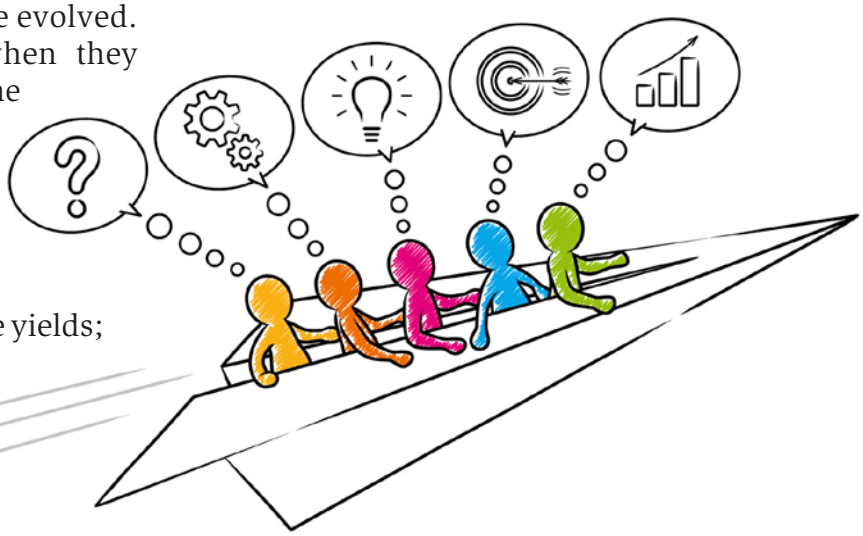
Manufacturing goals must improve yields; this can be accomplished by reducing defects, which provides better quality and results in customer satisfaction. Be transparent with your employees who are making the products, so they know how they are performing against the goals. Make them aware of how minimizing the number of defects positively affects the company. Employees do want to do a good job, so these efforts will, ultimately, improve your relationship with your customers.

Product Changes

What is the Impact of Product Changes?

Product changes must be defined, acted upon, and factored into the cost of operations. To use an old phrase, "One cannot build tomorrow's product with yesterday's skills." People joining the workforce today don't remember—or were never exposed to—something developed more than 10 or 20 years ago. Cars always had FM radios and air conditioning, computers are commonplace, and they have no idea what a slide rule is, never mind how to use one. Many of the products your manufacturing staff will be working on had not yet been invented when they were in school. Technology changes, however, mandate the need for new knowledge. Determine how this will be accomplished—more schooling, more in-house seminars, or maybe more training?

How do we get them up to speed in a hurry so, as an industry, we don't fall behind in the global marketplace?



How Do We Account for Process Changes?

In the electronics business, smaller components require different tooling and soldering irons. Solder alloys are continuously changing, and employees are required to understand the differences between the old alloys and the new. These differences can include changes in temperature, and flow and solidification, among others. Changes to laminate materials require adapting to the higher reflow temperature commensurate with the new solders. Inspectors look for anomalies such as board damages, board discoloration, etc., and this is all part of the training required to produce quality products.

Engineers must search and experiment with new chemicals, such as fluxes, due to higher temperature solder alloys, to determine and define how they work, and whether they need to be cleaned to meet the operational functionality of the product. Additionally, you must keep environmental requirements in mind.

Training

How much training do we provide, and what can we afford for our employees? Mistakes in manufacturing are expensive. Are corporate budgets created to plan for this training and certification? It should be a business requirement that corporations mandate their employees to improve their knowledge and skills base on a yearly basis just to keep abreast of the new technologies they will be dealing with. Training and educating employees also help customers understand their products are being manufactured by people who are proficient in their jobs.

"Workforce performance will determine which organizations prosper and survive in the marketplace of the foreseeable future." [3]

The importance of training can be summarized in these two questions:

- What are the advantages to the employees from acquiring more education?
- What are the corporate benefits from having knowledge and skill-trained employees?

There must be a return on investment. A company is comprised of the intellectual capacity of its employees; to grow, a company needs employees with skills at all levels.

The 'Hawthorne Effect'

In the 1920s, Elton Mayo, a professor at Harvard Business School, conducted a landmark study of worker behavior at Western Electric in Chicago, which revolutionized the theory and practice of management.[4] Researchers concluded that the principle of human motivation through recognition resulted in the individuals improving their productivity. Just by making people part of a team, the company saw improved output and quality. To illustrate this, one of my customers recently reported a 26% reduction in defects because of attending a training session. Improved quality resulted in higher productivity.

Conclusion

There is often a debate between training and product value. We always want a return on investment in any of our expenditures; in this situation, that investment is with your employees doing the physical work who must have the tools to manufacture your product.

Employees

Employees must be able to understand new subjects and learn new skills as demanded by the product or process requirements. Doing this keeps up employee morale, as training will make them feel they are part of the solution

as opposed to just being operators. Training and recognition increase their self-esteem and creates a feeling of appreciation. A company should have an intrinsic value system where employees are people and nothing is permanent, therefore you should make every effort to keep your employees as employable as possible. This also helps with cross training programs so all employees can do many different jobs within the facility.

Training Reduces Cost of Quality

What is the cost of quality? Every time you must spend time fixing something, the cost of quality increases. So, any cost that would not have been expended if quality were perfect contributes to the cost of quality. It's best when problems can be discovered immediately and not later when it gets to the field. See Table 1 for an explanation of costs rise depending on where defects are found.

Assembly	Factor = 1
Inspection	Factor = 10
Test	Factor = 100
Field Service	Factor = 1,000

Table 1: The exponential cost of finding defects.

What is the value of training? The bottom line is, "You don't get paid for what you know; you get paid for how you use what you know." **SMT007**

References

1. Peter F. Drucker (November 19, 1909–November 11, 2005) Peter Drucker was a prolific writer and professor of management studies. His writings have predicted many of the major developments of the late 20th century, including privatization and decentralization, the rise of Japan to economic world power, the decisive importance of marketing, and the emergence of the information society with its necessity of lifelong learning. In 1959, Drucker coined the term "knowledge worker" and later in his life considered "knowledge work productivity" to be the next frontier of management.

2. "Designing Training Programs, the Critical Events Model," by Leonard Nadler.

3. "The ASTD Training and Develop Handbook: A Guide to Human Resource Development," by Robert L. Craig.

4. "The Human Relations Movement: Harvard Business School and the Hawthorne Experiments."

Leo Lambert is technical director at EPTAC, where he oversees content of course offerings and provides customers with expert consultation. Leo's career spans 40 years in the industry; he is a recipient of the IPC President's Award.

Engineering Technology Team's Printed Circuit Board Design Improves Electric Guitars

Traditional electric guitars have a "pickup," a magnetic transducer made with miles of copper wire coiled around magnets via a tedious, time-consuming process.

Purdue Polytechnic's Davin Huston, Mark French, and Kathryn Smith (a former graduate student) have created a flexible, printed circuit board that imitates the conventional copper wire configurations inside electric guitars.

With a conventional electric guitar pickup, string vibrations cause the electromagnetic field to oscillate, induce a voltage in the coil, and generate an electric signal. The team's circuit board works the same way.

Davin Huston, assistant professor of practice in engineering technology, said, "Our circuit boards can be printed in large quantities and fit inside just about any electric guitar, which simplifies the manufacturing process but keeps the sound quality and reliability."

"With typical pickups, the coils often produce undesired feedback and need to be potted with wax or a polymer," said French. "Our circuit board provides an alternative that is easier to produce with manufactured consistency."

(Purdue Polytechnic Institute)

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MilAero007 Highlights

Use of IMS Thermal Materials in Multilayer Stackups for Power Applications ▸

This roundtable discussion brings together the expertise of Ventec International Group's Global Head of IMS Technology Chris Hanson and Technical Manager Denis McCarthy. Rax Ribadia of Excello Circuits provides hands-on fabrication experience from a specialist PCB manufacturer, and I-Connect007 editors Andy Shaughnessy and Pete Starkey contribute to a conversation that explores applications, materials, design considerations, and mechanisms of heat transfer.

Just Ask Tara Dunn: The Exclusive Compilation ▸

We asked for you to send in your questions for Averatek's Tara Dunn, and you took us up on it! We know you all enjoyed reading these questions and answers, so we've compiled all of them into one article for easy reference. And if you'd like to hear more from Tara, be sure to view her Flex007 column series "Flex Talk."

Just Ask Joe Fjelstad: The Exclusive Compilation ▸

We asked for you to send in your questions for Joe Fjelstad, and you took us up on it! We know you all enjoyed reading these questions and answers, so we've compiled all of them into one article for easy reference. We hope you enjoy having another bite at the apple. And if you'd like to hear more from Joe, view his column series "Flexible Thinking."

Comtech Releases Results for Fiscal 2021 Q1 ▸

Comtech Telecommunications Corp. has reported its operating results for the first fiscal quarter ended October 31, 2020 and updated its financial targets for fiscal 2021.

IPC President John Mitchell Releases Statement on NDAA Final Passage ▸

IPC President and CEO John Mitchell released a statement on final passage of the National Defense Authorization Act.

Understanding MIL-PRF-31032, Part 6 ▸

Concluding this six-part discussion on understanding the military printed circuit board performance standard MIL-PRF-31032, Anaya Vardya examines the remaining procedure required to address the unique requirements of the military.

SpaceX, NASA, ESA Launch Sentinel-6 Michael Freilich Mission ▸

Fresh off their second crewed launch for NASA, SpaceX temporarily shifted focus on launches to the U.S. West Coast, where a Falcon 9 rocket launched the Sentinel-6 Michael Freilich oceanography satellite in cooperation with NASA, the National Oceanic and Atmospheric Administration (NOAA), the European Space Agency, and various other partners.

Stephen Chavez, Happy Holden on Designing Reliable Vias ▸

Andy Shaughnessy and Happy Holden speak with Stephen Chavez, a staff engineer with an aerospace company and chairman of the Printed Circuit Engineering Association (PCEA), about designing vias for greater eliability. They also address several areas where they can look to improve reliability, a variety of steps that designers should take to help ensure more robust vias, and some testing and educational resources that PCB designers and design engineers should be aware of.

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Building A Better, Brighter LED Headlamp with Top-Side Alignment (TAP)

Article By Glenn Farris
UNIVERSAL INSTRUMENTS CORPORATION

Abstract

An emerging trend in the automotive industry is the adoption of advanced LED headlamp lighting systems. These systems drive challenging placement requirements for LED Packages. In this paper, we will review these unique challenges and discuss a novel approach to high-accuracy placement of LED packages enabling a scalable production solution.

Drivers

LED lighting technology for automotive headlamp applications provides improved safety and lighting intelligence. LED automotive headlamps are becoming the standard for even the most affordable automobiles and the automotive LED market is expected to reach $3B by 2022.

Challenges

LED automotive headlamps and emerging applications like LIDAR are complex, requiring ultra-precise assembly to achieve extreme performance standards. High-accuracy placement and exact LED alignment are essential in building brighter and more adaptive (color, direction, intensity) LED automotive headlamps.

Some of the manufacturing challenges of rapidly and accurately placing LEDs include:

- Requirements for accurate top-side vision correction
- Need for high throughput at 10–25µm accuracy
- Non-standard fiducials
- Need for material, process, and application know-how

The most effective way to achieve this is to utilize a top-side alignment (TAP) process for placement of LEDs.

