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SMT007 MAGAZINE

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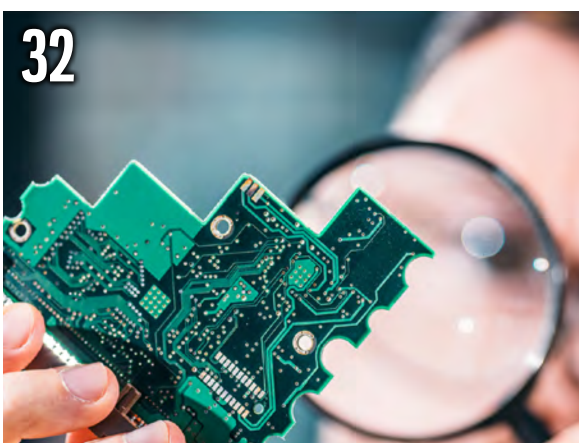
5G: Testing the Future Impact

In line with its significant improvement over the current generation of wireless technologies, 5G also offers device and systems manufacturers a challenge—electrical and functional testing, among others–as they deal with the technology's millimeter wave frequencies. This month's issue of *SMT007 Magazine* looks into how the industry can successfully tackle this process.



SMT007 MAGAZINE

5G: Testing the Future Impact

Editor's Note
by Stephen Las Marias, I-CONNECT007

The 2018 Winter Olympics in Pyeongchang, South Korea, proved to be a successful real-life demo of the performance, reliability, and use cases of 5G. Intel, in collaboration with South Korean telecoms provider KT Corp., delivered a broad-scale 5G network to the Olympic Games that provided spectators the opportunity to immerse themselves in the event through live 360-degree video streaming, virtual reality, and augmented reality (VR/AR). The company also set up multiple ultra-high definition cameras, connected via 5G, to show athletes' views from various angles as they performed incredible stunts and performances. The event also served as a real-life testbed as to how different devices interoperate with the new technology.

Following this successful demonstration of 5G, Japan, meanwhile, is also planning to showcase 5G innovations throughout the Tokyo 2020 Summer Olympics. According to Persistence Market Research, this will add to the forecast growth of the 5G market, on top of the enhanced internet coverage, increased adoption of mobile broadband, and growing machine-to-machine communications.

"It's a new network architecture, an extension of 4G technology," says Jacky Yeung, regional operation head of China for EMS firm Integrated Micro-Electronics Inc., in a recent interview. "5G is much faster than 4G or 3G. It also can apply to wider application areas apart from mobile communications, such as AR/VR applications, industrial automation, smart homes, autonomous vehicles, and intelligent logistics. This new technology certainly will bring new opportunity, promote

Jacky Yeung

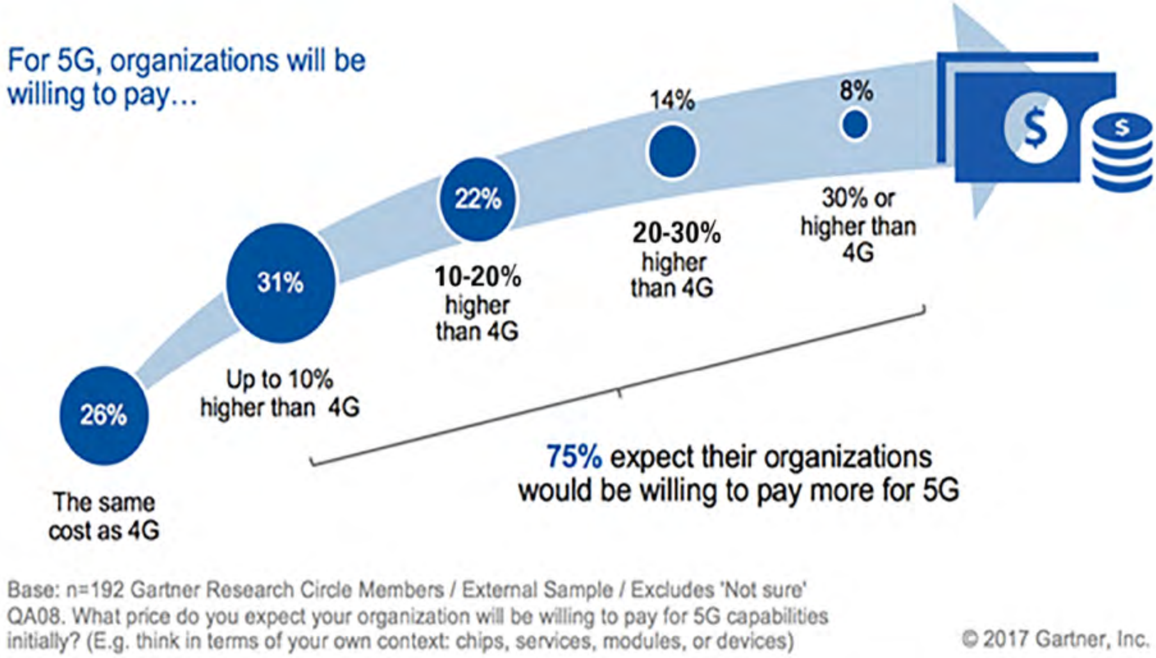


Figure 1: Three out of every four end-user organizations say they would be willing to pay more for 5G.

significant change in various industries, and create new business structures."

Industry analyst firm Occams Business Research Consulting expects the global 5G network infrastructure market to register a 70% CAGR from 2016 to 2023 and reach up to $28 billion by the end of the forecast period. North America is the leading market for 5G network infrastructure technology and is a strong player of the R&D in 5G, with key market players including Verizon and AT&T having plans for establishing 5G networks. The two companies have successfully completed trials to ensure deployment of 5G by 2023, according to Occams Business Research Consulting.

In fact, a recent global survey by Gartner found that 75% of end-user organizations would be willing to pay more for 5G, especially those in the telecom industry (Figure 1).

Testing 5G

Despite these bullish projections, however, the impending arrival of 5G is not without its entourage of challenges that will require a different approach in the electronics manufacturing process. One that is already impacting the electronics manufacturers and assemblers is the testing of the devices.

In our discussion with Stig Källman, component engineer, PCB, at Ericsson, he mentioned that the testing of the devices is challenging because they cannot connect a cable to the antenna. Therefore, signal testing must be done over-the-air.

The advent of millimeter-wave in mainstream electronics means that manufacturers, in some cases, are insisting that these radios be tested in the manufacturing process, according to Roger Nichols, 5G program manager at test and measurement provider Keysight Technologies Inc. "But these measurements must be made not only within chambers that are shielded, but also anechoic, and, in some cases, temperature-controlled. All these technologies are not new to the industry, but what is new is the aspect of applying them all to a relatively high-volume manufacturing process. This adds the complexity of making an accurate measurement, quickly, over-the-air (no galvanic connections), and moving the device-under-test (DUT) in and out of the chamber in an efficient manner. This also implies a robust repetitive controlled environment with minimal down-time and the flexibility to change the DUT form-factor."

The same is being said by Mathieu Kury, business development manager of EMS provider Asteelflash USA Corp., in another interview. He notes that the challenge they are currently seeing with existing devices is mostly around functional testing targeted towards mass production. While it's relatively easy to test one device at a time, it's another story to test hundreds of them at once. He said these aspects must be taken into consideration at the design stage through a thorough design for testability (DFT) analysis targeted towards mass production. "To do so, it will require not only to be supported by design firms, but more importantly, by a manufacturing/assembly company integrating these DFT principles into their operations and processes," adds Kury.

Yeung (IMI) said functional testing is a challenge, therefore test equipment manufacturers need to develop corresponding advanced testing devices to support 5G technology in different application areas. "It's important for test manufacturers to promote 5G R&D, because with these test systems, designers will be able to verify their 5G systems and project commercial capabilities." Yeung also highlighted several challenges that need to be ironed out when it comes to 5G, such as the lack of unified standards and the shortage of spectrum.

Once these barriers have been overcome, 5G will be a revolution, says Yeung. "When 5G becomes widely available, it will be the era of the Internet of Things, and peoples' lives will be more convenient than ever."

This month's issue of *SMT007 magazine* examines these issues pertinent to the assembly industry when it comes to 5G; strategies—from a testing standpoint—to address these manufacturing issues; and the overall opportunities 5G will offer. **SMT007**

Stephen Las Marias is managing editor of *SMT007 Magazine*. He has been a technology editor for more than 14 years covering electronics, components, and industrial automation systems.

Demo Shows How 5G Enables Real-Time Data Analyses and Adaptive Control of Production Processes

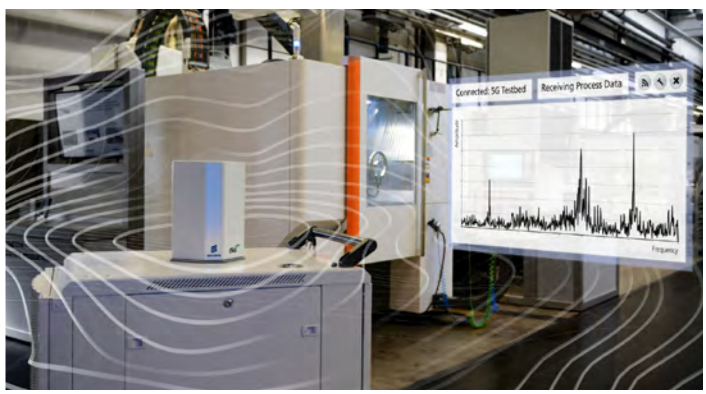
The production of aero engines is a complex and expensive business, with the whole manufacturing chain of a compressor component known as blisk (blade-integrated disk) easily costing up to ($241K USD). In this environment, the highest levels of safety and quality standards must be observed, and computer-controlled machine tools have to be programmed to ensure that the components are produced exactly as stipulated in the design plans.

While sensors continuously record measurements to check that everything is running according to plan and to enable any errors in the industrial production environment to be recognized at an early stage, however, as a rule, evaluation of the data is decentralized and takes place after a time lag.

To address this, Fraunhofer-Gesellschaft teamed up with Ericsson to offer a unique test environment for 5G applications in industry. The partners used aero-engine component manufacture as an example to demonstrate live, for the first time, the opportunities provided by the technology at the Hanover Fair last month.

In this demo, Fraunhofer has attached a specially-developed sensor directly to the component, which transfers the vibration spectra of the blisk via 5G with sub-millisecond latency to software that recognizes immediately whether the vibrations exceed the permitted maximum or have reached critical frequencies and adapts the production process accordingly without delay.

This demo underscores how 5G technology accommodates the use of wireless sensor connections for real time data analyses and adaptive control of production processes with short reaction times.



The Role of Bismuth (Bi) in Electronics, Part 4

SMT Prospects & Perspectives

by Dr. Jennie S. Hwang, CEO, H-TECHNOLOGIES GROUP

To link science and technology with commercial applications, Part 4 of this series continues to address two pivotal questions: Why SAC is not able to be a universal interconnecting material for electronic circuits, and why a quaternary alloy system offers a more wholesome approach (note: a quaternary system referred herein does not include SAC incorporated with one or more doping elements).

The baseline for designing a viable solder joint material for applications in advanced electronic circuit boards that require increasingly higher functionalities and higher power in a small form factor is to deliver reliable physical properties and mechanical performance that are not lower than 63Sn37Pb alloy. Another baseline characteristic is to provide an alloy that can adapt to the established electronics manufacturing infrastructure including production flow, process parameters and compatibility with the thermal stability of a PCB and a variety of components. One of the critical process parameters is the required minimum peak temperature in the reflow process that enables mass production capable of delivering high throughput without introducing production defects and/or insidious thermal damage to the internal structure of a PCB and components. To this end, the alloy shall possess "agile" wetting ability and a compatible melting (liquidus) temperature. In this regard, wetting ability controls not only interfacial metallurgical interaction but also the rate of interaction that needs to be in sync with the inherent characteristics of the reflow process.

With these baselines in mind, a viable alloy should possess an adequate thermal fatigue resistance to withstand the increasingly adverse and harsh conditions in microelectronics and electronic applications while providing a moderate melting temperature (170°C–215°C, more desirably 175°C–213°C) suitable for sound manufacturability without causing undue thermal damages.

This was the genesis of designing quaternary alloys, as stated in many of my professional development courses, workshops, webinars and publications since the late 1980s, including the U.S. Patent 6,176,947 (1999).

The ability to deliver a higher performance level in thermal fatigue resistance is particularly critical to connecting those high-power, large-size IC components onto the circuit board, as these components impose a larger amount of thermal stress on solder joints during power-on/power-off and/or elevated temperature excursion. In mobile electronics, these thermal excursion-related stresses may be compounded with machinal-shock related stresses that could be occurring during the product's useful life.

SnAgCuBi is one of the quaternary systems studied[1]. Again, it is important to accentuate that the scientific base to design the SnAgCuBi system was not to add an element (in this case, Bi) to an SAC alloy. Rather, it was a material innovation holistically using the underlying science and engineering of metallurgical principles by taking the commonly-occurring solder joint failure mechanisms into consideration. In other words, the objective was to mitigate those likely failure mechanisms so that solder joints can reliably connect the ever-powerful semiconductor chips to the outside world by serving as electrical, thermal and physical conduits at chip level, package level and on circuit boards.

How do the proper compositions of the SnAgCuBi alloy system (containing 2.5–3.5 % Ag, 0.2–2.5% Cu, 0.5–4.0% Bi, balance Sn) perform in comparison with the standard alloys? (Note: All compositions expressed herein are in weight percent.)

Comparison with SnPb Eutectic–63Sn37Pb

As an example, take Sn3.0Ag0.5Cu2.0Bi as the composition. It offers higher strength as well as more than 200% higher fatigue life than 63Sn37Pb in accordance to ASTM Standard E606-92 (Standard Practice for Strain-Controlled Fatigue Testing).

Comparison with SnAg Eutectic–96.5Sn3.5Ag

The composition of Sn3.0Ag0.5Cu3.0Bi has a melting temperature 209-212°C that is 9°C lower than the eutectic 96.5Sn3.5Ag (221°C). When comparing the basic mechanical properties with 96.5Sn3.5Ag, Sn3.0Ag0.5Cu3.0Bi composition performs better in strength and fatigue life—more than 150% higher in fatigue life.

Comparison with SnCu Eutectic–99.3Sn0.7Cu

Sn3.0Ag0.5Cu3.0Bi demonstrates significantly better performance in strength and fatigue, but lower plasticity than 99.3Sn0.7Cu. Its melting temperature is 15°C lower than 99.3Sn0.7Cu.

Comparison with SnAgCu Near-eutectic–Sn3.0Ag0.5Cu (SAC305)

Sn3.0Ag0.5Cu2.0Bi exhibits high strength (both yield and tensile strengths and higher thermal fatigue life). Another important advantage of SnAgCuBi over SnAgCu is the ability to offer lower liquidus temperature. The composition of Sn3.0Ag0.5Cu2.0Bi offers 7°C lower than SAC305. Further, the intrinsic wetting ability of SAC system does not measure up to that of SnPb or SnCu. With SAC305's high liqiudus temperature, the tendency to use a process peak temperature below the optimal temperature often leads to a marginal process, which further aggravates the SAC305's lower wetting ability, thus increasing potential production defects.

Focusing on the integrity of a printed circuit board assembly, the liquidus temperature of the interconnecting solder alloy plays an important role in alleviating any potential defects or thermal damages to components or PCB, which can be detectable or undetectable on the production floor or during quality control verification. Concentrating on solder joint reliability, the thermal fatigue resistance sits front and center to the performance and reliability of a circuit board.

Overall, the SnAgCuBi system offers more robust performance than any of practical binary alloys, such as 63Sn37Pb, 96.5Sn3.5Ag, or 99.3Sn0.7Cu, and ternary alloys, such as SnAgBi and SnAgCu. In comparison with SAC305, Sn3.0Ag0.5Cu2.0Bi exhibits higher strength (both yield and tensile strengths). More importantly, its thermal fatigue life is higher under harsh conditions (e.g., a large temperature swing, high-temperature excursion). Further important advantages of SnAgCuBi over SnAgCu are its lower melting temperature and superior intrinsic wetting ability. The practical compositions can offer as much as 9°C lower in melting temperature than SAC305.

Melting at a few degrees lower, SnAgCuBi compositions are advantageously positioned for circuit board manufacturing. Embracing diverse PCB assemblies and process window requirements to achieve high yield, low-production defect rates, an alloy having a melting temperature below 215°C is considered necessary to deliver robust manufacturability.

Part 5 in this series will outline the underlying operating mechanism among the four elements (Sn, Ag, Cu, Bi) of SnAgCuBi system and elemental dosages in relation to desirable performance properties. SMT007

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Environment-friendly Electronics—Lead-free Technology, Chapter 10, Electrochemical Publications, Great Britain.

About the Author: **Dr. Hwang,** an international businesswoman, international speaker, and business and technology advisor, is a pioneer and long-standing contributor to SMT manufacturing since its inception, as well as to the lead-free electronics implementation. Among her many awards and honors, she is inducted to the International Hall of Fame for Women in Technology, elected to the National Academy of Engineering, and named an R&D-Stars-to-Watch and YWCA Achievement Award recipient. Having held senior executive positions with Lockheed Martin Corp., Sherwin Williams Co., SCM Corp, and IEM Corp., she is currently CEO of H-Technologies Group, providing business, technology and manufacturing solutions. She serves as Chairman of Assessment, on the Board of DoD Army Research Laboratory, on the Commerce Department's Export Council, on the National Materials and Manufacturing Board, and on various national panels/committees, Fortune-500 NYSE companies, and civic and university boards. Hwang also holds various international leadership positions. She is the author of 500+ publications and several books, and a speaker and author on trade, business, education, and social issues. Her formal education includes four academic degrees as well as the Harvard Business School Executive Program and Columbia University Corporate Governance Program. For more information, please visit www.JennieHwang.com.

