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SMT007 MAGAZINE

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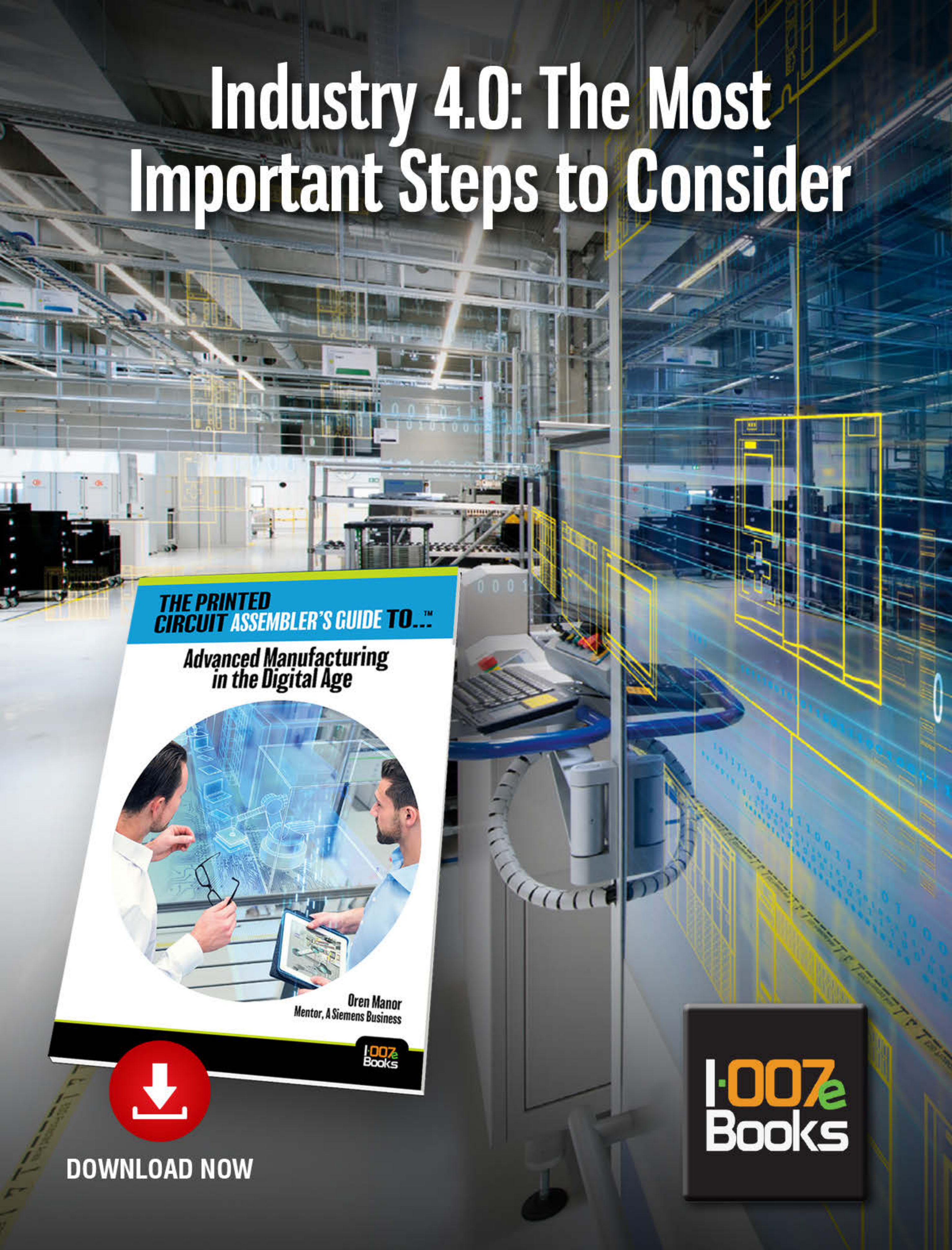
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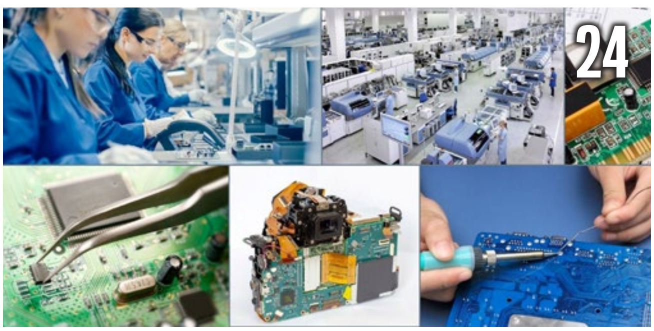
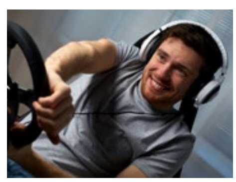
Hiring and Training

Even in our skilled, technology-heavy industry, some entry-level manufacturing positions seem to turn over as rapidly as the drive wheels of a locomotive. You can, however, stop the churn-and-burn approach and start recruiting young, well-trained employees more likely to stay put. How, exactly? That's what this issue is all about.





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Hiring and Training

Nolan's Notes
by Nolan Johnson, I-CONNECT007

Some jobs are simply a revolving door. Have you noticed? A close friend of mine lost her job at the start of the pandemic, but she bounced back. In her case, work in her previous field wouldn't be returning to normal for some time, so she started seeking an interim job. That's how she ended up attending a job fair, participating in a screening interview with a potential employer, and, ultimately, got short-listed. In this case, short-listing meant that she was to attend a two-day pre-hire training class. If she passed the class, she would get the job.

As she told me about this process, I wasn't sure whether it was genius or sketchy. This was equal parts audition, interview, and seminar. When I asked what the job was, she said "retail auto sales and support." When I asked how many people in her class, she estimated 20 or more. That seemed to me like quite a lot of people who would work on the dealership floor if everyone passed.

My friend passed the class, but not everyone did. When she showed up for her first day of work, only about 10 of her classmates' names were on the work schedule. Before she even received her first paycheck, that group of 10 was already whittled down to five. Thirty days in, and only two remained: my friend and one other employee.

Meanwhile, the dealership hosted two other hiring events. My friend watched two batches of 10 come in behind her and quickly start paring down, just as her class had. As she got to know her colleagues, she quickly learned that only two had been on staff for a year or longer.

She stayed with the job for about 60 days. Though she was successful selling cars, she also deduced why the turnover was so high. To her credit, she was fortunate enough to land a different interim job closer to her chosen profession, so she moved. Just two months after her training, she left the dealership—the last one from her class.

Listening to the stories, I couldn't help but think that it's like watching sea turtles race for their lives to the safety of the ocean. Are there any jobs like that where you work?

The auto dealership saga points out that training is either just a cost of doing business or an investment in your company's future. Which it is for you depends upon your approach, doesn't it? The dealership was uninterested in making changes to keep salespeople on staff; I guess they just decided that 100% turnover

every 60 days was as good as it was going to get. Paying for the monthly recruiting program was just a cost of doing business for them, much like keeping the lights on.

In this issue, we look at how training and hiring have adjusted to the times and to the immediate staffing needs for our industry. Even in our more skilled, technology-heavy industry, some entry-level manufacturing positions seem to turn over rapidly. You can, however, stop the churn-and-burn approach and start staffing with young, well-trained employees more likely to stay put—but how? We learned a lot as we put this issue together.

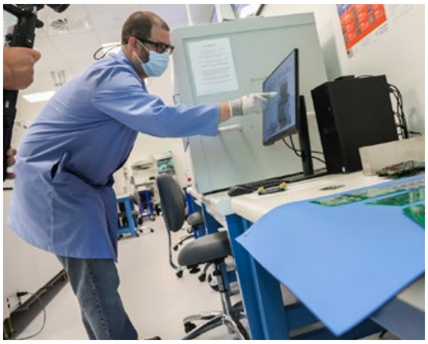
Take, for example, the MEMS Program at Lorain County Community College in Ohio. Johnny Vanderford and Courtney Tenhover detail how and why their program is so successful. Likewise, Dave Hernandez and Carlos Plaza outline IPC's training and certification programs, continuing to push toward the million jobs commitment. Jahr Turchen discusses not only certifications and hard skills but also soft skills training and Blackfox's curriculum development in those topics. Finally, Happy Holden details a pair of his essential skills and shares his approach to recruiting and hiring.

Our columnists are all on-point this month as well. Eric Camden puts your operators in the driver's seat, Alfred Macha redefines recruiting to find the right talent, and Michael Ford considers the changing roles in a digital factory.

Finally, in the spirit of increasing your skill level, we bring you two pieces of technical content: a paper from 2020 IPC APEX EXPO titled "High-Density PCB Technology Assessment for Space Applications" by Maarten Cauwe, et al., and "High-Tech, High-Value Cleaning Answers Made Easy With KYZEN's Tech-2-Tech," a webinar review by Pete Starkey.

Training will continue to be a key part of the infrastructure of our industry. While it is a cost of doing business, it need not be an expense; it most certainly can be turned into an asset for your company if you bring the right mindset to it. **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.



Lorain County Community College's Successful MEMS Program

Feature Interview by the I-Connect007 Editorial Team

The I-Connect007 editorial team had the pleasure of an extended and detailed conversation with Johnny Vanderford and Courtney Tenhover from Lorain County Community College (LCCC). Vanderford and Tenhover are at the heart of the microelectromechanical systems (MEMS) program at LCCC that is emerging as a model for a successful technical higher-education program. This conversation was lively, and the enthusiasm at LCCC is infectious, as it should be; their results are impressive.

Nolan Johnson: Can you please introduce who you are and what you do?

Johnny Vanderford: I'm an assistant professor and coordinator of the MEMS program at LCCC. I am also the director of LCCC's new Manufacturing Electronics and Rework Institute for Training (MERIT). The content of our degree and institute is primarily focused on training with hands-on skills in electronics manufacturing.

Johnson: We need a lot of that in this industry.

Vanderford: I couldn't agree more.

Courtney Tenhover: I'm a program developer at LCCC. I work on the earn-and-learn side of the program with Johnny, including getting job placements for students, working with employers to understand their needs, and pairing students and employers together. I have an HR and project management background, so bringing that to this program helps me work with employers on the HR side. Johnny is the technical expert.

Vanderford: My background is in electrical engineering. I have a master's degree from Northern Illinois University. A primary part of my degree is based on electronic materials and hybrid board manufacturing, including a variety of different types of PCBs. The degree we teach is microelectronics manufacturing. It's how PCBs are manufactured, assembled, repaired, reworked, and designed with some additional skills in microelectronic packaging, such as wire bonding, die attach, and even a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little bit of some chemical fabrication of silicon wafers and PCBs.

The degree is heavily focused on career placement in electronics manufacturing. It is designed to be a workforce generator to help fill the pipeline. We require every student in our program to have accumulated 600 hours of paid workforce experience, or the student doesn't get their degree, and the community college won't get state share of instruction (i.e., additional funding for continuing) for helping students get degrees. We all know someone who has a degree in one thing, but they're working in a completely separate field. We have tailored the program using input and feedback from our industry supporters so that we can train students in necessary electronics manufacturing skills, such as hand soldering, hot air rework, loading pick-and-place systems, and stencil printers with solder paste.


Johnny Vanderford

Students can get trained at the college while they're taking classes, and they get employed at companies working part-time from one to three years while they continue toward their bachelor's degree. My role is to give them the technical content, and Courtney's role is to connect the students with the companies on an HR level. When we go to companies, I talk engineering with engineers. Courtney finds out what the job needs are, gets those job requests to our students and alumni, gathers the resumes of those interested students and alumni, and sends them back to the company's HR line. That way, the engineers tailor the technical content to the program, and the company has a steady flow of workforce that is ready to begin working.

Throughout the last eight years since we've started, we have had 100% of all students in the program who have graduated placed in careers at our 70 supporting companies. Everyone who has graduated out of this program has been hired at a company doing electronics manufacturing.

Johnson: How far afield from LCCC do these 70 companies range? What's your circle of influence here?

Vanderford: LCCC is located in Elyria, Ohio. Around 90% of these companies are within a 40-mile radius around the center of Cleveland. We've had companies in the surrounding area, including as far as Indiana and Pennsylvania, that need a similar skill set. If students were interested in moving toward another place, they would have careers there as well. We tell the students the same thing. It's nice to have opportunities and options available for you.

Johnson: What sorts of jobs do students land?

Tenhover: Predominantly, students land assembler, hand soldering, electromechanical, and SMT operator, technician, and engineering positions as they near more of the end of their bachelor's degree. Those are the most common titles. Some are hired as electrical interns, and other smaller employers just don't have a job description with the title, so they hire them in and use them in a wide range of areas.

Johnson: With eight years of history, I'm sure you can look back to some of your first students. How have their career paths progressed?

Vanderford: The first student who graduated from our program did an internship working part-time with a small company in Elyria that is a contractor for packaging. They are a high-mix, low-volume contractor for sensor packages, so they do die attach, wire bonding, and testing facilities involving HAST, X-ray, and SEM imaging. One student had his first internship and then used his associate's degree, as well as his experience, to go down to the Ohio State University in Columbus while also working for the NanoTech West Laboratory on campus. He expanded on his packaging skills. After he had his bachelor's degree, he was hired as an engineer by GM to work on transmission sensors with the Corvette with the central engine.

Many of our students see a similar type of progression. They can go from a smaller company to a larger company or help a smaller company grow. They use a soldering iron or a hot air gun after reflow or AOI, and they do small touch-ups and repairs, or they solder through-hole components. It's a skill set that's needed to be able to produce a product. They get to know the company and product and develop relationships there, which leads to higher roles on the SMT or AOI lines as operators. We have one student who runs AOI, pick-and-place, and stencil print all on one line. We have students who are progressing into more box build testing and becoming quality supervisors too.

Most of these companies are extremely happy to get someone who knows how to do soldering without any upfront training. We provide the training in the first year of the program, and then they get hired into the company, and they're able to "hit the ground running." We teach them the do's and don'ts. We show them what happens when you leave the hot air pen on the board for too long. You burn the board and pads, and it smells really bad. At that point, it's a damaged product, and you can't do anything very easily with it. We detail lead solder processing versus lead-free solder processing. We train them in industry-relevant skills that will help get them jobs with minimal training at the company when they first get hired.

Sure, they make mistakes in college, no one is perfect at first, but when they get to the company, they have experience that they received through training. We've had some students get hired at companies that normally take two to three months of training before they can do any processing. But after going through our program, in less than a day, they are on the floor producing and helping the company make products. They stay in the business. This model has worked well.

Dan Feinberg: They need to realize that no matter what the job is, when they start their career, they're at the bottom. And there's nothing wrong with that because we all start at the bottom. But on the second day, they're no longer on the bottom.

Vanderford: This is one of the hardest things to talk to students about because every student coming out of high school wants to make an impact. A lot of them think, "I can make an impact by working at a higher-level job and making a big salary." That's not how most companies work. We tell students, "You're not going to get hired for a managerial position. You need to build a relationship with that company and the product."

Tenhover: We know that not every employer is able to hire students. In defining our employer partners, we invite employers to be a part of the design of the program and provide feedback on the curriculum because we want them at the table from day one. When they are ready to hire someone, they've been a part of the process the whole time. That has been really helpful in engaging employers. We want them at the table, even if they can't hire an intern.

Courtney Tenhover

College is expensive any way you look at it, but our community college price is on the lower end. For a full-time student, our bachelor's degree in microelectronics manufacturing costs $3,800 per year. That's $1,900 every semester, which is one of the lowest-cost bachelor's degrees in Ohio. Our product is our students. In the end, the companies that hire our graduates are our customers.

Feinberg: Not only are they the customers, but the people who buy their products are your customers, too.

Vanderford: Exactly.

Feinberg: Do you see any effect of the movement out of China and, in some cases, back to the U.S. for manufacturing?

Vanderford: As we approach this situation, we look at companies that are increasing their

Johnny Vanderford, assistant professor and MEMS program coordinator, demonstrates manufacturing processes in the lab.

manufacturing capabilities within the local area. We saw an article in *Forbes Magazine* from around 2017 that called the Midwest the new Silicon Valley of the U.S. Overall, manufacturing is coming back to the U.S. strong. We're in the Rust Belt, so we're very interested in getting folks within the area. But we've had companies from as far away as Florida that want more manufacturing of their products done in the U.S., and they want people trained to be able to do that. That same company said, "Pass our job descriptions to your students. It would be great if they could move down here."

The big manufacturing necessity is making products to fight COVID-19. An excellent example of this is an EMS company in LaGrange. They have about 100 employees who can manufacture products with their biomedical ISO 13485 certificate. When COVID-19 hit, they received a contract order to make portable ventilators, which were desperately needed in hospitals. They considered building a new line, they hired more people in, and they're producing things on additional shifts as well. Their manufacturing is strong for them, making products to fight COVID-19. I couldn't agree more with how manufacturing has increased in the area. And who's helping this company make these products? LCCC MEMS students, a degree that this company, and many more companies helped tailor so that they could get their workforce pipeline filled.

The other side is different. We tell students that this isn't a dirty factory position. If you go into some of these factories, they're gorgeous. You might have to wear clothes that protect from static discharge and ESD, but it's clean and amazing. Students see videos of these factories, and their jaws are wide open, and their eyes brighten up. They say, "That's not how the factory looked that I'd pictured." Factory manufacturing is different from electronics manufacturing. It's becoming more and more appealing the more that we show it.

Feinberg: I totally agree with you. At a recent virtual technical conference I attended, they toured a PCB facility, and I was just totally amazed. When I started, we had to figure out how to manufacture. There weren't many resources to document the industry we were creating. Now, those people have exited the industry or are about to.

Vanderford: There is a gap there. Some have called it the "silver tsunami." Everyone with decades of tribal knowledge, skill sets, and experience at a prosperous company in manufacturing is getting ready to retire. When a company has this happen to them, they can pull from one of two places: a traditional university or off the streets.

With someone who has gone to a traditional university, they may not necessarily have hands-on skills, and they may require additional training, but at least they have a degree. However, they may ask for additional funding because they have an expensive degree.

Meanwhile, people who are green off the street have no training or background experience, but they can get hired for less money. However, they require so much training that some of the companies can't keep up. Some of this training and application takes six months to a year of production time and product. Ten people might get hired, and one year later, only one employee might remain as a viable worker. For many companies, especially smaller ones, that's completely unacceptable in terms of what they need for competent technical staff. They want people who are better trained and able to do manufacturing.

Johnson: With those numbers, you're not talking just 12 months. For all 10 workers, you're talking about 10 years.

Vanderford: Exactly. That's a long time. One of the big reasons for this is internal training mechanisms. For many companies, training isn't a primary part of what they do. As a manufacturing facility, they produce products. Training is important to them but not as important as production. Many companies say, "Here are some videos to watch. Now, shadow this person for the next three months. Maybe we'll get an issue that shows up."

At LCCC, we force those issues on them. We purposely put a little goblin in the room to mess up the equipment. We do the opposite thing that companies want to have happen to all of their equipment so that students gain timely troubleshooting skills. They have to set it right by the end of the day so that they can make boards, or they're not going to get points for their lab. It's this level of how we train people at the college that sets us apart from more traditional training programs.