Top-Side Alignment

Top-side alignment process (TAP) ensures an accurate, repeatable, high-speed and economical production solution for the placement of LEDs. The TAP process precisely places and aligns LEDs based on top-side features. A top-side inspection of LED (light-emitting diode) features is performed on a back-lit vacuum

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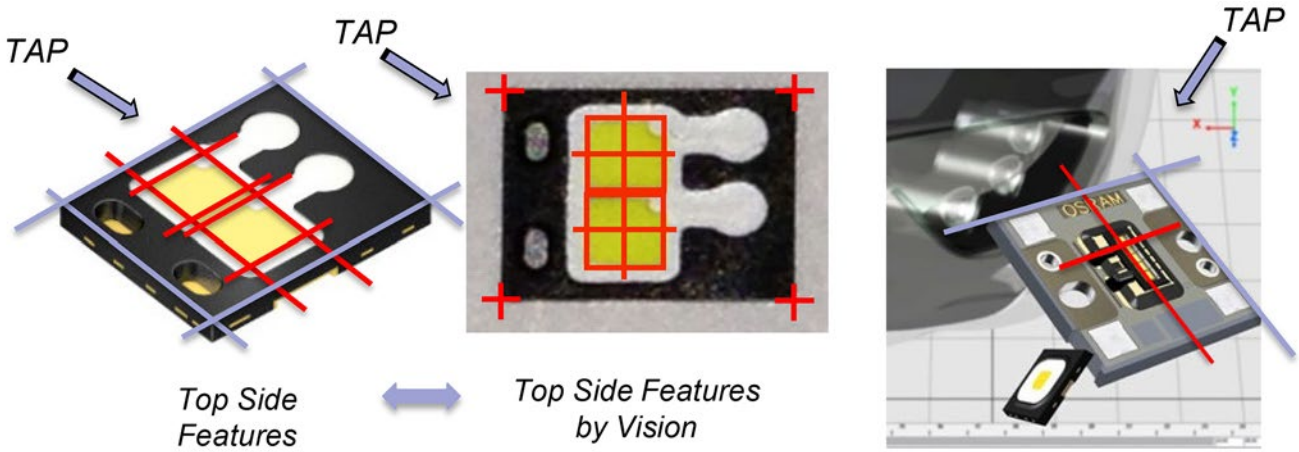


Figure 1: Top-side alignment process features.

nest, followed by a bottom-side inspection of critical features. TAP eliminates the inaccuracies of alternative solutions caused by part movement during a post-inspection (top side only) pick process.

Top-Side Alignment Process Steps

1. Machine starts by feeding the component to the feeder location.
2. The Pattern Error Correction (PEC) camera locates the programmed topside features on the component. The topside feature is referred to as the artwork.
3. The PEC camera locates a reference feature with respect to the artwork.
4. The machine then calculates and stores the artwork-to-reference feature offset.
5. The head picks and scans them over the upward looking camera (ULC). Using ULC, it recognizes the same reference feature used by the PEC.
6. The artwork-to-reference feature offset is considered in the determination of the final placement location.
7. The components are then placed on the substrate.

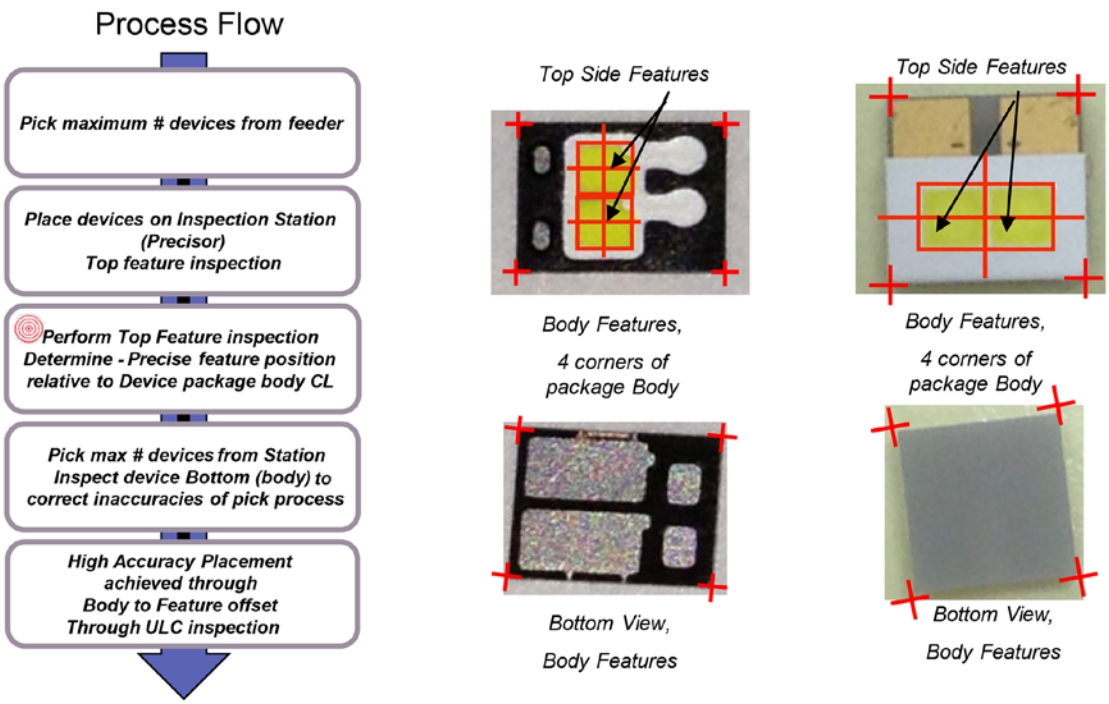


Figure 2: TAP process flow.

Case Study

In order to exactly measure the results of the TAP process, we undertook the following case study. Objectives were as follows:

1. Achieve LED placement accuracy within +/-25-micron accuracy post reflow.
2. Measure baseline accuracy.
3. Document the full process for a repeatable solution.

Goal: Achieve LED placement accuracy within +/-25-micron accuracy post reflow.

Process:

- Use of two drill holes on each circuit for alignment reference
- Placement accuracy measured from a reference hole on each circuit
- Pick and place of typical SMT devices for LEDs to mimic process

The following materials were used for the test (Tables 1 and 2):

Component type	LED LUXEON F Plus CW
Component size	2.5 mm x 2 mm x 0.8 mm
Number of components per unit	4
Total components per panel	32
Packaging type	Tape & reel
Feeding method	8 mm

Table 1: List of LED accuracy materials.

Placement process	TAP-place
Placement pressure	150 grams
Placement dwell time	0 sec
Placement correction method	TAP (Top-side alignment process)

Table 2: Process information for LED accuracy test.

Process Steps

Step 1: Solder paste printing

- Print solder paste
- Speed: 25 mm/sec
- Pressure: 4.0 kg

Step 2: Adhesive dispense

- Dispense low temperature cure adhesive

Step 3: Automated optical inspection

- Inspect solder paste volume

Step 4: Pick & place

- LED placement with TAP process
- Place force 150 grams

Step 5: Reflow oven

- Ramp rate: 1.4°C/sec
- TAL: 50 sec
- Peak: 237°C

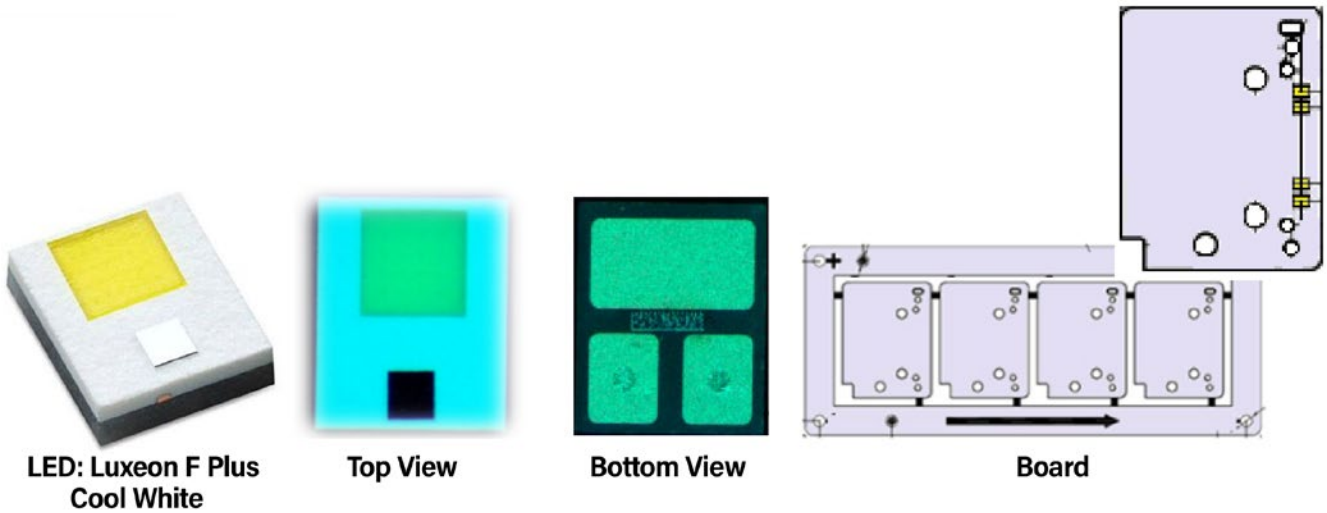


Figure 3: Image of LED accuracy materials.

Step 6: Automated optical inspection

- Check placement accuracy

Step 7: X-ray

- Examine components for voids

Goal: Measure LED placement accuracy baseline.

Process

- Measure LED placement accuracy on glass plate
- Measure LED placement accuracy verification on panel
- Dry assembly no wet process
- Compare adhesive and solder paste after both pre- and post-reflow

Measure LED placement accuracy on glass plate

- Place 32 LEDs on each board
- Orientations of 0, 90, 180 and 270
- Sample size, 5 boards, 160 data points

Accuracy Results—Glass Test Board

Purpose: Measure LED placement accuracy verification on panel

- Capability prior to paste and adhesive on glass board
- 5µm repeatability, all placements within 18µm

Results

All 160 data points within 20µm

Accuracy Results—Panel

This test was done to test the baseline placement test/analysis "on panel":

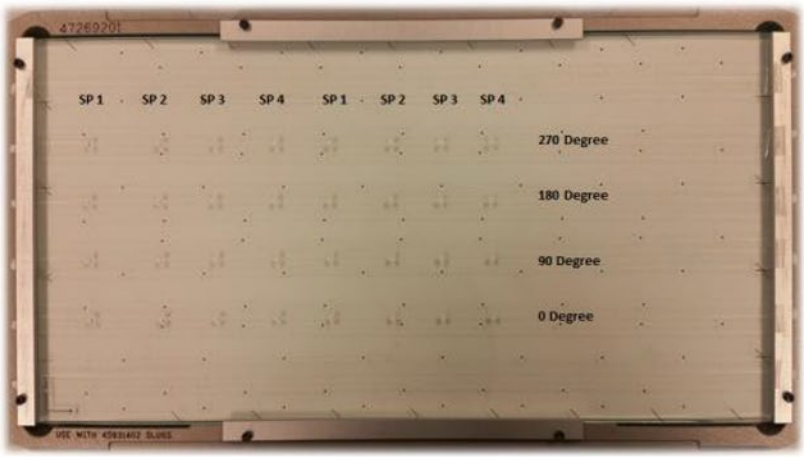
- Capability prior to paste and adhesive
- <4.5µm repeatability, all placements with 15µm

Results

- No influence on accuracy due to panel implementation
- All samples are placed within +/-25 microns as per assembly requirement

Head 1	X Axis	Y Axis
Max	15	11
Min	-18	-15
Range	33	26
Average	-1.99	-0.60
Stdev	5.22	5.07
Upper Limit	25	25
Lower Limit	-25	-25
CpU	1.73	1.68
CpL	1.47	1.61
Cpk	1.47	1.61

Figure 5: Test results.



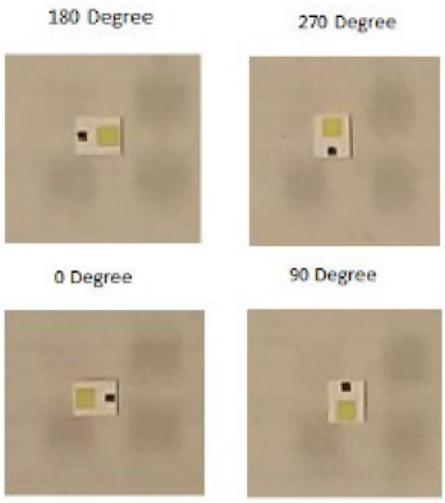


Figure 4: Glass test plate.