Growing Rework Demand from Assemblies for 5G, Communications Systems

Don Naugler, president and general manager of VJ Electronix Inc., talks about the challenges in rework and inventory control during the recent NEPCON China 2018 event in Shanghai. He sees increasing demand for rework solutions for larger board assemblies, in particular, for 5G communications technologies.

Naugler also discusses the challenges in reworking flexible circuit assemblies, and how operators can address them. Click image to watch this video.

Feature by Stephen Las Marias
I-CONNECT007

When the industry first had the concept of 5G, the International Telecommunications Union (ITU) proposed a framework of three main use cases that 5G is expected to solve.

First is the EMBB or enhanced mobile broadband, according to David Hall, chief solution marketer at National Instruments. "That's the idea that we can get higher throughput, higher data through mobile communications. Another one is EMTC or enhanced machine-type communications, which is more about being able to have time-critical communication with many devices. The third use case was more of the IoT, where we had this notion of needing to support large numbers of wireless devices on the network. We need a network that could handle that type of capability," he explains.

Out of those three use cases, the one that is by far the most difficult for engineers designing and testing products is the EMBB use case. The reason for this is that the industry will be deploying 5G at millimeter wave frequencies between 28 and 40GHz, with significantly wider bandwidths than the current instrumentation.

"The rules about how you design a test fixture, or conduct testing of those products is changing," says Hall. "As an example, in the past, you might connect a device under test (DUT) to a test instrument over a long cable, because at 1 GHz or 2 GHz, you don't worry about insertion loss. But now, when you are looking at a 28GHz or a 40GHz center frequency, you can't have a long connection between the device under test and the instrument because it is subject to significant attenuation."

Therefore, manufacturers should re-architect their test systems to get the instrument closer to the DUT. Hall adds that they are also seeing the move for radios at 28GHz to have much more integrated antennas into the actual package itself.


David Hall

"What that means is it increases the likelihood of needing to do over-the-air testing, which is once taboo—a no-no in the wireless community for many years," Hall says. "But now, it's actually essential when you have antennas that are tightly integrated with the radio itself. By far, 5G is one of the biggest test challenges of mobile communications today, even as other standards are coming out—such as IEEE 802.11ax and Bluetooth Low Energy. But for the other standards, they sort of follow all the same rules. But 5G, and the use of new bands, creates a lot of challenges."

One of the biggest challenges that their customers are facing right now is the accelerating rate of technology changes. The time it took for the industry to go from 2G to 3G was longer than what it is when going from 4G to 4.5, to 5G.

"What that means is that customers have less time to react to handling new test challenges and new technical challenges. Our goal to provide a platform-based approach is to allow our customers to develop a test system—the main IP for the customers is their software—and allow them to continue to reuse that software for long periods of time and be able to insert new hardware as the needs arise," explains Hall. "An example of that is the vector signal transceiver, which we announced in 2012. If you wrote a piece of test software that uses the vector signal transceiver back in 2012, you can still use that software today with the newest vector signal transceiver. But now, the new vector signal transceiver has better error vector magnitude (EVM) performance, better noise floor performance, and over 10x the bandwidth. That's a good example of helping customers preserve their investment—by giving them access to the latest and greatest hardware, without having to do significant rework."

Developing 5G Test Systems

National Instruments provides automated test equipment and virtual instrumentation solutions. To help customers going into 5G, the company is working with several lead users of the 5G test front, "because many of these customers are looking at millimeter-wave testing systems for the very first time, and it is something they have never dealt with before," says Hall.

NI is working closely with them in lead-user engagements where it gives them the first prototype of some of the company's test technologies, and the users give feedback on what's working and what's not, and some of the challenges that they are uncovering in test.

In this way, the company—with the help of their customer manufacturers—are defining some of the 5G test products together.

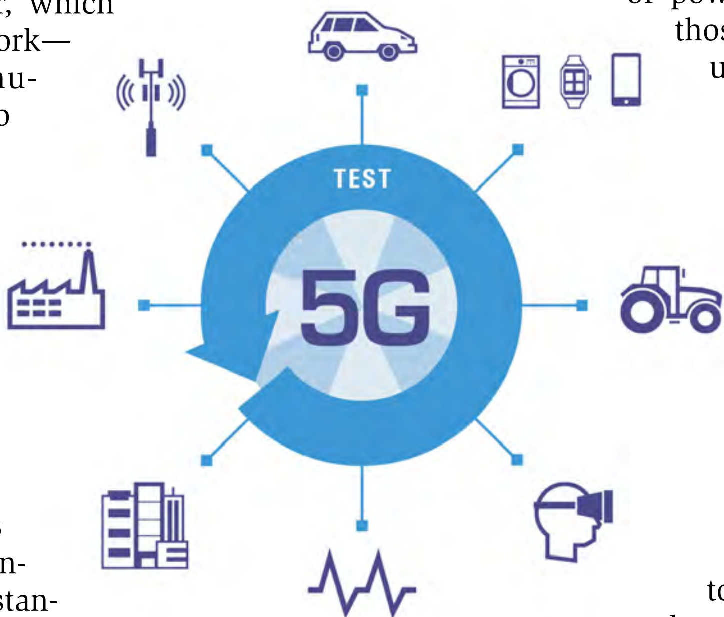
According to Hall, the company recently collaborated with AT&T is to help them build a channel sounder, a system used to measure some of the real-world electromagnetic propagation effects in the 28GHz spectrum. In that collaboration, NI provided the software-defined radio hardware as well as engineering resources to help AT&T develop the system. "With this system, AT&T is already taking real measurements and being able to characterize the channel in a way that was impossible before," notes Hall.

5G Use Cases

According to Hall, the 3GPP—the standards body responsible for 5G—is simultaneously working on additional wireless technologies to support more of the IoT use case.

"This is a little bit of a shift from years past, where we start with GSM, then we did 3G, then we did LTE, and we saw people attempt to use the cellular technology to support the non-cellular use case. An example of that is in automobiles, there's a technology called OnStar, which uses CDMA network—2G mobile communications—to radio a base station if there's a problem with the vehicle. Obviously, CDMA wasn't designed for that use case, but it's a good enough technology to solve that problem," says Hall.

Hall says 3GPP is shifting towards designing one flavor of standards for mobile broadband, a different flavor for the IoT, and even a different flavor for automotive. Two of the technologies that are actively being developed—one of them is called NB-IoT (Narrowband IoT), is an implementation effectively like LTE, that's designed for low-power, long-range transmissions and to support many devices on the network. Another one that's happening in parallel is LTE V-to-X and 5G V-to-X, which is a vehicle-to-vehicle communications standard based on some of the 5G and LTE technologies, but designed for high-doppler situations, such as moving vehicles communicating with each other.



Machine-to-Machine Communications

As the manufacturing industry moves toward a smarter manufacturing vision, it will be needing more and more machine communications. So how is 5G impacting or helping that? Some of the critical requirements for machine-type communications are: the latency— tight synchronization between one device transmitting and another device receiving; the robustness of that communication; and low-power consumption.

"Those transmissions tend to be lower data rate, but you also have the desire for them to be lower power, too, especially when you have many devices in the network—you don't want to consume a significant amount of power," says Hall. "All of those reasons are why, ultimately, many of the machine type communications will use the NB-IoT standard. The NB-IoT standard addresses the low-power considerations, uses a relatively small amount of spectrum, so you can have a lot of devices in your network, and the improvements to the MAC and PHY layers of 5G address some of the latency and reliability concerns, which are important in machine-type communication environments."

The Future of the T&M Industry

There's certainly a tremendous amount of change in the industry. Hall says every time you get a new major innovation, and a significant change in measurement type, you see an opportunity for disruption.

"And there are a couple of opportunities that we are seeing right now. In the mobile communications space, the advent of millimeter-wave and the challenges associated with millimeter-wave test are creating an opportunity for disruption. The test and measurement vendors that can address that measurement challenge first will find themselves in a good position in the market. We also see opportunities in the automotive space. With vehicle electrification and the use of technologies like radar for autonomous driving, the implications of test are significant. Autonomous driving can be dangerous. There's a tremendous need to thoroughly test those systems. So, that also creates an opportunity for disruption, for a new measurement type and a significant market opportunity.

Autonomous driving can be dangerous. There's a tremendous need to thoroughly test those systems.

With customers dealing with the challenges of faster time-to-market, greater device complexity, more test cases, and less time to accomplish what they need to do, NI's ability to provide a platform that enables them to quickly take advantage of new measurement techniques, with the measurement speed to handle the increasing device complexity, is a pretty compelling reason to adopt PXI," according to Hall.

"Just to give you a history, 10 years ago, we saw customers doing 4G tests at the time. From 3G to 4G, we really started using automation in R&D for the first time. Because prior to that, you do measurements manually—when there was a two-band device, you just test one band, and then you test the other band. When we migrated from two-band components to 20-band components, the test component escalated to the point that automation become a critical factor. Some of the first and most compelling reasons to choose PXI had to do with measurement speed, because using PXI and automation, you can characterize a product in a few days, versus a few months it would have taken," says Hall.

That problem is going to persist, so a platform-based approach with fast measurement speed and broad measurement flexibilities is the only way to address these challenges, according to Hall.

"It's an exciting time to be working in the electronics industry. Technologies like autonomous driving and 5G are pushing the boundaries of what we thought was possible with technology. Ten years ago, you thought it was crazy. But now, I think it's an exciting time to be an engineer to work on some of these challenges and solve them," Hall says. **SMT007**

Thermaltronics Discusses Smarter Robotic Soldering System

At the NEPCON China 2018 show in Shanghai, China, Michael Gouldsmith, Director of Thermaltronics, discusses the innovations they made in robotic soldering systems. He also speaks about their hand soldering technology, which helps operators avoid temperature overshoot while soldering. Click image to watch this video.

MilAero Highlights

Sanmina Achieves FDA Registration at Its India Facility ▶

Sanmina Corp. has received FDA registration at its manufacturing facilities in Chennai, India, enabling the company to manufacture finished medical instruments and devices in India.

Sparton to Supply BAE Systems with Over $13M in Ruggedized Displays ▶

Sparton Corp. and Ultra Electronics Holdings plc (ULE) announce the award of subcontracts valued at $28.4 million to their ERAPSCO joint venture, for the manufacture of sonobuoys for the United States Navy.

Interview with Dave Hillman: IPC's 2018 Raymond E. Pritchard Hall of Fame Award Winner ▶

In this interview, I-Connect007's Patty Goldman gives Dave Hillman of Rockwell Collins, the recipient of this year's Raymond E. Pritchard Hall of Fame Award, a chance to tell his story.

Don Dupriest to Chair Top IPC Standards Leadership Committee ▶

Don Dupriest of Lockheed Martin Missiles & Fire Control has been elected chair of the IPC Technical Activities Executive Committee (TAEC) for a two-year term.

Stadium Strengthens Quality Team at Hartlepool Plant ▶

Stadium Group has announced the appointment of Gabriel Iancu as quality and test manager and Paul Adgar as senior test and technical engineer at the Hartlepool UK electronics assembly plant.

Interview with Bob Cooke: IPC President's Award Recipient ▶

Patty Goldman speaks with Bob Cooke of NASA's Johnson Space Center (JSC), this year's recipient of IPC's President's Award.

Celestica Completes Acquisition of Atrenne Integrated Solutions ▶

Celestica Inc. has completed its previously announced acquisition of Atrenne Integrated Solutions Inc.

SigmaTron International Posts Q3 Results for Fiscal 2018 ▶

Revenues increased to $65.7 million for the third quarter of fiscal 2018 from $62.2 million for the same quarter in the prior year.

PowerAmerica Executive Director and National Defense University Study Group Visit ACDi ▶

ACDi Nashville hosted Nickolas Justice, Executive Director of PowerAmerica, and 16 students plus two faculty from the National Defense University (NDU) Dwight D. Eisenhower School for National Security and Resource Strategy out of Washington, DC.

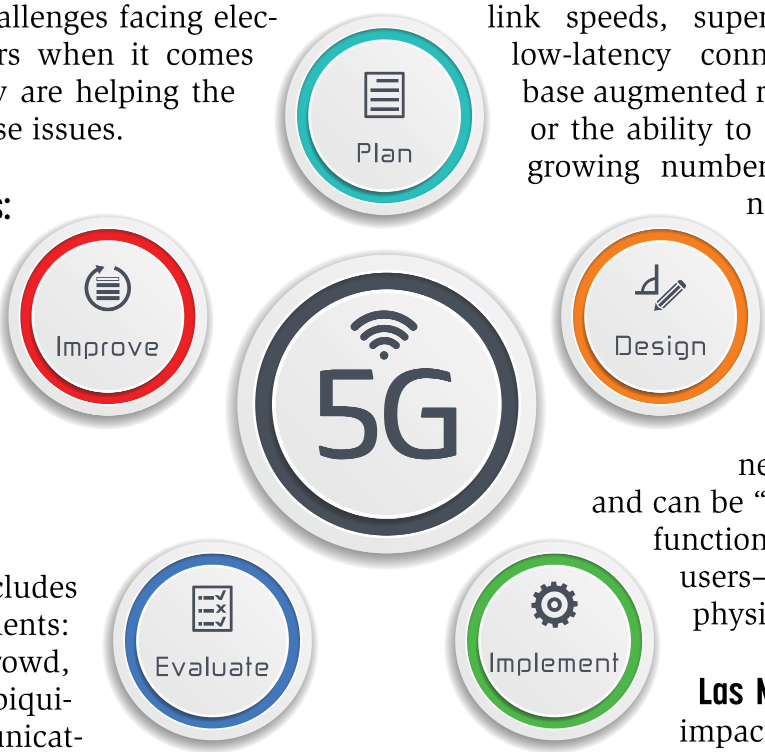
Nortech Systems Reports 2017 Results ▶

Nortech Systems Incorporated reported net sales of $112.3 million for the year ended December 31, 2017, compared with $116.6 million for fiscal 2016.

Conversation with... Keysight: Challenges and Opportunities in Testing 5G

Feature Interview by Stephen Las Marias
I-CONNECT007

In an interview with *SMT007 Magazine,* Roger Nichols, 5G program manager at test and measurement provider Keysight Technologies Inc., discusses the opportunities that 5G will enable, the many challenges facing electronics manufacturers when it comes to 5G, and how they are helping the industry address these issues.



Stephen Las Marias: Please give us a brief overview of 5G. How will this differ from 4G, and what other applications do you think it will enable?

Roger Nichols: The vision for 5G includes the following elements: great service in a crowd, amazingly fast, ubiquitous things communicating, super reliable and real-time communications, and the best service for the user. This was postulated by the Mobile and Wireless Communications Enablers for the Twenty-Twenty Information Society (METIS) program in 2013, and still holds. The best way to interpret the vision is that we will have a network that is not just faster and more real-time, but also one that is highly reliable and can handle business models and applications that today's network cannot.

The objective is not just super-fast data-link speeds, super high-reliability or low-latency connections—for video-base augmented reality, for example—or the ability to connect the quickly-growing number of devices to the network; the objective is to create a network architecture that takes advantage of virtualization. This means a network that is flexible and can be "sliced" into different functionality for different users—regardless of their physical location.

Las Marias: How will 5G impact the electronics assembly industry?

Nichols: The electronics assembly industry has already met an amazing change in demands for speed and circuit density. These demands will continue to increase with miniaturization being driven by the need for portability, reduction in power-consumption, and integration of

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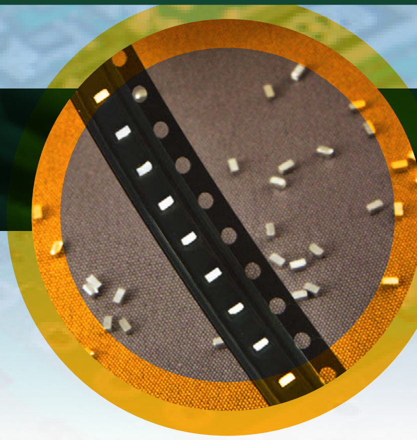

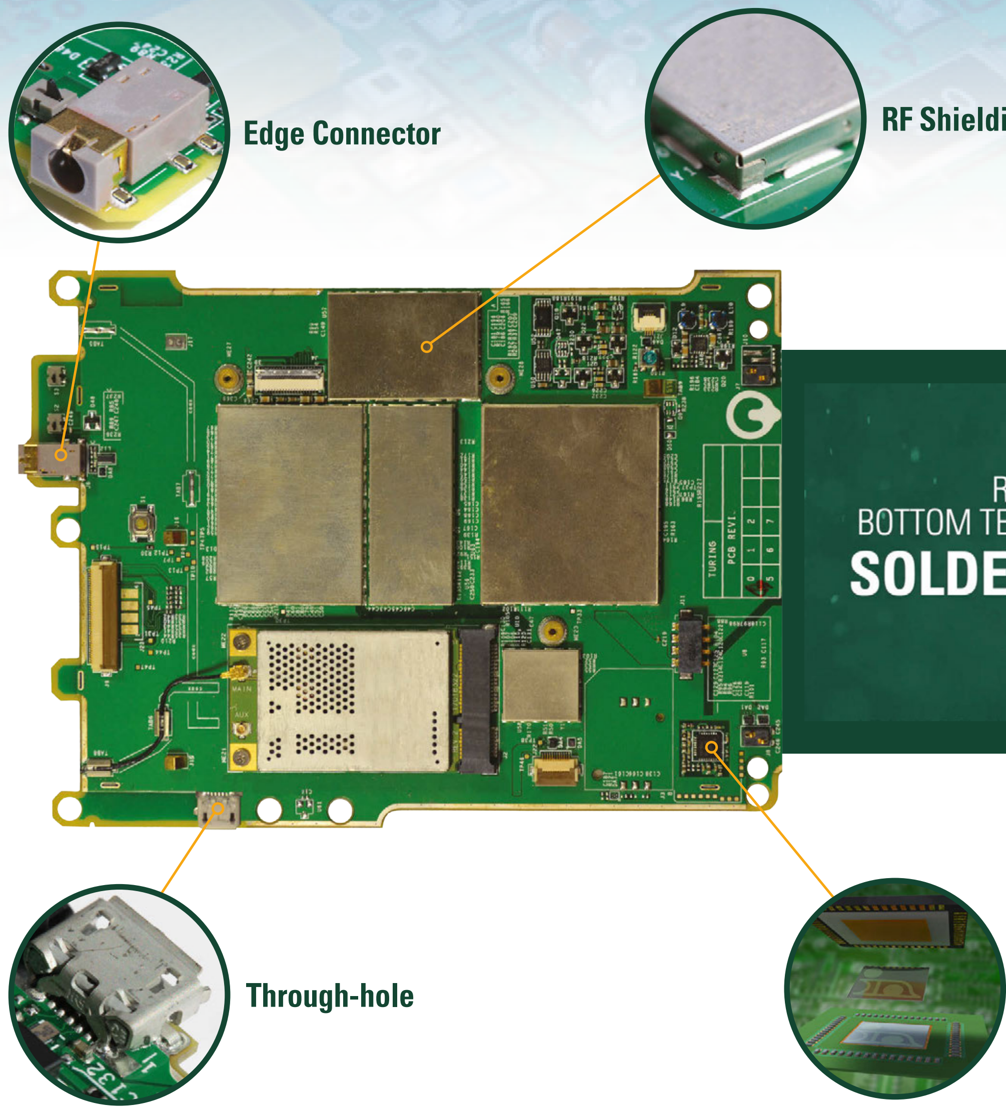

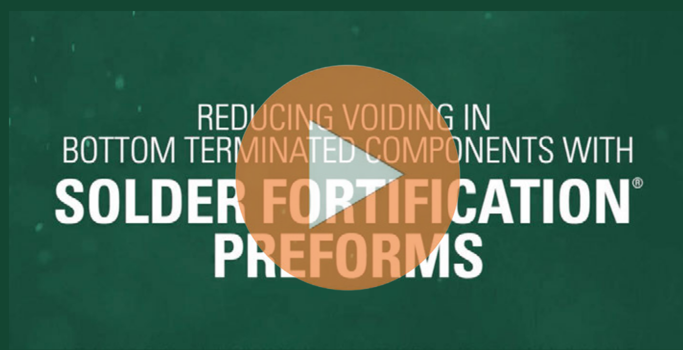

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ever-more diverse functionality. The mobile communications industry adds the needs of portable devices that are water-proof and drop-proof—accommodations that complicate the assembly of these devices and will continue to do so. And fixed infrastructure needs to tolerate weather, temperature change, lightning, and even vandalism. The electro-mechanical design of these devices means ever-more complex and demanding assembly processes.