For example, we show them what the issue is and the dangers of having the pick-and-place machines down because one of the nozzles is jammed. We tell them, "Your stencil printer is sitting there and waiting because the machine is down. The stencil print inspection system before that is now waiting, too. We have to get the pick-and-place back up and running because the whole line is not producing. Everything down the line is waiting on you. It's up to you to fix this efficiently and effectively so that we can continue producing again." Some people say, "I'll get this done tomorrow," but when the machine is down, the yellow light is flashing, and nothing is producing, you have to fix it right then. We encourage the people we train to learn how to troubleshoot effectively and efficiently.

Lorain County Community College students gain practical skills in operating and troubleshooting machinery across the entire assembly process.

The luxury of being a training institute is we can offer a way to not only show them the right way to do things but also the wrong way. Many people learn based on a limited amount of training experience, and they don't learn to do hand soldering effectively. While instructing on hand soldering and hot air rework, we don't have to worry about products being destroyed. In our case, they're built to be destroyed and burned so that the students can see what it looks like and how bad it is.

Feinberg: It's too bad you're not enthusiastic about this (laughs).

Vanderford: I love what I do. I love it when I see a student say, "I got the job." It's the best thing in the world because you know a company got a good employee and the student has a career and will get a quick return on the investment because the degree costs less than most universities.

Feinberg: The value of the industry just went up a little bit.

Vanderford: Exactly. It's growing the manufacturing community around us.

Holden: How much academic theory or engineering methodology is included in the program?

Vanderford: We get questions like that a lot, such as, "Why doesn't your degree have any calculus or advanced physics? Why do students learn how to do photolithography and chemical etching on PCBs without having three or four chemistry classes?" They have only one chemistry class behind them before they start doing PCB etching and fabrication for one of our classes. Our program is how it is because the industry drives it. We only teach coursework that the companies around us want students hired in.

We have three PCB fab houses in our area. Two of the companies have hired our students, not because we made them experts, but we gave them the gist. They understand what photoresist is. They know what it's like to process it in an amber-lit room, expose it underneath the mask, and etch it in a tank of hot ferric chloride. We cover the types of chemicals, the dangers of handling the chemicals, developing formulas, and why they shouldn't bring a given chemical near the ferric chloride etch.

These aren't extremely advanced things that require huge amounts of advanced theory, but at the same time, that person walks into the door of these companies, and upper management says, "They already know a little bit more than some of my employees here, and they know 10,000 times more than anyone else who has ever walked through my door before." They're not an expert, an advanced physicist, or an advanced material science person, but they are valuable from the start.

Feinberg: Are you building a relationship with not only the component suppliers but also others?

Vanderford: We have a pretty good relationship with a few companies, including two PCB fabrication houses near us in Grafton and Westlake, Ohio. One manufactures some of our PCBs for free for the intro class. With the very first PCB that most students get, on the front part, there's a bunch of 1206, 0805, 0603, 0402, and 0201 resistors that are all in series with the back of it on here having parts for capacitors, diodes, transistors, and SOP chips.

This is something that they learn how to solder in the first six months of the program. And we don't just give them one; we give them a good five or six. We tell them, "You have 24 resistors that you must solder by hand." The

MEMS student training also includes inspection and testing.

next day, we say, "Twelve of those resistors are bad. Hot air and rework them. Put new ones on that are going to look different." We also have a working relationship with a company in Colorado. We've received products from them, too.

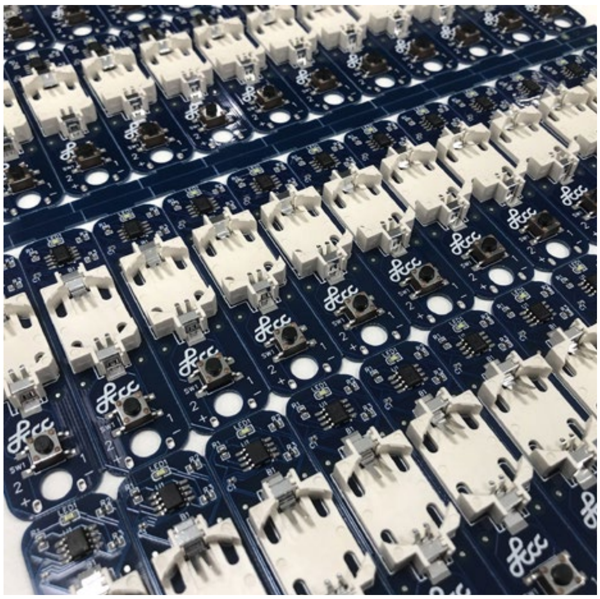
Johnson: How did such a focused electronic manufacturing program get started in Ohio?

Vanderford: This program started in 2013, when we asked for money from the state to begin a program that was involved with electronics manufacturing. We thought it would be an interesting skill set. But the question came from the state, "Why do you want to do this, and why here?"

LCCC's president at the time was interested in doing this as well, but at the same time, the state said, "We'll give you funding, but there has to be a career path reason behind this." That's when I was hired and started asking, "How many companies around our area do any sort of microelectronics manufacturing?" At first, we found eight companies in the Ohio area that said, "We need technical help." We worked quickly, funding was available, and we didn't want to lose that.

Companies told us what coursework the students should be trained in and asked if there was a way the college could help feed the workforce pipeline with these students. We said we'd make working a credited requirement of the program. Our TRAIN OH model that the NextFlex Institute of San Jose, California, helped us implement moves as much of our collegiate classes onto a two-days-per-week schedule, leaving the remaining three days per week to work. Here, the link was made that our whole program was built on—a bridge between industry and education.

These aren't big manufacturing companies in Ohio; there's no Apple, HP, or Google here, but there are lots of mid-sized and smaller companies that make the products for the bigger companies around us. There is a company that manufactures the parts that go into hospital equipment for a large biomedical manufacturing company. One company manufactures all of the products that go into a leading blender and food processing brand. Another company with around 120 employees manufactures products for a well-known MRI system. Other companies we're in contact with include one that makes radios for the nautical industry that are built to block sailing environments, one that does contract-level packaging, and one that makes small PCBs for camera lens systems for vision placement robots.



Every time we find a new company that's interested, we're excited. A lot of these companies and startups don't have globally recognized names, but they manufacture for them, and they need help, too. On top of that, LCCC has a business incubator, the Desich Entrepreneurship Center, where companies with up to 25 employees can rent space for low-volume manufacturing general office stuff. There are approximately 20 companies in those buildings right now. If those companies hire a student out of the college, their rent that they pay to the college goes down, and Courtney and I are the ones knocking on their doors, asking, "What do you want your workforce trained in?"

Johnson: How active are your employers in defining the course material?

Vanderford: We meet twice a year as a group to talk about how we can tailor the program. Once they hire someone in, we ask, "How is this person doing? Can we do anything to help train them further in some of our classes?" The degree becomes dynamic at that point. It's not the same program year after year, especially since everyone's electronic products change.

We just got the request last year to start doing hand solder training in 01005 SMT resistors. We've been doing 0201s, and the company said, "We just bought more equipment for putting down smaller components, so we need someone familiar with hand dexterity." That's the skill that will get someone hired at one of these companies. It comes from the college taking accountability for their degree, talking to these companies, and discussing what their needs are. The companies drive the content of the curriculum, so we're teaching skills that are valuable toward that career path.

Holden: There are lots of community colleges in the U.S., but I don't know if their graduates get good-paying jobs or have a work-study program like this, where they work and get paid while taking classes. This is financially an outstanding solution rather than going into heavy debt.

Vanderford: Some of the bigger companies find that our tuition is so low and say, "A year in this degree costs as much as a class at a bigger university, so we'll just pay for your degree."

We get students who come out debt-free with a job. That's a great way to exit college.

We tell all of the students, "You're not taking a class. You are getting trained in something that a company has said they need skilled workers for." Some of our classes are not all electronics. We offer classes on AutoCAD, SolidWorks, mechanical drafting, and GD&T. We teach them to make PCBs, but there are a lot of mechanical parts of those PCBs. Quality is important too. Our students get Yellow Belt/Six Sigma certified, as well as gain Lean manufacturing experience.

Lorain County Community College students have access to the MEMS lab during evening hours as well, minimizing conflicts with their current jobs.

Feinberg: Not only that, but they learn what is being dealt with by those in the same industry.

Vanderford: This is something that every student goes through and that our local companies have been really happy with. For instance, we were even contacted by a company in Boston, Maryland, that wanted people who could wire bond, do photolithographic processing, and had SMT pick-and-place experience.

Other companies have said, "We need 25 people trained up now. How can we do that?" They can send them over to LCCC and/or the Manufacturing Electronics and Rework Institute for Training (MERIT). We will train them on the same SMT equipment. It's the same thing that our bachelor's degree students are getting in a shorter period of time. Rather than offer the traditional 16-week classes at the community college level of $3,800 per year for full-time student tuition, we'll open up our doors and offer hands-on training with our equipment during daytime seminar hours, offering classes that will last 3–5 days with a customized training fee.

We'll put them on an SMT line and show them how to put solder paste down on a stencil. We'll show them how to clean up a stencil, ensure that the fiducials are clear, load feeders, program and do AOI, hand soldering, and hot air rework, as well as what will happen when a feeder is loaded incorrectly with the wrong part. That's what MERIT is going to be all about.

The cost is going to be increased compared to the tuition because they're going to be private classes offered at a faster pace where someone could get potentially 24–36 hours of experience on a pick-and-place tool. But we've received requests from all over the U.S., including Michigan, Pennsylvania, Florida, Indiana, Kentucky, and more.

This could be for people who have worked slide line and want to work as an SMT operator. Another case might be when a company hires a sales manager, but how many people with a sales degree know anything about PCBs? Not that many of them do when they first come out of college, but you send them to us, and we give them a crash course with hands-on experience, detailing what a PCB is and how it's manufactured. All of a sudden, they have an edge.

Johnson: You've created a consistent onboarding training program for the employers. You have become their training department.

Vanderford: That's what we want to become. As a community college, we train in skill sets. The students that we have in the MEMS program are usually working during the daytime. When they're done with classes, they come to us at night and train on our equipment during the late afternoon and evening hours so that we're using the equipment all day and all night long for training purposes.

It's a fully functional production line. Some companies have asked to use it for prototypes, but we recommend the production be done at our company supporters. We don't want to be in competition with them. We're not set up with quality inventory liabilities. We want to train their workforce.

Johnson: What's it like interfacing with the companies themselves?

Tenhover: They're all very enthusiastic. In Johnny's advisory committee meetings, there's high attendance, participation, and feedback. They usually go overtime because everyone is so excited to share their feedback and talk with Johnny. A lot of the employers want to hear about the degree and what students are learning. They're very eager to send us their job openings and to interview students. For example, an employer recently shared some of their openings, a student was interested, and they interviewed later that same afternoon. They make room to interview our students as quickly as they can.

A lot of their excitement also comes from the way Johnny interacts with them. He constantly seeks feedback and adjusts the program. If Johnny learns that many employers are trying to have one particular skill, he changes his plan for the day, takes all the students in the lab, and teaches them that skill. It's not a stagnant degree; it's always developing to what employers need. If a student comes in from their internship and doesn't know something they need to do on the job, Johnny and our lab instructors teach them so that they go back to work and have the increased scale that they need.

Johnson: I have talked with a handful of other programs, and they're not all having the same results that you are.

Tenhover: That sounds about right in some places. Even with COVID-19, we haven't seen a decrease. There's still that need for students.

Vanderford: The need for a trained workforce seems to have become a lot more important lately. At the same time, colleges are experiencing a low rate of incoming students enrolling. For the last four years, we have had every seat in our program maxed out at the very beginning, while touring interested students throughout the year.

One of our areas that we'll be growing in will be hiring additional instructors. As a public community college, we require people with a particular degree to teach. Typically speaking, if you want to teach for an associate's degree, you have to have a bachelor's degree, and if you want to teach for a bachelor's degree, you have to have a master's degree, etc.; however, we're not just going to hire someone with a Ph.D. who hasn't worked for the industry. We need instructors who've gotten their feet wet!

After college, I worked for a solar cell company, which was a private company that manufactured a vertical multi-junction photovoltaic solar array that used an amplified mirror to increase the light. We had investors that came in, and if they didn't invest in the company, we didn't have a paycheck. These companies

Vanderford talks soldering details with MEMS students.

Workbenches with inspection equipment in a MEMS program lab space.

expect results, and that's how we treat this program. We ask ourselves, "Are the companies happy with the workforce that they get?"

Companies often want to hire out of our program. For instance, Lincoln Electric hired two students out of the program. They put them through the company's two-week training program. The company found out in the first week that they were so good at what they've been trained in from the MEMS degree that they were outperforming people who had been there for years. They told us, "We haven't seen people like this for a while." Afterward, they created a position just for MEMS students from LCCC. They've since then called back and asked, "Can we please get more?"

Companies are realizing more and more that students trained in the MEMS degree know what they're doing, and they don't have to train them because they can just hit the ground running right when they hire them. It's fantastic. That's how you produce.

Johnson: It's an amplification loop. You dialed in some very specific needs for the employers. You started delivering on that, which created more demand and spread the word about how students can get a job and career out of this program. It's almost guaranteed. Now, you have people interested in the program, motivated students, and ongoing feedback from these employers who are hiring. As long as you're listening and adapting, your program continues to spin up.

Vanderford: One of the things that we get that's different as a community college is the variety of incoming students. I like to say that this degree is from kids aged six to 60, which doesn't fall too far from where the fence is. For example, we have high school students taking college classes so that they can earn an associate's degree while they're in high school, which is called College Credit Plus.

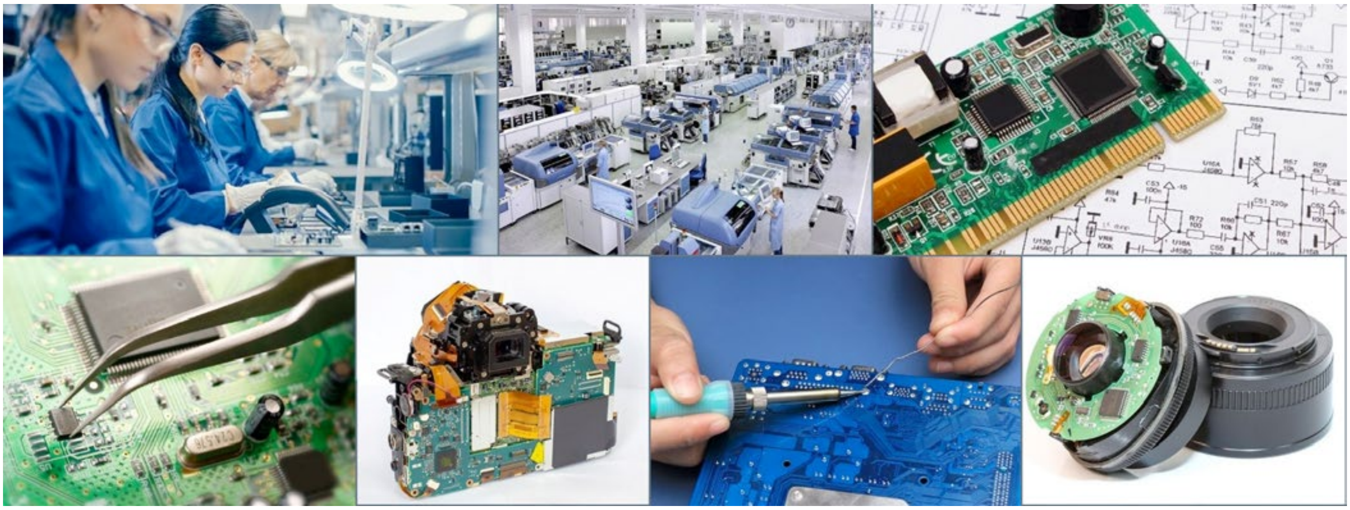
One man got his degree at age 61 through our program. Now, he's working for a company in Wooster, Ohio, doing PCB manufacturing. They're one of the only companies in our area that has a machine to automatically place through-hole components, and he also does box builds. He came into college originally as a retired letter carrier from the U.S. Postal Service, and he wanted to say to his grandchildren, "If Grandpa can get a college degree, so can you." He walked out with a degree and a job and told his grandchildren, "If Grandpa can get a job, so can you."

We also have military veterans using their VA and GI Bills, and this program is appealing because it's low-cost, career-centered, and offers job security. Many DoD contractors like hiring veterans. One of our participating companies designs and manufactures infrared cameras for detecting human heat signatures to help rapid-fire artillery equipment lock onto human targets through walls. They like getting military personnel that come in because they have clearance. That's what they need in order to hire someone in.

Johnson: Thank you both very much for your time.

Vanderford: This has been great.

Tenhover: Thanks so much. SMT007



IPC Addresses Critical Industry Skills Gaps With Electronics Workforce Training

Feature by David Hernandez and Carlos Plaza
IPC—ASSOCIATION CONNECTING ELECTRONICS

Our commitment at IPC is to help the world build electronics better, and a core component of that promise is education. In this article, we will review how IPC certification and workforce training programs work to fulfill the pressing educational needs of the electronics industry.

Over the past three decades, IPC standards and certification programs have played a critical role in protecting public safety and promoting excellence by ensuring the quality, reliability, and consistency of electronic products. In 2019, IPC worked with its global network of certification centers to certify over 108,000 individuals across 200 countries and 21 languages to seven IPC standards. The ubiquitous adoption of these programs speaks to the strong partnership forged between IPC and the electronics industry.

Just like certification, training has always been an indispensable part of doing business, and rarely has it been more so than the present. The rapid pace of technological innovation and new ways of working require skills that most potential employees simply do not have. In fact, a recent report by Deloitte [1] revealed that the skills gap—the difference between the skills that employers need and those that are available from workers looking for a job—may leave an estimated 2.4 million U.S.-based manufacturing jobs unfilled between 2018 and 2028. The resulting loss in productivity, revenue, and missed opportunities for expansion could cost as much as $2.5 trillion.

While the IPC certification programs serve a critical role in ensuring that our workforce is knowledgeable about IPC standards and their requirements, the industry has been clear that these programs are only part of the solution. Throughout 2017 and 2018, IPC interviewed over a thousand industry members across the globe to better understand their training needs. The results of this study, as well as subsequent interviews with both IPC members and non-members, led to the development of the IPC Electronics Workforce Training Initiative. In 2018, IPC signed the Pledge to America and committed to deploying this initiative in combination with its certification programs to train one million workers in the electronics industry over a five-year period.

Operators

The Electronics Assembly for Operators (EAO) training program was released in August. This program introduces operators to the key concepts, tools, materials, and processes required to consistently assemble high-quality PCBs and is comprised of 18 training modules. The first nine modules are mandatory and cover topics the industry determined are critical for every assembly operator. These include PCB assembly, safety, ESD and product handling, component identification, drawings and specifications, basic PCB and PCBA defects, and the use of standards. The second set of nine modules are optional and include more detailed information about specific areas of assembly such as SMT and TH technologies, hand soldering, conformal coating, hardware, and press fit.