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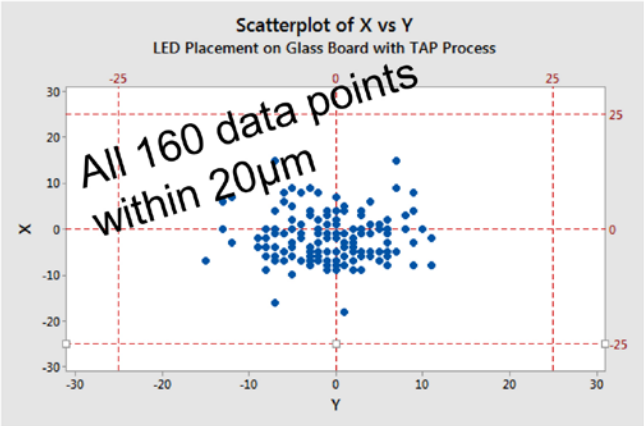


Figure 6: Graph of LED placements.

Head 1	X Offset	Y Offset	Theta Offset
Max	12.93	2.29	0.68
Min	-2.95	-12.44	-1.24
Range	15.88	14.73	1.92
Average	4.92	-5.24	-0.04
Stdev	4.41	3.90	0.41
Upper Limit		25	
Lower Limit		-25	
CpU	1.52	2.58	
CpL	2.26	1.69	
Cpk	**1.52**	**1.69**	

Figure 7: Test results.

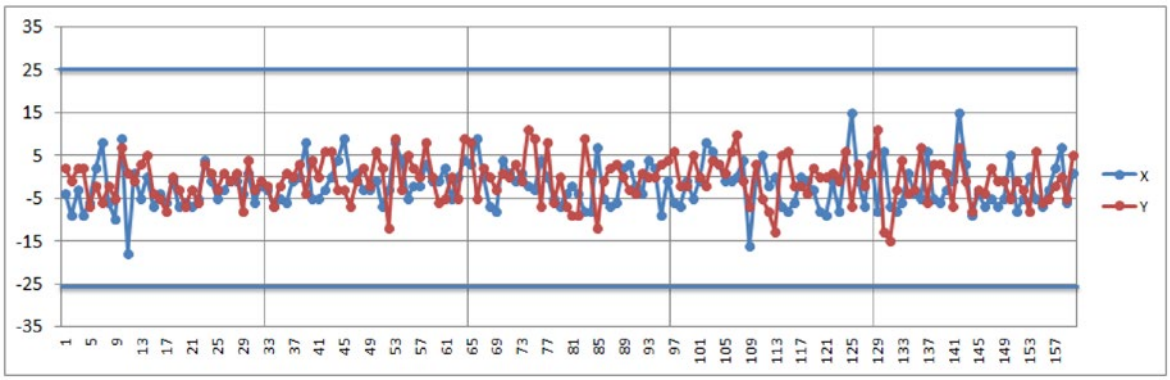


Figure 8: X, Y accuracy data.

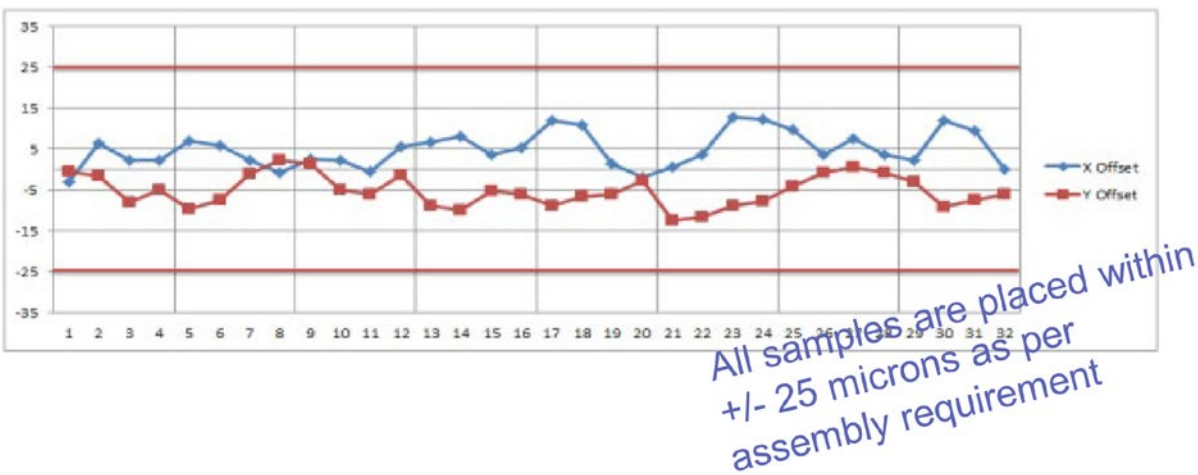


Figure 9: X, Y accuracy data.

Goal: To test and document the full process for successful LED placement, including:

- Solder paste printing and inspection
- Low temperature cure adhesive dispensing
- AOI for solder print characterization
- Pick and place
- Reflow profile setup
- X-ray for void inspection
- AOI accuracy measurement
- Cross-section test

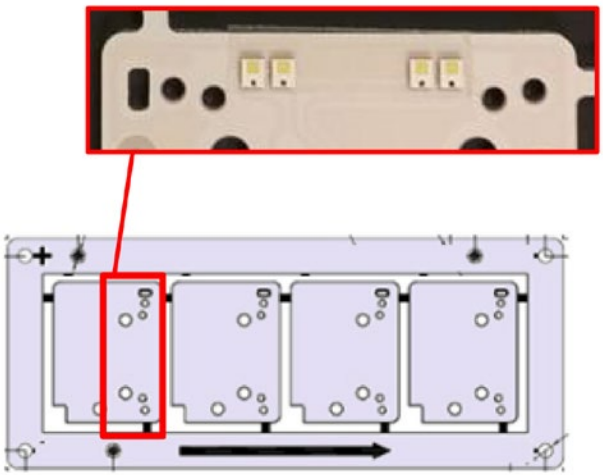


Figure 10: LED placement locations.

Solder Paste Printing Inspection

We used a solder paste inspection SPI machine to conduct a thorough solder paste inspection to evaluate the quality of the paste, and that the paste was printed correctly and without manufacturing faults. Solder paste volume was evaluated for process consistency, and or process influence.

Low Temperature Cure Adhesive

To conduct this test, we followed standard print recommendations by LED manufacturing for solder paste print. Note that glue performance is critical to accuracy results.

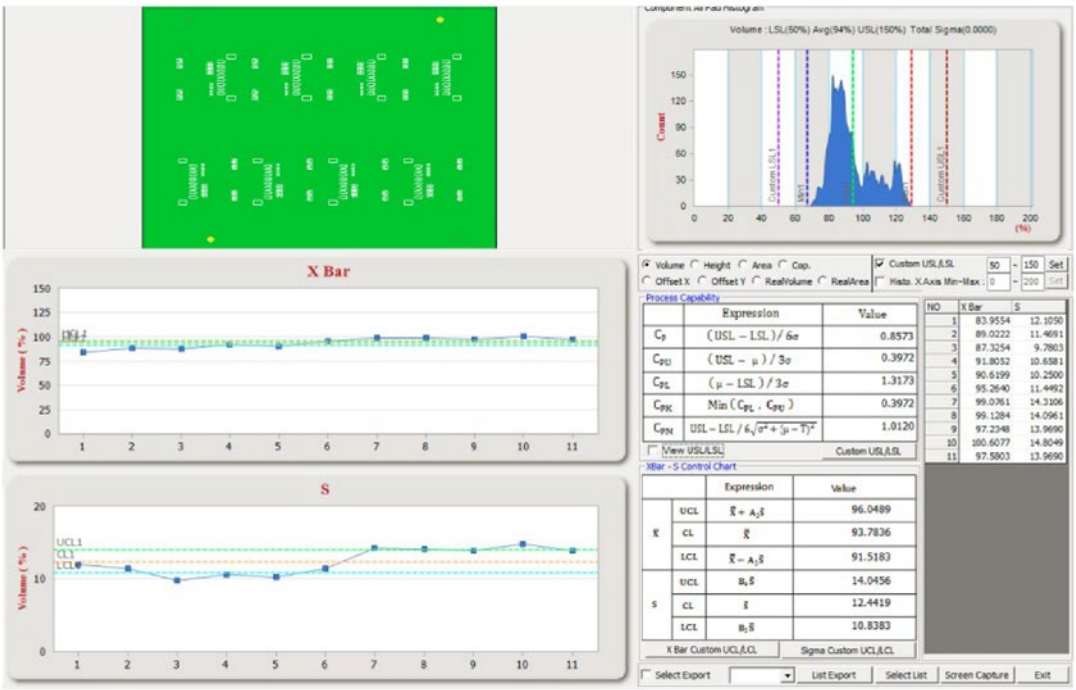


Figure 11: SPI data–solder paste volume evaluated for process consistency.

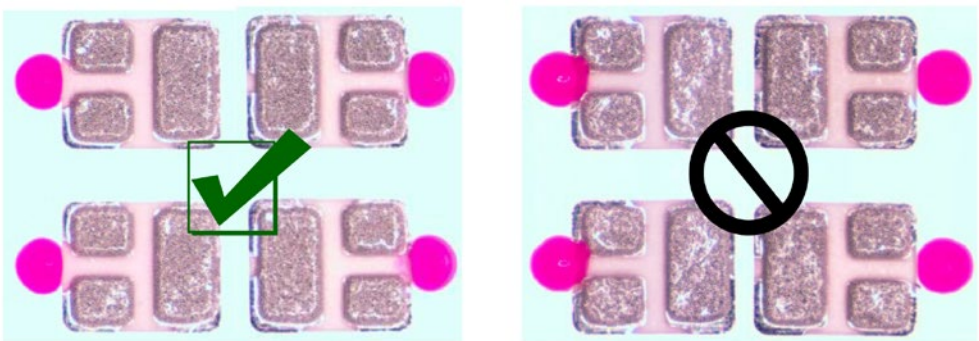


Figure 12: Adhesive dispense test results.

Head 1	X Offset (µm)	Y Offset (µm)	Theta Offset (degree)
Max	8.47	13.48	2.34
Min	-17.11	-12.31	-3.40
Range	25.58	25.79	5.75
Average	-4.00	2.20	0.13
Stdev	4.88	5.25	0.76

Upper Limit		25
Lower Limit		-25
CpU	1.98	1.45
CpL	1.43	1.73
Cpk	**1.43**	**1.45**

Figure 13: Test results.

Adhesive dispense:

- Maintains LED position from surface tension effects during reflow
- Proximity shall not contaminate pad
- Only a single dot under LED body sufficient
- Proximity nearest to pad and body

Accuracy Results—Before Reflow

Baseline placement test/analysis "on wet panel"

- Capability on wet paste and adhesive
- 5 µm repeatability, all placements with 18 µm
- 32 samples per panel

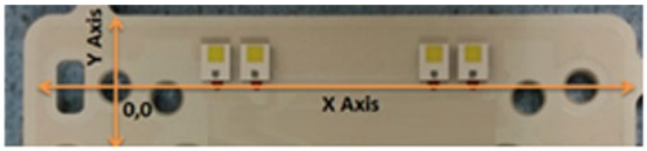


Figure 15: Accuracy measurement locations.

Results

- *No influence on accuracy due to wet material*
- All 256 placements within +/-25 microns specification

Reflow Profile

To test curing time, we ran the board through a reflow process. The results below show a typical ramp to spike profile, SAC 305, air atmosphere.

Results

- Cure transition is below liquidous phase of solder paste, eliminating LED movement from self-centering effects of surface tension.