Another key demand that 5G will drive is much heavier use of wireless communications in the transportation and industrial businesses. Costs, regulations, and reliability all mean demands on manufacturing technologies with the relentless pressure on cost. One other element that 5G will bring into mainstream regards millimeter-wave frequencies, which mean very different electromechanical designs—active antenna array systems, disaggregation of the radio and the antenna (e.g., in automobiles), etc. The assembly industry will be expected to keep up with these new ideas and improve the quality of the process.

Roger Nichols

Las Marias: From your perspective as a test and measurement systems provider, what electronics manufacturing/assembly challenges do you foresee facing your customers when it comes to 5G?

Nichols: Answering this would make a pretty long list but I can call out one specific example we see often. The advent of millimeter-wave in mainstream electronics means that manufacturers, in some cases, are insisting that these radios be tested in the manufacturing process. But the state of the art is such that these measurements must be made not only within chambers that are shielded, but also anechoic, and, in some cases, temperature-controlled. All these technologies are not new to the industry, but what is new is the aspect of applying them all to a relatively high-volume manufacturing process. This adds the complexity of making an accurate measurement, quickly, over-the-air (no galvanic connections), and moving the device-under-test (DUT) in and out of the chamber in an efficient manner. This also implies a robust repetitive controlled environment with minimal down-time and the flexibility to change the DUT form-factor.

Las Marias: How are you helping your customers address these challenges?

Nichols: We are very excited about the opportunity to flex our muscles as a solutions-provider. This means going beyond the electronic measurement. We are working closely with our customers, bringing in our own expertise, even from the teams who design our own manufacturing processes, and partnering with an impressive group of companies to present a comprehensive set of solutions. Sometimes, this has put us out of our comfort zone, but we have learned a lot and been able to present some truly innovative thinking to our customers. This also means empowering these solutions with our PathWave framework to help our customers plan their automated manufacturing test processes, manage the information generated, and even manage the test assets themselves within a common platform.

Las Marias: In our discussions with electronics manufacturers, they say functional testing is one of the critical issues when it comes to electronics assembly of 5G devices/systems. What are your thoughts?

Nichols: The industry must manage both parametric measurements and functional test. I do not see a future in which both are not required. But regarding this functional test need, my comments above relate to one other relentless trend in electronics and that is ever increasing integration. This means that the manufacturing process is presented with subassemblies and assemblies with incredible levels of functionality. Simple tests are no longer a sufficient proxy that the supply-chain and upstream manufacturing process have not caused any problems. In my example of over-the-air testing in production, it is not difficult to see a scenario of an operational device with an active antenna that would change its characteristics simply by being measured. This means that functional testing becomes a must since they are testing a functional device—a mobile radio system.

Las Marias: What developments in T&M technologies are geared toward addressing the new challenges offered by 5G systems?

Nichols: We must do the obvious like implement measurement capabilities to the new standards, make sure we can test the new frequencies and bandwidths not previously used in mobile communications, and in some cases address performance improvements needed to meet these needs. We also are working on more over-the-air test technologies not just for mmWave but also for <6GHz—in both cases due to increasing integration of these radio systems and the elimination of RF connectors. We have always been in the test-via-emulation business in mobile communications, and 5G will be no different. We have recently demonstrated network emulation systems for mobile test that work in the new 5G NR standard and these manage that functional test domain. We also have an array of non-signaling and parametric test solutions available for the process steps that have been streamlined for those needs. We must not forget the high-speed digital domain where our time-domain solutions require more and more functionality to address high-speed data-bus and interconnect specifications. We are adding more and more functional test capability to ensure we can cover these demands as well.

Las Marias: Is there any difference between the manufacturing process/set-up for 5G-enabled devices and that of previous generations?

Nichols: 5G manufacturing is still constrained to building for trials and perhaps the very first phases of early deployment. In these cases, we have already seen some changes from 4G, but I believe that the demands will drive changes much like what 4G did to the manufacturing processes we developed for 3G. It is difficult to predict where these trends will go, but one thing is for sure and that is the mmWave technologies will drive manufacturing test and assembly process innovation to move a technology previously in the domain of high-cost aerospace and defense applications. The commercial communications market is a different beast and will make amazing changes to this set of technologies.

The commercial communications market is a different beast and will make amazing changes to this set of technologies.

Las Marias: Ever finer pitches and line spacing will continue to become a trend in 5G devices. From your perspective, what challenges do these present, and how are you addressing them?

Nichols: Such has been a trend for decades and we are excited about these opportunities to provide tools for innovators. In many cases, this is about managing speed, since such fine pitches are needed for higher speeds. So, we continue our trends of ever-faster digital capabilities. Hyper-fast arbitrary waveform generators, BERTs, and time-domain analysis are the core for this. Over a year ago, we announced the technical capabilities to do real-time time-domain analysis with bandwidths exceeding 100GHz. This is a combination of high-speed sampling and ADC, plus signal processing capabilities of which we are super proud. You can watch this space for exciting announcements based on that technology.

Las Marias: What can you say about the future of 5G? Do you see it emerging this year?

Nichols: Verizon and AT&T have both announced they will launch 5G fixed-wireless services at the end of 2018. KT just announced they plan to launch services in March of 2019, and many more expect to launch in late 2019 and early 2020. These are all aggressive plans, but we have already seen some remarkable trials and demonstrations. It is exciting to be in the middle of this and working with the leading companies in this business to make these things happen.

Las Marias: What other issues do you see that will need ironing out when it comes to 5G? Standards?

Nichols: Standards evolve over time and the continuing addition of capability and standardized test processes is something we can expect to see. We are involved with the wireless bodies like 3GPP and CTIA as well as with digital standards bodies related to digital interfaces and capabilities. Some of the technologies we are helping with are over-the-air testing capabilities, radio-resource-management, and how best to validate the digital interface standards.

Las Marias: Is there anything we haven't talked about that you think we should be talking about when it comes to 5G?

Nichols: 5G impacts every part of the network. This means new radios, faster connections inside of the radios and in the networks, new network protocols, and a host of new applications. The applications will expand into areas of the industry that are in some ways hard to predict. This means plenty of opportunity for all of us. I have stated for years that I am excited about this because it impacts almost everything Keysight does and that means opportunities across the board. With our recent integration of the Ixia company, we are in a position now to provide solutions across the entire workflow—from research to deployment, and from the physical layer up to the application layer and everything in between. This means new electronics demands and new software demands in many disciplines.

The other facet of 5G is paying close attention to the policies that enable and sometimes constrain our industry. We need to keep in mind the regulatory and sustainability framework in which we operate to ensure not only a robust communications system, but also one that connects the world in a secure way.

Las Marias: What do think should our readers know about 5G in terms of the big picture?

Nichols: It will not happen overnight. Like other new generations, the hype is always more than the reality. But it will happen, and it is our opportunity and privilege to be part of making it real. So, we start with the leaders and trailblazers in the industry to make them successful and then facilitate a broader rollout. It means innovation and looking at technology from a new perspective. We will have some of the same traditional processes and measurement and we will augment that with new capability that will make this vision real.

Las Marias: Do you have any final comments?

Nichols: I will reiterate—and I can speak for my entire company and our strategic partners—how excited I am about being part of this. Of course, this is a great business opportunity for all of us but being part of the communications revolution is being part of something bigger. We are looking forward to accelerating this innovation to connect and secure the world.

Las Marias: Thank you very much, Roger.

Nichols: Thank you. **SMT007**

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Supply Line Highlights

Creative Electron Premieres TruView 10 X-Ray Software ▶

Creative Electron unveiled its new TruView 10 X-Ray Software at the recent IPC APEX Expo trade show.

Nordson ASYMTEK Launches Helios Automated Fluid Dispensing Platform ▶

Nordson ASYMTEK introduces the new Helios SD-960 Series Automated Dispensing System for medium and bulk volume deposits of single- (1K) and two-component (2K) materials in electronics manufacturing and PCB assembly.

RTW IPC APEX EXPO: Blackfox–Training Program for Transitioning Military Personnel ▶

Al Dill, president and CEO, discusses a training program for transitioning military personnel provided by Blackfox, who is a certified IPC training organization around the world.

MIRTEC Partners with Vectralis Engineering and USM Reps ▶

MIRTEC has entered into a corporate agreement with Vectralis Engineering and USM Reps for sales and support of their award-winning SPI and AOI products and services for the country of Mexico.

RTW IPC APEX EXPO: Manncorp Expands with New Learning Center ▶

Ed Stone, sales manager of Manncorp, discusses the company's expansion, specifically their new application and learning center, their new equipment in the pipeline, and his outlook for this year.

RTW IPC APEX EXPO: Kyzen's Tom Forsythe Talks Tips for Better Cleaning ▶

Tom Forsythe, executive VP of KYZEN, offers his advice on designing for better cleaning. Forsythe also discusses customers' continuing demand for data and KYZEN's data management efforts.

Electrolube Addresses Market Changes in LED Thermal Management ▶

Ahead of emerging changes within the LED market, Electrolube has addressed growing concerns affecting LED manufacturers regarding the thermal management of LEDs.

RTW IPC APEX EXPO: Saki–The Smart Factory Concept ▶

Alex Malek, VP of sales and service for Saki, explains how the company's software and hardware provide a common platform for machine-to-machine interconnectivity.

Super Dry Unveils 'Dry Air Only' at One Fixed Monthly Price ▶

For value-conscious companies that wish to keep their safe storage of components and PCBs in-house but need an alternative to the capital investment typically required, Super Dry Totech has launched a new "Dry Air Only" solution.

Conversation with... Asteelflash: DFT Strategy Needed for 5G Assembly

Feature Interview by Stephen Las Marias
I-CONNECT007

In this interview, Mathieu Kury, business development manager of Asteelflash USA Corp., provides an overview of 5G, the opportunities in the market, and how it will impact the electronics manufacturing industry. He also discusses the key challenges from an EMS standpoint and how to become successful when 5G really arrives.

Stephen Las Marias: Give us a brief overview of 5G. How will this differ from 4G/3G, and, apart from mobile communications, what other applications do you think it will enable?

Mathieu Kury: 5G is really another level from what we've seen so far in telecommunications, mostly from a speed perspective and the ability to connect many more devices to each other—the real, connected world we've been talking about for quite some time now. More than just communications, when we think about the new technologies getting closer and closer to reality such as autonomous vehicles and smart cities, these verticals will not exist and/or not perform at the expected pace without a powerful infrastructure, which 5G will enable. The numbers are high: we're talking about 10,000 times more traffic than today; 100 Mbit/second wherever needed; low energy consumption; and further decreasing M2M communication cost. The impact of 5G will be huge!

Las Marias: Speaking of impact, how do you think will 5G impact the electronics assembly industry in particular?

Kury: From a design and assembly standpoint, 5G is not mature enough to have had an actual impact on product development, and therefore, assembly. Most of the connected devices on the market use a mix of different wireless communication protocols, and it will take a while until 5G is integrated as a design requirement for any new connected device. But it will certainly happen. We're talking at a horizon of 2020–2022 for me, where 5G will be accessible enough to most of the population. At that time, we'll witness the power of 5G.

Las Marias: Do you think manufacturing 5G devices will require a different electron-

ics assembly/manufacturing process set-up compared to previous generations?

Kury: It will certainly require specific components, therefore, specific testing at the electrical but also at the functional level. But from a purely assembly perspective, I believe the impact will be limited.

Las Marias: In our conversations with OEMs, one of the critical issues they see impacting the assembly process is indeed the functional testing of 5G devices/systems. Please give your comments on this.

Kury: Well, to be honest, any product has its fair share of functional testing specificities creating challenges for any manufacturing/assembly company. The challenge we currently see with existing devices is mostly around functional testing targeted towards mass production: it's relatively easy to test one device at a time. It's another story when you have hundreds of them to test at once, potentially communicating with each other already. These aspects must be taken into consideration at the design stage through a thorough design for testability (DFT) analysis targeted towards mass production, which is something we do on most projects we serve, from the get go.

Mathieu Kury

Functional testing requirements can be very complex even without talking about 5G. The objective is to understand what the true requirements are, and to provide a design proposal that is ready for mass production. To do so, it will require not only to be supported by design firms but more importantly by a manufacturing/assembly company integrating these DFT principles into their operations and processes.

Las Marias: Ever finer pitches and line spacing will continue especially in 5G devices. What challenges do these present, and how are you addressing them?

Kury: Ultra-fine pitch components have been here for quite some time and supporting wearable or sensor products have required us to adapt to these challenges. I believe we'll still see a lot of that coming within the next few years as 5G will downsize any connected device we can think of. From an assembly standpoint, investing in cutting edge equipment will be key. Our current equipment already supports nanoelectronics placement as well as flexible circuit assembly.

Las Marias: How do you see the future of 5G? Do you see it emerging this year?

Kury: I believe we'll really see the push in 2019–2020. This is when, according to major telecommunication service providers, 5G will start being accessible and affordable to a good share of the population, at least in the United States. This will be one of the major criteria to 5G adoption, and therefore to the success of connected industries—self-driving cars, smart cities, etc.

Las Marias: Thank you, Mathieu.

Kury: Thank you. SMT007

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The Automated and Digital Factory - Navigating Technology Disruption
Shawn Blakney, Celestica, Inc.

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It's Time to Retire ROSE Testing

Article by Joe Russeau,
PRECISION ANALYTICAL LABORATORY
and Mark Northrup, IEC ELECTRONICS

For decades now, the electronics industry has had a growing need to understand the impacts of chemical residues on PCB and PCBA reliability. Residues left from flux and other process chemistries can potentially lead to premature failure of assemblies once in the field. Understanding where such residues originate and their impact on product function is paramount to mitigating product failures due to cleanliness issues. One tool that has been used for decades to evaluate printed board and assembly cleanliness has been the resistivity of solvent extract (ROSE) test.

The ROSE test was developed in the early 1970s by the Naval Avionics Warfare Center in Indianapolis, Indiana. The early test used a squeeze bottle containing a solvent comprised of 75% 2-propanol and 25% deionized water (75/25). The surface of an assembly was rinsed with the 75/25 mixture and any material (e.g., flux) easily soluble in the mixture was dissolved and captured in a beaker. The resistivity of the captured solution was measured, and the result was expressed in terms of sodium chloride equivalents (NaCl eq.). Later versions of the test were automated and a 10.06 microgram (µg) of NaCl eq./in^2 (1.56 µg of NaCl eq./cm2) limit was eventually ascribed to the test. That limit became enshrined in various military specifications, such as MIL-P-28809 and WS-6536 and eventually became the industry pass/fail standard. The limit persists today and is used across a wide base of material sets, from bare boards to assemblies to components.

Over the last two to three years, there has been considerable discussion within various IPC committees about the role of the ROSE test in today's assembly environment. The transition from predominantly water wash processes to "no clean" has meant the advent of very different flux compositions. The question has been posed—on numerous occasions, we might add—as to whether the ROSE test is still a viable option for evaluating PCB and PCBA cleanliness. There have essentially been two camps of thought on the subject: those who want to continue using the test and re-invent it as a process control tool and those that think the test has run its useful course.