The program's modular structure allows for flexible implementation. Those organizations that need generalists can have their students complete all 18 modules, while those that require specialists may opt to have students complete the first nine modules and only those optional modules that relate directly to their specific job role. Since each block of nine modules requires an average of 16–20 hours to complete, the total commitment to the program is one week at the top end.

A second operator focused program, Wire Harness Assembly for Operators (WHO), is nearing launch. This program's 14 modules are also divided into mandatory and optional units. The first seven modules cover core knowledge and skills such as safety, documentation, materials and components, tools and equipment, wire preparation and processing, and inspection and testing. The second group of modules is focused on specific job tasks such as crimped and soldered terminations, splicing, connectors, labeling, securing and coverings, and finished assembly. The program has entered the beta testing phase

The IPC Electronics Workforce Training Initiative

The goal of the IPC Electronics Workforce Training initiative is to provide easy-to-implement, cost-effective, and efficient training programs that teach the knowledge and skills needed to perform specific job functions to industry-defined levels of proficiency. Each of our Workforce Development Programs is built through a partnership with the industry. We routinely speak with dozens of industry members around the world about the issues they face.

If training is identified as a solution, a volunteer group of industry subject-matter experts works with IPC learning professionals to design and develop materials and courses that meet these specifically defined needs. Finally, we test the resulting educational solution in real-life settings and make any required changes before making it available to the wider public. The IPC EDGE online education platform allows anyone, anywhere, to access this content at any time.

The IPC Electronics Workforce Training initiative adheres to three core principles: Training solutions must address real-world skills gaps, be developed through industry partnerships, and provide for flexible implementation. We have begun by addressing critical skills gaps that industry members are experiencing with new operators and PCB designers.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with novice wire harness operators at volunteer organizations and is scheduled for public launch early in the first quarter of 2021.

Both operator workforce training programs are available in online self-paced and instructor-led formats. Self-paced courses can be completed independently from any device with an internet connection. The instructor-led format allows instructors to stream the course to their students from any connected device. Students in instructor-led courses will also access the IPC EDGE online platform to complete exercises and assessments. In either format, organization instructors may track student progress through the IPC EDGE platform.

Workforce training programs also include a series of optional hands-on activities that help reinforce learning. Students that complete the required modules and at least one of the additional modules earn an IPC certificate that identifies them as a Qualified IPC Operator. These certificates are serialized with a unique ID number that can be utilized for validation.

PCB Designers

Our approach to PCB design training differs from operator level training in two ways. First, the programs are taught live on IPC EDGE by IPC instructors that have decades of high-level industry experience. This allows us to combine the practical experience of our instructors with the convenience of online education. Second, these programs utilize a project-based curriculum. The program instructor introduces new concepts and leads discussions twice per week. Weekly projects are assigned to reinforce learning and to provide students an immediate opportunity to implement their new knowledge. Each of these programs will be offered at least once in 2021.

The two core courses in the IPC PCB design curriculum are the six-week PCB Design I Introductory-Level Course and the eight-week PCB Design II Intermediate-Level Course. These courses are supplemented by a series of advanced-level courses focusing on specific areas of design, such as extreme environments, military and aerospace applications, rigid-flex boards, advanced packaging, embedded components, RF boards, and printed and wearable devices.

What Is Coming Next?

If you are anything like us, then the next question has to be, "What is coming next?" Simply put, quite a lot. While it's still a little too early to announce the next set of programs, we can provide a preview. We are currently completing a job task analysis on PCB, PCBA, and wire harness inspectors and testers. Once completed, we will begin working on a series of training programs to address the various needs of these job functions. The first of these programs are scheduled for release in late 2021.

To stay up to date on the latest news about the IPC Electronics Workforce Training Initiative, or to learn about the current programs, visit training.ipc.org. SMT007

Reference

1. Deloitte, "2018 skills gap in manufacturing study."

David Hernandez is the VP of education for IPC.

Carlos Plaza is the senior director of education for IPC.

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Put Your Operators in the Driver's Seat

Quest for Reliability
Feature Column by Eric Camden, FORESITE INC.

There are countless ways to optimize equipment and material to increase the quality and reliability of electronics. Millions of dollars are spent every year on measurement equipment to look at solder joint quality, part placement, solder paste application, and basically every possible measurable aspect of an assembly.

One part of the process that should receive an equal amount of time and attention is staffing and training, which is this month's topic. What a coincidence! Operator proficiency in larger contract manufacturers is most often an internal function with certified trainers overseeing classes of employees on a regular basis. From my experience, the most common type of training is IPC J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies and IPC-A-610, Acceptability of Electronic Assemblies. The J-STD-001 is how you build, and IPC-A-610 is what it should look like after the product has been built.

As part of my job, I have been either a CIT or CIS for both J-STD-001 and IPC-A-610 for pretty much the last 15+ years. That is a big requirement when I am tasked with putting my hands elbow deep in your process for evaluation and optimization. Most often, the teacher is a Certified IPC Trainer (CIT) and, if they pass, the students will be a Certified IPC Specialist (CIS) with the skills to build and inspect electronic assemblies.

There are other levels of certification available to include a new certification, Certified Standards Expert (CSE), which is specific to a single standard. This makes you an "expert" on a particular standard and can give you the abil-

ity to make final referee calls. There is also the Master IPC Trainer (MIT), which is the top of the training food chain. They are the ones who certify the trainers that train the specialist.

J-STD-001 and IPC-A-610 courses do not encompass every aspect of building or inspecting electronic assemblies, but they cover most topics. If need be, you can certify inspectors to look at bare boards, wire harnesses, rework and repair, and/or design, among others. No matter the size of the CM, it is imperative to have properly trained operators on the floor doing the work and inspecting it to make sure it meets whatever acceptance criteria are called out on the drawing.

Just as important as having training done to some standard like the IPC is having the operators trained to look at your specific assembly and knowing where to start looking when something is out of control. This goes back to another column I wrote some time ago talking about tribal knowledge. In lieu of a copy/paste situation, the CliffsNotes version is the industry is constantly losing more experienced employees who have been part of the build since its inception. With age comes experience, and often, that experience includes time on the equipment used to build your product. You can't teach experience, but you sure can write it down for others to learn from.

Assembly process equipment is often like driving a 1974 Buick Regal (which is not a random choice, by the way; that was my first car). By that, I mean it would make certain noises that I only learned the root cause of after driving it for many months (in the off chance I heard it between Mötley Crüe songs). I knew that one certain sound meant I was low on oil. Another sound meant my tire with the constant slow leak needed a few pounds of air.

In the same way, an experienced operator knows that when they see a bad solder joint or some other anomaly, they need to look at reflow profile, belt speed, or some other parameter. That is the type of thing that IPC (or any other industry body) cannot teach. That is the definition of tribal knowledge, and it's being lost all the time.

My point is that beyond the structured training sessions, there needs to be internal "lessons learned" training specific to your facility and equipment. Many times, this type of knowledge can play as big of a role in your product's reliability—that, and a 1974 Buick Regal that, while reliable, requires a lot of attention to stay that way. Just like an assembly line! Whew, that was certainly a drive to connect those dots.

Staffing is the second part of this month's topic, and having never been in the position to directly hire anyone, what I have to offer should be taken with a grain of salt. What I can say from personal experience is you don't need to hire anyone who automatically has every skill you are looking for. I was a drywall finisher for five years before being hired at Foresite. I started as a bench tech in the chemistry lab in a time before autosamplers, which afforded a lot of time for reading up on both the electronics assembly process and at the root cause of the failures we were testing.

Even back in the early 2000s, we had a few pretty good microscopes to go along with some experienced engineers who would take time from their busy schedules to teach me a thing or two here and there when time allowed. Sure, I had the luxury of time that others might not have, but the point is to hire people with a desire to learn more about what they are doing and why, beyond just being their job. There are no bad car puns or musical memories from the 1980s here—just a recommendation to hire people who are naturally inquisitive whenever possible.

Your assembly floor managers and line operators are the first and last line that steer your reliability numbers. (I knew I could get one more in there.) **SMT007**

Eric Camden is a lead investigator at Foresite Inc. To read past columns or contact Camden, click here.


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Training Is Hard, But It's Also Soft

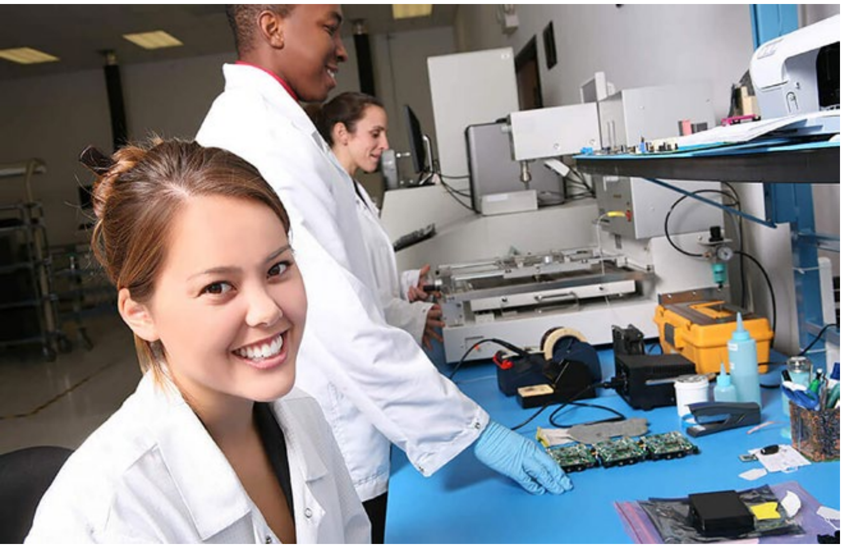
Feature by Jahr Turchan
BLACKFOX TRAINING INSTITUTE

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.

The result is that these businesses can't effectively communicate company vision to the tactical team they have employed to ensure the proper execution of the day-to-day tasks. Too often, these teams are left to focus on the immediate needs of today. The constant call for operational metrics—too often focused on the bottom line—draws the attention away from long term investments that will most likely have the greatest overall impact on the bottom line. This investment is one that will increase the value of the most valuable asset of the business, which is human capital. The investment is training.

In my job, I'm in a position to have conversations with dozens of EMS and fabricators as they book their employees in for IPC certifications and recertifications. Customer requirements demand that they employ certified technicians. But what about those skills that are not "required" by their customers? What about communication and team-building skills and customer service or time management? I have worked in and served industries with the most stringent of requirements like medical, DoD, aerospace, telecommunications, and automotive, and I have never seen a requirement for soft skills training or training of support job functions for employees. The question is, "If it is not required, does it merit our attention?" The answer is that it absolutely does because it benefits the bottom line.

It is no secret that more efficient operations yield better profit margins. Operations managers endeavor on a daily basis to improve processes and find other means to optimize. Oftentimes, this is done through the application of more efficient machinery and equipment. Other times, it is accomplished by removing redundancies in the workforce. All too often,



we overlook the opportunity to make our workforce more effective and efficient through the proper application of training, but why? Well, for one, it's difficult to measure. In a metrics-centric world, we prefer direct correlations. We like it when the new machine is two times faster than the old one or uses 75% of the process inputs for the same output.

Training our employees in soft skills, such as leadership skills, communication, conflict resolution, and reinforcement of general math, unfortunately, does not directly correlate to our production metrics. There are, however, several proven results that come from investing in training your employees, including attracting and keeping great employees, creating promotable employees, and keeping employees engaged. Disengaged employees can be poison in the workforce. At best, they are unproductive. At worst, they can actively work against the company and damage the culture that has been put in place. There is one more key aspect: It forces you to look to the future. There is a correlation between forward-thinking employers and successful employers.

In a recent discussion with a prominent Colorado Springs manufacturer about online learning platforms, the desire for soft skills training was identified. This company takes extremely good care of its employees. They have top-shelf benefits, excellent work accommodations and break areas, and even a giant playground for their employees' children. Whenever possible, they prefer to promote from within to give their employees a chance to evolve and grow with the company.

The trouble is just because an employee has put in the time to master a certain technical skill does not necessarily mean that employee possesses all of the tools needed for promotion. This customer was looking for a way to better develop in their hourly employees both the skills and the tools. To accomplish this will require a customized and online learning portal from which the customer can give access to its employees to learn skills such as critical thinking, teamwork, communication, and leadership.

A terrific real-world example of the value and benefit of soft skills can be found when we look at our military veterans who have transitioned into civilian careers. Military.com lists teamwork, leadership, cross-functional and transparent communication, critical thinking, and problem solving as some of the top soft skills that are taught in the military and are to be credited for a veteran's success in the civilian workforce. The success of that veteran will directly translate to a win for the company that hires them. If the employee is winning, the company is winning. And with the skill set mentioned previously, it is no wonder that many companies report having a 60% increase in retention rates when they hire military veterans. Soldiers exiting the military with these skills likely did not have them when they entered, which means they can be taught,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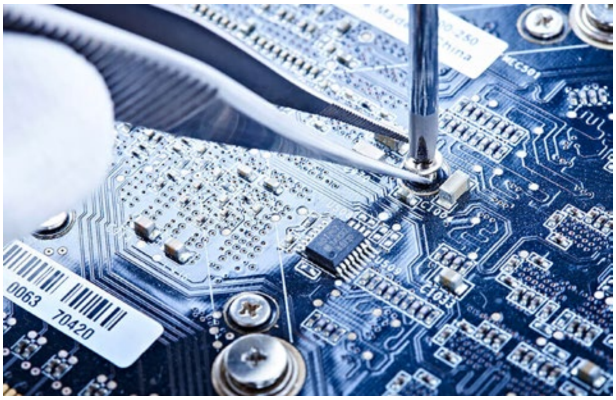
which is exactly what we are trying to get manufacturers to realize.

Blackfox has had veteran-focused training programs for several years now. We help returning vets translate their military-learned technical skills into applicable civilian technical skills. These highly trained transitioned soldiers are a hot commodity and are usually snatched up quickly by an employer partner.

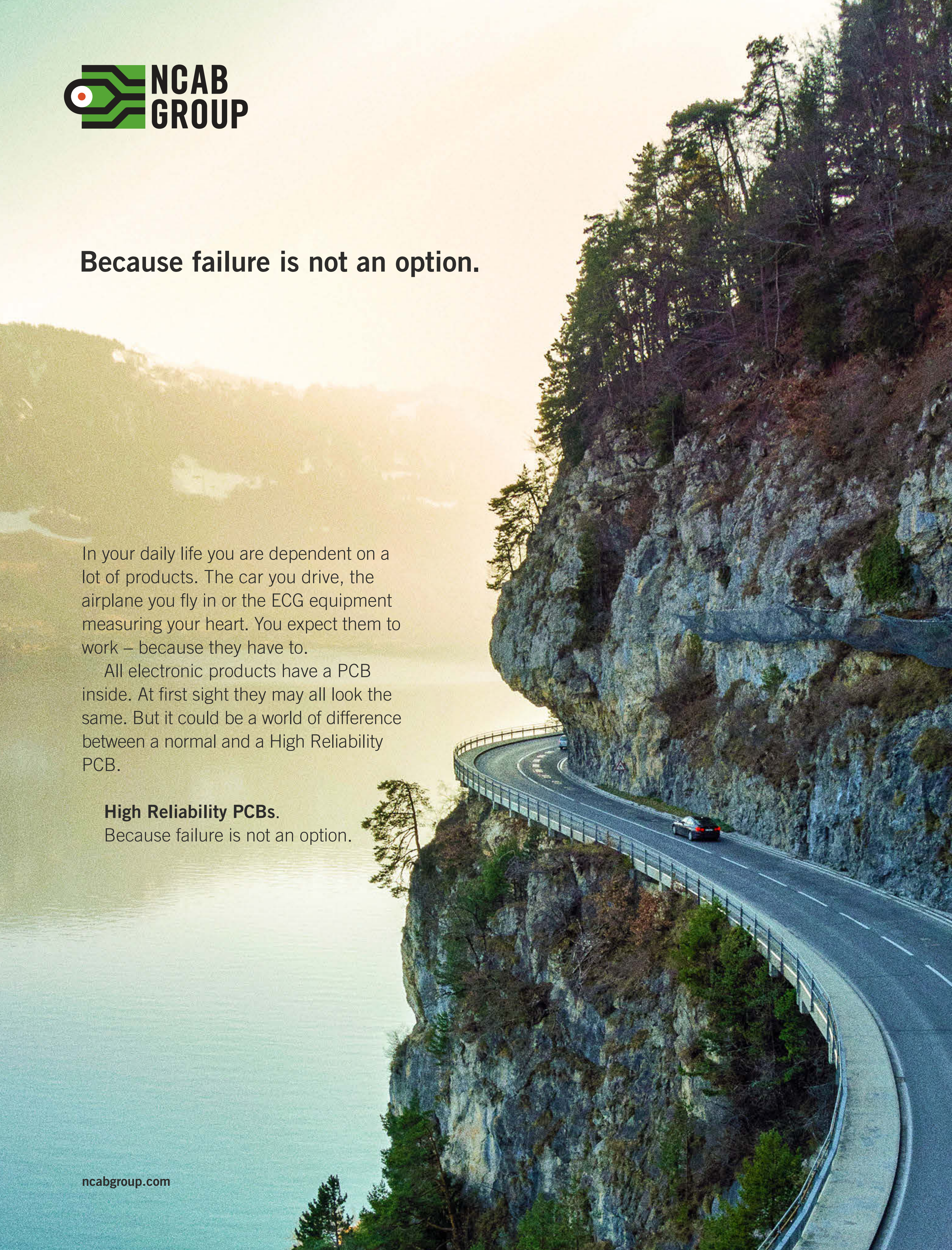
Looking ahead, in 2021 we will continue this work through a collaboration with the National Association of Manufacturers (NAM) to develop and deliver a new transitioning veteran training program as part of NAM's Heroes Make America Program. Soldiers will be trained through the pilot program at military bases in Colorado Springs, Colorado, and they'll be available for hire across the nation.



And while there is likely to be a large amount of similarity between the technical and soft skills that each manufacturing company is looking for, the exact method of delivery is bound to be fairly unique. While one manufacturer may want to give free for all access to a variety of technical and personal development courses that can be taken in a self-paced manner, other companies will establish strict—and possibly time-bound—learning paths that consist of a bespoke combination of skills and include virtual instructor-led trainings to affect the desired outcome.

Adult learning theory must be taken into consideration during any instructional design and content curation. The use of micro-learning, real-world examples, experiential learning, the establishment of personal relevance, and many other concepts are key to forming concrete solutions for training. Once the training is available and delivered, training must continue to interface with the manufacturer to deliver metrics on the training that is being consumed. We can also help with putting a plan together to track the impact of the training, whether this is through operational metrics, measuring employee engagement, or a variety of other methods.

Blackfox has been training manufacturers on technical and soft skills for about 25 years. But times are changing, and we are adapting. The world has been on a faster and faster pace of digitalization, and the global COVID-19 pandemic gave it a huge kick forward with the necessity to operate and interface with each other in a remote environment. We've been asked to help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A Blackfox in-person class, prior to social distancing requirements.

