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"This book is a terrific resource for those new to flex design and those more experienced looking to streamline the design to fabrication transition."

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I-Connect007 is excited to announce the release of the next title in its ***Printed Circuit Designer's Guide to...***™ series, *The Printed Designer's Guide to…Flex and Rigid-Flex Fundamentals*.

Written by Anaya Vardya and David Lackey, both of American Standard Circuits, this micro eBook provides circuit designers, both new and seasoned, with valuable, important information that will help to assure first-pass success in getting their products to market.

The Printed Designer's Guide to… Flex and Rigid-Flex Fundamentals is a must-read for anyone in the supply chain using flex/rigid-flex technology.

We welcome you to download this book free by visiting the book's website.

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- ***The Printed Circuit Designer's Guide to... Secrets of High-Speed PCBs*** by Polar Instruments
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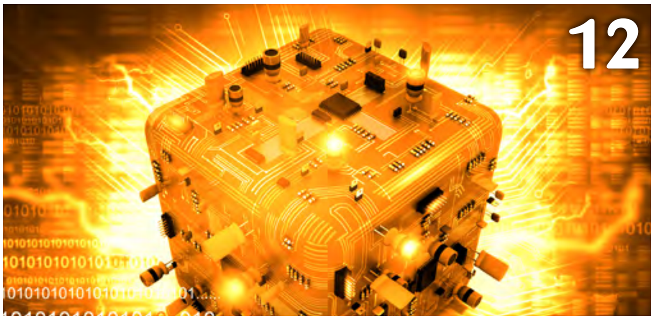
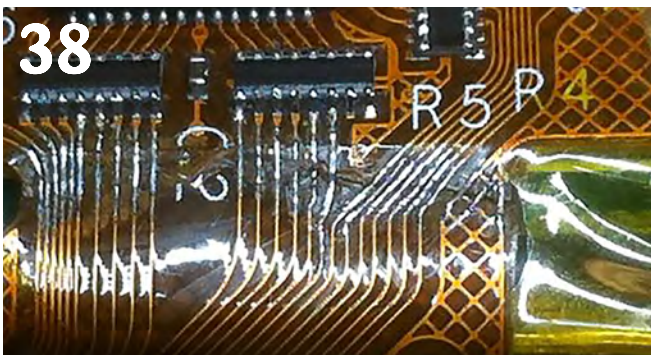
- ***The Printed Circuit Buyer's Guide to... Simulation and Analysis*** by Mentor Graphics

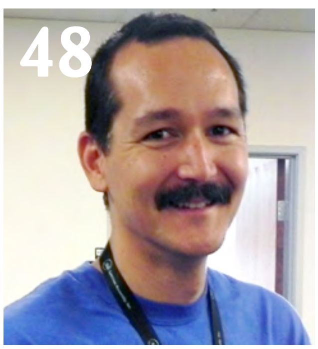
We hope you enjoy *The Printed Designer's Guide to… Flex and Rigid-Flex Fundamentals!*

SMT MAGAZINE

March 2017 • Featured Content







The Wide World of Flex Circuit Assembly

This issue of *SMT Magazine* looks into the different challenges that assemblers face when dealing with flex circuits, and highlights strategies to address them.

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Navigating the Complex World of Flex Circuit Assembly

by Stephen Las Marias
I-CONNECT007

The expanding use of flexible printed circuits in markets such as military/aerospace electronics, automotive electronics, and medical electronics is fueling the demand growth for this PCB technology.

According to a report by Global Industry Analysts Inc. (GIA), the global market for flexible printed circuits is projected to reach $15.2 billion by 2020, driven by the growing focus of electronics manufacturers on performance and design flexibility.

Allied Market Research (AMR), another industry analysis group, is likewise bullish. It projects the worldwide flex printed circuit market to reach $27 billion by 2022, with a compound annual growth rate (CAGR) of 10.4% from 2016 to 2022.

From a regional perspective, Asia-Pacific—which is considered the global hub for electronics production—ranks as the fastest growing market for flex printed circuits, registering a CAGR of 6.7% over the 2013–2020 forecast period, according to GIA.

AMR, on the other hand, notes that Asia-Pacific dominated the global flex printed circuit market in terms of revenue, accounting for more than 46% in 2015, followed by North America.