To update the test, IPC's J-STD-001 committee commissioned a subgroup of users and subject matter experts to determine if there was a best-practices use that would bolster its continued application. Two conclusions

Figure 1: The ROSE system.

were reached by that subgroup. First, the ROSE test should no longer be referred to as a cleanliness test, but as a process control tool. This was a reasonable conclusion since ROSE was never meant for cleanliness as industry had defined it. Second, users of the test must provide objective evidence, aside from just ROSE alone, to show that their manufacturing process is in control. More information about what the subgroup defined as "objective" evidence can be found in IPC-WP-019.

The statement made in the title to this article is where we want to focus most of our discussion. We are in the camp that believes the ROSE test provides little value for evaluating today's assembly products and here's why. The first significant concern with the validity of the ROSE test is the solvent. Back when the test was developed the predominant flux being used was heavily comprised of rosin (>30%). The 75/25 mixture was a very effective solvent for breaking down that flux and bringing it into solution. This is an important factor to consider because to accurately measure the amount of residual flux on a PCBA, you must first have a solvent that can dissolve it into solution. This is one of the major problems with the ROSE test today.

Why is the solvent an important consideration? Typically, four questions that are asked when performing cleanliness testing of assemblies. The questions are as follows:

1. What types of residues are on the surface of the assembly?
2. What are the concentrations of those residues?
3. Do those residues/concentrations pose any risk to product performance/function?
4. Where are the residues originating?

To have any hope of answering these questions, we need to consider a testing platform with two very specific attributes: selectivity and sensitivity. With the advances in board design, product miniaturization, process improvement and the myriad of chemicals used in assembly production today, a bulk-solvent measurement is not adequate for determining if there are any hidden residue traps.

Next, the ROSE test uses far too much solvent for an accurate test. This is a problem because too much solvent has a diluting effect that causes any extracted residue to be lost in the noise of the system. The solvent volume is a major consideration for residue evaluation because we need to get a more concentrated representation of what is on the surface. In the real world, failures rarely result from liters of liquid contacting the assembly. Quite often, all that is needed are droplets, and in some cases, only humidity.

Now to the issue of using the ROSE test as a process control tool. Before we discuss this any further, we must first define "process control" The following, taken from www.businessdictionary.com, suits this discussion the best:

"Activities involved in ensuring a process is predictable, stable, and consistently operating at the target level of performance with only normal variation."

Figure 2: Ion chromatography apparatus.

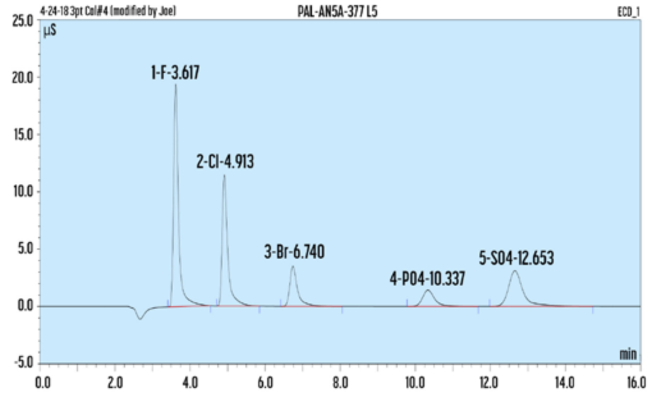

Figure 3: A representative example of a standard anion chromatograph.

Those in favor of continuing to utilize ROSE for process control might argue that it can and does meet the attributes in the definition. However, the bigger question that we pose today is does ROSE do so across all product types, designs and material sets? In our opinion, the answer is definitively no.

Having analyzed the cleanliness of assemblies for over 50 combined years, we can say one thing with absolute certainty: Not all assemblies have the same threshold of tolerance for process residues. Some assembly designs are far less tolerant than others. Considering the industry's drive towards reducing board real estate and increasing population density, then naturally there is a need for a more rigorous method for understanding what is lurking just on the surface. A bulk-solvent residue measurement from a 50-year-old methodology no longer meets the need, at least not across all industry segments. We cannot hope to achieve the level of understanding we need, related to the impact of our process residues, from a method that has not changed since the 1980s, when bulk-volume testers became the norm.

"I was asked how well the current ionic contamination method works for determining acceptable limits of contamination. ROSE (omega meter) definitiely does not do a good enough job of detecting ionic contamination on PCBAs. The current IC and SIR methods do not support volume production monitoring of real-time contamination feedback. The ROSE is obsolete, IC is the next best, and ultimately, we need a better test method," says Mark Talmadge, director of manufacturing at IEC Electronics.

In addition, the IPC task groups responsible for that method have not addressed its limitations and have not done their due diligence in keeping the method on par with the industry trends. This is not a slam towards those task groups. They are, after all, comprised of volunteers that have real jobs to focus on. However, we can't afford to be complacent any more. Our methods must attempt to keep pace with technology or we run the risk of gathering data that gives only a partial picture or worse, nothing of value at all.

What is the alternative? Since we are dealing specifically with ionic residues in this article, there is currently one tool that has both attributes described earlier and is primed for evaluating the ionic residues of modern assemblies—ion chromatography (IC), an accurate and repeatable tool. The volume of solvent used for an extraction can be substantially less. However, it is not without its limitations. IC is not particularly well-suited for operation on the production floor. It requires more qualified individuals to run it and to interpret the results and it currently uses the same solvent as ROSE. While there are some needed modifications with the IC method and equipment, we believe it is by far the best tool for tracking, investigating and monitoring the levels of ionic residues on your PCBs, PCBAs and even components (for you GEIA-STD-0006 folks).

If you would like to participate in advancing the cleanliness measurement technology, or have any questions or suggestions, please feel free to contact us. **SMT007**

Joe Russeau is president and CEO of Precision Analytical Laboratory. To contact Russeau with questions or comments, click here.

Mark Northrup is VP of Technology with IEC Electronics.

Modeling an SMT Line to Improve Throughput

Article by Gregory Vance,
ROCKWELL AUTOMATION INC.,
and Todd Vick,
UNIVERSAL INSTRUMENTS CORP.

One of the major challenges for an electronics assembly manufacturing engineer is determining how an SMT machine will impact throughput. Typically, an SMT equipment supplier will ask for a few (5-10) products to simulate the throughput capability of their machine. Unfortunately, if the engineer works in a high-mix, low-volume environment, he may need to know the impact of a new machine on 1,000 or more products. Currently, there are no simulation tools to effectively model this. This is confirmed in the 2015 IPC International Technology Roadmap for Electronics Interconnections, which states, *"In order to better deal with the demands for increased interconnection density and respond to market demands for better return on capital investment in assembly equipment, there is a need within the manufacturing industry for continued improvement in tools and software for modeling and simulation. Needs in this area include better methods of load balancing and improved machine utilization. The tools for determining the balance on assembly lines will need to be flexible to handle the mix of assembly types that manufacturers now face."* [1]

Rockwell Automation partnered with Universal Instruments to develop a tool to model a large quantity of products and the impact of varying SMT line configurations. The information used for the modeling includes placements per panel and components placed per hour. With these tools, an electronics assembly plant can be analyzed to identify improvement opportunities and perform "what if" analysis to model impact of machine changes.

Goals for the SMT Line Model

1. Determine the right machine for the product mix.
2. Determine if products are running as fast as they should.
3. Determine if electronics assembly products are built on the optimal line configuration. This is crucial in plants with multiple line configurations.

Development of the SMT Machine Model

1. Discovery that machine cycle times were poor

After sample product simulations were run by Universal Instruments, it was discovered that observed cycle times were two to three times longer than simulated cycle times. This led to a focused effort to understand why. A kaizen event was held to map out the process and observe product builds. Several items that impacted the product cycle time were uncovered. These items were:

1. Component library placement speed slowed down.
2. Imbalance between placement beams/ heads due to not having enough nozzles to pick and place the required component packages for the products.
3. Bypassed nozzles and spindles.
4. Large quantity of placements from a single component input.
5. Panel transfer rate into and out of the machine slowed down.
6. Poor optimization and component split between machines on an SMT line.
7. Operator variation in responding to the process.

The most significant item impacting cycle time was not having the necessary quantity of nozzles available for the mix of component packages for the products that the machine/line was building. To maximize flexibility to move products between lines, machines of the same type were equipped with a standard nozzle configuration. The nozzle configurations were changed only when a new component package was needed. To address this problem, a regular nozzle review was implemented to ensure the machines have sufficient nozzles available to optimize the machine programs.

Products were reviewed for the above issues. As items were addressed, the observed cycle times were reduced to align with the simulated cycle times.

2. Realization that cycle time does not represent SMT machine utilization

Cycle time represents how a product is running compared to a benchmark but does not reflect utilization of a machine based upon its throughput capability. For pick and place machines, throughput can be measured in components placed per hour (CPH).

$$CPH = \frac{Placements\ per\ panel}{Panel\ cycle\ time\ (hr)}$$

Manufacturers provide CPH specifications for SMT machines in two ways. The first method is what is often called "Maximum CPH" [2], which represents the maximum speed the manufacturer was able to achieve and the second is based on "IPC 9850" [3], which has CPH categorized by package type. The "placements per panel" required to run these tests are shown in Table 1.

The "IPC 9850" performance tests are useful to compare equipment models and manufacturers to each other, but they do not necessarily represent the products manufacturers are building. This complexity can be understood by comparing Table 1 to the sample product complexity of global product mix in Table 2.

Source	Test	Placements per Panel
IPC 9850	QFP-100	36
IPC 9850	QFP-200	30
IPC 9850	BGA-228	36
IPC 9850	1608C (0603C)	400
IPC 9850	SOIC-16	80
Manufacturer	Maximum CPH	?

Table 1: Sample of range of placements per panel to run IPC and manufacturer tests.

Range of Placements per Panel	Count of PCB Assemblies by Side	6-Month Panel Volume Forcast	Panel Volume %
0-299	1,250	682,380	44%
300-599	766	523,832	34%
600-899	401	178,584	11%
900-1,199	212	96,884	6%
1,200-1,499	60	59,540	4%
1,500-1,799	21	10,593	1%
1,800-4,500	31	7,134	0.50%
Total	2,741	1,558,947	100%

Table 2: Sample range of placements per panel versus count of assemblies and forecasted panel volumes.

The idea of using simple regression to develop a model of "placements per panel" to CPH began to develop. This relationship was first studied using production history.

Machine Mathematical Model for CPH

A report was available that contained panels built and total time to build a work order. This report was used to calculate the average CPH per panel for an SMT machine model. A scatter plot with a smoother line was used to view the relationship between the variables for a machine model. The smoother line is a line fitted to the data to explore the potential relationships between two variables, without fitting a specific model, such as a regression line.

There is a relationship between "placements per panel" and CPH but there are points that do not follow the smoother curve. The other observation is that actual CPH values vary greatly compared to the specification value the manufacturer stated.

Since production data was used to model this relationship, all the problem areas outlined earlier represent part of the performance and added noise in the model. Another idea was to use generic product simulation data from the manufacturer. The product simulation information included:

1. Quantity of placements per panel
2. Simulated cycle time for a SMT machine
3. CPH (calculated)

This would filter out the noise from production and machine configuration issues and could then be used to establish a realistic CPH equation. With the simulated cycle time data, the relationship between "placements per panel" and CPH was then studied.

The scatter plot revealed a relationship between "placements per panel" and CPH. Using the Pearson Correlation Coefficient, the strength of the relationship is assessed. At 0.536 it is considered moderate and P-Value of 0.000 means the relationship is statistically significant. This indicates that "placements per panel" is a good predictor of CPH.

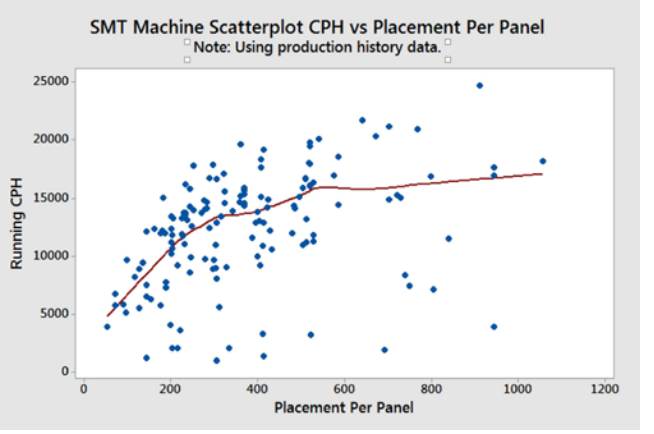

Figure 1: Scatter plot of CPH versus placements per panel from production data.

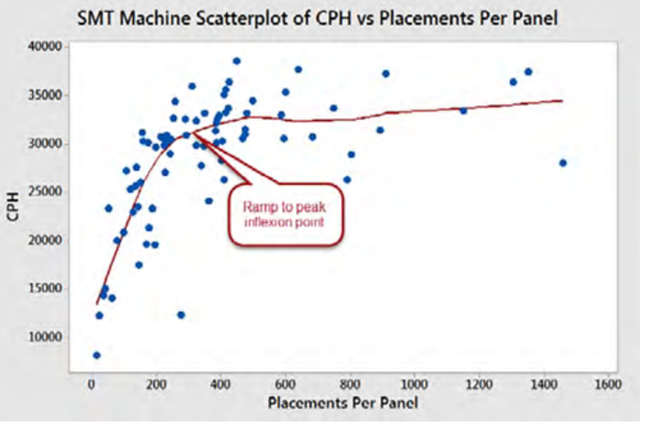

Figure 2: Scatter plot of CPH versus placements per panel from SMT machine product simulations.

Using the scatter plot, the inflexion point where the red smoother curve flattens out is determined. The CPH values for "placement per panel" data points beyond this inflexion point are averaged and labeled the "Max CPH" for that model machine. For this SMT machine, the "Max CPH" is 32,311 and is achieved at 300 or more "placements per panel." The "Max CPH" is closer to the machine's IPC 9850 1608 four-board test of 37,000 CPH [2] with some simulations performing at the IPC 9850 1608 four-board test rate.

Simple regression was used to create a fitted line plot to generate an equation for the sloped part of the curve up to the "Max CPH" value. For this SMT machine, a quadratic equation provided the best fit.

When performing regression analysis, the R-Square and residual plots need to be

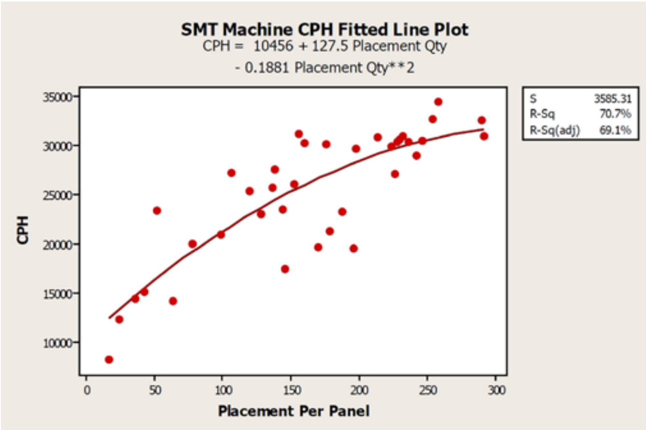

Figure 3: Fitted line plot of SMT machine CPH predicted by placements per panel for less than 300 placements per panel.

reviewed to determine how well the equation fits the raw data.

The R-Sq term shown in the fitted line plot represents how much of the variation the predictor (placements per panel) is accounted for by the CPH equation. The closer to 100%, the better. This model's R-Sq (adj) term is 69%. Since the model is intended to be used as a barometer of how well a product is running on a given SMT machine, this R-Sq term is acceptable.

The difference between the data points and fitted line are called residuals. Residuals represent the error or amount of variation not explained by the regression equation. There are four items to check to confirm that there are no unusual data points in the model. These are:

1. Normal Plot: Residuals form a straight line.
2. Histogram: Residuals appear to form a normal curve.
3. Versus Fits: Residuals are contained in a straight band, with no obvious pattern in the graph.
4. Versus Order: Residuals appears to be in statistical control.

This process of reviewing the "placements per panel" versus CPH, identifying the "Max CPH" and modeling the ramp to "Max CPH" with a regression equation (linear, quadratic or cubic) was completed for all other SMT machine models Rockwell Automation uses.

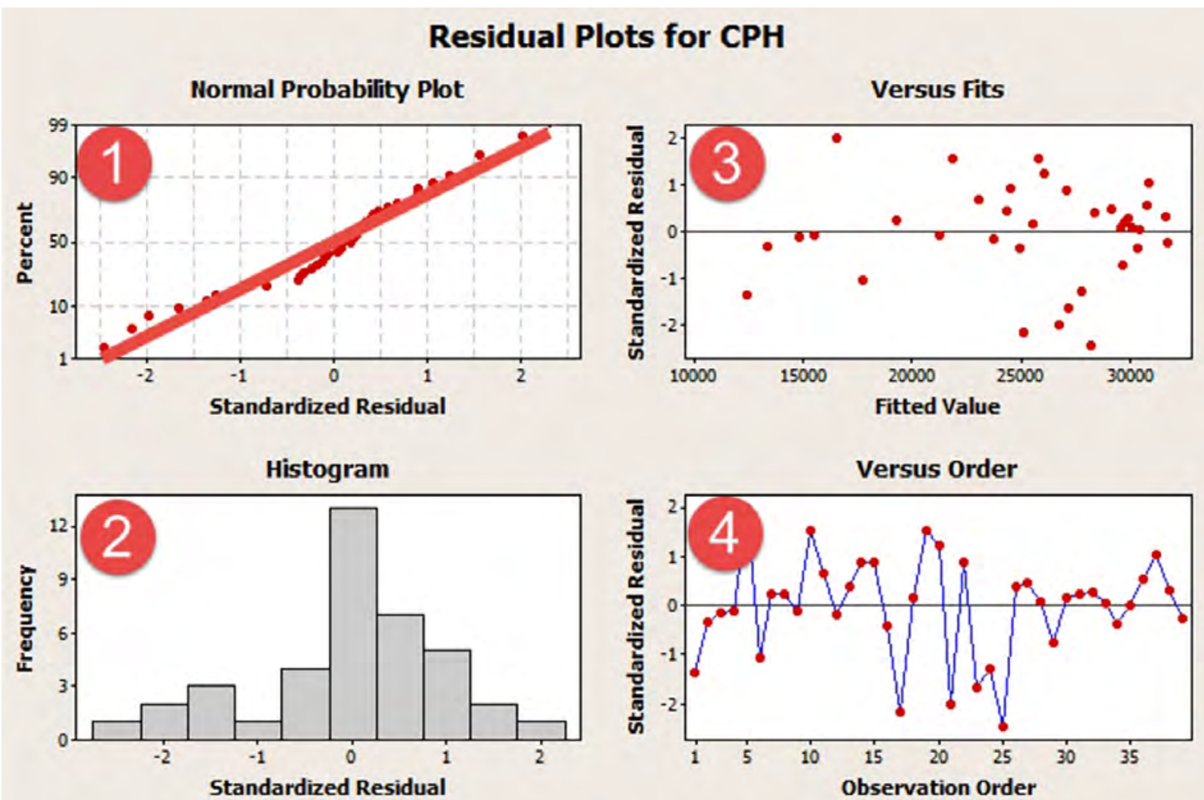

Figure 4: SMT machine CPH residual analysis.