Accuracy Results—After Reflow

Placement test/analysis "on wet panel" post reflow

- Capability on wet paste and adhesive
- 5.5 µm repeatability, all placements with 18 µm
- 32 samples per panel

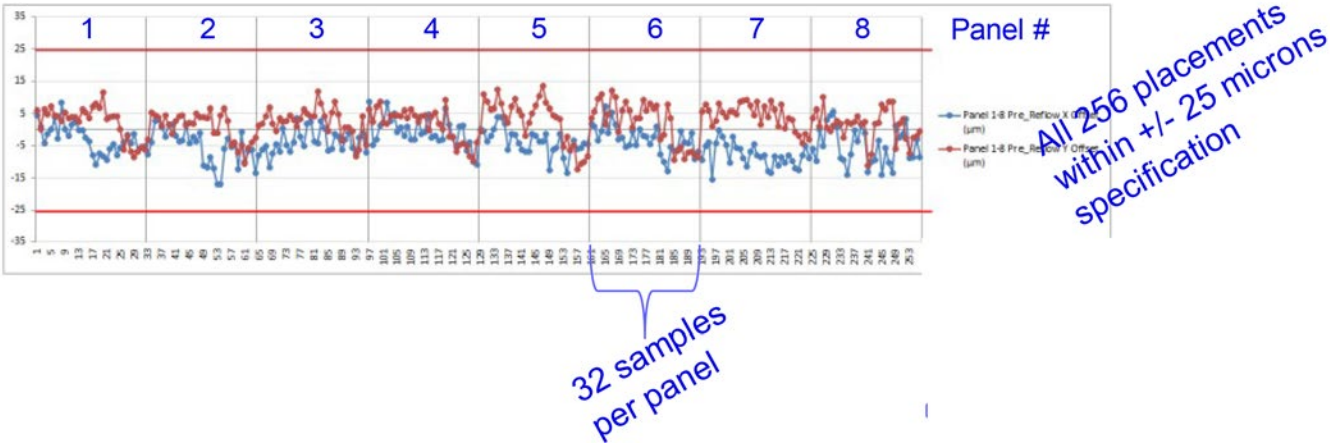
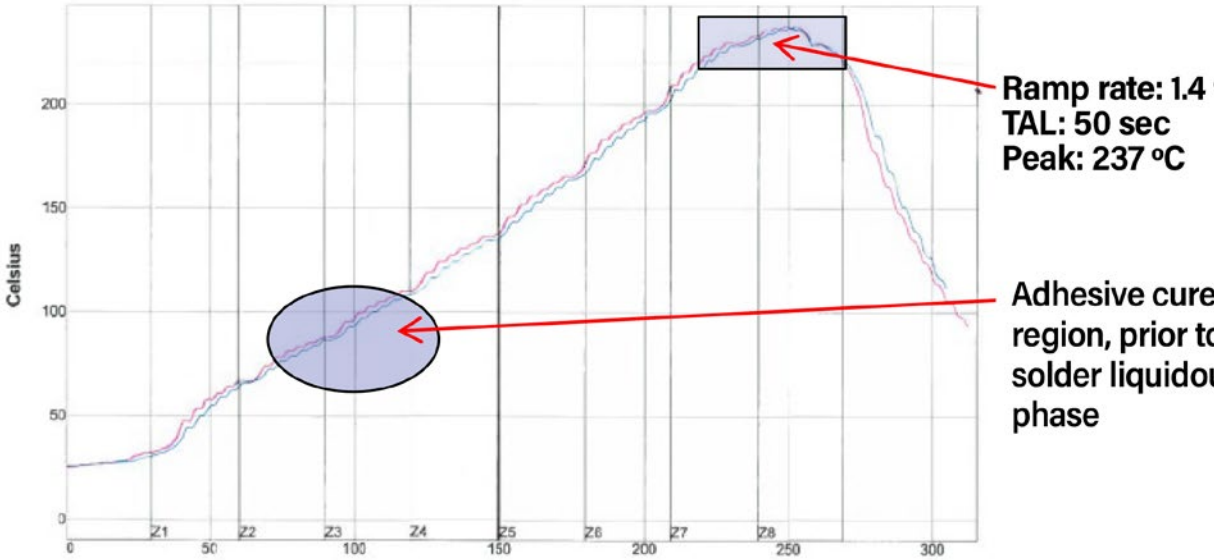


Figure 14: X, Y accuracy data.



PWI= 129%	Max Rising Slope		Reflow Time /220C		Peak Temp		TvsT Time (Rise) 130/220C	
<TC2>	1.46	91%	50.17	3%	237.56	2%	82.92	129%
<TC3>	1.41	77%	49.03	-19%	236.84	-26%	80.30	103%
Delta	0.05		1.14		0.72		2.62	

Process Window:

Solder Paste:	Sn96.5/Ag3/Cu0.5 NC Air/N2		
Statistic Name	Low Limit	High Limit	Units
Max Rising Slope (Target=1.1)	0.8	1.5	Degrees/Second
(Calculate Slope over 20 Seconds)			
Time Above Reflow - 220C	45	55	Seconds
Peak Temperature	235	240	Degrees Celsius
TvsT Time (Rise) 130/220C	60	80	Seconds

Figure 16: Reflow test results.

Results

- *Adhesive controlling LED movement during reflow within specification*
- All 256 placements within +/-25 microns specification

Accuracy Before and After Reflow

Below are the accuracy results before and after reflow:

- Individual error measurements between pre- and post-reflow
- All samples pass Cpk >1.0 @ 25mm post reflow

Results

- Good post reflow accuracy results
- No change in standard deviation
- Minimal change in y-axis mean ~5mm

Head 1	X Offset (µm)	Y Offset (µm)	Theta Offset (degree)
Max	8.82	23.23	21.52
Min	-16.28	-13.58	-3.33
Range	25.1	36.81	24.85
Average	-3.43	7.16	0.22
Stdev	4.74	5.48	1.54

Upper Limit		25
Lower Limit		-25
CpU	2.00	1.09
CpL	1.52	1.96
Cpk	1.52	1.09

Figure 17: Test results.

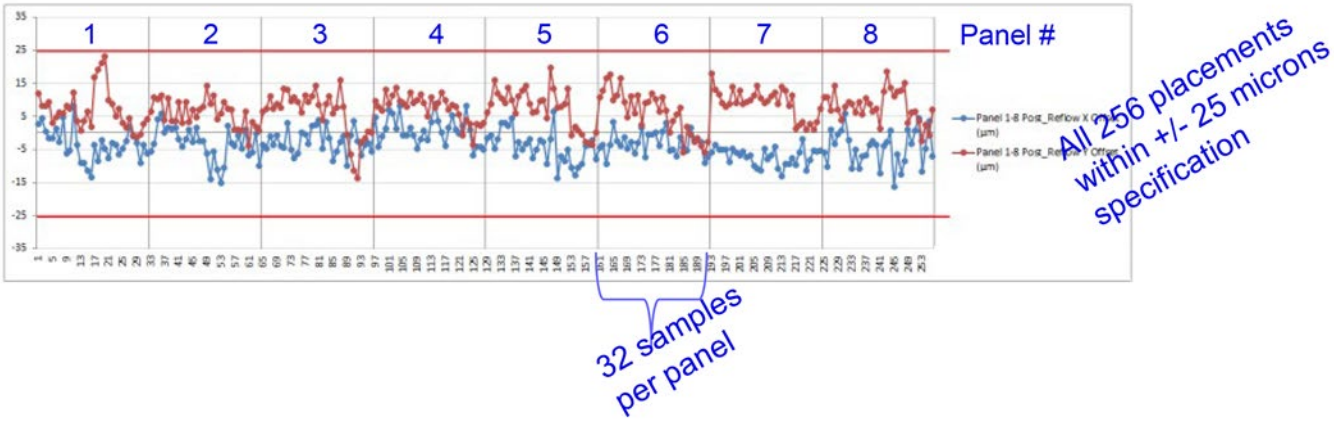


Figure 18: X, Y accuracy results.

Before Reflow			
Head 1	X Offset (µm)	Y Offset (µm)	Theta Offset (degree)
Max	8.47	13.48	2.34
Min	-17.11	-12.31	-3.40
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Upper Limit		25	
Lower Limit		-25	
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CpL	1.43	1.73	
Cpk	**1.43**	**1.45**	

After Reflow			
Head 1	X Offset (µm)	Y Offset (µm)	Theta Offset (degree)
Max	8.82	23.23	21.52
Min	-16.28	-13.58	-3.33
Range	25.10	36.81	24.85
Average	-3.43	7.16	0.22
Stdev	4.74	5.48	1.54
Upper Limit		25	
Lower Limit		-25	
CpU	2.00	1.09	
CpL	1.52	1.96	
Cpk	**1.52**	**1.09**	

Figure 19: Accuracy comparison error chart.

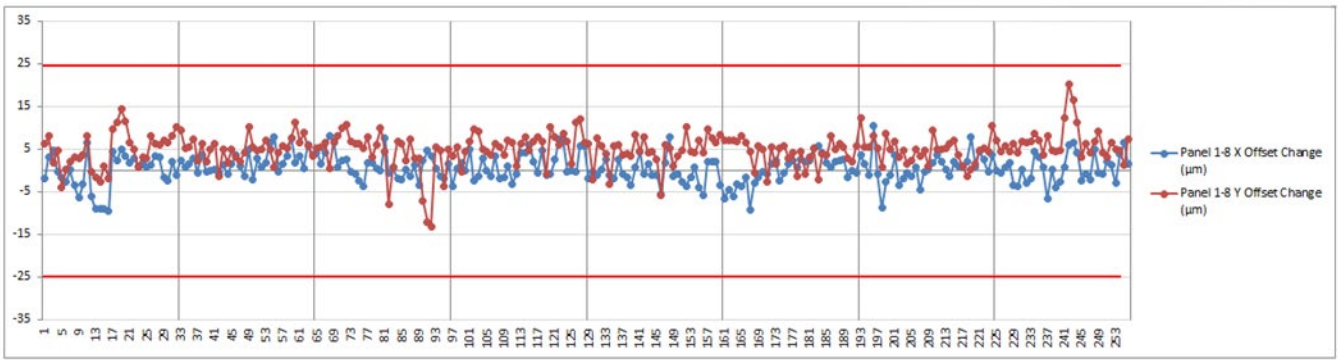

Figure 20: X, Y accuracy results.

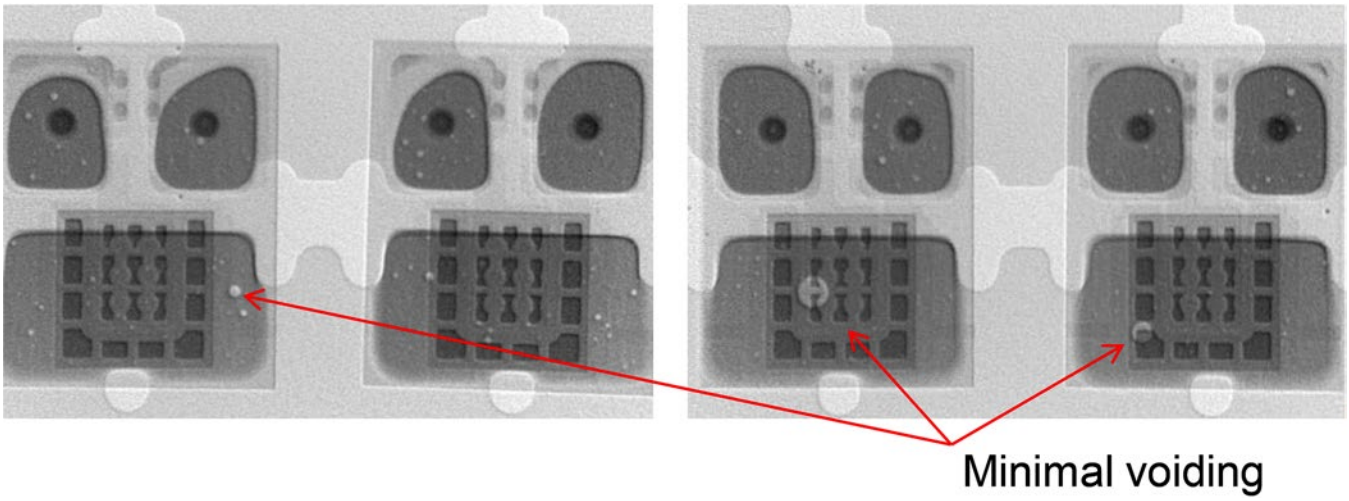

Figure 21: X-ray image.