We at I-Connect007 recently conducted a survey on flexible printed circuits to know more about the challenges that designers, fabricators, and assemblers face when dealing with flex circuits. They were asked about the steps in their processes that have the biggest effect on yields; the challenge when dealing with flex circuit materials; as well as the factors that have the greatest impact on the quality of their flex circuit design, fabrication and assembly.

Another question focused on market demands that are driving the increasing use of flexible printed circuits. Majority of the respondents highlighted the trend toward smaller form factors, which is leading to space-constrained designs. From a market applications perspective, the aerospace and defense segment, consumer electronics, and medical electronics were

found to be the key industry sectors seeing increased use of flexible circuits, as per our survey.

Also, most respondents consider the design of the flex circuit, the handling, and soldering processes as among the key factors that have the biggest effect on yields.

Another issue is moisture control. In a short email interview, Brian Tracey, group vice president of business development at Interplex Industries Inc.—a provider of design and manufacturing services for custom flex circuit assembly—says the hydroscopic nature of the flex circuit makes it difficult to process, therefore drying the flex circuits prior to soldering can help improve yields. Directly related to this is the soldering process, which he considers as a key process step that has the biggest effect on yield as it can sometimes create solder voids, cold solder joints or incomplete circuits.

Meanwhile, Tracey notes that the limitations with the adhesives used between the insulation and copper layers offer a major challenge in flex circuit assembly as these adhesives are sensitive to water absorption as well as heat, which can break down the adhesive layers and cause the traces to fracture.

Regarding new technologies that will significantly benefit the flexible printed circuit process, Tracey says they are seeing potential benefits in including direct solder attachment to leads as well as utilizing eye-of-the-needle press-fit technology to further expand the range of manufacturing solutions for their customers. He adds that they are starting to see slight improvements in materials used to produce the flex circuits that is helping with overall yields throughout the process.

This issue of *SMT Magazine* features articles and interviews with companies such as Saline Lectronics, Tramonto Circuits, Firstronic, JJS Manufacturing, Spectrum Assembly Inc., and Screaming Circuits, about flexible circuit assembly challenges, as well as strategies to help you address your pain points. Contributors provide important points to consider when selecting an electronics contract manufacturing partner for your flex printed circuit assembly.

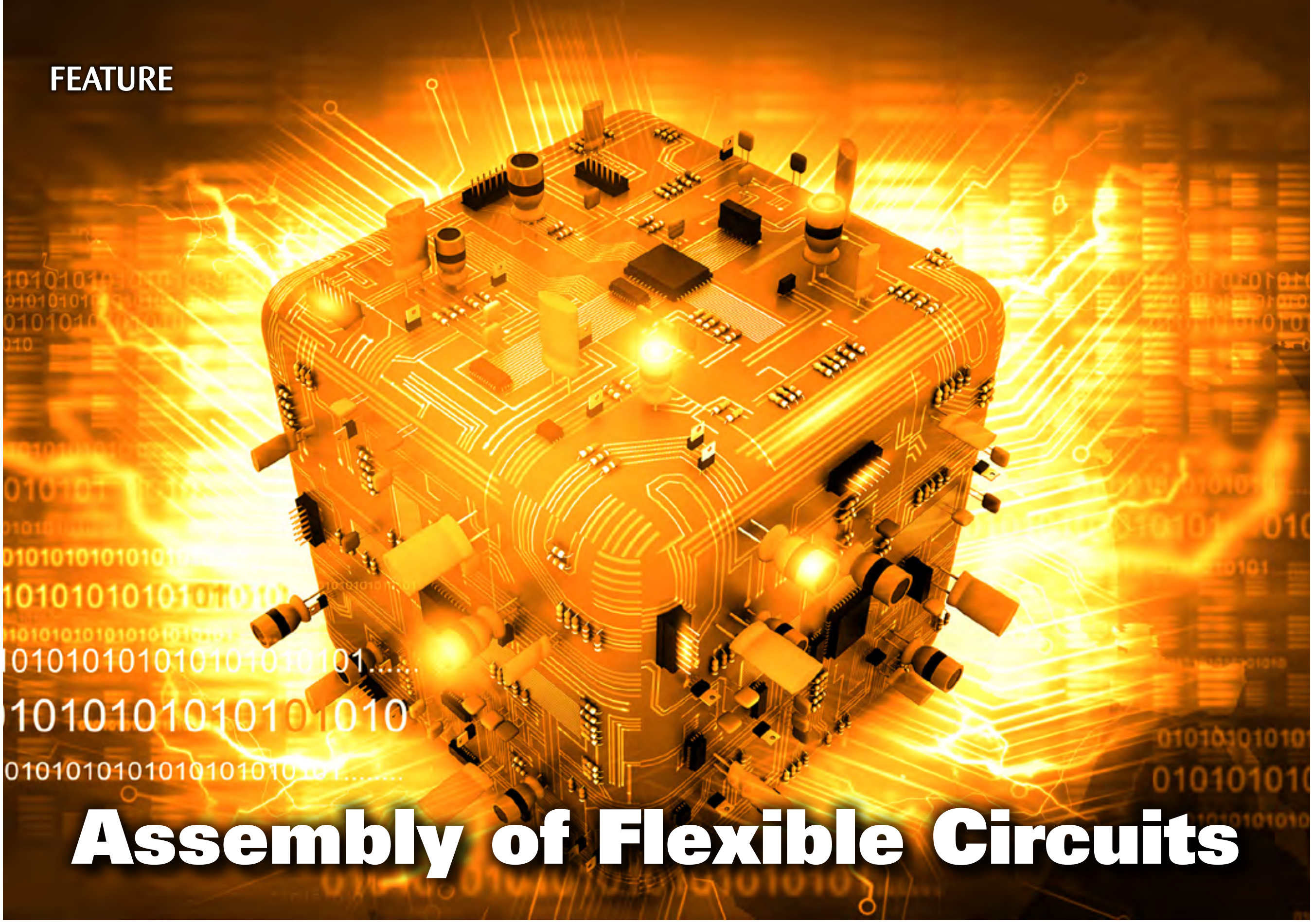
Regular columnists Michael Ford, Rich Heimsch, Tom Borkes, and Bob Wettermann provide their expert views on the latest issues in the electronics assembly industry.