Final Line Model

The line model consists of three sections:

1. Plant product inputs.
2. Product CPH & cycle time computations.
3. Product impact analysis.

Plant product inputs are:

1. Product number.
2. SMT line name (important if there are multiple line configurations in a plant).
3. Process side of the product—top or bottom.
4. Forecasted product panel volume (PPV), four to six months' forecast is recommended to capture low-volume products. The product panel forecast is totaled to determine the total panel volume forecasted for the plant (TPV).
5. Placements per panel from each SMT machine on the line.
   a. For better resolution for future what-if analysis, it is recommended to define placements per panel from each machine by feeder width (4 mm, 8 mm, 12 mm, etc.).
   b. Total placements per panel can be calculated.
6. Product observed cycle time (POCT) that represents the observed cycle time constraint for that product on an assembly line.

CPH and cycle time computations:

1. Regression equations and "Max CPH" for each SMT machine type on the line.
   a. With the actual placements per panel

Plant Product Inputs							
Product	Line	Side	Panel Forecast (PPV)	SMT 1 Placements	SMT 2 Placements	Total Panel Placements	Observed Cycle Time (POCT)
P841	1	Top	6,800	102	44	146	35
P1134	1	Bottom	9,000	428	342	770	76
P1146	1	Bottom	6,800	214	128	342	34
P862	1	Bottom	1,300	68	76	144	50
P1124	1	Bottom	6,931	682	282	964	97
P1151	1	Bottom	8,500	336	144	480	42
P797	1	Top	56	35	70	105	36
P798	1	Top	80	105	0	105	32
P1152	1	Top	4,358	342	66	408	66
P1142	1	Bottom	900	778	228	1,006	89
P1129	1	Top	1,067	1,632	264	1,896	166
P783	1	Bottom	24	324	6	330	53
P1148	1	Top	48	1,394	598	1,992	115
P1140	1	Bottom	640	540	238	778	69
P1126	1	Bottom	559	1,200	384	1,584	205

Figure 5: Line model inputs.

the product CPH (PCPH) and cycle time (PCT) for the product is calculated. These are the potential of the product being produced on that line when the line running.

b. The sum of the machines "Max CPH" on a line represents the line CPH.

2. Typical panel transfer time into the work nest of the SMT machine. Typical is between 2–6 seconds.
3. Typical stencil printer and oven panel to panel takt time.

Product impact analysis (outputs):

1. Line constraint cycle time (LCCT) is the constraint machine cycle time. If the constraint machine on the line is a placement machine, the typical panel transfer time is added as the machine is not producing product when the panel is transferring. (Many SMT machines have the option to pre-pick components to reduce the impact of panel transfer time. The line model is configured assuming this feature is not enabled.)

2. Net CPH Loss by SMT machine (NCLM) when running that product. This represents the CPH potential lost when running a product based upon the amount of time that machine is not picking and placing components due to another constraint on the line and panel transfer time.

$$NCLM = (PCT - LCCT) * PCPH - (MaxCPH - PCPH)$$

NCLM = Net CPH loss per machine
PCT = Product cycle time for a machine
LCCT = Line constraint cycle time
MaxCPH = Max CPH of that machine
PCPH = Product CPH for that machine

			CPH & Cycle Time Computations							
			SMT Machine 1			SMT Machine 2			Typ. Panel Transfer Time (sec)	Typ. SP/Oven Panel to Panel CT (sec)
			Max CPH			Max CPH				
			32,311			13,976			4	30
Product	Line	Side	Comp	CPH (PCPH1)	Cycle Time (PCT1)	Comp	CPH (PCPH2)	Cycle Time (PCT2)	Constraint Cycle Time (LCCT)	Is Stencil Printer/Oven Constraint?
P841	1	Top	102	21,504	17	44	7,496	21	30	Yes
P1134	1	Bottom	428	32,311	48	342	13,976	88	92	No
P1146	1	Bottom	214	29,127	26	128	11,238	41	45	No
P862	1	Bottom	68	18,256	13	76	8,922	31	35	No
P1124	1	Bottom	682	32,311	76	282	13,976	73	80	No
P1151	1	Bottom	336	32,311	37	144	11,951	43	47	No
P797	1	Top	35	14,688	9	70	8,655	29	33	No
P798	1	Top	84	19,839	15	21	6,472	12	30	Yes
P1152	1	Top	342	32,311	38	66	8,476	28	42	No
P1142	1	Bottom	778	32,311	87	228	13,976	59	91	No
P1129	1	Top	1,632	32,311	182	264	13,976	68	186	No
P783	1	Bottom	324	32,311	36	6	5,804	4	40	No
P1148	1	Top	1,394	32,311	155	598	13,976	154	159	No
P1140	1	Bottom	540	32,311	60	238	13,976	61	65	No
P1126	1	Bottom	1,200	32,311	134	384	13,976	99	138	No

Figure 6: Line model computations.

3. Product running line CPH (PRLCPH). This represents the CPH potential of that product on that SMT line configuration when the line is running.

$$PRLCPH = LineCPH + \sum NCLM$$

PRLCPH = Product running line CPH
LineCPH = Line CPH
NCLM = Net CPH loss per machine

4. Percentage of line CPH capability (%LCC). This represents the percentage of line CPH capacity a product utilizes on that line configuration.

$$\%LCC = \frac{PRLCPH}{LineCPH}$$

%LCC = Line CPH capability percentage
PRLCPH = Product running line CPH
LineCPH = Line CPH

5. Panel volume percentage (PV%). This is percentage of panel volume that product represents relative to the total panel volume (TPV) in that plant.

$$PV\% = PPV/TPV$$

PV% = Panel volume percentage
PPV = Product panel volume
TPV = Total panel volume

6. CPH Category (CPHC). This is a weight assigned to a product based upon the %LCC that it utilizes when running.

a. If %LCC < 25% CPHC = 10
b. If 25% < %LCC < 50% CPHC = 7
c. If 50% < %LCC < 75% CPHC = 3
d. If %LCC > 75% CPHC = 1
%LCC = Line CPH capability percentage
CPHC = CPH category

7. Volume category (VC). This is a weight assigned to a product based upon the percentage of panel volume that it represents. The total panel volume (TPV) is split into three segments: product panel volumes that represent the top 40%, middle 40%, and bottom 20% of the total panel volume for that plant.

a. Top 40% VC = 10
b. Middle 40% VC = 4
c. Bottom 20% VC = 1
VC = Volume category

8. (CPHC x VC) product. A product weight ranging from one to 100 that represents the volume and CPH utilization to rank the products on that line. This is a prioritization factor; the larger the number the more potential impact relative to improving CPH utilization based on line configuration and its panel volume.

9. Product cycle time ratio (PCTR). A ratio of the observed cycle time (POCT) to the calculated line constraint cycle time (LCCT) for a product. A PCTR greater than 1.0 represents a product running slower than its calculated potential. Ideally, this value would fall between 0.8 and 1.2 which represents the typical error in the model.

$$PCTR = POCT/LCCT$$

PCTR = Product cycle time ratio
POCT = Product observed cycle time
LCCT = Line constraint cycle time

Results & Conclusions

1. The machine and line models can be used to quickly evaluate the throughput and CPH utilization for an entire line to select the best machine. With additional tabulations, estimates can reflect the return on investment of replacing a machine. When replacing two SMT machines on an existing line, the line model estimated product run time would be reduced by 44 hours per month (32% reduction).

2. Using (CPHC x VC) and the product cycle time ratio (PCTR), an engineer can evaluate an entire plant by line to identify products with greatest improvement opportunity. When used to evaluate a SMT line, eight products with a large product cycle time ratio (PCTR) were identified and optimized, saving 136 hours of product run time per month (30% reduction).

			Product Impact Analysis								
						Line CPH 46,287	Total Panels (TPV) 220,233	10 = Low CPH	10 = High Volume		
Product	Line	Side	Net M1 CPH Loss (NCLM1)	Net M2 CPH Loss (NCLM2)	Product Running Line CPH (PRLCPH)	% of LineCPH Capability (%LCC)	Panel Volume % (PV%)	CPH Category (CPHC)	Volume Category (VC)	Product (CPHC x PV)	ObsCT/ ConstraintCT (PCTR)
P841	1	Top	-20,071	-8,696	17,520	38%	3.09%	7	10	70	1.2
P1134	1	Bottom	-15,580	-607	30,100	65%	4.09%	3	10	30	0.8
P1146	1	Bottom	-15,192	-3,737	27,358	59%	3.09%	3	10	30	0.8
P862	1	Bottom	-25,249	-6,084	14,954	32%	0.59%	7	4	28	1.4
P1124	1	Bottom	-1,616	-1,284	43,387	94%	3.15%	1	10	10	1.2
P1151	1	Bottom	-6,780	-3,034	36,473	79%	3.86%	1	10	10	0.9
P797	1	Top	-28,506	-6,367	11,414	25%	0.03%	10	1	10	1.1
P798	1	Top	-22,231	-11,456	12,600	27%	0.04%	7	1	7	1.1
P1152	1	Top	-3,070	-8,333	34,884	75%	1.98%	1	4	4	1.6
P1142	1	Bottom	-1,425	-4,925	39,937	86%	0.41%	1	4	4	1.0
P1129	1	Top	-695	-8,862	36,730	79%	0.48%	1	4	4	0.9
P783	1	Bottom	-3,223	-13,437	29,627	64%	0.01%	3	1	3	1.3
P1148	1	Top	-811	-463	45,013	97%	0.02%	1	1	1	0.7
P1140	1	Bottom	-2,543	-856	42,888	93%	0.29%	1	1	1	1.1
P1126	1	Bottom	-939	-3,937	41,412	89%	0.25%	1	1	1	1.5

Figure 7: Line model impact analysis.

3. By evaluating the (CPHC x VC) and brainstorming alternative line configurations, an engineer can perform what-if analysis to ensure a product is being built on the best line configuration to maximize capacity utilization and throughput. Products "placements per panel" and "forecasted panel volume" are important factors to consider when choosing what capacity SMT machine to purchase.

With information equipment manufacturers have today, they can calculate the CPH equations for their equipment to share with customers to supplement the "IPC-9850" and "Manufacturer Maximum CPH" figures. Together the supplier and customer can understand the impact of different machines for all their products on an SMT line. **SMT007**

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2. GS-426-00 Rev. D, Genesis Platform GC120Q, GC-60D, GI-14D, GX11D, GC30S, GX-11S General Specification, 2009, pp. 45.

3. IPC-9850, Surface Mount Placement Equipment Characterization, 2002, Form 9850-F1 Performance.

Editor's Note: This article was originally published in the proceedings of SMTA International 2016.

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Masking of Conformal Coating During Assembly and Rework

Knocking Down the Bone Pile

by **Bob Wettermann,** BEST INC.

Masking of printed circuit boards post rework/repair as well as for initial PCB assembly is often required if the PCB is to be conformal coated. If a board that has conformal coating on it needs to be reworked or repaired, the conformal coating needs to first be removed before the operation of rework or repair can take place. Once the board has been inspected, tested and cleaned, the conformal coating needs to be re-applied to the area of rework or repair. A conformal coating keep-out area drawing is essential in determining which components require masking. The following discussion centers around the various options for conformal coating masking via a liquid application process.

For purposes of this discussion, rework is defined as the removal and replacement of a component to meet initial specifications and performance characteristics of the board. Repair is defined as restoration of physical damage done to a PCB that brings the board back to functionally but may not meet the original performance intentions. Parylene masking and de-masking is not part of this discussion.

There are numerous options available for conformal coating masking. The most common methods for masking off or protecting select areas of the PCB or components themselves are the following:

- Precut tape dots
- Laser-cut custom tape shape
- Tape that is hand cut and trimmed to size
- Liquid latex
- Silicone boots
- 3D printed custom shapes

Precut Tape Dots

Precut tape dots are effective for conformal coating masking of flat areas to the PCB areas like test points and mounting holes. These are precut stickers, usually round, of standard sizes and die cut; they are available in polyester, polyimide, Kapton [1] and other materials. They are supplied on a roll and are pulled off the release liner one at a time. They are cost-effective for small to medium production runs.

Laser Cut Tape Shapes

Laser cut tape shapes are precision cut from flat sheets of tape material and can be fabricated using Kapton, flexible tape like 3M Type 401 [2] or others. This method is ideal for complex shapes for prototype or small-volume builds as they reduce masking time and can be delivered quickly. The shapes are generated from the board's Gerber files and can be used not only to protect flat areas but can be designed to tape over 3D components like connectors and headers requiring masking. The technician simply peels the material off the release liner and places it on the board or over the component. The shapes can be grouped together to visually indicate that each tape has been removed from the backing material, helping ensure that all areas requiring masking are masked.

Hand Cut and Trimmed Tape

In this masking method, the tape shapes are cut to size either coming right off the roll or the component is wrapped by the rework technician and trimmed afterwards. Performing the cutting operation on the board is dangerous as parts or boards can be damaged. Performing the cutting after peeling back the roll can be dangerous as the operator can potentially cut their hands. For prototypes or for very odd-shaped areas, it is a very flexible masking method. However, it is a very time-consuming process for both masking and de-masking. The charge generation process during de-masking operations must ensure that the components and assembly are protected from any adverse ESD events (sometimes requiring an air ionizer in the masking/de-masking area).

Liquid Latex, aka "Peelable Mask"

Liquid latex is a thixotropic material designed to be, among other things, a protection against unwanted conformal coating spray. It can be dispensed from a syringe or plastic-tipped squeeze bottle. It is typically cured on the board at room temperature over a three-hour range. After curing and application of the conformal coating, the masking material is simply peeled from the board and disposed of with the regular waste stream. This is ideal for areas that may be tough to get at with the tape. In addition, this type of masking material is ideal if you do not want the conformal coating "wicking up" the contact leads. At times, both the taping methods and the peelable mask method will be employed on the same board with the peelable mask at the board interface. Be careful in using natural latex as these formulations are heavily ammoniated and therefore can impact the PCB lami-

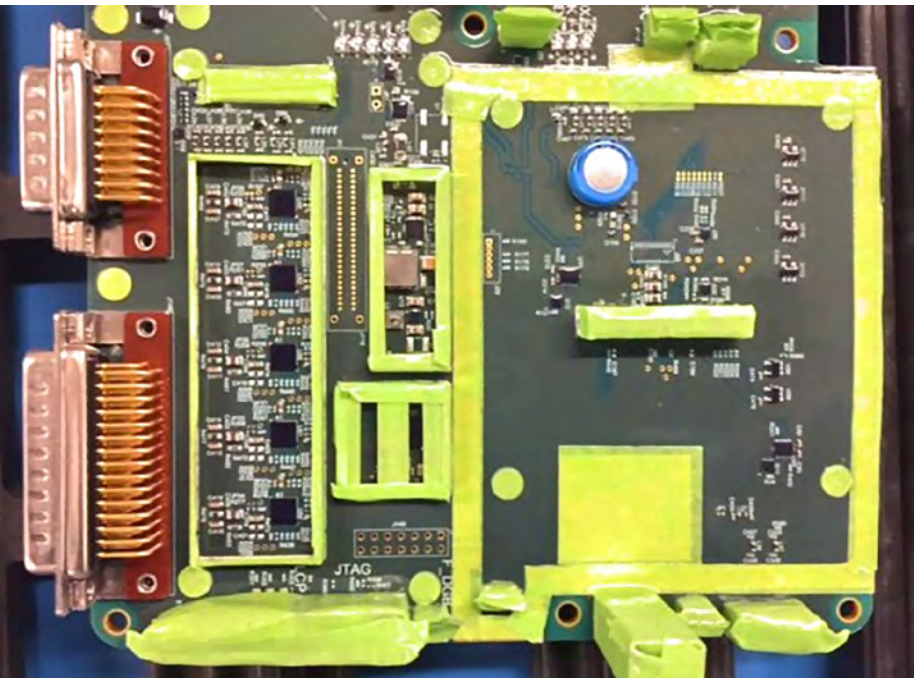

Figure 1: Pre-cut tape shapes for masking.

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nate surface. If the peelable mask cures very hard, it may rip off components, component leads or PCB laminate during the de-masking process. Conversely, the peelable mask breaks up easily during removal, so you may leave behind residual material, which may cause long-term reliability problems.

Silicone Boots

Silicone boots, customized for different connector and other electronic components, is another conformal coating masking method. They are often used for higher assembly volume jobs to greatly reduce the time and effort required for masking. The boots, due to their self-sealing nature, do not leak as frequently as tape dots and masks, thereby eliminating the need for coating re-work. For higher board volumes, these boots are very cost-effective and can reduce the masking time by 60-70%. One drawback to this masking method is that they will not work in conformal coating dip applications. Some boots can be re-used 125-200 times, depending on their care, and thereby driving the cost-per-use down.