X-ray Image for Void Inspection

Void Specification

- All pads < 25%, single pad < 10%

Results

All samples meet voiding specification

LED Cross-Section

We conducted a SEM (scanning electron microscope) image analysis to look at both tilt and voiding under magnification.

Results

- Minimal to no effect on package tilt from adhesive positioning
- Minimal voiding

Conclusions

- TAP offers a novel approach to high-accuracy placement of LED packages enabling a scalable production solution
- TAP eliminates the inaccuracies of alternative solutions caused by part movement during a post-inspection (top-side only) pick process

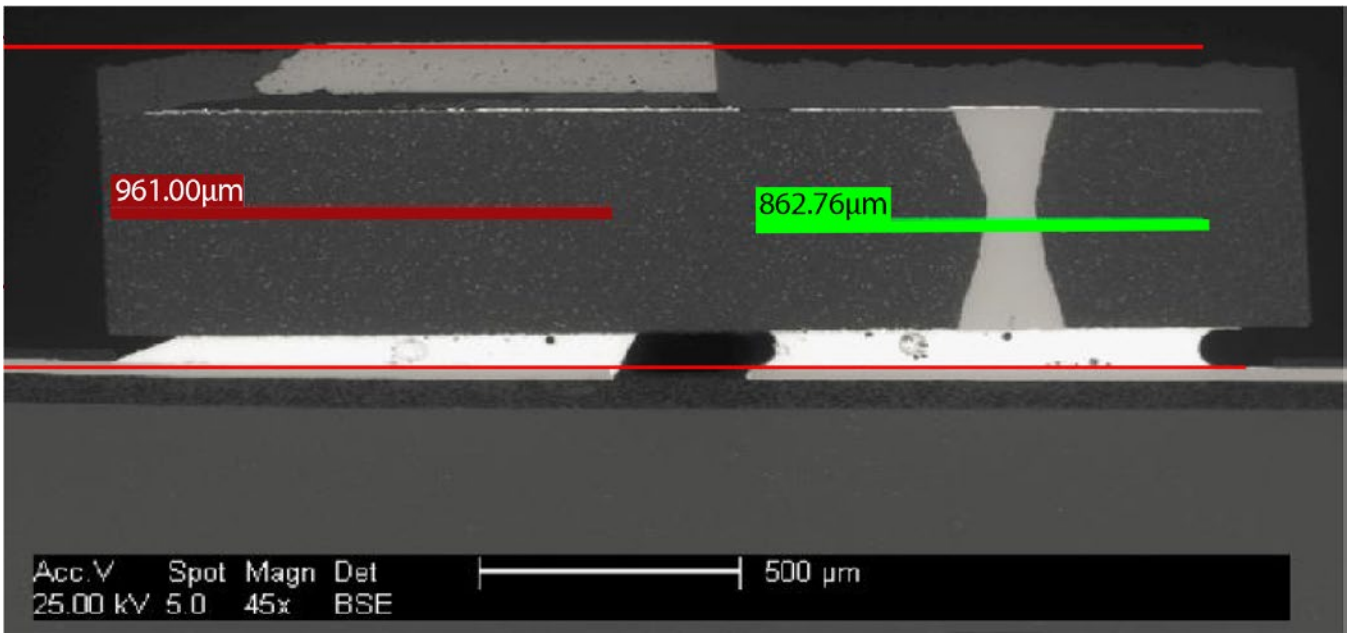

Figure 22: Cross-section under magnification.

Figure 23: LEDs placed on epoxy demonstrating no thermal shift.

- TAP aligns placement based on top feature, in any rotation, enabling high-accuracy placement for a wide range of applications, including automotive, solar CPV and semiconductor
- TAP is an excellent solution to the many challenges faced by those manufacturing LED headlamp assemblies, as it ensures fast, repeatable and accurate placement of LEDs

Acknowledgements

Process development, product assembly and process analysis provided by Universal Instruments Advanced Process Laboratory (APL). Contact: David Vicari, Director, APL, Vicari@uic.com. SMT007

This paper was presented at SMTA International 2020. All images provided by Universal Images.

Figure 24: Side view of epoxy under magnification.

Glenn Farris is Vice President, Strategic Marketing, for Universal Instruments Corporation.

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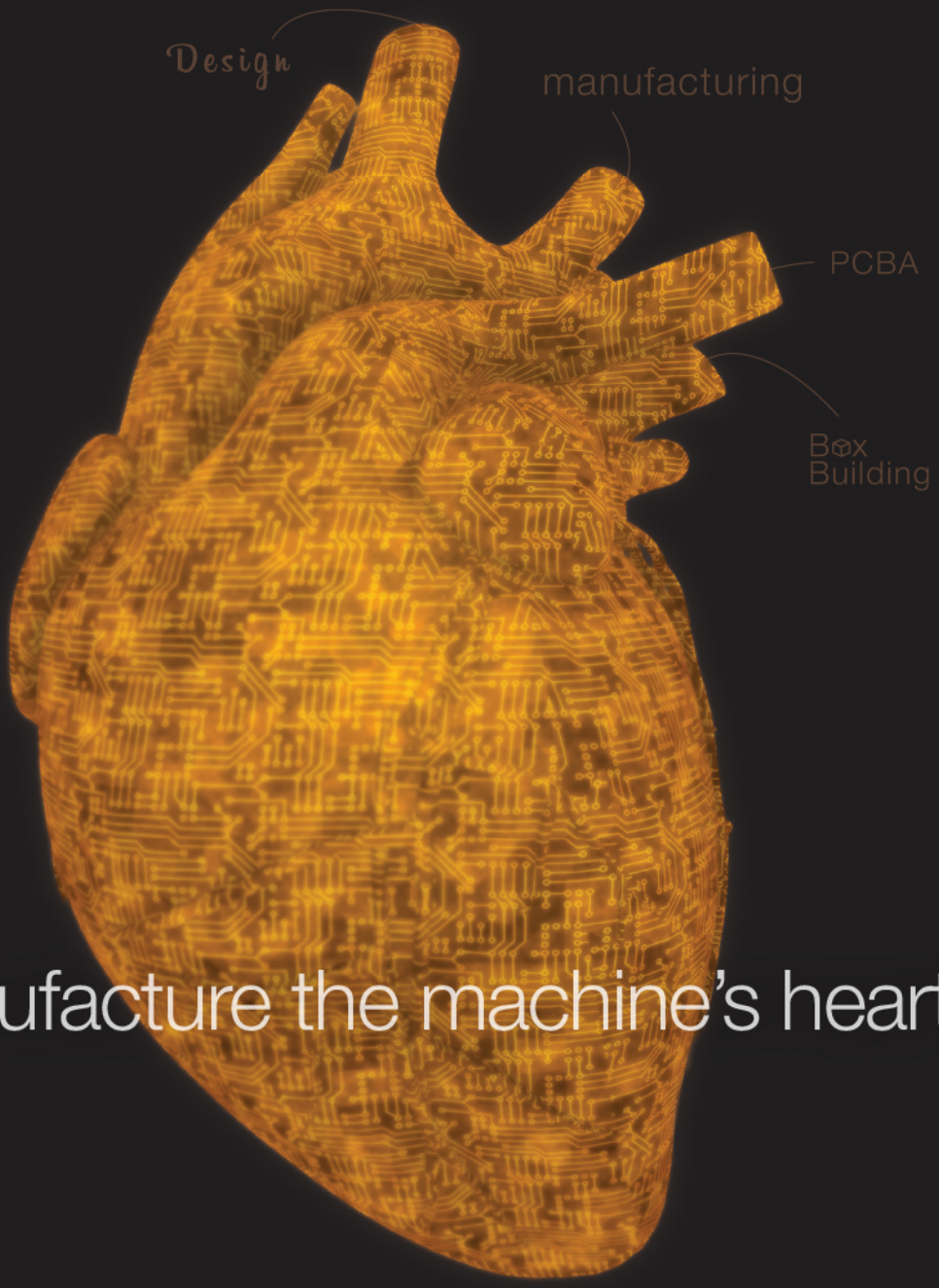

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How to Audit OEM-EMS Assembly Capability, Part 3

SMT Solver
by Ray Prasad, RAY PRASAD CONSULTANCY GROUP

In my September 2020 column I discussed the overview of an audit process to assess the manufacturing capability of OEMs or EMS companies. In my second column in this series in November I focused on technology and manufacturing capabilities of the supplier. We will conclude this three-part series with questions on quality and RoHS compliance.

Even though I have divided the questions into various areas, there are going to be overlaps because they are interconnected. As I mentioned in my previous columns, it is not important which category these questions fall into, but they are asked. These questions are intended to help generate questions that are relevant to your product and the manufacturing site you plan to audit—be they at an OEM or EMS site.

Quality and RoHS Related Questions

There is a lot of interest in AOI machines these days and there is a good reason for it. AOI systems not only collect the defect data, but they also analyze and plot the data to help you do the root cause analysis. The problem with most AOI systems, however, is that they are wrong quite a bit. So, it is not uncommon for companies to buy multiple AOI systems and then not really use them since operators lose confidence in them. The reality is that it is not really the fault of the AOI machines but how they are used. Most AOI systems are nothing more than a few cameras that take pictures of what you are interested in, like components and joints, and compare them to an acceptable standard (image sensor technology with computer analysis of the digital images).

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Most AOI systems are very good at giving you data on simple defects like wrong components, wrong orientation, wrong polarity, and insufficient paste height or paste volume. Unfortunately, most AOI systems are placed after the reflow ovens and asked to make some difficult calls like cold solder, non-wet, de-wet, and insufficient joints. These are even difficult for well-trained human inspectors who would disagree with each other. It is no wonder that AOI systems are wrong quite often.

Therefore, when trying to assess the quality approach of a company, you need to focus on whether the company's focus is on quality assurance or quality control. There is a big difference between these two approaches. For example, quality control implies activities after product is built such as inspection, test and repair. On the other hand, quality assurance involves activities before product is built such as DFM, use of only acceptable parts (coplanarity, solderability, moisture and temperature sensitivity), and use of a documented process recipe for all the process steps (printing, placement and reflow profiles). Quality control may not add value, but quality assurance does.

Quality control may not add value, but quality assurance does.

When you place the AOI system before the reflow oven in the SMT line, your focus is on preventing the defects before they happen—a quality assurance approach where AOI machines provide more reliable answers. On the other hand, when you place the AOI system after the reflow oven, your focus is on quality control so that defective products don't get shipped to the customer. I am not suggesting that you ship the products without inspection or test which are non-value-added steps but necessary and also more difficult for most AOI machines. If you plan to place AOI machines after the reflow oven, you should lower your expectations from the AOI machines. Managing your expectation is key to happiness whether you are dealing with people or machines.

With the above background in mind, when auditing a site that uses AOI machines, you could ask questions to determine if enough thought has gone into selecting the location of the AOI machine in the SMT line. For example: Why was that location of the AOI machine in the SMT line chosen? The answer to this question will give you an idea whether the company's focus is on quality control or quality assurance and whether the company knows the difference.