Finally, we also have interesting articles from Microcare, which discusses flexible cleaning methods, and PCBCart, which provides pointers on how to evaluate a PCB assembler.

By the way, we had a great show last month at the IPC APEX EXPO 2017 event in San Diego. Our booth featured a micro studio, where we did more than 70 in-depth Real Time with…IPC interviews. We also created a time-lapse video, which is made up of over 50,000 photos taken from the event setup to closing. So if you didn't make it to IPC APEX EXPO this year, just visit our RealTimewith…IPC APEX EXPO 2017 site to get all the show coverage and view the event photo gallery. **SMT**

Stephen Las Marias is managing editor of *SMT Magazine.* He has been a technology editor for more than 12 years covering electronics, components, and industrial automation systems.

FEATURE



Assembly of Flexible Circuits

by John Talbot
TRAMONTO CIRCUITS

Introduction

A flexible circuit assembly consists of a bare circuit with conductive patterns etched onto it that allow the attachment of components that, when completed, results in a working electronic product. Components are available in different shapes, sizes and methods of attachment. There are through-hole components that have wire leads that, as the description states, go through-holes in the circuit and are soldered. Surface mount components, intuitively, are placed on surface pads and soldered to the circuit. The number of different configurations of through-hole and surface mount components are vast. The typical method of attachment is by soldering the component to a conductive pattern. Some components are soldered one lead at a time by hand. Others are placed automatically by machine and run through an oven to solder the entire board at the same time. No matter the method, the assembly of electronic flexible circuits is tedious because of its inherent flexible nature. Therefore, we must give extra attention to the assembly process.

Flexible Circuits

Flexible circuits are made from a thin plastic substrate of polyimide or polyester. The most widely used material for flexible assemblies is polyimide (poly im id) because it can withstand the high temperatures required to solder components without negative effects. Polyester circuits shrivel up when exposed to those temperatures and make them less appropriate for flexible assemblies. The polyimide material is laminated to conductive layers and insulating layers with epoxy or acrylic based adhesives. The final product is a very thin, typically .010”, overall thickness. This is the characteristic that makes assembly on flexible circuits more difficult than traditional printed circuit boards which are 1/16” thick and sturdy. The inherent nature of a flexible circuit demands high attention to handling during the assembly process. Whether hand soldering or automated soldering, the circuits must be supported for consistent results. The discussion below will focus on the processes that will make any flexible circuit assembly successful.