IPC beta test how they deliver and assess IPC instruction and certification online.

As such, we were one of the first to offer online IPC training. It was clear that these newly developed training vehicles are not a fad or quick fix, but rather it was a crash introduction to a new norm. To be more responsive and to have the best possible impact, we established a cloud-based learning management system that will enable us to have an even deeper impact on our customers. Blackfox will continue to deliver IPC instruction and assessment in the manner directed by IPC.

In addition to delivering complementary content for IPC-related instruction, organizations can now leverage a training platform they aren't required to maintain for themselves to increase their efficiencies with the dissemination of knowledge, as well as training and policies for their organization. For example, a company's onboarding process can be streamlined while adding a layer of accountability and automated follow up from either HR or that employees' manager.

Blackfox will have over 700 skills courses (technical and employability skills) that focus on more than 40 areas of competency. These courses and learning paths are designed to lead to nationally and internationally recognized certifications and credentials. The skills being offered are not limited to electronics manufacturing, but rather the entire manufacturing industry. Tribal knowledge of processes can be digitized and delivered to ensure an effective and efficient cross-training that will create required redundancy where necessary.

Training your workforce is akin to investing in R&D. There is no formula that will tell you what your return will be, but you know that if you don't invest in R&D, your business will stagnate. With improved HR metrics, such as cost per hire, employee turnover, employee engagement, absenteeism, etc., it certainly seems compelling to make that investment in your human capital. **SMT007**

Jahr Turchan is the director of veteran affairs and advanced manufacturing programs at Blackfox Training Institute and can be reached at jahrt@blackfox.com.

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2/3 of electronic industry companies have difficulty finding production workers.[1]

VS

Upskill Your Employees with IPC Electronics Workforce Training

IPC Electronics Workforce Training helps you bridge the skills gap. Throughout 2020 IPC will launch a series of training courses curated to the needs of the electronics industry. We're working to make effective training easier for you to deliver.

See our current course listing on IPC EDGE.

Courses can be offered directly to employees or integrated into your training programs.

[1] IPC. (2017). Findings on the Skills Gap in U.S. Electronics Manufacturing.

Electronics Industry News and Market Highlights

Applied Materials, BE Semiconductor Industries to Accelerate Chip Integration Technology ▶

Applied Materials Inc. and BE Semiconductor Industries N.V. announced an agreement to develop the industry's first complete and proven equipment solution for die-based hybrid bonding, an emerging chip-to-chip interconnect technology that enables heterogeneous chip and subsystem designs for applications including high-performance computing, AI, and 5G.

NIST Releases Draft Cybersecurity Guidance ▶

Taking another step toward strengthening the nation's critical infrastructure, the National Institute of Standards and Technology (NIST) drafted guidelines for applying its cybersecurity framework to critical technologies, such as the global positioning system that use positioning, navigation, and timing (PNT) data.

Pacific Green Acquires Battery Energy Storage System Design Company Innoergy Limited ▶

Pacific Green Technologies Inc. announced that it acquired Innoergy Limited, a designer of battery energy storage systems whose clients include Osaka Gas Co. Ltd. in Japan and Limejump Limited, a subsidiary of Royal Dutch Shell plc.

Samsung, VeriSilicon Support Blaize AI Platform ▶

Samsung Electronics Co. Ltd., a world leader in advanced semiconductor technology, in collaboration with design services provider, VeriSilicon, successfully supported the on-time market launch of AI Edge computing startup Blaize's hardware platform, despite the COVID-19 pandemic.

Rohm Reducing Size of Automotive Designs With Ultra-Compact MOSFETs ▶

ROHM released the ultra-compact AEC-Q101 qualified MOSFETs, RV8C010UN, RV8L002SN, and BSS84X, best-in-class 1-mm2 size that delivers automotive-grade reliability. The products are suitable for high-density applications, such as ADAS and automotive ECUs.

2020 IEEE International Electron Devices Meeting (IEDM) Announces Virtual Events Schedule ▶

The 66th annual edition of the IEEE International Electron Devices Meeting (IEDM), a forum for the presentation of applied research in transistors and related devices, announced the details of its virtual schedule.

NVIDIA Xavier Shatters Records, Excels in Back-to-Back Performance Benchmarks ▶

AI-powered vehicles aren't a future vision; they're a reality today. And they're only truly possible on NVIDIA Xavier, our system-on-a-chip for autonomous vehicles.

North American Semiconductor Equipment Industry Posts September 2020 Billings ▶

North America-based manufacturers of semiconductor equipment posted $2.75 billion in billings worldwide in September 2020 (three-month average basis), according to the September Equipment Market Data Subscription (EMDS) Billings Report published by SEMI.

SoftBank Group, NVIDIA CEOs on What's Next for AI ▶

Sharing a vision of AI enabling humankind, NVIDIA CEO Jensen Huang joined Masayoshi Son, chairman and CEO of SoftBank Group Corp., as a guest for his keynote recently at the annual SoftBank World conference.

Happy's Essential Skills: RECRUITING AND INTERVIEWING

Feature by Happy Holden
I-CONNECT007

Editor's note: This article was originally published online in 2016 and has since been updated.

Hopefully, your career has progressed to the point that you are empowered to recruit your own team or a key person for your team. There are always technical people looking for better jobs, but many times, the most talented are busy doing their work and not looking for new opportunities. If you are fortunate enough to work for a company that has established a stellar reputation, the job of recruiting becomes a lot easier. This was what I found after working a few years for Hewlett-Packard.

Recruiting

As a result of our rapid expansion and automation due to the phenomenal sales of the HP-35 scientific calculator, I was promoted to process engineering manager. I needed to recruit more printed circuit process engineers. HP had a unique method of distributing engineering resources. It was a kind of free-market method for the workforce. Management would approve 10 times as many "internal hire only," as they would "authorized for external hire" and "relocation authorized."

What this meant was that there was always a lot of competition for the most talented engineers in the company, as they could easily transfer to any of the open "internal hire only" jobs. If the recruiting manager pulled you into the new job, your current manager could not stop or oppose the transfer. This placed a lot of burdens on managers to properly coach, lead, and challenge their team. Any team manager who was dominating, lacked delegation skills, or always issued orders instead of letting engineers do their job was soon exposed because people transferred out, and no one wanted to transfer in. Without hiring from the outside (any good engineer would take any job just to get in), the lack of personnel became apparent.

Printed circuit manufacturing was not one of the jobs that electrical engineers in HP wanted to do. EEs were also not the best choice for printed circuit manufacturing because chemical engineers, chemists, and mechanical engineers had more skills useful to support the PCB manufacturing process. Therefore, I was

authorized to recruit external hires. I was part of the college recruiting team, as 90% of HP engineers were recruited from universities (BS, MS, or Ph.D.). HP's process for college recruiting was based on an early form of networking. HP maintained close contact with department heads and head professors of engineering departments at favored universities.

To recruit chemical engineers, we went to those universities noted for their focus on industries like electronics, process control, and environmental. I contacted the department heads for chemical engineering at five noted universities, including my alma mater. We asked professors to give us the names of their most talented graduating students that would likely be interested in a career in electronics. We contacted the students and scheduled appointments to interview them at a time convenient for them rather than the fixed slots at the engineering placement office. Most chemical engineers were not looking for careers in electronics, but rather in petroleum, chemicals, pulp and paper, or energy.

Recruiting in Good Times and Bad

New university graduates proved to be excellent PCB process engineers. However, if you are looking for experienced engineers or scientists, then other tactics are in order, such as:

- Networking with peers
- Professional organizations
- Conferences and seminars
- Industry newsletters and magazines
- Internet job postings/social media
- HR departments and professional recruiters

Networking With Peers

This is always my first choice. If you've met other engineers that have impressed you and may be interested in your job, then you are on your way. That is one reason I recommend that you should write technical papers for publications. It makes your name visible in the industry. Delivering papers at conferences increases your network and opportunity to meet peers. The majority of jobs are found through contacts, so network, network, network!

Professional Organizations

Joining a professional organization is another way of increasing your network, but most POs have a website with job postings or "situations open" that you can take advantage of. The most useful organizations are those that have monthly or bi-monthly meetings. They are great places to meet and get to know your peers.

Conferences and Seminars

There is always an abundance of conferences and seminars going on in electronics, especially printed circuit manufacturing, design, and assembly. IPC is the most visible in North America, but it has its counterparts all over the world (EIPC in Europe, ICT in the U.K., JPCA in Japan, TPCA in Taiwan, etc.). There are also various SMTA conferences and seminars, as well as other trade shows and events held by other organizations.

Industry Newsletters and Magazines

There are numerous electronics newsletters that may have job postings as part of standard features. The same is true of industry magazines. If recruiting efforts have not returned any results, then an ad placed in one of the magazines may be the ticket. Just remember, magazines have a longer lead-time than newsletters or newspapers.

Internet Job Postings/Social Media

There are many sites that cater to job searching, including professional contacts through LinkedIn. Through networking, a job posting may be forwarded to someone who is looking for something in your field.

HR Departments and Professional Recruiters

If you are in a larger company, the HR department will be involved, especially with newspapers or professional recruiters. For smaller companies, it depends. Professional recruiters are usually my last resort. Although they are effective, they offer the service of finding candidates at a price in order to make money, which can be expensive.

Interviewing

Once you have a short list of candidates, how do you select the right individual for your job opening? Interviewing is much more than reviewing their resume. You have to read that document. What you need to discover is whether this individual can think, solve problems in production, work on new ideas, innovate, and work in your team. Is this individual the kind of engineer that can replace you?

Interview Steps

Before you start interviewing, there are seven steps to be aware of (Table 1):

1. Anticipate the need.
2. Specify the job.
3. Develop the pool.
4. Access the candidates.
5. Close the deal.
6. Integrate the newcomer.
7. Audit and review.

TABLE 1: Comprehensive End-to-End Process for Hiring Top Talent

Steps	Poor Practices	Best Practices	Implementation Challenges
1 Anticpate the Need	• Hiring only when you have an opening • Having an ad hoc succession plan • Overlooking the skills your organization will need in the future • Indulging in irrational optimism about attrition, succession depth, or recruiting yields	• Conducting ongoing, proactive analysis of future needs • Continually evaluating the pool of potential talent • Developing rigorous periodic forecasts of the company's talent needs	• Linking your talent plan to your strategic plan • Incorporating input from HR professionals into the strategic-planning process
2 Specify the Job	• Relying on generic competency models • Looking primarily for charisma, general ability, and track record	• Defining the specific demands of the job • Specifying which skills and experience are relevant • Identifying the team that the candidate will need to work with or recruit • Considering how company culture and context affect the role	• Ensuring a close dialogue between HR and management • Building up-front consensus among key decision-makers about job requirements
3 Develop the Pool	• Taking a scattershot, ad hoc approach to finding candidates • Limiting the pool • Looking only for external candidates or only internal candidates	• Developing a large pool • Including insiders, outsiders, inside-outsiders, and outside-insiders • Considering people on the periphery of the organization (employees in remote offices, consultants, suppliers, customers) • Tapping your network and involving the right external partners • Asking candidates' peers for nominations	• Transcending organizational silos • Encouraging open discussion at the top about when and how to conduct external talent searches
4 Access the Candidates	• Settling on the first adequate choice • Looking endlessly for the perfect choice • Going with your gut only • Using the wrong interviewers • Including too many unreliable filters and bureaucratic steps • Employing unstructured or generic interviews • Conducting inadequate (or no) reference checks	• Using a small number of high-caliber, well-trained, properly motivated interviewers • Employing rigorous behavioral event interviews • Conducting detailed reference checks • Including top stakeholders in candidate assessment	• Educating and training line/engineering managers in interviewing techniques • Ensuring the right level of involvement of both HR and the relevant line/engineering managers
5 Close the Deal	• Assuming money is everything • Showing too little commitment to the candidate's success • Discussing only the positives of the job • Failing to involve C-level in discussions	• Demonstrating active support for the candidate's interests • Describing the job realistically • Involving the hiring manager personally, not just HR, in closing the deal • Ensuring that compensation is fair to other employees • Involving C-level for the position	• Ensuring commitment of top managers to closing the deal • Ensuring compensation equity
6 Integrate the Newcomer	• Assuming the new hire is "plug and play" • Providing inadequate support and mentoring	• Using veteran top performers as mentors • Making sure the newcomer checks in regularly with boss, mentor, and HR, even when no problems have arisen	• Providing adequate ramp-up time • Rewarding mentors
7 Audit and Review	• Hanging on to bad hires • Failing to review hiring practices and institutionalizing the best ones	• Removing bad hires within the first year • Regularly reviewing recruiting practices • Identifying and rewarding excellent interviewers • Holding all assessors accountable for the quality of their evaluations	• Institutionalizing audit and review • Being willing to admit mistakes, learn, and move on

(Source: Harvard Business Review [1])

Interview Advice

Advice on interviewing style and questions include:

1. Be prepared with the right questions.
2. Ask open-ended questions that require a thoughtful, complete answer and not just "yes" or "no."
3. From the resume, select a noted accomplishment and ask open-ended questions about specifics, processes, and results.
4. Have a group of questions already prepared that gets to the body of experiences and skills needed for the job.
5. Have questions prepared that give you a clearer idea of how this candidate's mind works.
6. Be prepared with other questions that look for specific examples of their skills in leadership, communication, adaptability, organization, innovativeness, etc.
7. Ask a fundamental question that dates back to a person's schooling. If it is a chemical engineer, ask a question like, "Explain your understanding of the second law of thermodynamics." A good chemical engineer will always remember the fundamentals of their profession.

Conclusion

Just remember, the skills you demonstrate in recruiting and interviewing will be good when you want to find a new job or be considered for promotion. The better your network, the more opportunities that may find you. SMT007

Reference

1. Groysberg, B., and Fernandez-Araoz, C. "The Definitive Guide to Recruiting in Good Times and Bad," Harvard Business Review, May 2009.

Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa/Westwood, Merix, Foxconn and Gentex. He is currently a contributing technical editor with I-Connect007.

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

by Sagi Reuven
SIEMENS DIGITAL INDUSTRIES

As promised, 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. What follows is a brief excerpt from this month's column.

What Is the Most Used App on Your Smartphone?

I am constantly looking for bottlenecks and barriers to improve what I do. I'm not sure if it's a leftover from my military service or just a part of my personality and education. Last week, I checked the iPhone screen time feature in more detail to answer an important question: Am I really over-using my phone? The answer is yes, for sure. But the answer is also much more complicated. If I'm using my phone to do things that I used to do with my laptop, it's really over-use. Surprisingly, one of the most used apps was a simple calendar. I guess that a big part of my productivity is impacted by a very simple solution.

Click here to read this entire column at SMT007.


Sagi Reuven

Sagi Reuven is a business development manager for the electronics industry, Siemens Digital Industries. Download your free copy of the book *The Printed Circuit Assembler's Guide to... Advanced Manufacturing in the Digital Age from Mentor, a Siemens Business*, and visit I-007eBooks.com for other free, educational titles. You can also view Siemens' free, 12-part, on-demand webinar series "Implementing Digital Twin Best Practices From Design Through Manufacturing."

MilAero007 Highlights

PCB Technologies Focuses on an All-in-One Solution ▶

Recently, PCB Technologies reached out to us with news about their new All-In-One offering. Intrigued, we followed up and spoke with VP of Marketing and Business Development Arik Einhorn to get more details on the All-In-One services. We've included the short article and the interview.

Insulectro Opens Shop With All-New Printed Electronics E-Commerce Site ▶

Insulectro, a distributor of materials for use in the manufacture of printed circuit boards and printed electronics, rolled out its new online shopping center for conductive inks and pastes plus advanced substrates and films.

Understanding MIL-PRF-31032, Part 4 ▶

Continuing with Part 4 of the discussion on understanding the military PCB performance standard MIL-PRF-31032, Anaya Vardya explains how the next step in the process is to create four new procedures to address the unique requirements of the military.

Jaunt Air Mobility Establishes Access Skyways to Support Integration of Advanced Air Mobility ▶

Jaunt Air Mobility announced the establishment of Access Skyways, a group of partner companies providing expertise to support the integration of Advanced Air Mobility.

The Government Circuit: As 2021 Nears, What's on IPC's Government Policy Radar? ▶

In the United States, Election Day 2020 has come and gone, and all signs indicate that former Vice President Joe Biden is the presumptive President-elect. It's shaping up to be a busy month here at IPC, heading into a busy new year. Chris Mitchell details some of the top issues we're following this November.

U.S. Air Force, Lockheed Martin to Transform Airlifters Into Potent Strike Weapon Platforms ▶

The U.S. Air Force Strategic Development Planning and Experimentation (SDPE) Office awarded Lockheed Martin a $25 million contract to support the next phase of the service's Palletized Munitions Experimentation Campaign.

Perspecta Labs to Improve 5G Security for DARPA ▶

Perspecta Inc. announced that its innovative applied research arm, Perspecta Labs, received two awards on the Defense Advanced Research Projects Agency's (DARPA) Open, Programmable, Secure 5G (OPS-5G) program for work to improve the security of 5G networks.

TTM Technologies: Defense, Data Drive Profits in 3Q ▶

TTM Technologies Inc., a leading global printed circuit board and radio frequency components manufacturer, reported results for the third quarter of fiscal 2020, which ended on September 28, 2020.

ST Engineering iDirect Achieves World's First Live MF-TDMA Demo ▶

ST Engineering iDirect announced the successful completion of the first Over-the-Air (OTA) testing of iDirect's Multi-Frequency Time Division Multiple Access (MF-TDMA) return link on the Telesat Phase-1 Low Earth Orbit (LEO) satellite.

Redefine Recruiting to Attract and Hire the Right Talent

Operational Excellence

Feature Column by Alfred Macha, AMT PARTNERS

Should you hire the most talented candidate for the open position in your department? The answer is no. Hire the right talent for the position. The concept is straightforward to understand, but achieving success can be complicated without a structured recruiting process. The process starts with an evaluation of the company's core values and branding. Once that has been accomplished, then screening candidates and selecting the right talent for your hiring needs becomes much easier.

Understand Your Organization's Core Values

Before you start searching for new employees, you should clearly understand the core values that allow your company function. This is important as you determine the culture fit of prospective candidates for the job position you plan to hire for. One Forbes' article [1] described "key strategies for establishing your company's core values and ensuring your people, from new hires to tenured employees, know the traits that define and exemplify your culture." Here are the four steps with commentary from me.

1. Identify Key Traits That Describe Your Culture

Establish a cross-functional team representing most functions of your company to get inputs. These inputs should consist of adjectives, verbs, or phrases that define how the company operates and what behaviors the organization expects of all employees.

2. Narrow the List to Establish Your Core Values

Attempt to capture values that are unique that go beyond the common ones of commitment, teamwork, reliability, etc., to name a few.

3. Share Your Core Values Companywide

Once you've determined your core values, share them throughout the company with a marketing campaign aimed at informing

employees. Again, these values should capture the company culture, and employees should embody them.

4. Share Your Values With the World

Once core values are defined and communicated to the workforce, the final phase is to write these values down and discuss behaviors that support these values to the management team. The goal is to establish common ground with the hiring managers to assess candidates on culture fit. Align your core values with prospective candidates.