Here are some other questions related to quality worth asking during your audit:

- Which flux are you using for touch touch-up and rework?
- Have you implemented no-clean board processes?
- Do you clean the boards anyway even though the flux is no clean? Why?
- How clean is and how do you measure board cleanliness?
- Do you perform any type of accelerated stress screening? If so, what are the range, temperature ramp and length of the test? What percent of boards?
- Do you perform any type of functional tests? What percent of boards?
- Which debugging analysis tools do you use for troubleshooting defective boards? Do you prefer a specific set of equipment and why?

To get an idea of the overall quality focus of the company you could ask them to describe their overall quality organization and reporting structure and question such as:

- Is there a formal Quality Manual and procedures?
- Are there different manuals for tin-lead and lead-free? If so, are those manuals under controlled distribution?
- What type of indicators do you use to monitor overall quality?

- Are formal reports issued to top management on a regular basis? If so, describe the reports.

To determine if the company really is focused on quality assurance and not on quality control, you could ask them to describe their overall SPC implementation and ask which manufacturing processes are under SPC control and review their SPC procedures and sample SPC charts. You could ask:

- Is there formal SPC training for all levels of employees?
- How is the data used for process control or process improvement?
- Is remote access into the Quality Data System made available to your customers?

Also, ask them for the type and frequency of reports available from the data system.

It may also be worth looking into their ESD implementation procedures. For example:

- Are sensitive areas clearly identified (i.e., any areas where ESD sensitive material is handled out of ESD protective enclosure including transferring components from one tube to another)?
- Do all personnel and visitors wear approved ESD protective clothing and wrist straps while in the ESD-sensitive area?
- Are all work surfaces, dissipative or conductive, grounded through a resistor per specification?
- Are conductive or antistatic containers used to transport ESD-sensitive material from one location to another?
- Are ESD-sensitive areas and containers periodically audited for conformance to documented ESD guidelines?

It is also useful to get some sense of how their other customers view them. For example, you could ask if they conduct customer satisfaction surveys. And ask them to provide the customer survey form if available. You could also find out if the company also conducts an independent (unbiased) customer survey and whether they have a measurement system in place to assess the customer's perception of their performance.

- Is there an internal measurement system within the organization which correlates to the level of customer satisfaction?
- Do they have specific goals for achieving total customer satisfaction, both internal and external? If so, to what extent are customer satisfaction goals disseminated and understood by everyone in the organization?
- Does management regularly review and assess all operating systems to determine if barriers to customer satisfaction exist and are appropriate action plans then implemented?
- Is there a method in place to obtain future customer requirements?
- Are all findings of customer dissatisfaction reported back to the proper organization for analysis and corrective action?
- Are customer satisfaction requirements formally defined and documented, and are they based on customer input?
- Do all support organizations understand their role in achieving total customer satisfaction?

You could also ask what percentages of their customers provide input on their satisfaction on their own. Are their customers aware of the role of DFM (design for manufacturability) on yield and their approach in persuading their customers to follow DFM?

Equipment maintenance and calibration procedures play a key role in achieving consistent quality.

- Are records kept for each affected piece of equipment?
- Is the status of calibration or maintenance required clearly visible on each piece of equipment?

You could also ask whether their Quality Program has been surveyed and approved by other customers. If yes, by who? Are they cer-

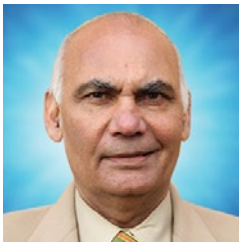
tified as an ISO 9000 supplier? You need to keep one thing in mind about ISO certification though. These days most companies claim to have a process recipe since most of them are now ISO certified. However, most of them do not even come close to defining what variables are important for yield. ISO certification is a good thing but very often it is more of a marketing tool and not very helpful for building products with high yield. The ISO requirement: "Say what you do and do what you say." So, most companies don't say much but you need a detailed recipe to produce quality product.

And finally, when assessing the capability of a company to produce quality product on a consistent basis, it is important to keep in mind that having the right design, good quality incoming materials, and an in-house process document are necessary but not sufficient. Training of personnel at all levels, from senior managers to engineers, operators and purchasing agents is critical for addressing all the issues needed to improve yield. You want to look into the training program of the company for its personnel at all levels. Remember, no one gets up in the morning and says they're going to screw up three things today. It is management's responsibility to provide training at all levels. Unfortunately, training is the area that gets cut when companies face hard times.

Conclusion

The idea behind all the questions in this column and previous two columns is to establish whether the company has done extensive process evaluation and whether they understand the importance of critical materials and process variables on product quality and reliability.

I should also note that as mentioned in the previous column, but worth repeating, is that the intent of these questions is not to dictate the process to the company but to assess their understanding and capability. You should focus mainly on the end requirements. Let the assembler worry about how best to meet those requirements. You are simply trying to establish whether they can meet your requirements. SMT007



Ray Prasad is the president of Ray Prasad Consultancy Group and author of the textbook *Surface Mount Technology: Principles and Practice.* Prasad is also an inductee to the IPC Hall of Fame—the highest honor in the electronics industry—and has decades of experience in all areas of SMT, including his leadership roles implementing SMT at Boeing and Intel; helping OEM and EMS clients across the globe set up strong, internal, self-sustaining SMT infrastructure; and teaching on-site, in-depth SMT classes. He can be reached at smtsolver@rayprasasd.com. He has an upcoming SMT class on April 26-28, 2021. To provide you added flexibility, this class is being offered both on Zoom and in person in Beaverton, Oregon simultaneously. Details about classes can be found at rayprasad.com. To read past columns or contact Prasad, click here.

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Supplier Highlights

Henkel joins The Climate Pledge by Amazon and Global Optimism ▶

Henkel reinforces its commitment to climate protection and joins The Climate Pledge, an international cross-industry commitment co-founded by Amazon and Global Optimism. As a signatory, Henkel commits to achieve net-zero annual carbon emissions 10 years ahead of the 2050 target set by the UN Paris Agreement—an ambition in line with the company's long-term target to become a climate-positive company by 2040.

The Test Connection's Bill Horner Remembered ▶

Bill Horner, the founder of The Test Connection Inc. and a well-respected engineer, passed away on September 21, 2020. He was 81 years old.

Mycronic Partners with Cogiscan to Provide Machine Connectivity for Industry 4.0 Applications ▶

Mycronic, the leading Swedish high-tech company providing flexible production solutions to the electronics manufacturing industry, announces a new strategic partnership with Cogiscan Inc., supplier of Track Trace and Control (TTC) and IIoT solutions, to provide machine connectivity for Industry 4.0 applications.

Amtech Reports Record Sales for Advanced Packaging Reflow Systems ▶

Amtech Systems, Inc., a manufacturer of capital equipment, including thermal processing and wafer polishing, and related consumables, announced that its subsidiary, BTU International, Inc., achieved record sales for its PYRAMAX™ reflow systems sold into advanced packaging applications in fiscal year ending September 30, 2020.

PDF Solutions to Acquire Cimetrix ▶

PDF Solutions, Inc. announced it has entered into a definitive agreement to acquire Cimetrix Incorporated. The combination of Cimetrix® connectivity products and platforms with PDF Solutions' Exensio® analytics platform powered by machine learning, is intended to enable IC, assembly, and electronics manufacturer customers to extract more intelligence–not just data—from their factory floor, to build more reliable ICs and systems at lower manufacturing costs.

MacDermid Alpha Releases HELIOFAB AG 7921 High-Brightness Silver for Leadframe Based LED Packages ▶

MacDermid Alpha Electronics Solutions, a global leader in specialty materials for electronics, announces the release of HELIOFAB AG 7921, a high brightness silver electroplating process for leadframe based LED packages.

Indium Corporation's Proven Jetting Paste Recommended by NSW Automation ▶

Indium Corporation's newest jetting and microdispensing solder paste, Indium12.8HF, has been officially recommended by NSW Automation for use with their newest microfluid dispenser, SD1.

Seika Machinery Announces Year-end Sale on Select Products ▶

Seika Machinery, Inc., a leading provider of advanced machinery, materials and engineering services, announces its year-end sale on select products. Significant savings are available for McDry cabinets, Sawa portable handy cleaners and Sayaka PCB routers while stock lasts.

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Fixing Vertical Hole Fill in Plated Holes

Knocking Down the Bone Pile

by Bob Wettermann, BEST INC.

For PCBs with larger thermal mass—such as found in high layer count boards or boards with higher weight copper layers—proper and consistent hole fill can be a challenge. It is critical to make sure that these non-visible defects do not become quality escapes while also making sure the proper rework techniques are applied; to get these plated holes properly filled is important.

There are some common board layout or design challenges which can lead to improper or inconsistent hole fill for those PCBs with high thermal mass. When plated through-holes are connected to ground planes or higher-weight inner layer copper, the thermal mass of that component lead is higher than surrounding ones. This means that to get the board up to the correct reflow temperature requires a longer period of time. If the lead/hole is not brought up to the proper temperature, the wettability of the solder in the hole is lower, thereby not allowing the solder to flow all the way up the barrel.

In other layouts there may be an uneven distribution of thermal mass to each of the component leads which may then have the same impact on hole fill. Another design challenge comes into play when more temperature-sensitive devices are in close proximity to the through-hole devices thereby causing the process engineer to "dial back" the temperature during wave soldering preheat in order to not damage the component. This lower temperature can cause the same insufficient lower

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hole fill. These are just some of the implications of the design and layout challenges on the hole fill.

Not only can board layout and design challenges cause inconsistent or poor hole fill but assembly processing problems may result in the same deficiency. A recent work [1] indicated that choosing the proper flux was one of the biggest influences on hole fill during wave soldering. A second large influence of improper hole fill is poor penetration of the flux into the through-hole. Another source of improper hole fill is improper board preheating and a lack of dwell time in the wave soldering source. Too long a dwell time can lead to copper dissolution of the plated holes (Figure 1). If pin-in-paste solder printing is used in lieu of wave or selective soldering, insufficient solder paste volume or the location of the print may be cause for improper hole fill. These and other process problems are some of the more common causes of process-related hole fill deficiencies.

Discovering improper hole fill requires that the proper inspection protocols are in place in order to detect a defect. Per the IPC A-610 standards, there are a couple of ways to inspect for proper hole fill. Visual inspection can infer

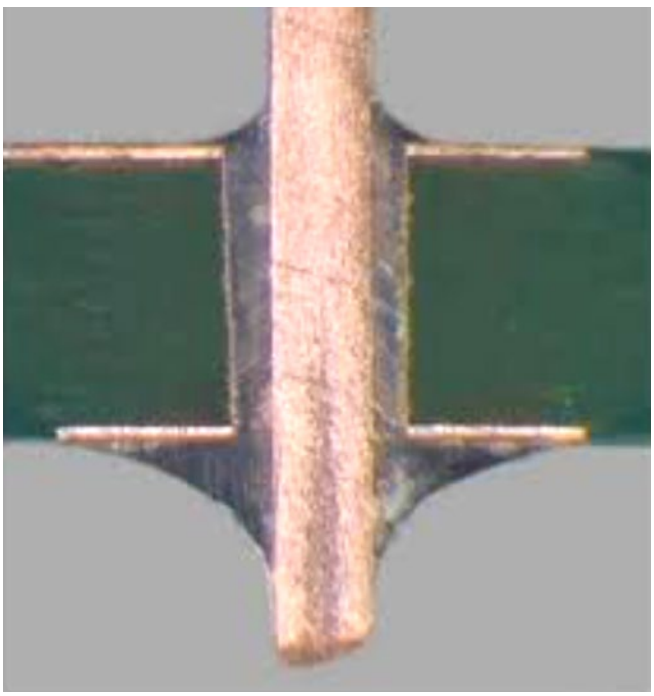

Figure 1: Plated through-hole cross-section indicating copper dissolution of barrel walls.