Moisture and Flexible Circuits

Before we can start any assembly on a flexible circuit, we must first bake out the moisture.

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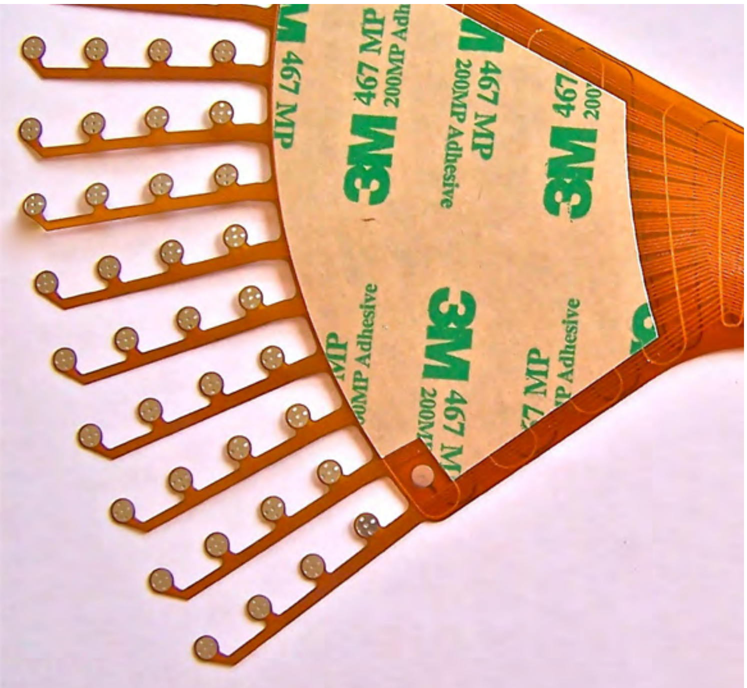

Figure 1: Flexible circuit.

This is done in a dry oven at low temperature for several hours. The intent is to evaporate all moisture that has been absorbed by the plastic and adhesive layers during storage. This is a bigger problem during the summer months when atmospheric humidity is high. Less of an issue during the dryer winter months. However, no matter the season, if the moisture is not baked out, negative results are possible.

When introduced to the high temperatures required to melt solder, 680°F to 750°F, the moisture trapped between the layers can boil quickly and cause the laminated layers to separate. Once the layers are separated the flexible circuit cannot be used reliably as it allows air into the circuit which contains water, that will eventually corrode and render the circuit useless. It is a prudent first step in any circuit assembly process to bake out the moisture.

Solder Choices for Assembly of Flexible Circuits

Before the year 2000, most circuit assemblies used solder that consisted of tin and lead. A popular ratio of the alloy was 63% tin and 37% lead. However, the European Union passed a directive named Restriction of Hazardous Substances, commonly known as RoHS, or Directive 2002/95/EC. It restricted the use of lead, mercury, cadmium and other substances in products sold there. Electronic industries worldwide were affected and had to come up with a substitute for the tin/lead alloys that had been used for decades.

Today, both RoHS and non-RoHS solders exist and are used. A typical RoHS compliant solder will contain no lead and be made instead of tin, silver and copper. This new solder requires higher temperatures to melt than the tin/lead versions and looks differently as well.

Both RoHS and non-RoHS solders come mixed with flux that must be cleaned or flux that does not require to be cleaned. The flux in the version that requires cleaning is very corrosive and can be conductive if left on the circuit, but is easily cleaned with water. The flux in no-clean solder leaves an inert clear residue that may remain on the circuit forever without adverse effects. The use of these solder options on flexible circuits is common and generally requires no special considerations, aside from the melting temperature.

Hand or Manual Soldering Process

The hand or manual soldering process requires a skillful assembler to attach components to a flexible circuit one solder joint at a time. A compliant solder joint, defined by the governing body, IPC, makes no distinction for flexible circuits. The complications added to the solder process come from the thin flexible na-

Figure 2: Hand solder.