3D Printing of Custom Boots

Another possibility for masking certain areas of a PCB includes the 3D printing of covers or boots to cover components. These 3D printing covers can be made from a variety of materials and offer the same potential benefits as the silicone boots. The material of the boots will determine the seal around the devices as well as temperature that the boots can withstand in the curing process. While the 3D printers are very cost-effective today, their low precision, the length of time to print, the lack of ability of the lower end machines to print heat-resistant pliable materials, and the need to have 3D CAD capability within the SMT assembly operation make this option limited.

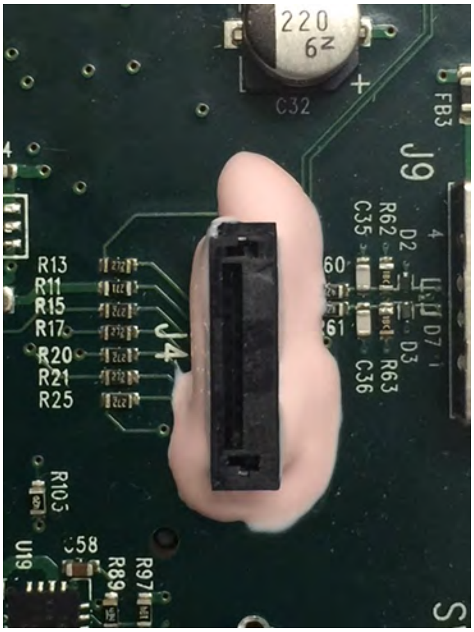

Figure 2: Peelable mask for conformal coating.

Tape Materials

All the tape derivative options may need to be tested. For example, they may or may not be able to prevent uncured coating material from leaching underneath the tape parting line. For example, some tape adhesives leave residues behind that may inhibit the long-term reliability of the electronics assembly by reducing SIR values or allowing accelerated dendritic growth to take place. Adhesives used in these tapes must have properties such that they do not peel off the cured coating material, leave unwanted residue on the PCB, or damage components. If the OEM specifies the allowable materials it may limit your options on material choices and type of masking. For example, even the slitting knife-coating material may cause unwanted silicone debris or de-wetting problems. Ensure that when these tape-based masking methods are used, all tape materials are compatible with the coating materials and the coating process being employed.

Summary

Whatever spraying method is employed in applying the conformal coating, having a handle on what type of masking method to use is critical to making sure the PCB assembly, rework or repair process is done properly and cost-effectively. **SMT007**

References

1. Kapton is a trademark of EI DuPont.
2. 3M Type 401 is a trademark of 3M.

Bob Wettermann is the principal of BEST Inc., a contract rework and repair facility in Chicago. To contact Wettermann, or read past columns, click here.

Electronics Industry News and Market Highlights

NAND Flash Prices Will Continue to Decline as the Slight Oversupply Continues in 2Q18 ▶

The NAND flash market has witnessed a slight oversupply in 1Q18, and while demand increases, the growth momentum remains weak in 2Q18, according to DRAMeXchange.

Technologies Enabling Smart Cities Initiatives to Reach $28.3 Billion in 2018 ▶

The market for technologies that enable Smart Cities initiatives in Asia/Pacific (excluding Japan) is expected to reach $28.3 billion in 2018, according to the first-ever IDC Worldwide Semiannual Smart Cities Spending Guide.

SSD Price Drop Will Drive the Adoption Rate of SSD in Notebooks to 50% ▶

In 1Q18, the traditional off-season, SSD market has seen obviously less stock up orders from PC OEMs compared with 4Q17, according to DRAMeXchange, a division of TrendForce.

Organic and Printed Electronics Industry Expects 7% Increase in Sales Revenue in 2018 ▶

The signs are still set for growth in the organic and printed electronics industry, according to results from the latest business climate survey conducted by the Organic and Printed Electronics Association (OE-A).

Global Semiconductor Sales Up 21% Year-to-Year in February ▶

Worldwide sales of semiconductors reached $36.8 billion for the month of February 2018, an increase of 21% compared to the February 2017 total of $30.4 billion, according to the Semiconductor Industry Association (SIA).

Server DRAM Prices Will Continue to Rise as Server Demand from China Boosts in 2Q18 ▶

According to the latest data of DRAMeXchange, the top three server DRAM suppliers are progressing towards the specification of 32GB RDIMM, and the 1Q18 quotes offered by server DRAM suppliers will grow by only 4% compared with 4Q17 in order to ensure sales by favorable prices.

Singapore Manufacturing Sector Leads IoT Readiness in APEJ ▶

Singapore spearheads the manufacturing industry IoT readiness index in the Asia Pacific (excluding Japan) (APEJ) because of its strong government thrust and robust FDI investment to drive technology and digital transformation initiatives.

GaN Power Device Industry: The Supply Chain is Acting to Support Market Growth ▶

The GaN power business was worth about $12 million in 2016, but at Yole Développement, analysts project that the market will reach $460 million by 2022, with an impressive 79% CAGR.

Enabling an Intelligent Supply Chain for Electronics Manufacturing

Article by Thilo Sack, Alex Chen, James Huang, and Sam Khoo, CELESTICA INC.

The first three industrial revolutions came about because of mechanization, electricity and IT. Now, with the advent of the Industrial Internet of Things (IIoT) and services making their way into the manufacturing environment, we are seeing the arrival of a fourth industrial revolution, Industry 4.0.

In this future, businesses will need to establish global networks that incorporate their production facilities with associated machinery and warehousing systems in the shape of cyber-physical systems (CPS). This new manufacturing environment will be comprised of smart machines, material storage systems and production facilities capable of autonomously exchanging information, triggering actions and controlling each other independently. This will also require a change in how production systems are managed and interact. Data must flow freely between one machine or system to another, unburdened from protocols or locked in standards. This will require that fundamental improvements be made to the industrial processes involved in manufacturing, engineering, material usage, supply chain and life cycle management. Many suppliers are already proposing solutions to enable the smart factories that are already beginning to appear to use some completely new approaches in production, which enables customizability. The smart products produced at these facilities will be

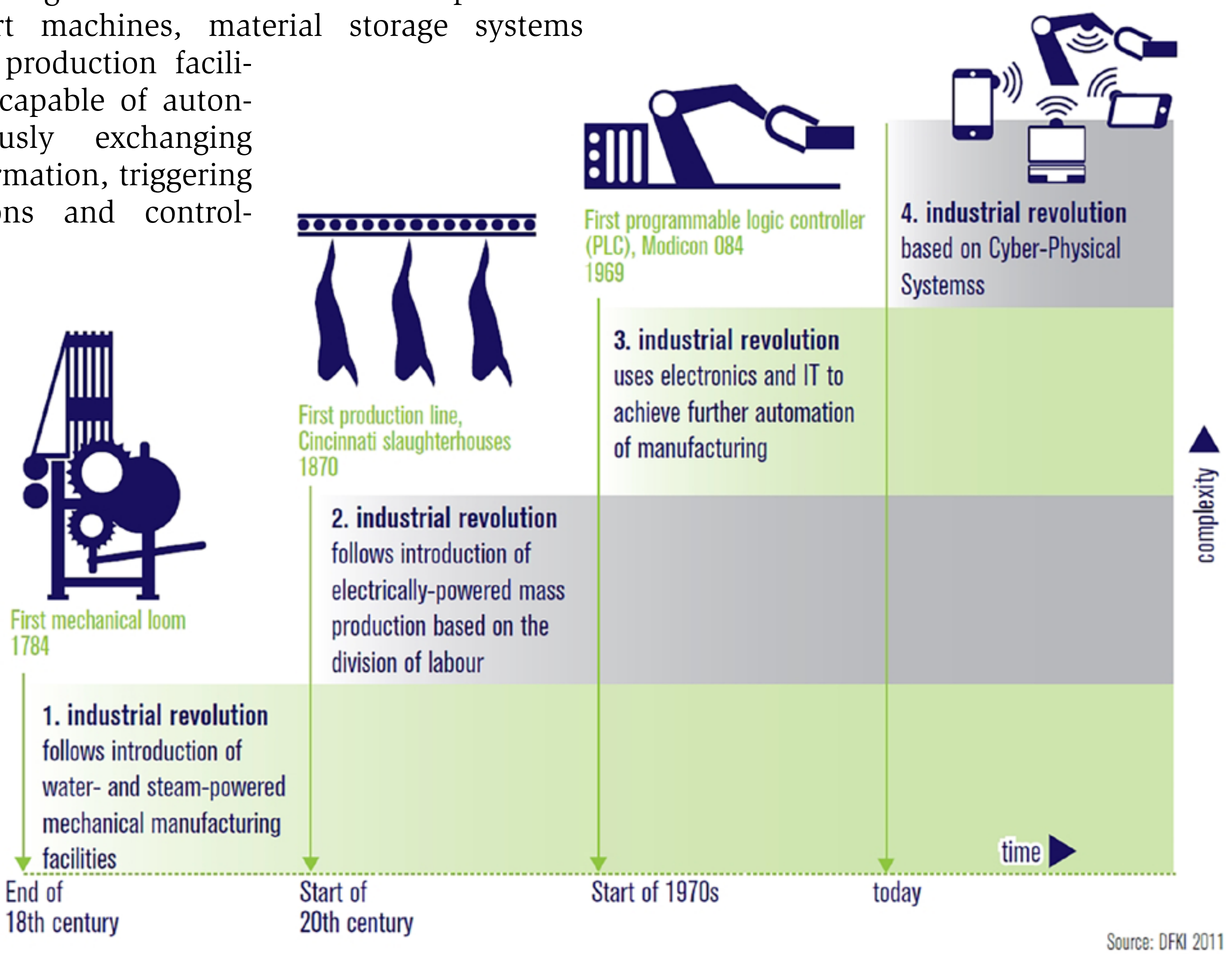

Figure 1: The arrival of the 4th Industrial Revolution [1].


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uniquely identifiable; they may be located at all times and know their own production history and current status; they must be able to generate alternative routings to be able to achieve their target state/shape/functionality.

Additionally, Industry 4.0 will address many of the environmental issues facing the world today, such as resource and energy efficiency. Industry 4.0 will provide a vehicle that enables continuous resource productivity and energy efficiency gains to be delivered across the entire supply chain.

These embedded manufacturing systems will be vertically networked within the factories' own business processes and enterprises while simultaneously being horizontally connected to the broader external supply chain that can be managed in real time—from the time an order is placed by a customer through outbound logistics to deliver the product. This will require that all aspects of the current MRP and MES systems be evaluated to understand how they can accommodate this new manufacturing paradigm.

The Connected Factory

Running a typical EMS operation requires the use of many disparate software platforms. Business processes in manufacturing are currently often still static and implemented through extremely inflexible software systems. Much of the capital investments made over the years to support the manufacturing operations cannot simply be ripped out or replaced with newer, more flexible/service-oriented applications. It therefore becomes essential to be able to integrate new technologies into older ones (or vice versa), with the older systems needing to be upgraded or enhanced with real-time capabilities. The magnitude of the challenges involved become quite evident once you look at the landscape of the all the different systems required to run a typical electronics manufacturing facility (Figure 2).

From the figure, it becomes obvious how challenging the task is to interconnect all the systems in such a way that data can easily be shared both vertically and horizontally across the factory infrastructure as you deal with not only engineering based tools but also all the planning and supply chain systems and the physical hardware producing the products.

Adding IIoT will make it possible to create networks providing much more detailed information around the entire manufacturing process that will convert factories into a more intelligent supply chain engine. As mentioned earlier, the production system will be comprised of smarter machines, material warehousing systems (i.e., automated material towers)

Figure 2: A typical electronics manufacturing facility.

and production facilities that have been connected digitally and feature end-to-end ICT-based integration. In addition to optimizing existing IT-based processes, the new environment will unlock the potential to track much more details about the production process than was able to be gathered before, which in the past was impossible to record and analyze. This does require the development of some unique IT infrastructure/protocols to permit the seamless gathering and exchange of information. Once deployed, big data can then be gathered, stored and ready for analysis.

The next challenge is how and what you do with the data to fully unlock the potential of this new supply chain model. Some examples of using this data to unlock potential improvements on the SMT production lines are already being deployed and piloted, including: feeding information from the API machine back to the screener to provide auto-correction of print parameters and using API to automatically adjust the placement locations of parts upstream on the SMT pick and place machines in the event of a shift in the actual printing. Many of these solutions are already available today from several of the equipment suppliers; however they tend to only be available if you use equipment from the same supplier.

Like most production facilities, individual pieces of equipment including screeners, API, placement, AOI, etc., might come from different suppliers based on capabilities or requirements. In that case, the transfer of data up and down the production line might require some custom development of the links and algorithms to perform the real-time corrections. This will also require that the individual equipment suppliers make available access to the data on their machines. Much progress has been made in that regard across all equipment vendors. Only then can the full potential of the intelligent supply chain be realized.

The future state of electronics manufacturing will involve the ability to connect, monitor and control every aspect of the production floor. Integration is key to be able to drive productivity as well as operational efficiencies in the future. The systems must provide seamless communication with managers, engineers, operators, control systems and software applications, thereby enabling automation and remote management to new levels.

Figure 3: Critical factors in EMS production.

The recent Hannover Messe automation show showcased many suppliers offering fully integrated connectivity framework and system architecture solutions to allow lots of big data to be gathered. The big challenge, which was yet to be addressed by most of these suppliers, was what to do with the data. In some ways, this makes sense since each industry will have unique needs and requirements for what the critical factors are, which would appear on a production dashboard, or what downstream factors should automatically adjust upstream processes. Only those folks directly involved in the day-to-day operation of their factory will know what those critical factors are.

As a case study for how a modern electronics manufacturer can leverage the benefits of big data and analytics in their own operations, we will look at the developments and deployment of an IIoT energy management solution within Celestica's factories.

Factory Energy Consumption

Today, energy efficiency is an important requirement for any manufacturing facility, as a large percentage of a factory's operating costs go into paying for electricity to both run the equipment and keep the facility cool. Figure 4 shows a breakdown of where energy is consumed in a typical EMS manufacturing factory in a warmer climate on products requiring post assembly burn in and reliability screening using thermal cycle chambers. It should come as no surprise that the energy required to run the air conditioning to keep the factory floor cool far exceeds that required to keep both the front SMT and backend test operations functioning.

The greatest potential for energy savings will therefore be realized from being able to minimize the amount of air conditioning which is required. Now most factories are setup from an air handling perspective to provide uniform cooling throughout the facility with a few strategically placed thermostats on the floor to dictate the cooling demand required. However, what generally happens is that the stress chambers are undercooled due to the localized concentration of heat generating sources, while areas further from the chambers are overcooled. The net result is uneven cooling across the entire factory, resulting in wasted energy. In an ideal scenario, cooling would only be provided to exactly where it was required and when. Also, production equipment could be shut down or put into stand-by mode when not needed instead of unnecessarily consuming power and venting heat into the factory.

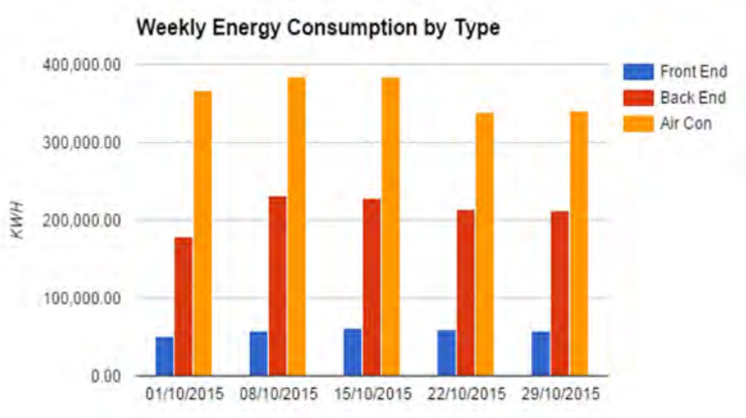

Figure 4: Energy consumption by type.

Dynamically controlling power consumption by systematically powering down inactive parts of a line during breaks in production is a key element of Industry 4.0. However, the entire planning and operation of the production facilities must be designed with this capability in mind to be able to meet this requirement. Currently, many production lines or parts thereof continue running and consuming high quantities of energy during breaks, weekends and shifts where there is no production. In a recently published case study at an automotive assembly line, nearly 12% of the total energy consumption of the vehicle body assembly line that uses laser welding technology occurs during breaks in production. The line operated five days a week on a three-shift pattern. Although this complex piece of machinery is not in use over the weekend, it remained powered up so that it could more quickly resume production once the weekend is over. If the source of the 12% energy consumption was further broken down, 90% of power consumption during breaks in production was accounted for by the following: robots (20–30%), extractors (35–100%) and laser sources and their cooling systems (0–50%) [1].

In this vehicle factory example, several steps could immediately be taken to help improve the energy efficiency of the operation: the robots could be powered down as a matter of course, even during short breaks in production. During longer breaks in production they could enter a kind of standby mode known as wake-on-LAN. The extractors could use speed-controlled motors that could be adjusted to meet requirements instead of motors that cannot be controlled. In the case of the laser sources, completely new systems were the only way of delivering improvements. Taken together, these measures enabled a reduction of 12% of total energy consumption to be achieved, together with a 90% cut in energy consumption during breaks in production [1]. However, the full extent of the potential gains cannot be met until

energy efficiency considerations are taken into account right from the earliest stages when designing the production system.

The Energy Efficient Production Floor Design

Celestica embarked on an effort to both understand and permit the full control of its factory floor from an energy consumption/efficiency perspective several years ago as part of its effort to understand the impacts of Industry 4.0 on its operations. As mentioned earlier, the first phase of this initiative required that the data collection backbone be designed in such a way that disparate pieces of equipment and software could easily gather and exchange information.