The Importance of Branding in Recruiting

Treat potential candidates as customers. Positioning your company in the marketplace to attract and acquire candidates will give you the edge in a competitive labor market. This requires a marketing and sales approach in your hiring process, which starts with understanding your company's branding. According to one article [2], "Your brand is the sum total of your customers' perceptions, notions, and experience. It is the face, personality, and the values espoused by your business and everything in between."

Keep in mind that high-performing employees want to develop a strong career where their contributions are recognized and where they can learn during each employment opportunity. Your organization's brand is important to attract and retain the right employees. Employees take pride in belonging to an organization that has a purpose and a brand that they identify themselves with.

Some examples where companies use branding to attract top talent include IBM, Square, Starbucks, and more [3]. IBM reinvented their culture to be more casual and informal. Square uses career videos to emphasize the company's mission and highlight talent. Starbucks leverages social media for connecting with prospective candidates and recruiting.

The majority of manufacturing organizations may highlight the nuts and bolts of their technology and capability when attracting talent. Creating a strong brand that highlights unique technologies, processes, or knowledge centers can create that branding differentiator to attract top talent.

Screening Candidates for Competency and Culture Fit

Once you are ready to post a job opening by promoting your values and brand, then you are ready to evaluate candidates. Many candidates may only be interested in the job title itself and the opportunity to get higher compensation. However, top candidates will do their homework on your company. Part of their homework will be about understanding your company's values and how working for the organization will add value to their careers.

One question that can give the recruiting manager a clue of a candidate's interest in the position is, "Why are you interested in applying for the position?" A typical response will be that the opportunity is aligned with the candidate's career aspirations and qualifications. However, there will be a few candidates who have done research on the company and will point to a specific strength or technology that the company offers that is of interest to them.

The recruiting manager needs to note those intangibles during the screening process before presenting candidates to the hiring manager. It's very important that the recruiting manager is able to evaluate a candidate's interests and EQ to determine a fit for the company's core values and brand. The hiring manager should also evaluate the candidate's IQ, EQ, and competency adequacy for the job position. A perception map analysis can be used as an objective tool to place candidates into four categories (Figure 1).

1. High-Value Candidates

Candidates in this category have a good culture fit and the right competency level for the desired job. These are your desired candidates. Also, these candidates are highly sought after by other companies and may have multiple job offers at the same time.

2. Medium-Value Candidates (High Risk)

These candidates can be the most talented and demonstrate a high level of IQ, but their

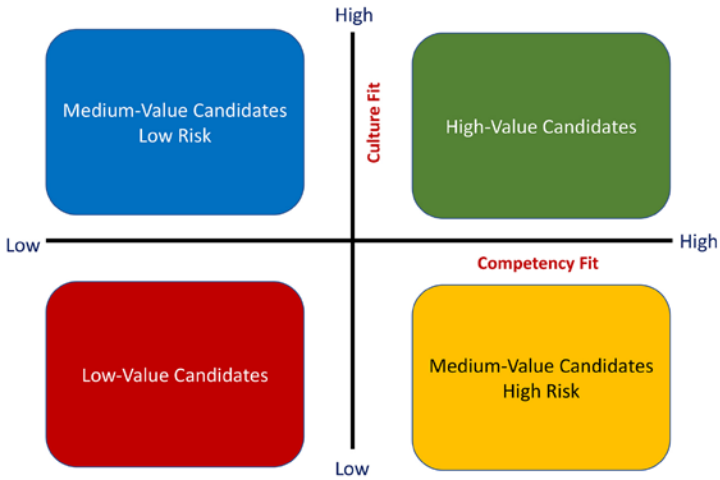

Figure 1: Candidate screening.

fit to culture may be problematic. Companies take a high risk when hiring these candidates, as they may create unnecessary conflicts in the organization. They can deliver exceptional work as individual contributors but may not work well with others or not support companywide initiatives that they don't agree with.

3. Medium-Value Candidates (Low Risk)

These candidates may not have the necessary competency to initially excel in the job but demonstrated the right culture fit during the interview process. The hiring manager will need to decide whether candidates in this category are trainable or can learn the skill sets required for the job in a short period of time. These candidates can be great employees if they can develop their skills to meet the job requirements.

4. Low-Value Candidates

Many of the candidates applying for the job will fall into this category. These candidates do not bring the right skills to the job and have not demonstrated alignment with the company's culture.

Move Fast to Make an Offer to the Right Candidate

Once the evaluation of candidates has been completed, it will be easier to select the right candidate for the job position. The candidates categorized in the high-value category are highly sought by other organizations. It is important for the company to move quickly and make an offer to highly competent candidates that demonstrate a culture fit with the organization's values and brand.

According to another Forbes' article [4]:

"Companies are competing in a war for talent where the best candidates are off the market in just 10 days. Job seekers are receiving multiple competing offers and won't waste their time going through a lengthy recruiting process. Glassdoor reports the average interview process takes 23.7 days. If longer, candidates perceive it to mean they're not the top pick or the company is unsure about advancing them to the next stage."

Conclusion

In summary, you must first understand your organization's core values and the importance of branding in recruiting. Next, screen candidates for competency and culture fit using the four recommended screening categories, and if you identify the right candidate, move fast to make them an offer. These steps will help you redefine how you recruit, attract, and hire the right talent. **SMT007**

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1. Vivian Maza, "The Importance Of Establishing Company Core Values—And How To Define Them," *Forbes*, March 26, 2019.

2. Arpit Sinha, "Six Reasons Branding Is More Important Than Ever Before," *Entrepreneur India*, May 14, 2018.

3. "13 Great Examples of Employer Branding," Uncubed.

4. Heidi Lynne Kurter, "Employers: Here Are 3 Reasons Why Candidates Are Ghosting You," *Forbes*, December 31, 2019.

Alfred Macha is the president of AMT Partners. He can be reached at Alfred@amt-partners.com. To read past columns or contact Macha, click here.

SMT007 Supplier Highlights

Computrol Takes Soldering Capabilities to Next Level ▶

Computro, Inc., a world-class provider of mid- to low-volume, high-mix electronic manufacturing services to OEMs, is pleased to announce that it purchased and installed a Thermaltronics TMT-R9800S Solder Robot at its Meridian facility.

Mek Launches Fast, Simple PCB Conformal Coating Inspection ▶

Mek (Marantz Electronics), a leading supplier of 3D automated optical inspection and solder paste inspection technologies, launched the iSpector JUz for conformal coating inspection.

Intellitronix Buys Cutting-Edge SMT Component Placement System ▶

Intellitronix Corporation, a wholly owned subsidiary of the U.S. Lighting Group Inc. and a leading manufacturer of automotive electronics, announced it purchased a state-of-the-art SMT Component Placement System from Europlacer (France).

Cogiscan Partners With AES in Vietnam ▶

Cogiscan, a leading provider of Track, Trace, Control (TTC) and IIoT solutions for the electronics manufacturing industry, is pleased to announce that it has teamed up with AES for sales and service throughout Vietnam.

Corelis Introduces New ScanExpress Version 9.8.0 Boundary-Scan Software Suite ▶

Corelis, the leading supplier of high-performance boundary-scan test and measurement software and hardware, announced today version 9.8.0 of its ScanExpress™ Boundary-Scan Suite of Software is now available.

Rehm Thermal Systems Expands Sales Structure in Southeast Asia ▶

Andy Wang, senior director of sales, is now responsible for sales and marketing activities in the Asia-Pacific region.

PVA Earns ISO 9001:2015 Certification ▶

PVA, a global supplier of automated dispensing and coating equipment, is proud to announce that the company received certification to the International Organization for Standardization (ISO) 9001:2015 standard. PVA's quality management system (QMS) governs processes for product design, development, and manufacture.

DELO Launches Liquid Pressure-Sensitive Adhesives ▶

DELO developed adhesives that have similar properties to (double-sided) adhesive tapes but are applied in liquid form. This helps users save time and costs in the production process.

Cabletree Appoints D.B. Management Group to Grow North American Presence ▶

Thomas Chang, president and founder of Cabletree industrial company, recently announced that the company chose D.B. Management Group to handle his company's growth into the North American marketplace.

Murray Percival Company Showcases MIRTEC MV-6 OMNI 3D AOI Machine ▶

Murray Percival Company is extremely pleased to feature one of MIRTEC's Award-Winning MV-6 OMNI 3D AOI machines within their fully functioning SMT product demonstration facility in Auburn Hills, MI. MIRTEC's MV-6 OMNI machine is the perfect 3D inspection solution to meet the needs of the Midwest electronics manufacturing industry.


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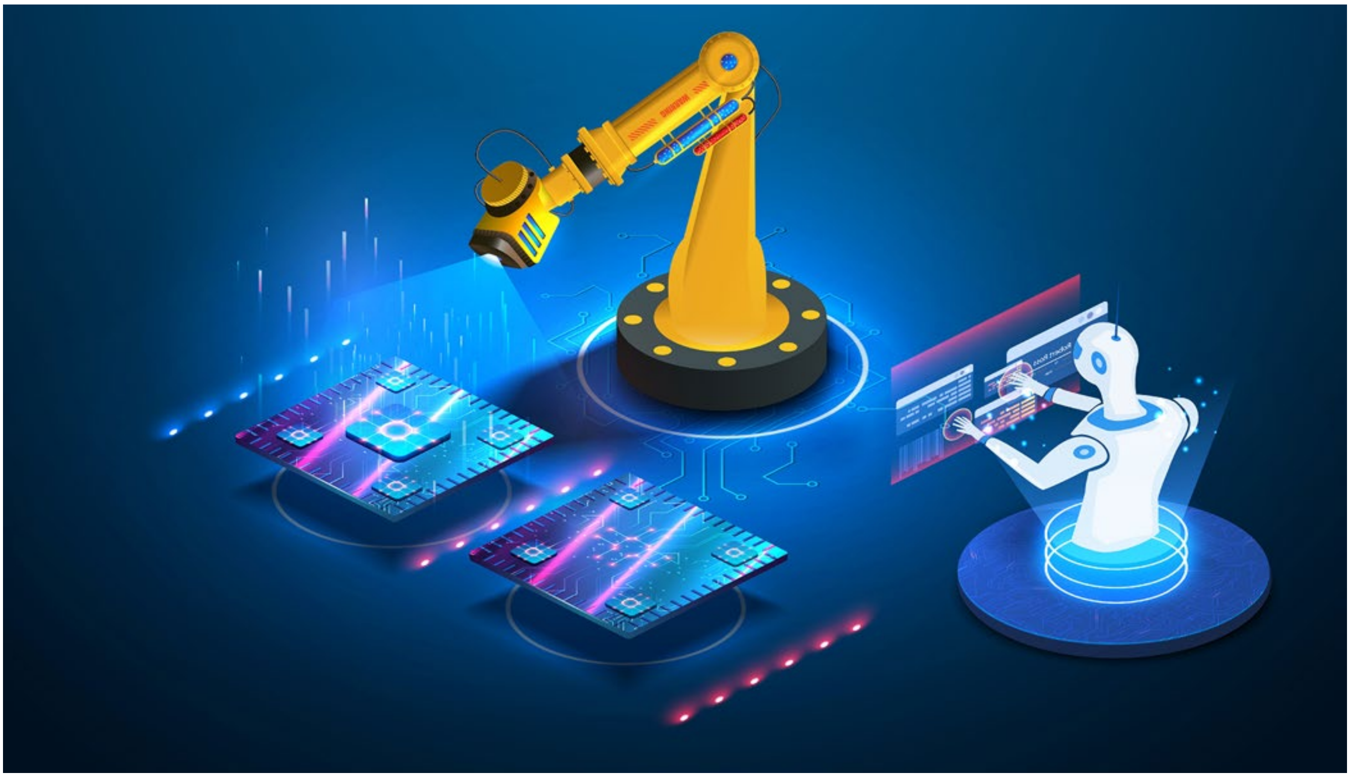
Changing Roles in the Digital Factory

Smart Factory Insights
by Michael Ford, AEGIS SOFTWARE

Obviously, the level of maturity within the electronics assembly industry, in terms of core technologies, is high and relatively stable. Experts once required to have a specialized knowledge of materials and processes are giving way to those experienced in the application of automated and computerized solutions. 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.

When SMT first came along, I naively thought that it could not be that difficult to pick up a component and place it on a PCB in the desired location, though there did seem to be challenges at times. Technology and expertise flourished, machines became faster, and materials became smaller. With PCB dimensions and spacing reducing in line with the material sizes, we saw the same challenges coming around, over and over again, related to cleaning and access for testing and inspection, for example.

After 30 years of SMT production, with an immense contribution of technology and work by people far more clever than myself in these specialized areas, I still maintain that PCB assembly is not complicated. This perspective



Up to 70% of Defects in Electronics Manufacturing are Related to Solder Paste

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comes from the observation that the location at which this know-how resides has changed from once being needed in each and every SMT factory across the world to now being within the domain of the machine vendor and materials suppliers. Today, we trust the machines and materials that we buy—sophisticated, matured, yet progressive commodities that simply perform the intended work efficiently and reliably. Creating an SMT configuration to meet any line configuration requirement is as easy today as ordering off-the-shelf products, selecting the best tools for the job from any one of many vendors.

This has all coincided with the trend of experts in the core technologies leaving manufacturing either to go on to work with machine vendors or simply retiring. The key question is, "Does this create a void?" Up to fairly recently, perhaps yes, but now I don't think that it is such a serious issue. If our minds stay in the "analog" factory of yesterday, we have everything pretty much covered, with results in terms of efficiency, productivity, flexibility, and quality being as good as they ever can be. Any incremental challenges today are met predominantly by vendors, and manufacturing can continue as is.

Any incremental challenges today are met predominantly by vendors, and manufacturing can continue as is.

Of course, this is not an option. Factory-centric improvements now become the differentiators. In many areas, the consequence of variation continues to present challenges, but the details needed to identify anomalies in a timely fashion and then track the root causes are not practically possible for humans to do unaided. In areas of low labor cost, we have already seen many people with relatively low skills being thrown at these challenges, such as material and product logistics, as well as planning optimization and quality control.

As product-mix has increased, the whole of the shop floor gets into a mess, with continuous fire-fighting. This is not the profile of people that we need for smart manufacturing; in other words, we cannot replace the skilled experts that we once had with unskilled workers. As the industry has trended away from mass production toward the extreme of mass-customization, we need to reinvent the technologies that are associated with these factory-level functions.

As automated machines reduced the need for manual work in terms of core manufacturing technology and assembly activities, software automation replaces the dull and repetitive calculations done currently by people who are using tools such as Excel to perform their planning, material management, and quality control, in addition to legacy ERP or even MES systems. The way going forward in terms of factory operational improvement is digital, and the people needed are those who understand how to utilize software and systems to improve manufacturing and how to differentiate between them.

The use of real-time data within manufacturing thus far has been limited; it has been constrained by a lack of timely availability of data that has a consistent meaning and can be trusted to be used for investigative processes and decision making. The main driver toward digitalization for most companies has been the gathering of traceability data, which itself has been a haphazard affair. Thankfully, the digital manufacturing world is finally going through the revolution long promised by Industry 4.0 and smart manufacturing. Industry standards—most notably from IPC in the form of the Connected Factory Exchange (CFX), the IPC Digital Twin, exact traceability of IPC-1782, as well as the Digital Product Model Exchange (DPMX), which is also known as IPC-2581—enable completely reliable interoperability of data when used with the right tools.

Having standards in place, however, is only the start. Few applications in the realm of MES, etc., have been ready for these tech-

nology changes, but the volunteer companies behind these open industry standards are clearly setting the pace, providing an unprecedented opportunity for factory visibility, control, optimization, and quality, as well as further automation opportunity. What is really needed now in manufacturing are people with the skills to understand the use of data in manufacturing, the difference and consequence of selecting technologies, and how to bring about changes and manage manufacturing based on what the data shows.

It is quite fortunate that skills and experience in computing are growing, but manufacturing is not the most famous or attractive place to which people with those skills are attracted. But this is something that needs to change, as this is the way in which factories will differentiate themselves within the industry against their peers. The whole approach to recruitment and role definition needs to change to take advantage of technologies that are now available. We all now need to market manufacturing careers in context with this new digital age and be less concerned about the loss of past dependencies.

There is still one final challenge, however. The momentum with legacy practices within manufacturing remains strong. As manufacturing has been slow to have easy access to good data, managers within manufacturing and the supply chain have become introspective, with the whole of their professional world contained within the four walls of the factory, believing—with very decreasing merit—that many that propose such pioneering digital technologies represent a risky path and that so-called experts are simply trying to make their bad business work. For sure, unless you have the skills in-house to know what technologies and solutions are out there—which work and which do not and how they specifically relate to the needs of production—it is very easy to make a mistake and go with a company name that "you will never get fired for choosing" only to find yourself locked into a solution that is isolated from the rest of the industry, including from machines themselves that you depend on. Trust needs to be built between incumbent senior management and the new profile of manufacturing engineers, managers, and operators. Successfully addressing new challenges always works best with an open mind. The reality is that with these new skills in new roles comes the need for training and experience in manufacturing itself. The incumbent skills are at least as important as the new ones. The successful companies will be those that create the right balance of hybrid sets of skills, manufacturing, and digital technology formed by communication, trust, and mutual respect. This is not politics, after all. **SMT007**

Michael Ford is the senior director of emerging industry strategy for Aegis Software. To read past columns or contact Ford, click here.

High-Tech, High-Value Cleaning Answers Made Easy With KYZEN's Tech-2-Tech

by Pete Starkey
I-CONNECT007

Thanks to KYZEN's Tech-2-Tech initiative, I've been taking the opportunity to broaden my knowledge of the fundamentals of cleaning electronic assemblies.

Tech-2-Tech offers a wide-ranging selection of well-chosen topics, covering diverse aspects of selecting, evaluating, operating, and maintaining cleaning processes. These were clearly explained in a series of focused 15-minute sessions, each one presented by a different member of KYZEN's team of industry experts. It's amazing how much practical information can be effectively transferred and explained in a 15-minute slot, especially one that's cleverly designed to fit conveniently into the working day with minimum disruption and includes time to grab a coffee!

The series began back in July, led by KYZEN Executive Vice President Tom Forsythe exploring the expectations of a cleaning process and the relative merits of short-term evaluation versus extended field trial for real-life characterisation. "Cleaning products must clean," he remarked, "Cleaning agents must touch the dirt, and contaminants must be managed."

Without getting buried in scientific detail, Forsythe described traditional cleaning technology and compared it with the complexity of soils currently encountered, the consequent complexity of the processes required to remove them, and the critical importance of effective rinsing. "It's about balance and strength–enough solvency power to clean and enough pH to manage the soils and keep them in solution."

Forsythe also discussed the dynamics of the cleaning process, particularly when operating in a real-world scenario, and the value of gathering and reviewing all the data from a trial before making production decisions. "It's a long journey, with some ups and downs and some bends in the road. Some days, it rains!"

Subsequent sessions have included discussion of the five forces of cleaning; the significance of pH and how to maintain it; the importance of rinsing; the causes, consequences, and avoidance of foaming; optimisation of cleaner concentration; manual concentration monitoring and the benefits of automated monitoring; determination of process bath life, and overcoming the challenges of cleaning under low-stand-off tight-pitch components.