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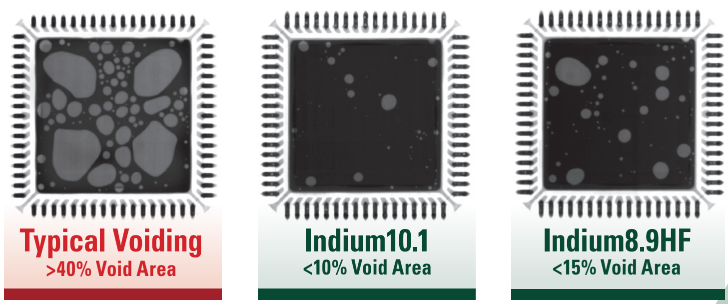

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ture of the circuit. For instance, if a component is inserted or placed with too much pressure, the material can wrinkle and may create a void under the component that could allow foreign material to gather.

Another concern during hand assembly is how to keep the circuit in a static condition so that it doesn't move when the solder or iron is placed on the component. It's difficult enough to solder components manually, but that difficulty is magnified when the circuit is not static. Trying to create a compliant solder joint on a moving target is the highest level of frustration.

Therefore, it is common to create fixtures to assist in the hand assembly of flexible circuits. The fixture is used to keep the circuit flat and still during the process. The fixture is an invaluable aid to the assembler.

Automated Soldering Process

The automated soldering process is typically done on multiple circuits designed in a matrix to form a panel. This panel can then have solder applied, go into a machine that will load all the components to their proper locations/orientations and finally run through an oven to solder the entire panel. This is much easier to describe than to put into practice.

The complications are many when flexible circuits are the point of discussion. The screening process and component placement puts a great deal of pressure on the circuit that requires tooling to be designed specifically for each circuit. A typical way to fixture a flexible panel is to create a "carrier" that is used to carry the circuit through the entire process. It provides a stable surface that assists in consistent assembly and eliminates much of the laborious tedium associated with the assembly of flexible circuits. With the use of carriers, the flexible circuit panel can run through the entire process with little or no issues.

Figure 3: Carrier panel.

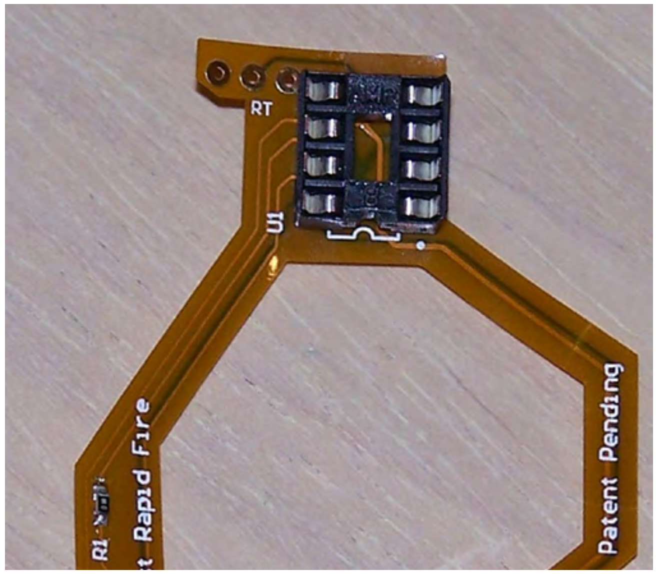

Figure 4: Surface mount components and through-hole components.

Flexible Circuits and Components

Every type of component can be soldered to flexible circuits with confidence. Through-hole components, SMT components, wires, switches, BGAs, etc. Some require more skill than others to be attached, but they all can be mounted reliably to flexible circuits. Some may be soldered automatically like through-hole or SMT components and others may have to be attached manually like wires or cables. The use of a microscope is necessary in assembly today. The components get smaller each year and we are now in an era where a component that measures .020" by .010" is common. That's not much bigger than a flake of black pepper. Most manual assembly and inspection, therefore, is done under a microscope or Automated Optical Inspection (AOI) device. With components that are too small to see with the naked eye, imagine the thought of identifying a non-compliant solder joint that is a fraction of the size of those small components. It's not of significant importance though. A skilled assembler armed with soldering tools and a quality microscope will be able to attach any component to a flexible circuit.

Protection of Solder Joints After Assembly

The concerns do not end with the attachment of components. Products developed with flexible circuits are intended to be flexed. Although the material is flexible, the solder joints are not! If components or solder joints are in, or near a bend area, then it is wise to protect the solder joints. If not, the joint may fracture and cause intermittent issues that are difficult to identify.