The second part involved the development of sensors and control circuits to permit for autonomous measurements and control of critical pieces of production equipment. Once deployed, data had to be gathered to understand energy consumption by factory floor location. This permitted detailed energy usage data to be gathered. Data analytics were then performed on this historical data to understand the relationship between energy consumption and resulting shop floor temperature. The first site deployment resulted in energy savings significantly exceeding that of the vehicle assembly plant example presented earlier. Eventually, an autonomous control system will be deployed and tied directly to the production MRP/MES system to permit for active control of air handling units and equipment on the shop floor based on the actual production forecast and schedule.

Measurement and Control Hardware

Specific measurement and control hardware had to be developed to facilitate both the monitoring of the shop floor temperature as well as the autonomous power on/off control of all the pieces of equipment on the production floor, which were either significant contributors of heat or large consumers of electricity. This included: SMT reflow ovens, wave solder machines, ICT testers, environmental test chambers, and the air handling control units. Custom I/O control boards/sensors were designed including temperature/humidity, power (high voltage and current), digital, analog and communication modules. This functional combination of sensors allows measuring, monitoring and control of almost any type of equipment including but not limited to lighting and air handling units (Figure 5).

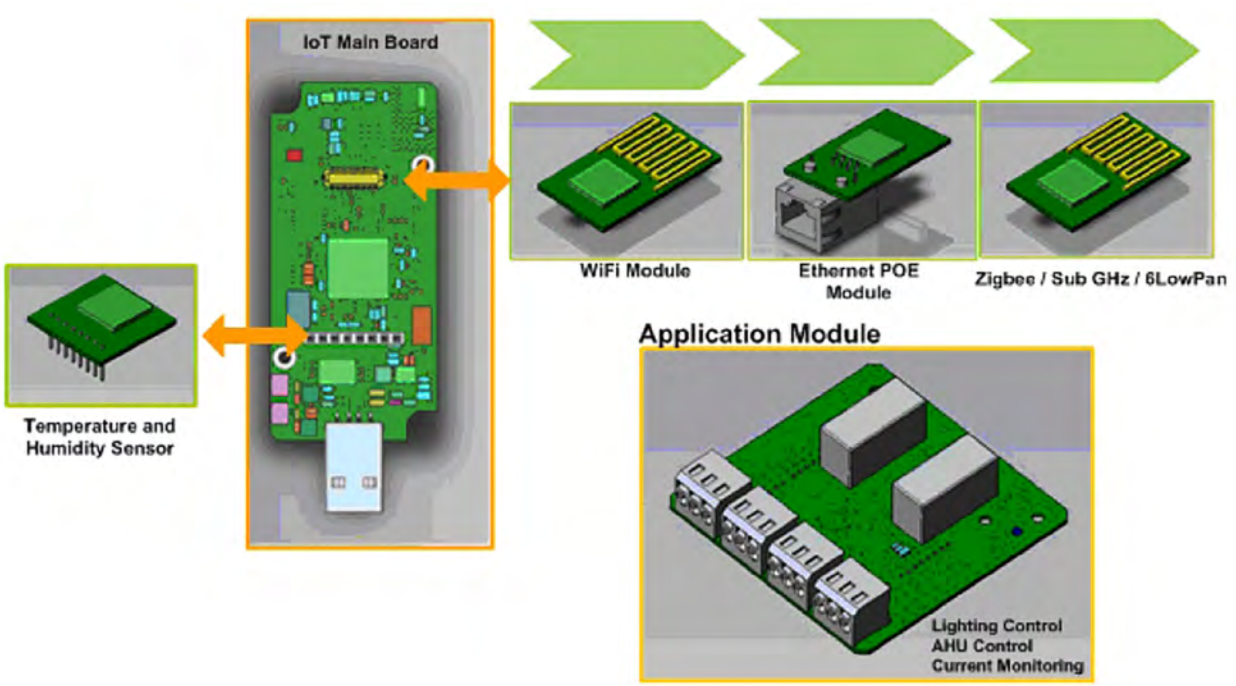

Figure 5: IIoT board designs.

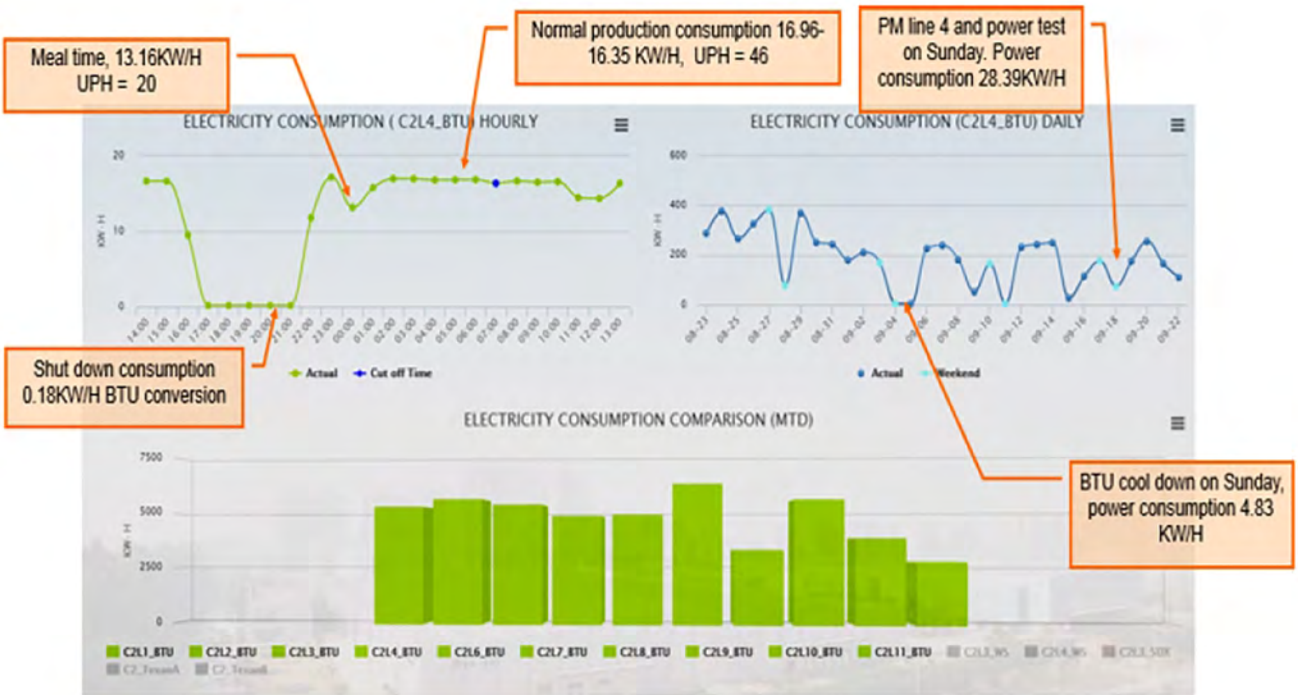

Figure 6: Detailed SMT reflow oven power consumption information.

An example of the detailed information that was able to be obtained from one of the reflow ovens appears below in Figure 6.

Control/Monitoring Hardware Deployment

The next stage in the deployment was deciding where to place the temperature sensors and controllers on the factory floor.

Figure 7 shows the layout of the production floor highlighting the location of the all air handling units (AHU) and the duct work feeding air to the floor. In this case, there are 6 AHUs feeding air ducts spaced at 20m-centers spread evenly above the factory floor. Each air duct line has a set of six diffusers to direct the air where needed. Prior to the deployment of the IIoT energy solution, all these AHUs would simply be running all the time pumping cool air indiscriminately throughout the entire floor based on some average temperature they were being asked to maintain. This resulted in obvious cool and hot spots on the production floor based on the concentration of equipment generating heat.

This concentration can be seen in the equipment line layout shown in Figure 8. The SMT lines are located at the top and left sides of the factory floor while all the environment test chambers are located on the right side. These chambers typically will consume lots of power

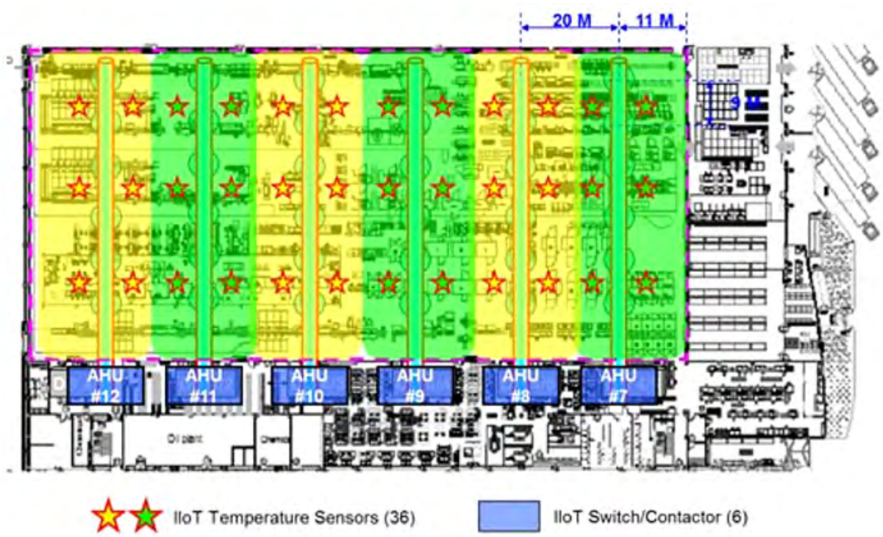

Figure 7: IIoT control vs. line layout (control air conditioning).

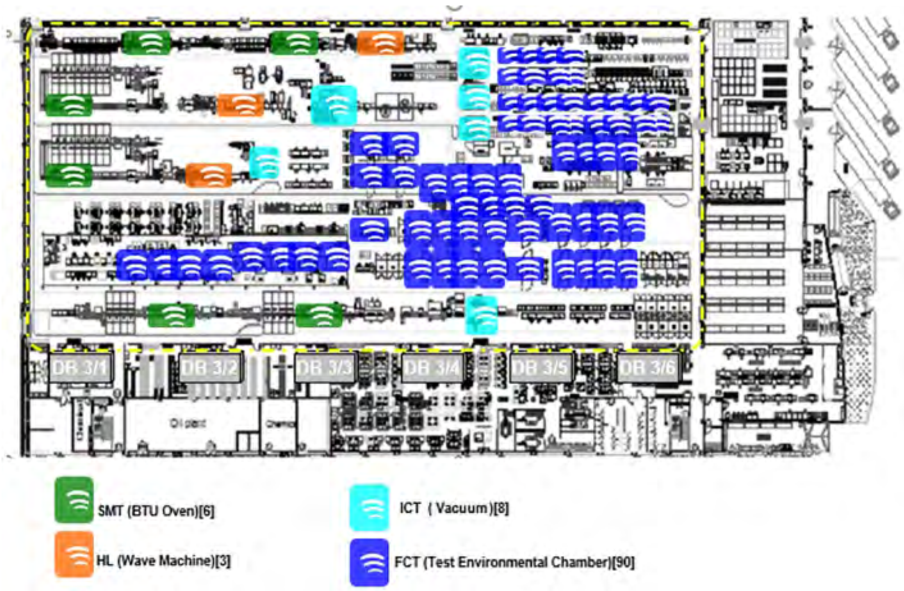

Figure 8: IIoT control vs. line layout.

and generate plenty of waste heat. Although most of the waste heat will be vented through the roof, due to the sheer number of chambers located in a single area of the floor, that area will always be hotter compared to the SMT lines.

As stated earlier, the IIoT solution deployed in the factory was comprised of two elements: monitoring and controlling the temperature/humidity to guarantee more uniformity and consistency across the entire floor; and secondly, permitting the remote control of all equipment that generates heat or consume more electricity/resources to be able to autonomously power them on/off based on production demand forecasts/breaks, etc.

Figure 7 shows the location where all 36 of the temperature and humidity sensors were deployed on the floor ("stars" in Figure 7). They were strategically placed in between each pair of diffusers near the factory floor on an equal grid with two sensors between each 20m air duct line. As well, switch/contactors were attached to each AHU at the front of each air duct to permit for independent on/off control of each AHU. Figure 8 then shows all the pieces of equipment that had attached to them IIoT control hardware to allow for remote power consumption monitoring and control. This included: the SMT line ovens, the wave solder machines, the ICT testers and the environment stress chambers.

Data Analytics

So now that the factory floor was fully wired up to both gather temperature/humidity data and control the hardware, the development of the logic necessary to intelligently control all the pieces of equipment had to be developed. This would be the next stage of the deployment of the IIoT energy solution.

Temperature/humidity and existing equipment energy consumption information was now gathered for several months. A real-time web-based dashboard was developed as part of this to permit for easier visualization of all the data (Figure 9).

Over a several-month period, the data was analyzed to permit control plans to be devel-

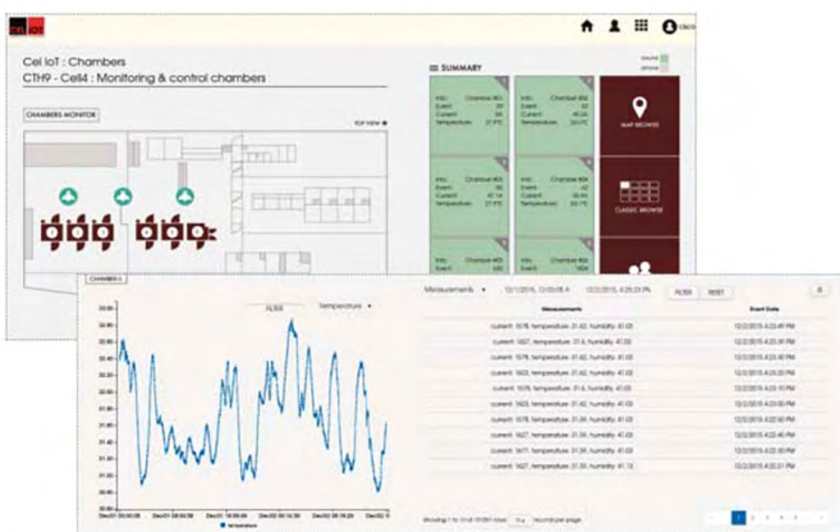

Figure 9: Real-time dashboard web application.

ENERGY SAVINGS
1. Stress chamber autonomous on/off control
2. Stress chamber utilization and peak demand controls
3. Chiller demand
4. AHU temperature controls
5. Reflow oven control
6. Wave solder machine pump controls
7. Air pressure system controls
8. Central vacuum system controls

Table 1: Rank order of energy savings.

oped based on actual energy consumption data and resulting temperature/humidity readings on the floor. Only then could the full benefits of the IIoT energy be realized through energy consumption shaping and allowing for autonomous on/off/standby mode (i.e., "factory on demand") approaches as mentioned earlier.

The complete solution will eventually be tied directly to the production forecast/control system to permit for autonomous energy control of the production facility.

Results

Since the deployment of the IIoT energy solution, net savings in energy consumption ranging from 10-20% have been realized across several of the factory installations. In order of magnitude of savings (from highest to lowest), the following resulted in the largest energy consumption reduction (Table 1).

Conclusions

Industry 4.0 represents be next phase of the industrial revolution where data is used to create a production environment with systems and machines that are capable of autonomously exchanging information, triggering actions and controlling each other independently. This will require a wholescale change in how the production floor is managed and how machines are interconnected. This paper presented one aspect of the Industry 4.0 journey by demonstrating how a factory outfitted with IIoT energy sensors and controllers can deliver significant reductions in energy consumption. The use of data analytics to both monitor, analyze and control the temperature/humidity in the factory, based on actual production equipment energy demand requirements, enabled a more intelligent supply chain on the electronics manufacturing production floor. **SMT007**

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- Celestica Toronto: Wes Karpiak, James Field.

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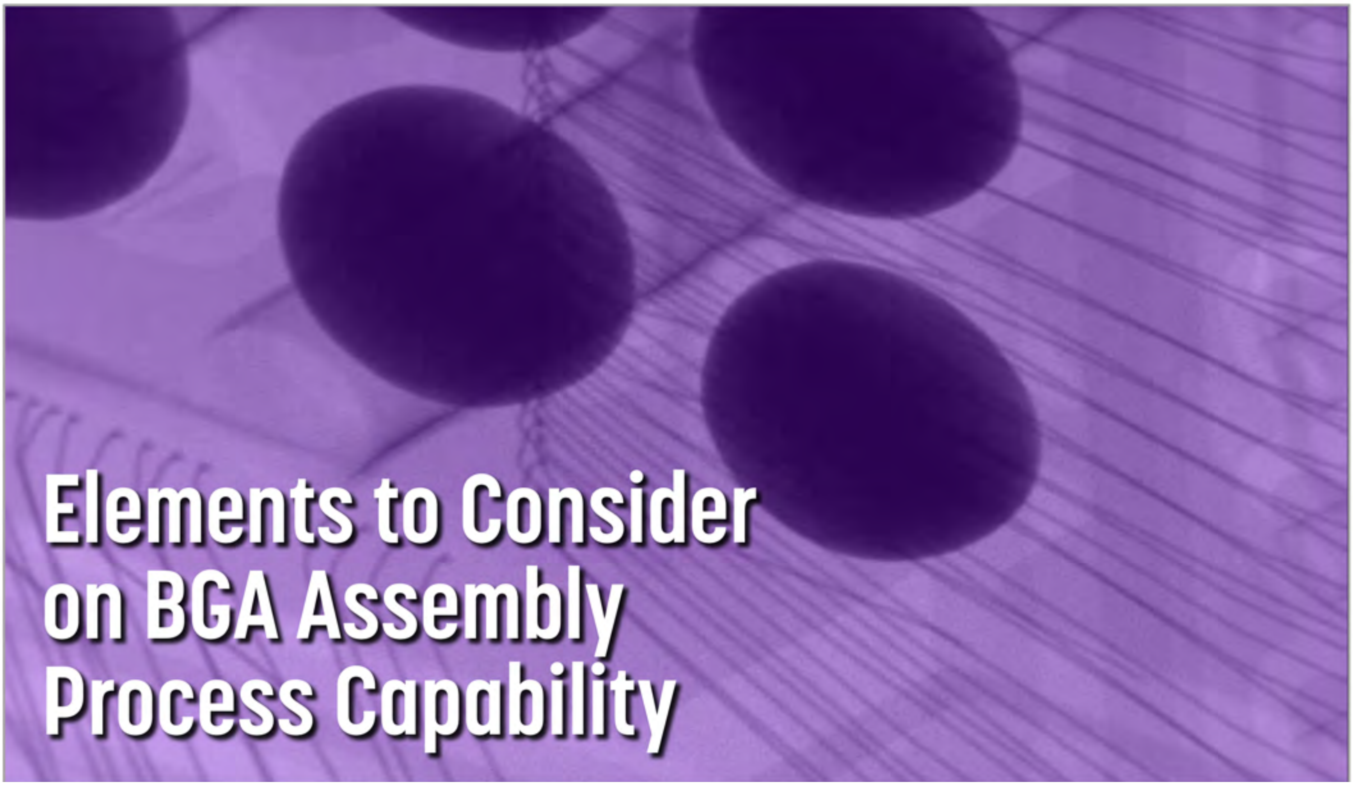

Elements to Consider on BGA Assembly Process Capability

by Dora Yang
PCBCART

BGA (ball grid array) assembly is totally compatible with soldering assembly technology. Chip-scale BGAs can have pitches of 0.5 mm, 0.65 mm or 0.8 mm, while plastic or ceramic BGA components feature wider pitches like 1.5 mm, 1.27 mm and 1 mm.