Recordings of all of these past sessions are readily accessible on-demand online, together with downloads of the corresponding Q&A sessions–practical answers to sensible questions! And, of course, the KYZEN team are always available to respond to any further queries which may subsequently arise.

Still to come, on December 3 at 3:18 p.m. GMT and December 4 at 1:33 a.m. GMT (the alternative time slots to align with North American, European, and Asian time zones) will be Jack Reinke's session on the environmental impact of a PCB cleaning agent: its potential effect on the waste stream and whether or not to put spent process solution down the drain. A definite date for our diaries!

For those whose primary interest is metal finishing, KYZEN provided a full alternative programme with each session focused on a specific aspect of cleaning in metal finishing. To KYZEN's great credit, the Tech-2-Tech initiative provides an intelligently constructed agenda of no-nonsense practical information, advice, and guidance for the benefit of decision-makers, engineers, and technical staff engaged in electronics assembly.

Presented in plain language with interesting analogies, KYZEN's webinar supplies a wealth of valuable information, presented in an informal and easily assimilated style, with intelligent answers to intelligent questions, refreshingly free from commercial promotion.

I have greatly enjoyed the experience and look forward to the next chapter.

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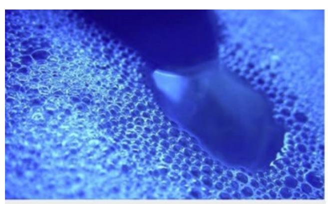

December 3, 2020

Environmental Impact: What Should I Look for in a PCB Cleaning Agent?

To drain or not to drain - What impacts my waste stream?

Presented by Jack Reinke

December 17, 2020

Smart pH Employment in Electronic Cleaning

What is pH of egg nog?

Presented by Jody Saultz

High-Density PCB Technology Assessment for Space Applications

Article by Maarten Cauwe, et al.
IMEC-CMST, ET AL.

Abstract

High-density interconnect (HDI) printed circuit boards (PCBs) and associated assemblies are essential to allow space projects to benefit from the ever-increasing complexity and functionality of modern integrated circuits such as field-programmable gate arrays (FPGAs), digital signal processors (DSPs), and application processors. Increasing demands for functionality translate into higher signal speeds combined with an increasing number of I/Os. To limit the overall package size, the contact pad pitch of the components is reduced. The combination of a high number of I/Os with a reduced pitch places additional demands on the PCB, requiring the use of laser-drilled microvias, high aspect ratio core vias, and small track width and spacing. While the associated advanced manufacturing processes have been widely used in commercial, automotive, medical, and military applications, reconciling these advancements in capability with the reliability requirements for space remains a challenge.

This article provides an overview of the ongoing European Space Agency (ESA) project on high-density PCB assemblies, led by imec with the aid of ACB and Thales Alenia Space in Belgium. The goal of the project is to design, evaluate, and qualify HDI PCBs that are capable of providing a platform for assembly and the routing of small pitch AAD for space projects. Two categories of HDI technology are considered: two levels of staggered microvias (basic HDI) and (up to) three levels of stacked microvias (complex HDI). In this article, the qualification of the basic HDI technology in accordance with ECSS-Q-ST-70-60C is described. The results of the thermal cycling, interconnection stress testing (IST), and conductive anodic filament (CAF) testing are provided. The test vehicle design and test parameters for each test method are discussed in detail.

Introduction

Two main drivers are commonly identified for HDI PCBs: (1) the small pitch and high number of I/Os of key components and (2) the increasing performance of these components resulting in high-speed signal lines on the boards. The use of microvias allows reducing the length of


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the signal path, improving both signal integrity and power integrity. Critical nets may suffer from crosstalk due to the dense routing within the fanout. The routing of differential pairs in between the pins of a 1.0-mm pitch component requires fine line widths and spacing. Differential pair routing in between the buried vias for 0.8-mm pitch components is no longer possible. The pairs need to be split within the fanout area, and the effect on signal integrity will depend on the length of the split. The change in width on single-ended nets, as well as a change in the spacing and/or trace widths of a differential pair, will cause an impedance discontinuity. Choosing the appropriate layer build-up and via types will thus improve both route-ability and signal integrity.

An important consideration in the definition of technology parameters for HDI PCBs is that component pitch, and the number of I/Os cannot be addressed independently. A high pin count component (> 1000 pins) with 1.0-mm pitch can require the use of microvias to reduce the total layer count or to improve the shielding of controlled impedance lines. On the other hand, the escape routing of a 0.5-mm pitch component with only two rows of solder balls can be performed without microvias and fine line widths and spacing. Increasing the layer count to be able to route one or more high pin count components will result in an increase in PCB thickness, which impacts the minimum via drill diameter through limitations on the via aspect ratio and thus again restricts routing possibilities.

To define the HDI technology parameters, the specifications of area array devices (AADs) used in past, present, and future space projects need to be known. Looking into the complex components for space that are currently under development, the ceramic column grid array (CCGA) with a pitch of 1.0 mm will remain the package of choice for the coming years. This is, for example, the case for the new Xilinx FPGA (RT-ZU19EG: CCGA1752) [1], the CNES VT65 telecom ASIC (CCGA1752) [2], and ESA's Next Generation Microprocessor (NGMP, CCGA625) [3]. Column grid arrays with smaller pitch (0.8 mm) have been demonstrated in R&D [4], although no commercial implementations have been found. Ceramic ball-grid arrays (CBGAs) with non-collapsing, high Pb solder balls are used in military and aerospace applications [5]. At 0.8-mm pitch and beyond (0.5 mm), ceramic (i.e., hermetic) packages become a reliability risk as the smaller solder balls can no longer support the coefficient of thermal expansion (CTE) difference between package and board. A recent NASA study, therefore, investigated the reliability of plastic ball-grid arrays (PBGAs) with up to 1704 pins at 1.0-mm pitch and 432 I/Os at 0.4-mm pitch [6].

Increasing the capability for dense routing, signal integrity at high speeds, and a high number of I/Os undoubtedly has its impact on reliability. Reducing line width and spacing, via pad size, and drill diameters all influence the manufacturing yield and quality and thus present a reliability risk. New materials need to be introduced to corroborate the increasing capability demands without diminishing the reliability standards.

High-density interconnect PCBs have been used for over three decades and are currently applied in all markets. Numerous studies on HDI technology and its reliability have been published. The returning theme in almost all HDI technology studies is that the technology can be very reliable if manufactured properly. Process control and quality assurance are key to reliable HDI PCBs.

HDI Technology Parameters

At the start of the project, a stakeholder workshop was organized at the ESA ESTEC facility in the Netherlands to provide an update to the HDI PCB section of the PCB and Assembly Technologies Roadmap for Space Applications [7] and to derive the requirements for HDI PCBs in space projects. Workshop participants were prime satellite contractors, equipment manufacturers, space agencies, ESA-qualified PCB manufacturers, ESA technical officers, and independent CAF experts.

In preparation for the workshop, a questionnaire was compiled to determine the drivers and technology parameters for HDI PCBs for near-term space projects (2018–2020) and future space projects (2020-2025). Feedback from the PCB/SMT WG members and other stakeholders was requested to specify the technological need while keeping in mind the possible repercussions on manufacturability and reliability. Starting from the functional requirements and component needs for future space projects, a set of advanced technology parameters is derived for evaluation within the project.

During the workshop, it became clear that the split into technology for near-term and future projects was not satisfactory as higher complexity was required in the near-term as well. The decision was made to differentiate between basic HDI technology, intended for qualification within the project, and complex HDI technology, including more advanced technology parameters. The workshop confirmed the large FPGA components—based on 1.0-mm pitch CCGA packages with up to 1752 pins—as primary drivers for the basic HDI technology. In addition, AADs with 0.8-mm pitch and a few hundred I/Os should be compatible with the basic HDI technology. Other driving components are small passives (0402 chip components), and fine-pitch lead frame components (QFP 0.5 mm) when routing space is limited. In future projects, components will have up to 2000 to 3000 I/Os and will use AADs with 0.8- and 1.0-mm pitch. These will likely be non-hermetic polymer-based packages (PBGA), as a package size of 45 mm x 45 mm for ceramic packages is the limit in terms of CTE mismatch. A further reduction in pitch to 0.5-mm pitch is expected for low I/O (200–300) and for memory devices.

The HDI technology parameters for basic and complex HDI, as agreed during the workshop, can be found in Table 1. The basic HDI technology consists of a single-sequence core

Technology Parameter	Basic HDI	Complex HDI
Conductor width and spacing as-designed	75-µm line width and 75-µm spacing on non-plated inner layers (17 µm Cu foil). 120-µm line width and 100-µm spacing on plated inner layers (12 µm Cu foil with plating).	50-µm line width and 50-µm spacing on non-plated inner layers (12 µm Cu foil). 100-µm line width and 100-µm spacing on plated inner layers (12 µm Cu foil with plating).
Configuration of microvias	Two levels of microvias, staggered, Cu filled, 175 µm diameter as-designed.	Three levels of microvias, Cu filled, 125 µm diameter as-designed. Semi-stacked preferred, all staggered as backup.
Number of layers	≤20	≤26
Construction of HDI layers	Staggered to core, two sheets of prepreg.	Staggered to core, one sheet of prepreg.
Aspect ratio of core vias	≤8	≤10
PCB thickness	2.8 mm	Approx. 3 mm
Filling medium for core vias	Prepreg (from HDI layers)	Via plugging (with cap plating)
Construction of core	Single sequence, 300 µm drill diameter and 600 µm pad diameter for buried vias.	Single sequence, 250 µm drill diameter and 550 µm pad diameter for buried vias.
Back drilling	No	Back drilling on core
Presence of non-functional pads	As per ECSS-Q-ST-70-12C [8]	Full pad stack removed on core vias
Dielectric material	Polyimide (Ventec VT-901)	Polyimide (Ventec VT-901)
RF material	No	Panasonic Megtron 6
Surface finish and solder mask	SnPb, no solder mask	ENIG or ENEPIG with solder mask

Table 1: HDI technology parameters for basic and complex HDI technology.

with two levels of copper-filled microvias. Two levels of microvias are considered sufficient to route the AADs with 0.8-mm and 1.0-mm pitch. To minimize the reliability risk, the microvias are staggered with respect to each other and to the buried via in the core. Filling of core vias with prepreg from the HDI layers is preferred, and two sheets of prepreg are applied.

The complex HDI technology will use three levels of microvias. The microvia configuration of choice is the semi-stacked option consisting of two stacked microvias plus one staggered microvia. Stacking three levels of microvias is considered a reliability risk. An IST prescreening is performed within the project to determine if the semi-stacked microvia configuration can meet the required reliability. If this is not the case, the full staggered configuration will be used as a backup solution. Via plugging and capping will be used for the buried vias in the complex HDI technology. The effect on the reliability of removing the non-functional pads and back drilling of the buried vias will be investigated as part of the complex HDI technology evaluation.

Polyimide remains the material of choice for HDI PCBs in space applications. To accommodate the needs for RF and high-speed digital applications, Panasonic Megtron 6 is included in the complex HDI technology evaluation. Low in-plane CTE materials are not seen as a priority for HDI in future projects. The use of a single sheet of prepreg for the microvias will be evaluated.

Solder mask is a requirement for the complex HDI technology. Other surface finishes (ENIG, ENIPIG, ENEPIG, and EPIG) are of interest, but the focus of the project is not to evaluate alternative surface finishes. The complex HDI technology will be evaluated with both ENIG and ENEPIG (one finish per base material).

Project Plan

Figure 1 shows the overall concept for the HDIPCB project. During the workshop, the relevant AADs for space applications were identified. Based on the mechanical (pitch, number of pins) and functional (data rate, controlled impedance) requirements of these components, the technology parameters and associated design rules were determined. The goal is to achieve qualification status for the basic HDI technology. The PCB qualification is followed by assembly verification for 1.0-mm pitch CCGA1752 and 0.8-mm pitch CBGA323 components.

Before launching the evaluation of the complex HDI technology, an IST prescreening will be performed to decide on the use of stacked

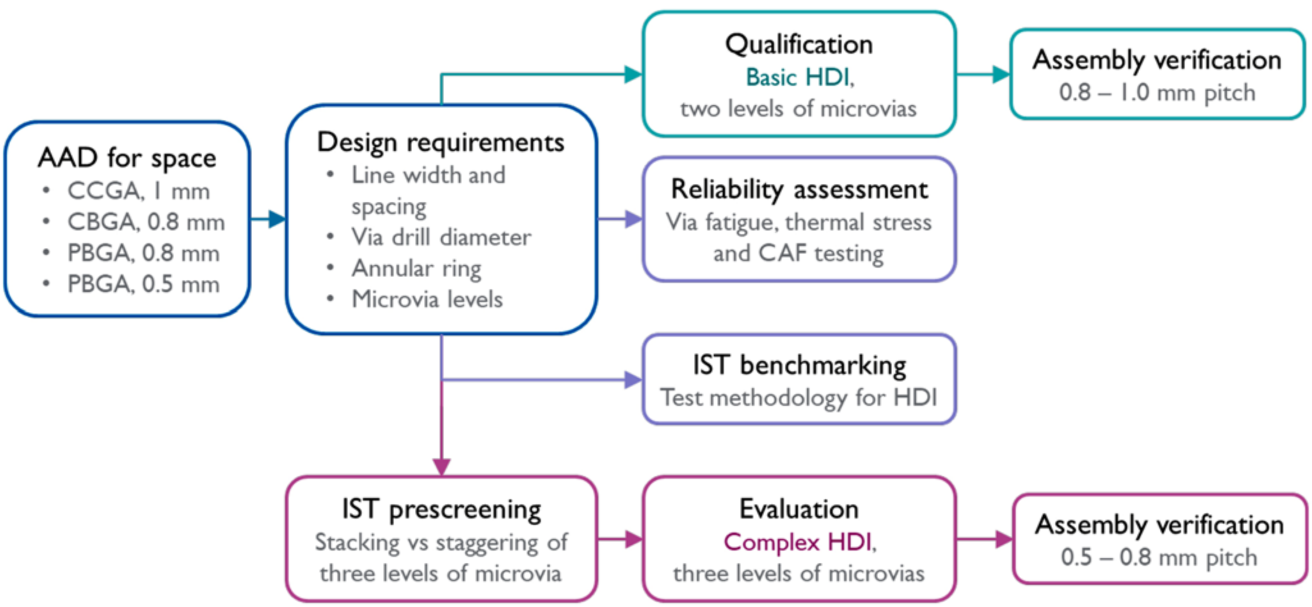


Figure 1: Overall concept for the HDIPCB project.

or staggered microvias. The evaluation of the complex HDI technology may lead to formal qualification for all or a subset of the technology features, depending on the occurrence of nonconformances in the evaluation. The subsequent assembly verification for 0.8-mm and 0.5-mm pitch PBGA components will be approached in the same manner, with the focus on evaluating the performance and identifying uncertainties.

Next to the qualification and assembly verification activities, an extensive HDI reliability assessment is performed. The study focuses on three aspects: thermal reliability, microvia testing, and CAF testing. The via fatigue and thermal stress evaluations will be correlated with the modeling of the bare PCB. For CAF testing, a dedicated test vehicle is designed to match the requirements of the HDI technology parameters. An extensive test campaign using thermal cycling, convection, and vapor phase reflow assembly simulation, and interconnection stress testing (IST) will be undertaken.

In this article, the test vehicles, test methods, and test results for the HDI qualification in accordance with ECSS-Q-ST-70-60C [9] are described. The outcome of thermal cycling, IST, and CAF testing is discussed. Other activities within this project will be published elsewhere over the course of the project.

Test Vehicles

The qualification test vehicle (QTV) consists of a full panel design, including the following features:

- Test structures for HDI qualification test flow
  - Coupon A/B with through-vias and component holes
  - Coupons B1, B2, and B3 for the microvia level 1, microvia level 2, and the buried vias, respectively
  - Coupon E for intralayer insulation resistance and dielectric withstanding voltage
  - Coupon H for interlayer insulation resistance and dielectric withstanding voltage
  - Coupon P for peel strength on outer layers
  - TVX and SLX procurement IST coupons
- Coupons for outgoing inspection as detailed in clauses 8.2.2 and 8.2.3 of ECSS-Q-ST-70-60 [9]
- BGA coupon which mimics (part of) an actual HDI PCB design
  - Real and daisy-chain component fanout for 1.0-mm and 0.8-mm pitch component
    - CCGA, 1.0-mm pitch, 1752 I/Os (Xilinx Virtex 5QV FPGA)
    - CBGA, 0.8-mm pitch, 323 I/Os (Teledyne e2v EV12AQ600 ADC)
  - Routing to Axon Nano-D (1.27 mm) and Smiths connectors KVPX (1.35 mm)

The BGA coupon (Figure 2) mimics (part of) an actual HDI PCB design and acts as a "PCB" for the qualification test flow. The real component fanout for 1.0-mm and 0.8-mm pitch components are based on the actual pinout diagrams for the Xilinx Virtex 5QV FPGA and the Teledyne e2v EV12AQ600 ADC, respectively. Controlled impedance differential pair routing was applied to all relevant output pins. As high-density connectors can impose restrictions on routing and are thus also driving components for HDI, two candidates are included in the BGA coupon. The differential pair interconnections of the Xilinx Virtex 5QV FPGA component fanout are routed to eight KVPX connectors. The fanout of the Teledyne e2v EV12AQ600 is combined with the Axon nano-D connector.