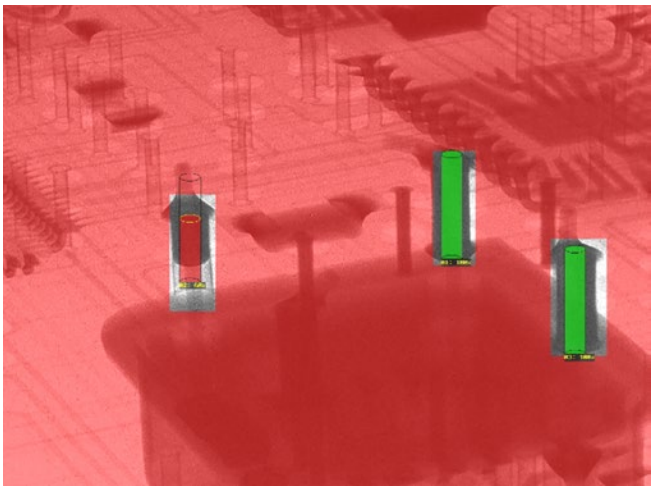

Figure 2: X-ray inspection and hole fill calculation inspection routine.

hole fill, but only if substantiated by other means through a process capability analysis. For example, if there is circumferential wetting on both source and destination sides of the plated hole, it can be inferred that the hole is filled. The process for assembly can be optimized and hole fill measured by cross-sectioning the plated through-hole. The process can be confirmed to be in control by linking this hole fill cross-section amount to the visual inspection of both source and destination leads and lands along with the appropriate confidence interval.

Otherwise, X-ray inspection (Figure 2) can confirm hole fill percentage by using built-in algorithms. While AOI systems can detect the presence of both source and destination fillets they cannot determine positively that there is solder in the barrel.

Once the defect is discovered and it has been decided that the component should be reworked as part of the boards' disposition, there are several rework processes which can be employed. Adding additional solder to the plated through-hole can take on several different forms. A solder fountain with the proper preheater along with the proper flux application can, in some cases, fill the remainder of the barrel. Care must be taken to ensure that the dwell time above the soldering source is kept to a minimum, especially as copper dissolution may result in thinning of barrel walls or

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incomplete knees in the barrel. Heating of the board in an oven prior to being subjected to the wave temperatures reduces thermal shock to the assembly while limiting dwell time. In the simplest of cases a soldering technician along with the proper flux and board preheater can solve the insufficient hole fill problem via flux and a soldering iron. In cases where the boards have a large thermal mass, the board may first have to be preheated in a controlled oven. Immediately upon removal from the oven the flux and solder can be added to the hole to fill the hole and meet the specification.

Through careful process troubleshooting along with an understanding how board layout can result in insufficient hole fill, the proper rework process can be chosen in order bring the barrel fill into compliance. SMT007

Resources

1. Thomas Shoaf, Joseph Clure, Denis Jean, "Achieving excellent vertical hole fill on thermally challenging boards using selective soldering," SMTAI Proceedings 2009.
2. IPC-A-610 Rev H 7.3.5.1 Supported Hole Solder Fill (a).
3. C Hamilton "A Study of Copper Dissolution During Lead-Free PTH Rework," Circuits Assembly, May 2006.
4. Brian Czaplicki, "Advanced Through-Hole Rework of Thermally Challenging Components/Assemblies: An Evolutionary Process," IPC APEX 2009.

Bob Wettermann is the principal of BEST Inc., a contract rework and repair facility in Chicago. For more information, contact info@solder.net. To read past columns or contact Wettermann, click here.

Scientists Find Upper Limit for the Speed of Sound

Sound waves can travel through different mediums and move at different speeds depending on what they're travelling through. For example, they move through solids much faster than they would through liquids or gases.

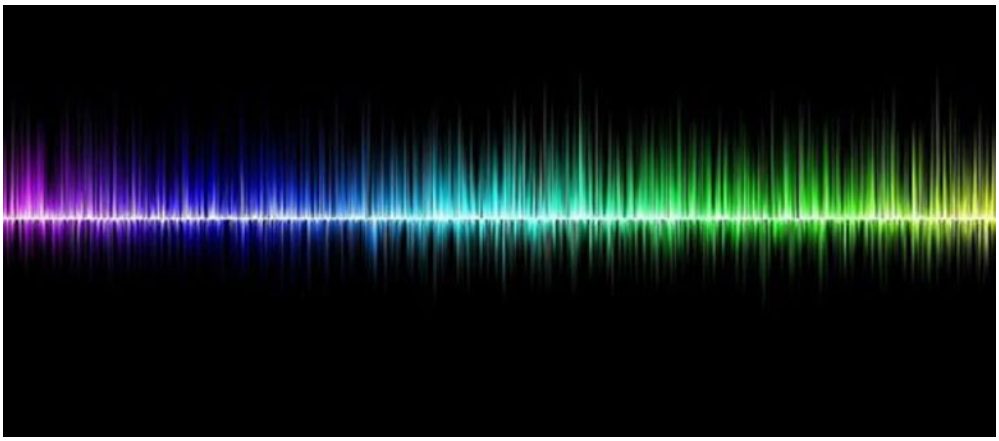
The result—about 36 km per second—is around twice as fast as the speed of sound in diamond, the hardest known material in the world.

Einstein's theory of special relativity sets the absolute speed limit for a wave at the speed of light, equal to about 300,000 km per second. However, it was not known whether sound waves also have an upper speed limit when travelling through solids or liquids.

The study, published in the journal *Science Advances,* shows that predicting the upper limit of the speed of sound is dependent on two dimensionless fundamental constants: the fine structure constant and the proton-to-electron mass ratio.

These two numbers are already known to play an important role in understanding our universe. These two fundamental constants can also influence other scientific fields, such as materials science and condensed matter physics, by setting limits to specific material properties such as the speed of sound.

The scientists tested their theoretical prediction and addressed one specific prediction that the speed of sound should decrease with the mass of the atom. This implies that sound is the fastest in solid atomic hydrogen. Hydrogen becomes a fascinating metallic solid conducting electricity just like copper and predicted to be a room-temperature superconductor. Researchers performed state-of-the-art quantum mechanical calculations and found that the speed of sound in solid atomic hydrogen is close to the theoretical fundamental limit.



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2020 M&A Wrap-Up

Punching Out!

by Tom Kastner, GP VENTURES

2020 turned out to be a strong year for M&A in the PCB and EMS/PCB Assembly markets. That is surprising considering the pandemic, US election uncertainty, and restrictions on travel. Although many people were traveling within the US, at least until the current surge in COVID-19 cases, international and domestic business travel has been greatly reduced, which has certainly dampened the M&A markets.

According to our count, there have been 19 EMS deals and 7 PCB (bare board) deals in North America so far in 2020. There are several deals that we heard of that are in the works and there are probably many small deals that we have not heard of. Given the general economic climate in 2020 and the virtual prohibition on overseas deals, the number of completed deals so far is impressive.

For calendar 2018, we counted a total of 18 deals in North America in these sectors: 11 in EMS and 7 in PCB. For 2019, we counted a total of 30 deals, 22 in EMS and 8 in PCB.

Here are some of the significant EMS and PCB deals so far in 2020:

PCB Deals:

- NCAB (public company in Sweden) acquired BBG (April 2020) (PCB Distributor)
- Fralock (owned by Arsenal Capital) acquired Career Technologies USA (June 2020)
- Additive Circuits Technologies acquired Winonics (June 2020)
- Epec Technologies acquired NetVia (November 2020)
- Printed Circuits, Inc. sold to PE Group Granite Equity (November 2020), which also owns All-Flex.

EMS Deals:

- Prime Technologies acquired TeligentEMS (January 2020) and I Technical Services (February 2020)
- Zentech (BlackBern Partners) acquires Trilogy Circuits (January 2020) and Camtek (March 2020)
- Princeton Technology Corp acquired by Intervala (April 2020)

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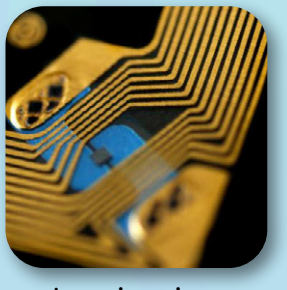

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- Creation Technologies (Lyndsey Goldman) acquired Applied Technical Services (May 2020)
- SigmaTron International (public company) merged with Wagz (June 2020)
- Sparton Corporation EMS Division sold to One Equity Partners (June 2020)
- Universal Electronics acquired by East West Manufacturing (Heritage Growth Partners) (September 2020)
- M-Wave International acquired by SlingShot Assembly (October 2020)
- EmeraldEMS (NewWater Capital) acquired Saline Lectronics (November 2020) and Veris Manufacturing (December 2020)

Once again, private equity was behind many of the deals in 2020 and is expected to be a major player going forward. PE firms have gained interest in the PCB and PCBA sectors and they are sitting on a lot of "dry powder" (raised funds that need to be deployed). PE firms have stepped into the place of public companies to provide liquidity to many retiring owners.

Many of the deals were completed by companies with less than $100 million in revenue. The one deal that was announced globally with over $1 billion in revenue was the USI (Taiwan) and AsteelFlash (France) transaction. Otherwise, the large, medium, and small-tier EMS and PCB companies were mostly quiet in 2020. The larger firms seem to be more interested in focusing on their core businesses rather than on growing through acquisitions.

Many of the completed deals in 2020 were most likely in discussions before the effects of COVID-19 started to hit in March/April. There was certainly a lull in activity in the March to June period, but activity seemed to pick up in July once buyers and sellers began to feel more comfortable with the current conditions. Greater use of video/Zoom calls in communications as well as video for due diligence has helped get deals done in 2020. Dealmakers will need to be flexible to complete deals going forward.

One interesting aspect of the current market is that we are not seeing a lot of distressed deals given the troubled economic environment. The PPP loans and other stimulus have certainly helped a lot of companies, and many manufacturers have been able to maintain their essential business status and stay open. We expect that more distressed deals will unfortunately come up unless the economy recovers quickly.

By our count, the number of PCB companies in North America continues to decline to approximately190 manufacturing companies and approximately 30 PCB distributors. Of the PCB companies, about 20 have over $25 million in revenue and over 100 have less than $5 million in revenue. There are probably 50 PCB shops with $2 million or less in revenue, the number of which is probably going to drop by 50% in 10 years. We expect that the larger, private equity-backed companies will continue to acquire the smaller companies, both in the PCB and EMS sectors. It is encouraging to see Schweitzer Engineering announce one new greenfield PCB shop in Moscow, Idaho, but overall, the number of PCB shops will most likely drop significantly in the coming years.

In the EMS industry, our count is about 700 companies in North America (note, this is companies, not the number of facilities, which would be greater). As more PE-backed companies make acquisitions and baby boomer owners retire, the number of companies will decrease (but the number of facilities may not change as much). The number of PCB shops that also do assemblies and/or PCB brokering will most likely increase, either through acquisitions or partnerships, as many customers prefer a one-stop option. In any case, 2021 will certainly be an interesting year. **SMT007**

Tom Kastner is the president of GP Ventures, an investment banking firm focused on sell-side and buy-side transactions in the tech and electronics industries. GP Ventures has offices in Chicago and Tokyo, with five people in total. To read past columns or to contact Kastner, click here.

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1 Siemens and Computrol: Achieving Operational Excellence in Electronics Manufacturing ▶

I-Connect007's Happy Holden and Nolan Johnson speak with Zac Elliott, technical marketing engineer at Siemens Digital Industries Software, and Farid Anani, VP of operations at Computrol, about how to achieve operational excellence in electronics manufacturing.

2 SMTA Europe Webinar: What Is a Good Solder Joint, and How Can Solder Joints Be Tested? ▶

Bob Willis

What is a good solder joint? How can they be tested not only for purposes of process characterisation, optimisation, monitoring, and control but also for ensuring their long-term reliability? Pete Starkey details a webinar organised by the Europe Chapter of SMTA that was presented by Bob Willis, an expert in soldering, assembly technologies, and failure analysis.