Fine-pitch BGA packages are more easily damaged than integrated circuits (ICs) with pin packages, and BGA components allow selective reduction of contact points to meet the specific requirement on I/O pins. As a cutting-edge technology applied in SMT assembly, BGA packages have quickly become a significant selection to conform to fine pitch and ultra-fine pitch technology, achieving high-density interconnection with a reliable assembly technology provided, which leads to the increasingly more applications of this type of package.

Application of X-Ray Tomography in BGA Assembly

Most PCB manufacturers and electronics manufacturers haven't noticed too much necessity to apply X-ray inspection in their manufacturing process until BGA components are applied in electronics assembly. Traditional inspection methods were regarded to be sufficient, such as manual visual inspection and electrical test, including manufacturing defect analysis (MDA), in-circuit test (ICT) and function test.

However, all those inspection methods fail to find out hidden solder joint issues such as cavities, cold soldering, and bad tin-soldering adhesion. X-ray inspection system is a type of inspection tool that has been verified to be capable of inspecting hidden solder joints and help establishing and controlling manufacturing process, analyzing prototype and confirming process. Different from MDA, ICT and AOI, an X-ray inspection system is capable of confirming short circuits, open circuits, cavities and BGA solder ball alignment, monitoring process quality and providing instant feedback data for statistical process control (SPC) with high manufacturing efficiency.

X-ray tomography inspection devices can generate tomography images through capturing images of solder joints that are able to implement automatic solder joint analysis and real-time tomography scanning. Moreover, they

can carry out accurate comparison analysis on all solder joints of components on both sides of a PCB board within a couple of seconds or two minutes, leading to a conclusion whether solder joints are qualified or not.

BGA Assembly Process and Variation Source

To use X-ray inspection system more effectively, control parameters of BGA assembly process and parameter control limitations have to be clarified. BGA assembly process conforms to the sequence in Figure 1.

When BGA components' eutectic solder balls are assembled in solder paste during assembly process, their positions are usually corrected through self-alignment of liquid soldering tin. Thus, mounting precision seems not so essential as fine-pitch lead components and the leading control phase in BGA component assembly technology is solder paste printing and reflow soldering. In addition, variation in terms of solder joint shape and size is also associated with many other elements.

It's almost impossible to eliminate all the variations, so the key point in manufacturing process control is to reduce variation in each manufacturing phase. The influence of different variations on final assembly products should be carefully analyzed and quantitatively processed. With the whole process from BGA components to PCB assembly process considered, leading elements affecting solder joint quality are:

- Volume of solder balls
- BGA component pad size
- PCB pad size
- Solder paste volume
- BGA component deformation during reflow soldering process
- PCB deformation at BGA mounting area during reflow soldering process
- Mounting placement accuracy
- Reflow soldering temperature curve

No matter what type of inspection device is used, there must be a basis when judging whether solder joints are qualified or not. IPC-A-610C regulates the definition of acceptance criteria of BGA solder joints in 12.2.12 item. Excellent BGA solder joints are required to be smooth, round, clear in edge and with no cavities. Diameter, volume, grayscale and contrast should be the same for all solder joints with position aligned and no displacement or twist.

BGA Assembly Process Capability

A type of BGA component is used as an example in the following discussion. This type of BGA components is PBGA (plastic ball grid array) with 520 pins and a size of 2-by-2 in, featuring eutectic solder balls and leveraging no-clean flux. Six Sigma process capability analysis is implemented to testify BGA placement accuracy, solder joint open circuits and short circuits occurring probability. The assumptions prior to calculation are:

- No variations take place on BGA component pad or PCB pad
- BGA components suffer from no deformation (reflow soldering process)
- The average deviation is figured out in accordance with the average volume of solder joints after reflow soldering;
- BGA component weight is assumed to be balanced by flotage and surface tension
- Pad and eutectic solder balls should feature good solderability
- All distributions are normal

1. BGA placement

Standard SMT equipment is used to get BGA components mounted. Ordinary mount-

Figure 1.

±3 mils	**@ 6sigma**
Other variations affecting placement process capability	
Solder paste printing capability = ±4 mils	@ 6sigma
X and Y position accuracy of PCB pad = ±3 mils	@ 6sigma
X and Y position accuracy of eutectic solder balls = ±3 mils	@ 6sigma

Figure 2.

ing equipment is capable of recognizing BGA eutectic solder ball images with placement process capabilities covered as in Figure 2.

Based on the above data, the maximum placement deviation is 6.53mil when process capability is Six Sigma. Since diameter of pad is 28 mil, the placement deviation can be neglected among components' self-alignment deriving from surface tension when solder paste is melted. When it comes to BGA components placement process, it conforms to Six Sigma level.

2. Solder joints with open circuits

Assembly process tends to see open solder joints due to insufficient eutectic solder ball collapse. As far as PBGA with 520 pins are concerned, eutectic solder balls are balls with diameter of 30 mils whose standard deviation is 5003 mils (with volume participated in) and volume is regulated to be 14,1303 mils. Diameter of BGA and PCB pad is 28 mil with its solder paste thickness being 6 mil. Therefore, the average height of BGA solder ball edge is approximately 24 mils. As Six Sigma capability reflecting solder ball volume variation is concerned (Figure 3).

After reflow soldering, the height of soldering bonding support determined by average volume of solder joints is 19 mils. As process capability is set to be Six Sigma, solder paste thickness is measured to be 4 to 8 mils. Moreover, BGA solder balls will be collapsed into solder paste for 3 mils, which leads to the following calculated data:

- *Minimum thickness of solder paste below solder balls = 3 mils*
- *Minimum collapse = 7 mils*
- *Minimum incorporated collapse = 10 mils*
- *Minimum security deviation generated to stop open circuits from taking place = 2.2 mils*

When above variations can be controlled into certain ranges, BGA reflow soldering process can achieve Six Sigma.

Unfortunately, deformation at BGA components and PCB usually leads to height inconsistency of soldering bonding during BGA reflow soldering assembly. BGA components and PCB pad features differences that lead to process variation. All in all, even though all variations are taken into consideration, open soldering joints will still take place. Thus, X-ray inspection system can be used to carry out defect inspection on open solder joints.

3. Solder joint bridging (short circuits)

The same method can be used to estimate the influence of short circuits of soldering joints on assembly process capability. Solder joints differ from each other in terms of diameter and measured data indicates that bonding volume of each solder joint is in the range from 12800 to 192503 mils under Six Sigma process capability. As a result, the height of minimum soldering bonding support is 15 mils and then maximum soldering bonding diameter can be as much as 38.5 mils. When it comes to BGA components with pitch of 50 mils, solder joint bridging will hardly take place.

Statistical Process Control Analysis

Effective BGA assembly process control leads fewer variations occurring to solder connections. In practical assembly process, however,

Solder ball height variation (coplanarity) = 5.0 mils	@ 6sigma
PCB deformation at component mounting area = 6.0 mils	@ 6sigma
Incorporated coplanarity = 7.8 mils	@ 6sigma

Figure 3.

the following variations usually make process fluctuate, calling for consistent monitoring:

- Solder paste height and volume
- Diameter of side connection of BGA components
- Diameter of side connection of PCB pad
- Central bonding diameter of connections
- Cavity size and occurrence rate
- Tin balls.

Solder paste thickness can be monitored by X-ray inspection equipment and process variations can be controlled within a certain level based on solder joint shape and consistency. **SMT007**

Dora Yang is a technical engineer from PCBCart, a China-based full turnkey PCB assembly service provider. For any questions related to PCB design, manufacturing or assembly, reach Dora on Twitter, @dorayang0227 or directly at www.pcbcart.com.

Rehm Discusses How Vacuum Reflow Technology Helps Reduce Voiding

At the recent NEPCON China 2018 trade show in Shanghai, Ralf Wagenfuehr, plant manager at Rehm Thermal Systems, discusses how vacuum reflow helps reduce solder voiding and ensure reliable and stable reflow soldering processes. Click image to watch this video.

1 One World, One Industry: Skilled Talent—Can We Meet Rising Demand? ▶

According to a study by the Manufacturing Institute, over the next decade, nearly 3.5 million manufacturing jobs are expected to become available in the United States—but more than 2 million of those jobs will remain unfilled due to a lack of available skilled talent.

2 IPC APEX EXPO Takeaways ▶

The IPC Connected Factory Exchange (CFX) live demo at this year's IPC APEX EXPO show in San Diego, California highlighted how the CFX standard will enable manufacturers to track their efficiencies better, prevent issues even before they happen, and make adjustments wherever needed.

3 The Direction of Autonomous Driving ▶

Eric Hoarau, senior director managing automotive innovation at Flex, discusses his company's views on where autonomous driving technology is heading in the next 10–15 years.

4 How to Prepare for a Smooth Pst-M&A Deal Transition ▶

Selling a company is an exciting process, as well as time-consuming, stressful, and complex. Both sellers and buyers are sometimes so caught up in the deal that they forget to properly plan the post-deal integration.

5 Techniques Used to Detect Counterfeit Electronic Components ▶

Although government pressure and private resources have helped minimize the risk of counterfeit components from entering the supply chain, there is still and will most likely continue to be, a prominent threat. So, what can you do to minimize this risk? Read on.

6 RTW IPC APEX EXPO: Zentech Discusses New NIST Legislation ▶

Matt Turpin, president and CEO of EMS firm Zentech Manufacturing Inc., speaks about the NIST 800-171 legislation published by the National Institute of Standards and Technology, and how it is different from other regulations such as ITAR.

7 Fabrinet Upgrades SMT Facility with Class 8 Clean Room ▶

Fabrinet UK has upgraded its On-Demand facility to offer a Class 8 clean room. The unit, part of its high mix low volume manufacturing facility in the UK is already being widely used by customers across both A&D and Telecoms.

8 RTW IPC APEX EXPO: Miraco Company and Services Introduction ▶

Miraco's current quality manager, William Pfingston, fills Guest Editor Steve Williams in on the company's contract manufacturing capabilities and services, including strengths in design and flex circuits. He also talks about the company's expansion and organizational changes.

9 Four Conferences for the First Time at electronica ▶

The conferences in the context of electronica are getting new additions this year. In addition to the Automotive Conference, Embedded Platforms Conference and Wireless Congress, the Medical Electronics Conference, all dealing with developments and trends in electronics, will take place for the first time.

10 IPC Publishes Standard on Low-Pressure Molding for Circuitry Encapsulation ▶

IPC announces a new standard, IPC-7621, Guideline for Design, Material Selection and General Application of Encapsulation of Electronic Circuit Assembly by Low Pressure Molding with Thermoplastics, a guidance document that offers instruction on using Low Pressure Molding (LPM) in place of potting for circuitry encapsulation.

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June 4–5 — Nuremberg, Germany
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June 7 — Frankfurt, Germany
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Do you have what it takes? MacDermid Enthone Electronics Solutions is a leading supplier of specialty chemicals, providing application-specific solutions and unsurpassed technical support.

The position of the Technical Service Rep will be responsible for day-to-day support for fabricators using MacDermid Enthone's chemical products. The position requires a proactive self-starter who can work closely and independently with customers, sales group members and management to ensure that customer expectations and company interests are served.

- Thoroughly understand the overall PCB business, and specifics in wet processing areas
- Prepare action plans for identification of root cause of customer process issues
- Provide feedback to management regarding performance
- Create and conduct customer technical presentations
- Develop technical strategy for customers
- Possess the ability to calm difficult situations with customers, initiate a step by step plan, and involve other technical help quickly to find resolution

Hiring Profile

- Bachelor's Degree or 5-7 years' job-related experience
- Strong understanding of chemistry and chemical interaction within PCB manufacturing
- Excellent written and oral communication skills
- Strong track record of navigating technically through complex organizations
- Extensive experience in all aspects of customer relationship management
- Willingness to travel

apply now

KYZEN
Where Science and Care Converge.

KYZEN Regional Manager – Midwest Region

General Summary: KYZEN is seeking a Regional Manager to join our sales team in the Midwest. This position is ideally suited for an individual that is self-motivated, hard-working and has a "whatever it takes," positive attitude, especially with customers. Being mechanically inclined is a plus. KYZEN will provide on-going, in-the-field training to help you succeed.

CORE FUNCTIONS:

- Collaborates with the Americas Manager in establishing and recommending the realistic sales goals for territory
- Manages the assigned geographic sales area to maximize sales revenues and meet corporate objectives
- Develops sales strategies to improve market share in all product lines (Electronics and Industrial)
- Ensures consistent, profitable growth in sales revenues through planning, deployment and management of distributors and sales reps as well as continued direct support for customers and prospects processes

REPORTING:

- Reports directly to Americas Manager

QUALIFICATIONS:

- A minimum of seven years related experience or training in the manufacturing sector or the equivalent combination of formal education and experience
- Excellent oral and written communication skills
- Working knowledge of Microsoft Office Suite
- Mechanically inclined a plus
- Valid driver's license
- Travel within the region up to 75% of the time with occasional travel outside the region

apply now

Career Opportunities

ventec
INTERNATIONAL GROUP
騰輝電子

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

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

Skills and abilities required:

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

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

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

apply now

CHEMCUT
BOUNDLESS INNOVATION | UNBEATABLE PRECISION

Field Service Technician

Chemcut, a leading manufacturer of wet-processing equipment for the manufacture of printed circuit boards for more than 60 years, is seeking a high-quality field service technician. This position will require extensive travel, including overseas.

Job responsibilities include:

- Installing and testing Chemcut equipment at the customer's location
- Training customers for proper operation and maintenance
- Providing technical support for problems by diagnosing and repairing mechanical and electrical malfunctions
- Filling out and submitting service call paperwork completely, accurately and in a timely fashion
- Preparing quotes to modify, rebuild, and/or repair Chemcut equipment

Requirements:

- Associates degree or trade school degree, or four years equivalent HVAC/industrial equipment technical experience
- Strong mechanical aptitude and electrical knowledge, along with the ability to troubleshoot PLC control
- Experience with single and three-phase power, low-voltage control circuits and knowledge of AC and DC drives are desirable extra skills

To apply for this position, please apply to Mike Burke, or call 814-272-2800.

apply now

Career Opportunities

Career Opportunities

ARLON

Arlon EMD, located in Rancho Cucamonga, California is currently interviewing candidates for **manufacturing** and **management positions.** All interested candidates should contact Arlon's HR department at 909-987-9533 or fax resumes to 866-812-5847.

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

Our facility employs state of the art production equipment engineered to provide cost-effective and flexible manufacturing capacity allowing us to respond quickly to customer requirements while meeting the most stringent quality and tolerance demands. Our manufacturing site is ISO 9001: 2008 registered, and through rigorous quality control practices and commitment to continual improvement, we are dedicated to meeting and exceeding our customer's requirements.

more details

IPS INTEGRATED PROCESS SYSTEMS INCORPORATED

PCB Equipment Sales

World-class manufacturer of wet process equipment for the PCB and plating industries, Integrated Process Systems Inc. (IPS) is seeking qualified candidates to fill a position in equipment sales. Potential candidates should have:

- Process engineering knowledge in PCB manufacturing
- Outside sales background
- Residency on the West Coast to manage West Coast sales
- Knowledge of wet process equipment
- Sales experience with capital equipment (preferred)

Compensation will include a base salary plus commission, dependent upon experience.

more details

Events Calendar

2018 SE Asia Technical Conference on Electronics Assembly
May 8–10, 2018
Kuala Lumpur, Malaysia

PCB EXPO Thailand
May 10–12, 2018
Bangkok, Thailand

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

IMPACT Washington, D.C. 2018
May 21–23, 2018
Washington, D.C., USA

EIPC 50th Anniversary Summer Conference
May 31–June 1, 2018
Bonn, Germany

JPCA Show 2018
June 6–8, 2018
Tokyo, Japan

SMT Hybrid Packaging & Micro Electronics 2018
June 5–7, 2018
Nuremburg, Germany

Sensors Expo & Conference
June 26–28, 2018
San Jose, California, USA

NEPCON South China 2018
August 28–30, 2018
Shenzhen, China

IPC E-Textiles 2018 Workshop
September 13, 2018
Des Plaines, IL, USA

electronica India 2018 / productronica India 2018
September 26–28, 2018
Bangalore, India

electronica 2018
November 13–16, 2018
Munich, Germany

Additional Event Calendars

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Tackling the challenges in flex circuit assembly.

JULY: **BEST PRACTICES IN ELECTRONICS ASSEMBLY**
Best practices to consider for the different processes in PCB assembly.