Two levels of staggered microvias can be implemented in different ways. For the 1.0-mm pitch fanout, the component pad is placed directly above the buried via. The microvia between layers 1 and 2 is placed partially inside the component pad. The capture pad of the microvia between layers 2 and 3 is tangent to the target pad of microvia 1-2. The target pad of microvia 2-3 is connected to the buried via using a short trace. The advantage of this microvia configuration is that microvia 1-2 is not located above the buried via, although the short trace between microvia 2-3 and the bur-

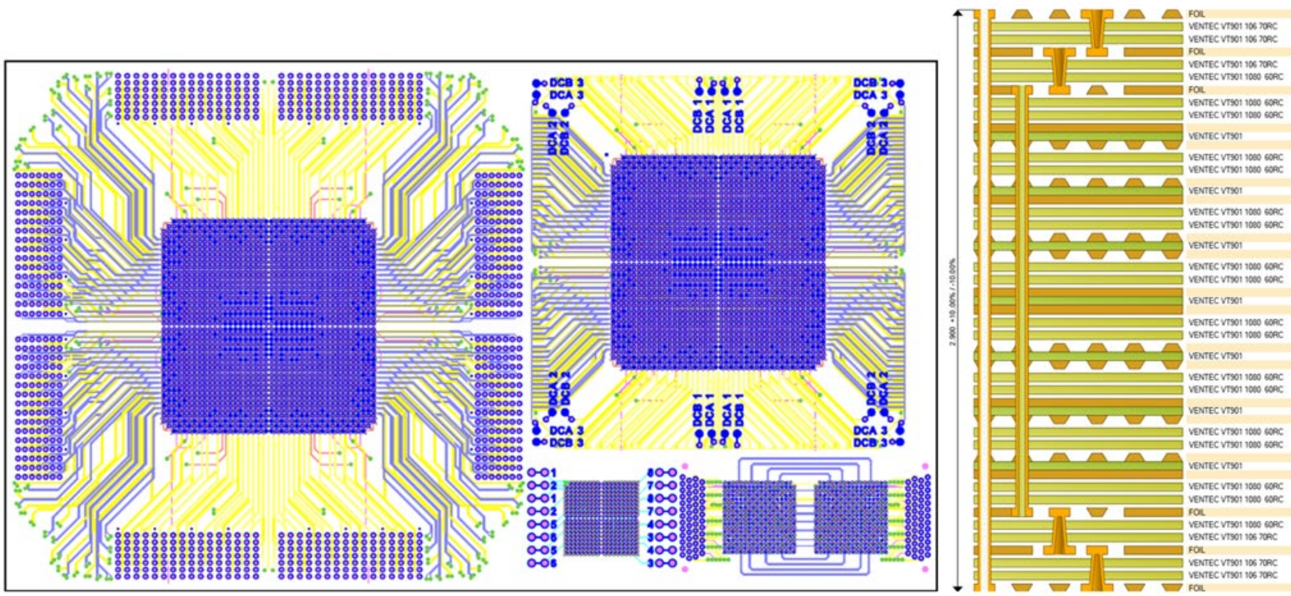


Figure 2: BGA coupon with real and daisy-chain component fanout for 1.0-mm and 0.8-mm pitch component (left) and build-up of the qualification test vehicle (right).

ied via sees higher stress than when the pads are tangent. The same configuration cannot be applied for the 0.8-mm pitch fanout as there is not enough space next to the buried via. The component pad, with microvia 1-2 partially inside the pad, is located above the buried via. Due to the smaller pad size, the microvia 1-2 is located above the buried via, which is considered a reliability risk. The target pad of microvia 2-3 is placed tangent to the pad of the buried via on the opposite side of the buried via.

Two IST coupon designs are included on the panel to cover the most critical design features of the BGA coupon. Next to a TVX coupon for through-vias, an SLX coupon with buried vias and microvias at 0.8-mm pitch is included (microvia configuration as described previously). This SLX coupon contains three sense circuits: buried via (S1), buried plus microvias (S2), and staggered microvias (S3). The coupons are placed on the panel in close proximity to the BGA coupons.

To assess the CAF performance of a given HDI PCB technology, an HDI CAF test vehicle is required that resembles the final product as much as possible (build-up, via configuration, routing, etc.). The HDI component fanout is represented by including buried vias with a pitch of 0.8-mm and 1.0-mm and microvias with a pitch of 0.5 mm. The highest CAF risk for through-vias on HDI PCBs is the high-density connectors with a pitch of 1.27 mm. The minimum distance between a via and a ground plane for buried vias and through-vias is defined by the design rules for minimum conductor spacing (75 µm for basic HDI and 50 µm for complex HDI). The drill diameter for buried vias (0.3 mm) and through-vias (0.5 mm) is copied from the qualification test vehicle design for the basic HDI technology.

Microvias are considered less prone to CAF due to the use of laser drilling instead of mechanical drilling, and their smaller diameter results in a smaller contact area with the glass fibers. Nevertheless, the wall-to-wall spacing of a microvia with 125 µm drill diameter at 0.5-mm pitch is only 375 µm. This is far below the wall-to-wall spacing seen for buried vias or PTHs. To assess this risk, a dedicated microvia test structure is added to the HDI CAF test vehicle. Due to the independent drilling processes, stacked microvias are not considered a higher risk for CAF compared to staggered microvias.

Six types of via-to-via test structures are included in the HDI CAF test vehicle: 0.3-mm drill buried vias with 0.8-mm pitch in a straight and a staggered alignment, 0.3-mm drill buried vias with 1.0-mm pitch straight and staggered, 0.5-mm drill through-via with 1.27-mm pitch straight, and the microvias with 0.5-mm pitch straight. (Straight alignment refers to vias which are directly adjacent, while the staggered alignment offsets the second via with half of the pitch. The term staggered can create confusion with the microvia configuration. IPC-9691B uses the terms in-line and diagonal, respectively.) A number of these test structures are duplicated to cover both the warp and weft fiber direction.

Although via-to-via filament growth is regarded as the dominant form of CAF, via-to-plane test structures remain relevant for HDI. Four via-to-plane test structures are designed with buried vias or PTHs. The diameter of the antipad is the sum of the pad diameter and two times the minimum as-designed spacing for basic HDI (75 µm) or complex HDI (50 µm). In the case of the buried vias (0.6-mm pad diameter), the antipad diameters will be 0.75 mm and 0.7 mm. For the PTHs (0.8-mm pad diameter), this becomes 0.95 mm and 0.9 mm. The test structures consist of 17x17 vias with all internal non-functional pads removed to ensure the failure mechanism is from the hole wall to the conductor.

A single design is used to cover both the basic HDI and the complex HDI technology. To mimic the presence of an additional microvia layer, a dummy lamination is performed before the PTH drilling. This covers the risk of material embrittlement as a result of multiple laminations, affecting the quality of the drilled holes.

The layout of the HDI CAF TV is shown in Figure 3. The distance between connected vias of a given test structure is varied to avoid possible alignment with the glass fiber bundles, resulting in worst-case (or best-case) performance. For the same reason, additional spacing between groups of vias in staggered test structures is foreseen.

Test Methods

The qualification test vehicle is subjected to the qualification test flow for HDI technology as defined in ECSS-Q-ST-70-60C. Group 1 (visual inspection and non-destructive test) consists of visual inspection, dimensional

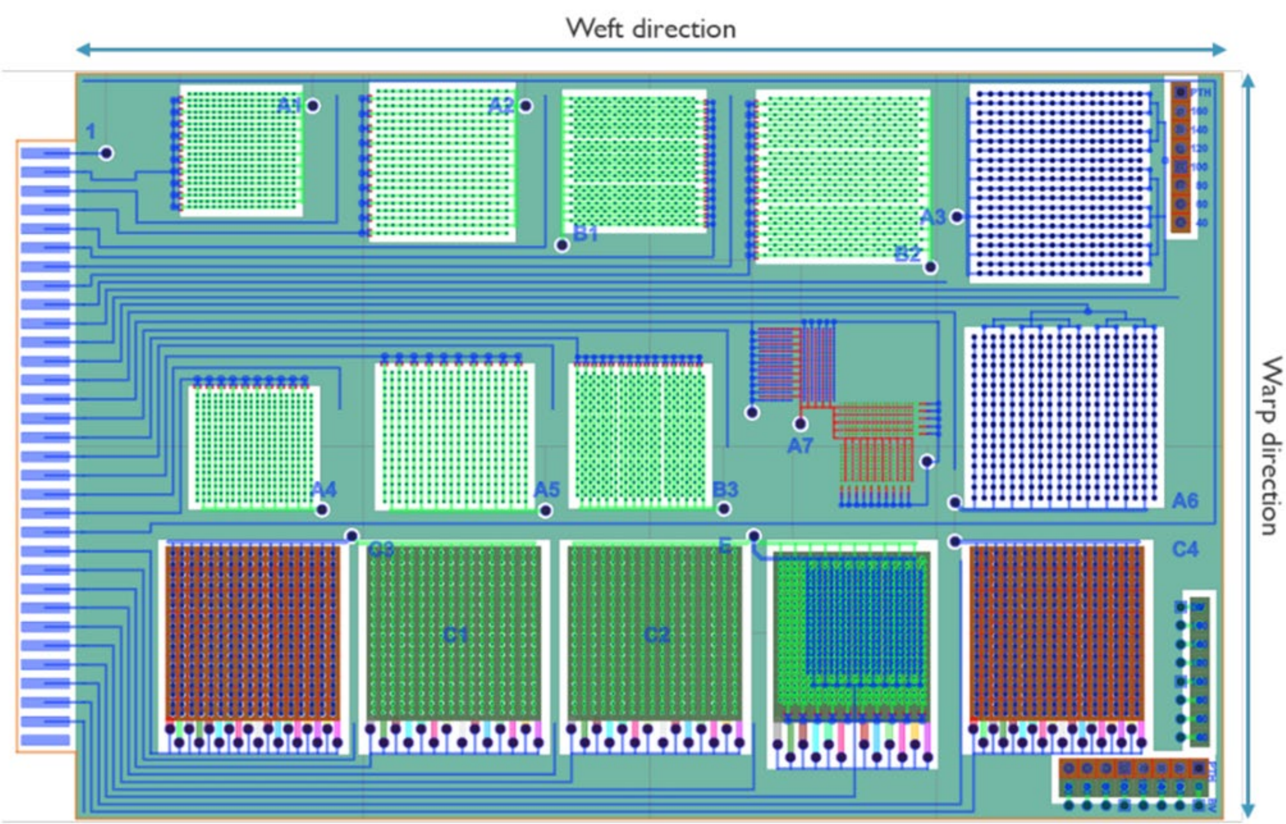


Figure 3: Design and build-up of the HDI CAF test vehicle.

verification, impedance test, cleanliness, and electrical testing. Peel testing is performed in Group 2 (miscellaneous testing), and Group 3 (thermal stress) covers microsectioning before and after solder bath float and rework simulation, and IST. Group 4 (assembly and life test) combines reflow simulation, rework simulation, and thermal cycling. ECM testing is part of Group 5. A selection of test methods is described in more detail later.

Within the ECSS-Q-ST-70-60C standard, IST is an important test method to evaluate the quality of a via (PTH, blind, buried, and microvia). The test method is applied for process monitoring, procurement, and qualification. IST is a form of current-induced thermal cycling and is described in IPC-TM-650-2.6.26 (Method A). The coupon is heated using a power circuit, and the resistance of the structures under test is monitored continuously via the sense circuit(s) of the coupon. The coupon design should represent the PCB technology of the highest complexity and cover all aspects of a given design or technology that are expected to affect thermal endurance.

Before cycling, the coupons are subjected to six times preconditioning to 230°C using a "superheat" circuit. This meandering circuit on the outer layers of the coupon is used to mimic the assembly process. The temperature of 230°C is chosen to represent SnPb assembly, and the six preconditioning cycles should cover the worst-case number of assembly, repair, and rework operations. Blind, buried, and through-vias are cycled from room temperature to 150°C (epoxy-based materials) or 170°C (polyimide) in a three-minute heating and two-minute cooling cycle. The testing is stopped as soon as one of the sensing circuits reaches a 5% increase in resistance at a high temperature compared to the first cycle. Based on an acceleration study, it was determined that an IST endurance of ≥400 cycles should be reached for blind, buried, and through-vias.

Microvia testing using IST follows a different approach. As microvias experience lower stress levels during cycling, the test temperature needs to be increased to apply sufficient stress to the microvia. For epoxy-based materials, a test temperature of 190°C is used, while for polyimide testing, it is performed to 210°C. This stress level is no longer related to the mission profile but applied to determine if the manufacturing quality of the microvia is adequate. Until recently, it was believed that the microvia would fail either early (less than 100 cycles) or not at all. An IST endurance of ≥100 cycles was specified with a maximum increase in resistance of 4%. After encountering failures on microvias that successfully passed the 100 cycles and observing wear-out type failure mechanisms in microvias after a few hundred cycles, it was decided to increase the threshold to 400 cycles, in line with the standard vias. This is further motivated by the microvia reliability concerns described in IPC-WP-023 [10].

An additional caveat with IST of microvias is that the standard power circuit cannot be used to heat the coupon. The (buried) vias within the power circuit would obviously fail before the microvias. For microvia testing, the coupon can be heated using the superheat circuit, or the power can be connected directly to a sense circuit containing the microvias. The drawback of the latter is that only one circuit can be tested at a time, but the temperature of the microvia can be better controlled. ECSS-Q-ST-70-60C specifies power-on-sense as the preferred method, based on the recommendation from PWB Interconnect Solutions Inc. (Ottawa, Canada).

The reference test method for evaluating thermal reliability remains thermal cycling. This is performed in a single chamber system at ambient pressure. The test samples are subjected to reflow simulation (two times vapor phase reflow at 215°C) and rework simulation (ten times manual soldering) after baking for eight hours at 120°C. Following the reflow and rework simulation, the coupons are submitted to 500 cycles from -55°C to +100°C (10°/min and 15 min dwell time). As this is commonly applied for project qualification, a shorter test consisting of 200 cycles from -60°C to +140°C is also applied. Electrical monitoring of daisy chains can be performed during testing in addition to the required evaluation method of microsectioning afterward.

ECSS-Q-ST-70-60C specifies the following protocol for CAF testing:

- Ambient phase using the parameters: 24h, 25°C, 50% RH, 0V
- Preconditioning phase using the parameters: 96h, 85°C, 75% RH, 0V
- CAF phase using the parameters: 500h, 85°C, 75% RH, 50V
- Ambient phase using the parameters: 24h, 25°C, 50% RH, 0V

The overall approach is in line with IPC-TM-650 2.6.25B, with two noticeable exceptions. The test voltage of 50 V is chosen to follow the guideline of two times the maximum voltage for HDI technology (in fact, the maximum voltage is 30 V, but 50 V is deemed a more standardized test voltage). The test applies a relative humidity of 75% RH, which is less than the 85% RH specified in 2.6.25B. But this still provides some margin and acceleration of test compared to the maximum relative humidity of 65% in cleanrooms for ground testing and assembly. Sample preparation before testing consists of electrical registration measurement and baking, followed by six times vapor phase reflow at 215°C, ultrasonic cleaning, and again baking for eight hours at 120°C.

Test Results

Three panels were selected from the QTV manufacturing batch and subjected to the tests described previously. Each panel contains three IST coupons (one TVX and two SLX coupons), two BGA coupons, and two times the dedicated test structures for HDI qualification test flow (coupons A/B, Bn, E, H, and P). For CAF testing, 10 samples of the HDI CAF test vehicle were manufactured. All manufacturing was performed by ACB (Dendermonde, Belgium).

Nine coupons from three different panels are subjected to IST. Plated through-holes and through-vias are evaluated on coupons TVX3A, 6A, and 9A. Buried vias are tested on coupons SLX3A, 6A, and 9A, and coupons SLX3B, 6B, and 9B are used for microvia evaluation. Prior to testing the microvias, the buried vias on coupons SLX3B, 6B, and 9B are subjected to 500 cycles to 170°C (with preconditioning) to reflect the test conditions for procurement.

The IST results are shown in Tables 2 through 5. The through-vias on the TVX coupon reach between 596 and 741 cycles. This is well above the requirement of 400 cycles, although a 500 µm via in a 2.8-mm polyimide board could be expected to sustain longer testing. The pitch ("grid") of the vias in the test coupon was 1.27 mm to represent the high-density connector layout, which could explain the lower number of cycles that is reached compared to the previous testing at a larger grid.

The SLX coupons contain three sense circuits. Sense 1 (buried vias only) and Sense 2 (buried vias and microvias) were monitored during testing of the buried vias. Testing is stopped when both sense circuits have reached the acceptance criteria of a 5% resistance increase. Sense 3 (microvias only) is used for

Coupon	Power Cycles	Power %	S1 Cycle	S1 %	Result
TVX3A	n.a.	2.0	596	5	PASS
TVX6A	n.a.	1.8	626	5	PASS
TVX9A	n.a.	1.5	741	5	PASS

Table 2: Results for through-vias tested at 170°C after six times preconditioning to 230°C.

Coupon	Power Cycles	Power %	S1 Cycle	S1 %	S2 Cycle	S2 %	Result
SLX3A	n.a.	1.6	493	5	528	5	PASS
SLX6A	n.a.	2.6	449	5	450	5	PASS
SLX9A	n.a.	2.1	559	5	560	5	PASS

Table 3: Results for buried vias tested at 170°C after six times preconditioning to 230°C.

Coupon	Power Cycles	Power %	S1 Cycle	S1 %	S2 Cycle	S2 %	Result
SLX3B	n.a.	2.6	407	5	407	5	PASS
SLX6B	500	0.8	500	3.6	500	3.5	PASS
SLX9B	500	1.2	500	4.8	481	5	PASS

Table 4: Results for pre-cycling of buried vias after six times preconditioning to 230°C.

Coupon	Power S3 Cycles	Power S3 %	Sense H Cycle	Sense H %	Result
SLX3B	285	4	n.a.	3.1	FAIL
SLX6B	500	2.3	500	1.3	PASS
SLX9B	500	3.0	500	2.4	PASS

Table 5: Results for microvias tested at 210°C after six times preconditioning to 230°C and 500 cycles at 170°C.

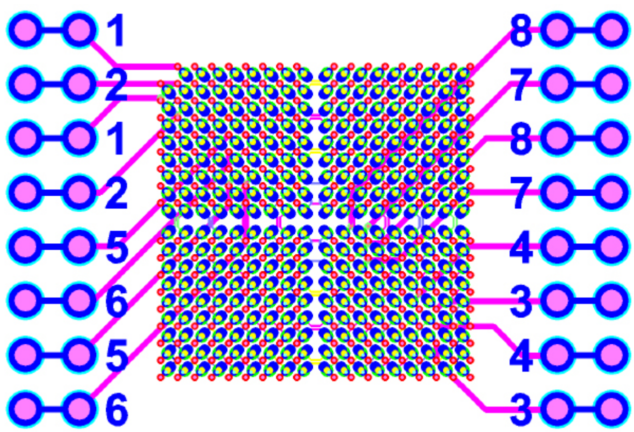
microvia testing (power-on-sense). The buried vias have an aspect ratio close to eight (300 µm drill diameter in a 2.4-mm core). The number of cycles reached is between 449 and 560, which is above the requirement and in line with expectations. Pre-cycling for the buried vias on the microvia test coupons (SLX3B, 6B, and 9B) shows a similar result of 407 to >500 cycles. The required endurance is reached on all coupons, although the margin on coupon SLX3B is slim.

Two out of the three coupons for microvia testing reached the required 400 cycles. Testing of these coupons was stopped after 500 cycles to 210°C. Coupon SLX3B failed after 285 cycles and did not reach the required endurance. As the failure could not be located using thermal imaging, failure analysis was performed by microsectioning the entire coupon row by row. Optical inspection revealed cracks near the target pad of microvia 1-2. These cracks are observed on two microvias in the central zone of the coupon. The other microvia levels in this zone did not show any cracks. In other areas of the coupon, no cracks were detected on any of the microvia levels. Microvia 1-2 in the SLX coupon is located partially above the buried via (0.8-mm pitch fanout configuration). It is known that this leads to higher stress. If the microvias in coupon SLX3B are slightly misaligned and thus overlap more with the buried via as compared to the other panels, this could explain the early failure.