3 X-Rayted Files: iPhone Transparency—A Window Into SMT ▶

Dr. Bill Cardoso

Teardowns are fun, but they have also taught us more than we could have imagined. Modern teardowns provide critical insights into the nature and construction of these devices. As an example, Dr. Bill Cardoso details the history of the iPhone as told through X-ray.

4 Smart Factory Insights: Changing Roles in the Digital Factory ▶

Michael Ford

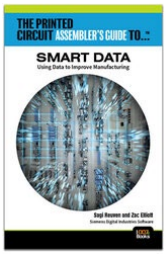
Experts once required to have a knowledge of specialized materials and processes are giving way to those experienced in the application of automated and computerized solutions. Michael Ford describes how it is time to reinvent the expectations and qualifications that we seek in managers, engineers, and production operators to attract and support a different kind of manufacturing innovation.

5 Lean Digital Thread: Micro-Solutions—Solving One Challenge at a Time ▶

Sagi Reuven

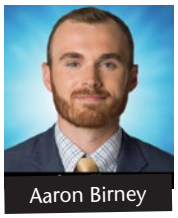
Sagi Reuven jumps back to the manufacturing floor and shares his thoughts on the role of a manufacturing execution system (MES), reporting, and analytics. Reuven describes in more detail the micro-solutions concept and why he thinks it will make a huge impact on achieving productivity excellence.

6 Free Download: Leverage Smart Data Analytics for Industry 4.0 Factories ▶



Learn how to leverage your manufacturing data with *The Printed Circuit Assembler's Guide to… Smart Data: Using Data to Improve Manufacturing*—the latest title in our I-007e library.

7 Foundation of the Future: IPC Students Chapters Gear Up for Competitions ▶

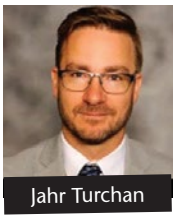

Aaron Birney

As colleges and universities continue to adapt to remote and virtual learning, the IPC Education Foundation has also adapted to support its IPC student members and 38 IPC student chapters across the U.S. With the increase in distance learning, Aaron Birney describes how the IPCEF has had to adapt its initiatives for student chapters.

8 IPC Launches IPC-CFX Self-Validation and Equipment Qualification Systems ▶

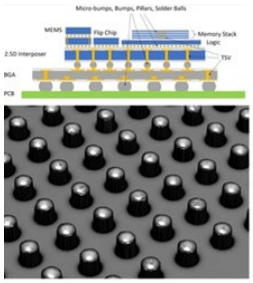
IPC has introduced IPC-CFX Self-Validation and Equipment Qualification Systems. The IPC-CFX Self-Validation System is a cloud-based test bed for equipment vendors and manufacturing facilities to self-validate CFX messaging.

9 Training Is Hard, But It's Also Soft ▶


Jahr Turchan

There is a disconnect in many manufacturing companies. This article is not about that disconnect, but rather a topic that gets clouded and the objectives made more difficult by that prevalent disconnect. Business owners, vice presidents, and operational executives are expected to have a vision for the company strategy. But what is not always fully known is the broad strokes of how to get there.

10 CyberOptics to Present 'Metrology and Inspection' Paper at Virtual IEEE PAINE Conference ▶



CyberOptics® Corp., a leading global developer and manufacturer of high-precision 3D sensing technology solutions, was scheduled, at press time, to present at the Virtual IEEE International Conference on Physical Assurance and Inspection of Electronics (PAINE) in December.

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

Qualifications

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

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

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

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Director of Process Engineering

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

Job Summary:

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

Duties and Responsibilities:

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

Education and Experience:

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

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Now Hiring

Process Engineering Manager

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

Job Summary:

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

Duties and Responsibilities:

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

Education and Experience:

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

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Indium Applications Manager

Responsible for identifying market insights and developing strategies, using market intelligence, emerging technologies, and industry feedback to promote an assigned series of products/offerings to a designated market space and will collaborate with other internal functions such as product management, marketing communications, sales, technical support, production, accounting, and quality to realize established goals.

Responsibilities:

- Own Indium Corporation's brand presence in an "identified market" as assigned by the position's supervisor
- Conduct market research to determine market opportunities and to develop competitive knowledge
- Mine customers, co-suppliers, competitors, employees, researchers, trade-shows, patents, publications, etc. for opportunity insights
- Identify preliminary market strategies to develop specific offerings
- Provide training on application technologies and specific products to sales and technical personnel
- Support new product development by determining customer needs and communicating these needs to the proper technical group(s)/product managers
- Network with relevant industry players to obtain market information/facilitate partnerships
- Perform other duties or special projects as assigned

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Our Summit Anaheim, CA, division currently has multiple open positions for planning engineers.

The planner is responsible for creating and verifying manufacturing documentation, including work instructions and shop floor travelers. Review lay-ups, details, and designs according to engineering and customer specifications through the use of computer and applications software. May specify required manufacturing machinery and test equipment based on manufacturing and/or customer requirements. Guides manufacturing process development for all products.

Responsibilities:

1. Accurately plan jobs and create shop floor travelers.
2. Create documentation packages.
3. Use company software for planning and issuing jobs.
4. Contact customers to resolve open issues.
5. Create TDR calculations.
6. Assist in the training of new planning engineers.
7. Review prints and purchase orders.
8. Create stackups and order materials per print/spec.
9. Plan jobs manufacturing process.
10. Institute new manufacturing processes and or changes.

Education/Experience:

1. High school diploma or equivalent
2. Minimum five (5) years' experience in the printed circuit board industry with three (3) years as a planning engineer.
3. Must be able to cooperate and communicate effectively with customers, management, and supervisory staff.
4. Must be proficient in rigid, flex, rigid/flex, and sequential lam designs.

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Quality Engineer:
West Haven, CT, USA

Support the West Haven facility in ensuring that the quality management system is properly utilized and maintained while working to fulfill customer-specific requirements and fostering continuous improvement.

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Chicago, IL, USA

The technical service rep will be responsible for day-to-day engineering support for fabricators using our chemical products. The successful candidate will help our customer base take full advantage of the benefits that are available through the proper application of our chemistries.

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South Plainfield, NJ, USA

As a key member of the Flexible, Formable, and Printed Electronics (FFPE) Team, the applications engineer will be responsible for developing applications know-how for product evaluation, material testing and characterization, and prototyping. In addition, this applications engineer will provide applications and technical support to global customers for the FFPE Segment.

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Career Opportunities

Manncorp™

SMT Field Technician
Hatboro, PA

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

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

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

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

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Manncorp™

SMT Operator
Hatboro, PA

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

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

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

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

We Offer:
- Competitive pay
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Sales Account Manager

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

Responsibilities

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

Qualifications

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

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

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

Contact Oscar Akbar at: hr@lenthor.com

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LENTHOR ENGINEERING
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Senior Process Engineer

Job Description

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

Position Duties

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

Qualifications

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

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

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Career Opportunities

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MivaTek Global: We Are Growing!

MivaTek Global is adding sales, technical support and application engineers.

Join a team that brings new imaging technologies to circuit fabrication and microelectronics. Applicants should have direct experience in direct imaging applications, complex machine repair and/or customer support for the printed circuit board or microelectronic markets.

Positions typically require regional and/or air travel. Full time and/or contractor positions are available.

Contact **HR@MivaTek.Global** for additional information.

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Qualifications and skills

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

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- Training and certifications provided and maintained by EPTAC

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Career Opportunities

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Passion | Commitment | Trust

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

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

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

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Sales Representatives (Specific Territories)

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

- Florida
- Denver
- Washington
- Los Angeles

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- Candidates must have previous PCB sales experience.

Compensation:

- 7% commission

Contact Mike Fariba for more information.

mfariba@uscircuit.com

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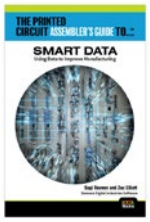

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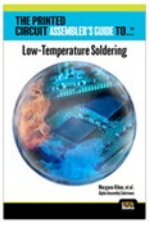

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SMT007 MAGAZINE

SMT007 MAGAZINE®
is published by BR Publishing, Inc.,
942 Windemere Dr. NW, Salem, OR 97304

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January 2021, Volume 36, Number 1
SMT007 MAGAZINE is published monthly,
by BR Publishing, Inc.

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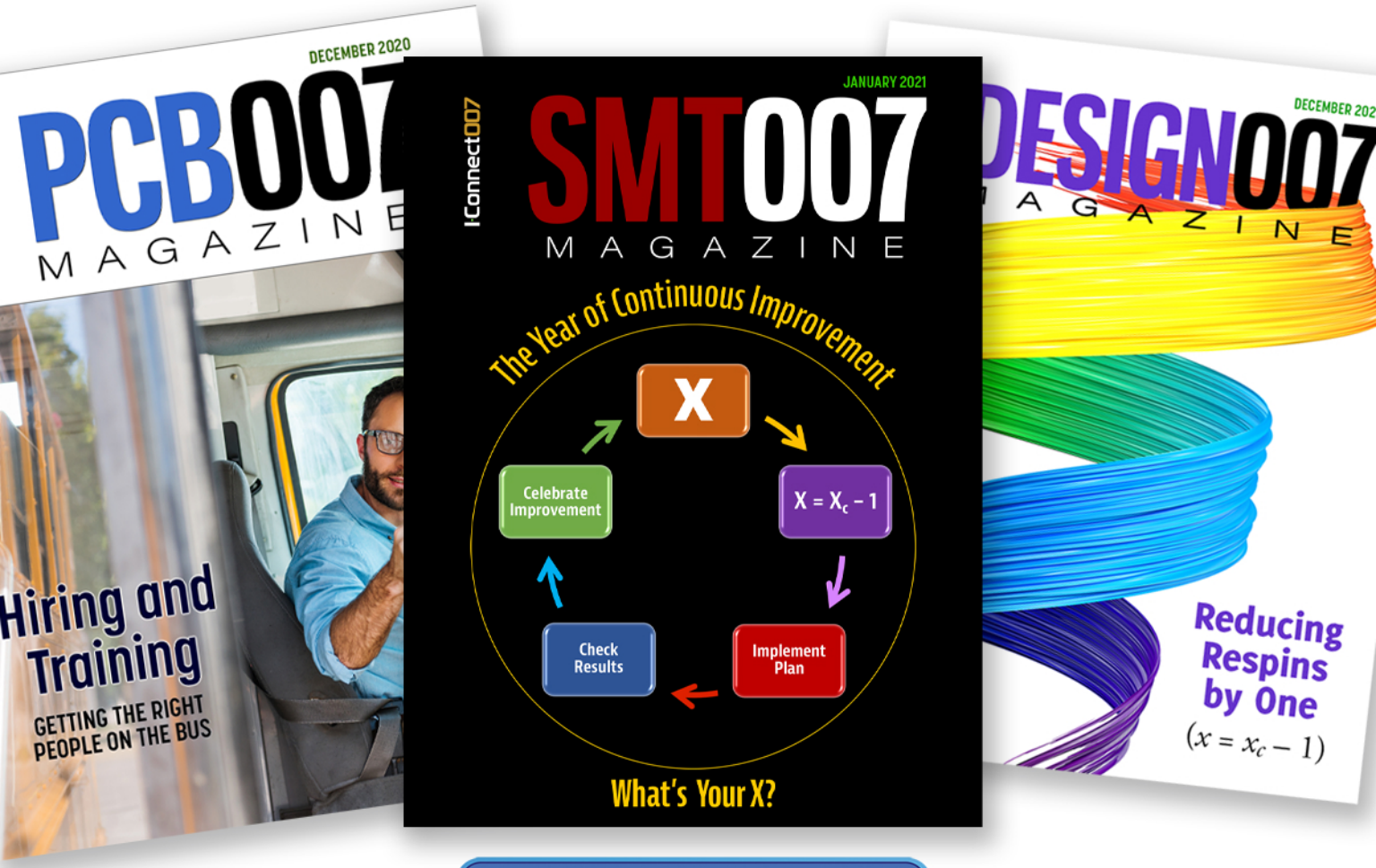

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