Three BGA coupons were submitted to the assembly and life test flow. The test samples were subjected to reflow simulation (two times vapor phase reflow at 215°C). In addition, rework simulation (ten times manual soldering) was performed on plated through-holes of the high-density connectors on the BGA coupon (two times four PTHs). All coupons were baked for eight hours at 120°C before reflow and rework simulation. BGA6A and 9B were subjected to 500 cycles from -55°C to +100°C, while BGA6B was subjected to 200 cycles from -60°C to +140°C. Thermocouples are attached to all BGA coupons to monitor the board temperature during testing. The interconnection resistance of the daisy chains in the 0.8-mm pitch fanout was monitored during testing (four-point resistance measurement every five seconds using Keithley 3706A Systems Switch/Multimeter). The final evaluation was performed by microsectioning.

Figure 4 shows the details of the daisy chains in the 0.8-mm pitch fanout used for electrical monitoring. DC1 connects all the vias in the outer row of the component fanout, DC2 connects all the vias in the second row, and so on. Only the buried vias are included in the daisy chains, and the number of buried vias per chain is indicated in the table on the right.

Electrical monitoring during thermal cycling (Table 6 and Table 7) showed only a minimal increase in resistance for both temperature ranges. This confirms the positive IST results for the buried vias. Microsectioning did not reveal any cracks initiating in the barrel of the buried via nor any anomalies in the microvias.



Chain	# vias	Chain	# vias
DC1	68	DC5	36
DC2	60	DC6	28
DC3	52	DC7	18
DC4	44	DC8	24

Figure 4: Layout and number of vias of the daisy chains in the 0.8-mm pitch fanout.

Board	Chain	R (Ω) at Room Temperature	R (Ω) at High T First Cycle	R (Ω) at High T Last Cycle	Resistance Increase (%)
BGA6A	DC1	0,801	1,045	1,058	1,2%
BGA6A	DC2	0,725	0,946	0,958	1,3%
BGA6A	DC3	0,616	0,803	0,813	1,3%
BGA6A	DC4	0,546	0,712	0,721	1,3%
BGA6A	DC5	0,429	0,559	0,567	1,5%
BGA6A	DC6	0,372	0,484	0,491	1,5%
BGA6A	DC7	0,278	0,361	0,368	1,8%
BGA6A	DC8	0,263	0,341	0,347	1,8%
BGA9B	DC1	0,824	1,056	1,086	2,8%
BGA9B	DC2	0,744	0,953	0,980	2,8%
BGA9B	DC3	0,635	0,814	0,836	2,8%
BGA9B	DC4	0,564	0,722	0,742	2,8%
BGA9B	DC5	0,445	0,570	0,586	2,8%
BGA9B	DC6	0,383	0,490	0,504	2,8%
BGA9B	DC7	0,273	0,350	0,360	2,8%
BGA9B	DC8	0,255	0,326	0,335	2,9%

Table 6: Results of the electrical monitoring during thermal cycling (500 cycles from -55°C to +100°C).

Board	Chain	R (Ω) at Room Temperature	R (Ω) at High T First Cycle	R (Ω) at High T Last Cycle	Resistance Increase (%)
BGA6B	DC1	0,817	1,190	1,200	0,84%
BGA6B	DC2	0,740	1,078	1,087	0,85%
BGA6B	DC3	0,632	0,920	0,928	0,88%
BGA6B	DC4	0,559	0,814	0,821	0,87%
BGA6B	DC5	0,441	0,641	0,647	0,91%
BGA6B	DC6	0,385	0,560	0,565	0,87%
BGA6B	DC7	0,295	0,429	0,433	0,97%
BGA6B	DC8	0,276	0,402	0,405	0,94%

Table 7: Results of the electrical monitoring during thermal cycling (200 cycles from -60°C to +140°C).

The CAF testing was performed on 10 samples in a CTS CS-40/200 climate chamber using a Gen3 Systems Auto-SIR 256 with a 256-channel test rack. Sample preparation started with the measurement of the registration on the electrical test structures included on the test vehicle. A maximum misregistration of ≤60 µm was measured for the PTHs on three samples. For all other samples, as well as for all the buried vias on all samples, the misregistration was below the lowest detectable level of 40 µm. Subsequently, the samples were submitted to reflow simulation (six times reflow at 215°C). After reflow simulation, the samples were visually inspected and cleaned using isopropyl alcohol (IPA). Finally, the samples were placed in the oven for baking (eight hours at 120°C).

The samples were mounted in the test rack and kept in the chamber for 24 hours before raising the temperature (85°C) and the humidity (75% RH). The first measurement was performed just before the temperature was increased. During the preconditioning phase (85°C and 75% RH without bias), measurements were taken every 24 hours. After 96 hours of soaking, the actual CAF phase started, and a bias voltage of 50 V was applied to the samples. Measurements were then taken from all samples every 15 minutes. The test continued for 500 hours, after which the bias was switched off, and the measurement programs stopped. The temperature and humidity were reduced to 25°C and 50% RH. The samples were kept inside the chamber for an additional 24 hours when the final measurement was performed.

A detailed overview of the HDI CAF test results and associated failure analysis will be published elsewhere. As an example, Figure 5 shows the results for buried vias in a straight configuration with a pitch of 0.8 mm and 1.0 mm for both the warp and weft direction of the glass fibers. Figure 6 shows the results of the microvia test structure.

The failure criteria is a drop in resistance of more than one decade compared to the baseline resistance after 96 hours of soaking. No failures are observed between microvias at 0.5-mm pitch, buried vias at 1.0-mm pitch, or PTHs at 1.27-mm pitch. Some failures occur between buried vias at 0.8-mm pitch. Most failures are detected in the via-to-plane test structures, especially for the PTHs. There is no significant difference between the antipad diameter for basic and complex HDI

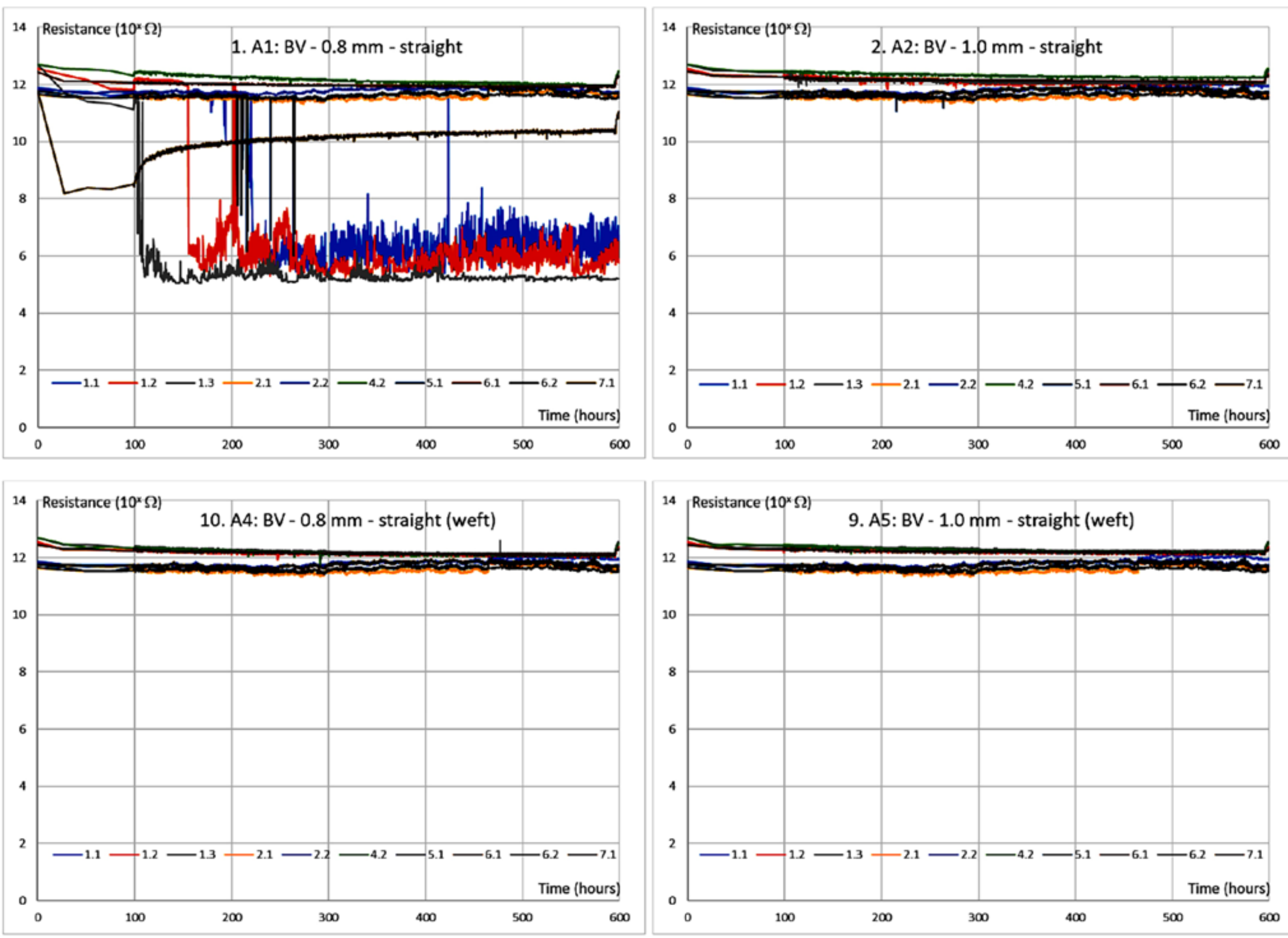


Figure 5: CAF test results for buried vias in a straight configuration with a pitch of 0.8 mm (left) and 1.0 mm (right) for both the warp (upper row) and weft direction (bottom row) of the glass fibers.

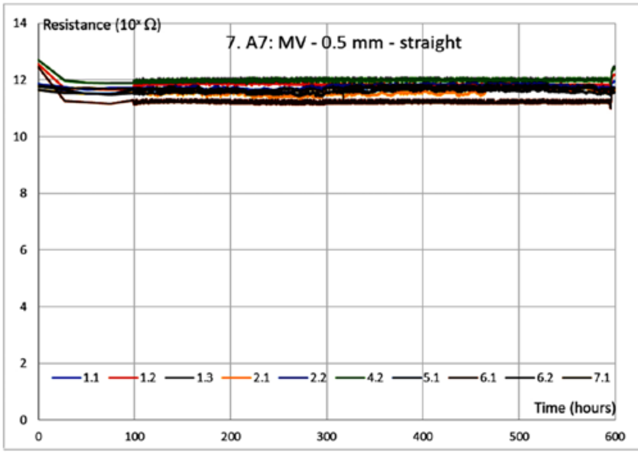


Figure 6: CAF test results for microvias in a straight configuration with a pitch of 0.5 mm.

(75 µm vs. 50-µm spacing). The exact nature of these failures is not yet known at the time of writing of this article, and failure analysis is ongoing.

A dedicated test vehicle was designed to match the requirements of the HDI technology parameters. The design of this HDI CAF TV differs significantly from the more widely used IPC test coupons and derivations. The layer count is twice as high (20 layers versus 10 layers typically), doubling the number of opportunities for CAF, affecting drill quality, and introducing a higher risk for contamination with foreign material. The use of sequential lamination (risk of embrittlement) and internal plated layers (thick copper) makes achieving a good drill quality more challenging and better represents the actual board.

The rationale behind this test vehicle and, by extension, the CAF test methodology can be debated. CAF testing can be performed at different levels: material evaluation, qualification of a given design and material at a selected manufacturer, or as a batch release for each procurement. While material screening, at possibly elevated stress levels, is relevant for material development and comparison, it is insufficient since it does not take into account the manufacturing. Some experts are of the opinion that CAF is batch related and should therefore be done as part of the release procedure during outgoing test. In the ECSS working group, CAF testing as part of a qualification test flow was deemed an adequate compromise. The possible variations in manufacturing can be considered covered by the use of qualified manufacturers having a PID (process identification document). The CAF risk of a given design needs to be reviewed case by case to ensure that the qualification testing covers (i.e., is representative of worst-case or highest technological capability) for the procured PCB design.

Conclusion

During the workshop, the relevant AADs for space applications were identified. Based on the mechanical and functional requirements of these components, the technology parameters and associated design rules were determined. Two categories of HDI technology are considered: two levels of staggered microvias (basic HDI) and (up to) three levels of stacked microvias (complex HDI).

This article presents the main results of the qualification test flow for basic HDI technology. The through-vias and buried vias reached the required IST endurance of 400 cycles. The microvia configuration for the 0.8 m pitch fanout might be the cause of the early failure in IST. Electrical monitoring during thermal cycling showed only a minimal increase in resistance for both temperature ranges. Microsectioning after cycling did not reveal any cracks initiating in the barrel of the buried via nor any anomalies in the microvias. For the CAF testing, no failures were observed between microvias at 0.5-mm pitch, buried vias at 1.0-mm pitch, or PTHs at 1.27-mm pitch. Some failures occurred between buried vias at 0.8-mm pitch. Most failures were detected in the via-to-plane test structures, especially for the PTHs. All other tests in the qualification test flow were passed successfully.

The qualification of the basic HDI technology is only the first step in this extensive study on HDI technology for space applications. An extensive reliability assessment is underway. Various test methods for microvias will be evaluated to arrive at a test flow that can assure an adequate confidence level for both procurement and qualification.

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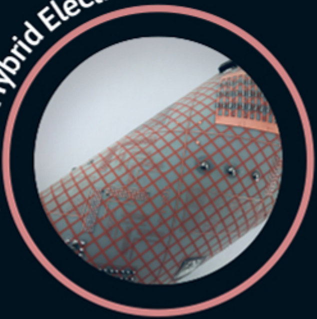

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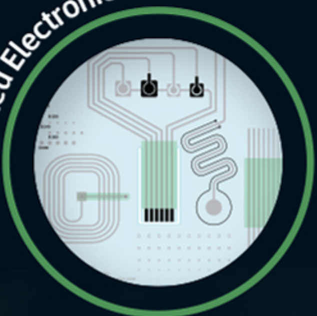

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Acknowledgment

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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.

Bill with his loyal Bernese Mountain Dog, Sawyer.

Bill received a bachelor of science degree in engineering, physics, and computer science from Loyola College and a diploma from Baltimore Technical Institute in electronics, broadcast engineering, and industrial electronics.

Before founding The Test Connection Inc. in 1980, Bill had advanced through 20 years in senior ATE and quality management positions at major corporations, such as GenRad, Bendix, Westinghouse, Plantronics, and Hydranautics.

The Test Connection Inc., located in Hunt Valley, Maryland, has been a reliable source for quality test engineering solutions. In light of the growing trend of outsourcing test engineering products and services, Bill founded TTCI and built this test engineering service with the purpose of responding to this need.

He proudly served as a member of the U.S. Army in the special Nike Hercules Fire Control Unit. As an active participant in the ATE community, Bill presented papers and co-sponsors events at major ATE seminars and user group meetings. He was a strong advocate for the local Capitol Chapter of SMTA.

Bill was born Wilbert August Horner on September 17, 1939, in Baltimore, Maryland. He was preceded in death by his wife, Margaret Horner. He is survived by Bert Horner and his wife Monica, Michele Reichart and her husband Shawn, and grandchildren Alex, Leah, Addison, and Cooper.

Editor's Picks from SMT007.com

1 Würth Elektronik Develops CHARM for Robust Electronics for Harsh Industrial Environments ▸

In June 2020, Würth Elektronik started the EU project CHARM together with 36 European partners. The goal of the ECSEL JU project CHARM is to develop industrial IoT solutions that have an improved tolerance to harsh industrial environments.

2 Lean Digital Thread: Accelerating Global New Product Introduction ▸

Sagi Reuven

James Dyson once said, "Manufacturing is more than just putting parts together. It's coming up with ideas, testing principles, and perfecting the engineering, as well as the final assembly." In this column, Sagi Reuven describes the importance of process engineering or new product introduction (NPI) and how process engineers can make a big difference.

3 X-Rayted Files: A Century of X-Rays in the Automotive Industry, Part 2 ▸

Dr. Bill Cardoso

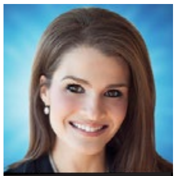
As one of the main users of X-ray inspection, the automotive industry has been one of the main drivers for the development of higher power and higher resolution X-ray imaging systems. Dr. Bill Cardoso continues with Part 2 of this column series.

4 Zulki's PCB Nuggets: What's Different Between C2 and C4 for PCB Microelectronics Assembly? ▸

Zulki Khan

In Zulki Khan's last column, he talked about flip-chip ball grid array (BGA), or FCBGA, making its grand entrance into PCB microelectronics assembly. But that subject requires a lot more digging to get the full story for OEMs planning highly advanced products that demand PCB microelectronics assembly.

5 Foundations of the Future: Inspirational Career Paths—Meet Tayler and Olivia ▶


Gunter du Plessis

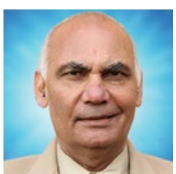
Charlene Gunter du Plessis connected with Tayler Swanson, an engineering team member at Digital Instruments Inc., and Olivia Lim, a manufacturing engineer at Kimball Electronics, to discuss their studies, professional career journeys, and exciting opportunities in the electronics manufacturing industry.

6 SMTA Additive TechXchange Keynote: An Outlook on Advanced PCB Fab ▶


Jeff Doubrava

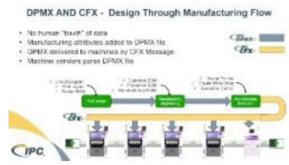
Tara Dunn of Omni PCB, SMTA's Additive TechXchange addressed additive technology specifically in the context of the electronics industry. Pete Starkey details the keynote presentation, an outlook on advanced printed circuit board fabrication, from Jeff Doubrava, managing partner at Prismark Partners.

7 SMT Solver: How to Audit OEM-EMS Assembly Capability, Part 2 ▶


Ray Prasad

During the past two decades, there has been a tremendous increase in outsourcing by OEMs to EMS companies, which also results in a decrease in yield. In this column, Ray Prasad focuses on the technology and manufacturing capabilities of the supplier.

8 Koh Young Joins IPC-DPMX Consortium to Further Enable Smart Factory Automation ▶



Koh Young, an industry leader in True3D™ measurement-based inspection solutions, proudly announced it joined the IPC-DPMX (IPC-2581) Consortium to advance the adoption of a data and transfer methodology, which will improve efficiency and reduce costs for electronics manufacturers.

9 Part 7 of Siemens' Digital Twin Webinar Series: Optimizing Inspection and Test Engineering ▶

In Part 7, Gorajia's discussion centers on how to "Optimize Inspection and Test Engineering." In this segment, he focuses on building the best inspection and test outputs, leveraging learning libraries, and allowing some "art."

10 IPC Standards Development: Business Challenges and an Inside View ▶


Graham Naisbitt

The rapid pace of technology development, miniaturisation, and high-density packaging is presenting new opportunities, but with them come challenges involving traceability and quality control. Graham Naisbitt addresses SMT-related IPC standards as a chair and vice-chair of several committees.

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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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U.S. CIRCUIT

Sales Representatives (Specific Territories)

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

- Florida
- Denver
- Washington
- Los Angeles

Experience:

- Candidates must have previous PCB sales experience.

Compensation:

- 7% commission

Contact Mike Fariba for more information.

mfariba@uscircuit.com

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