A flexible epoxy or conformal coat may be added to the solder joints after the product has been tested and confirmed. This will keep the bends and flexing away from the solder joint and in the material where it is intended to be. This added safety feature will add robustness to flexible circuit assemblies and likely reduce the risk of failures in the field.

Conclusion

Flexible circuits have many advantages. They're lightweight, thin and flexible. This allows products to be lighter, smaller and thinner as well. Although the typical circuit assembly is not intended to be bent, formed or even dynamic, it can be done confidently with flexible circuits. The added time spent on the design of fixtures to assist in the assembly process is time well spent and will allow the circuit to flow through the assembly line smoothly and consistently. The result will be a robust flexible circuit assembly. SMT

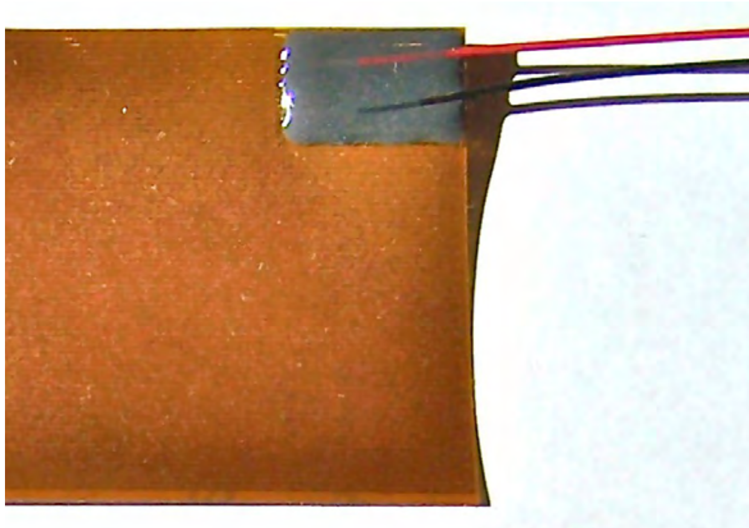

Figure 5: Epoxy covered solder joints.

John Talbot is the president of Tramonto Circuits, which designs, manufacturers and supplies flexible circuits and printed circuit boards (PCBs) for customers around the world. For more information, click here.

MilAero007 Highlights

Colonial Assembly and Design Earns IPC J-STD-001 and IPC-A-610 QML

IPC's Validation Services Program has awarded an IPC J-STD-001 and IPC-A-610 Qualified Manufacturers Listing (QML), meeting Class 3 requirements, to Colonial Assembly and Design LLC, a wholly owned subsidiary of Zentech Manufacturing.

Celestica Posts $6B Revenue for FY2016

Celestica Inc. has announced financial results for the fourth quarter and fiscal year ended December 31, 2016. Fourth quarter revenue was $1.62 billion, up by 4% sequentially and 7% compared to the fourth quarter of 2015. For the fiscal year 2016, revenue was $6 billion, up by 7% year-on-year.

Plexus Receives Innovation Supplier Award from Bombardier Transportation

Plexus Corp. has been recognized for its support and innovative ideas by the Rail Control Solutions (RCS) Division of rail manufacturing company Bombardier Transportation.

Circuit Check and ASSET InterTech Partner on Boundary-scan Test Solutions

Circuit Check Inc. has announced a collaboration with ASSET InterTech to more closely integrate ASSET's ScanWorks boundary-scan test tools with CCI's flexible, configurable functional test systems, the CCI 1000 Series Configurable ATE and CCI 6000 Series Rotary Handler.

NEO Tech-built Battery Packs Successfully Launched into Space, Installed at ISS

NEO Tech has announced that six Lithium-ion Battery Orbital Replacement Units (ORUs) that it assembled for Aerojet Rocketdyne were launched into space for the International Space Station (ISS) on December 9, 2016, with the first three successfully installed in the ISS on January 6, 2017.

Zentech Manufacturing Adds Advanced Clean Room Capability

Zentech Manufacturing Inc., in support of a major customer engagement in the homeland security market segment, is pleased to announce the addition of a sub-Class 5 cleanroom operating environment.

Plexus Posts Q1FY2017 Results

Plexus has announced revenue of $635 million in the fiscal first quarter ended December 31, 2016, well within its guidance of $620 million to $650 million. Operating profit reached $33.9 million, and net income was $28.18 million.

Sanmina Reports Q1 Fiscal 2017 Results

EMS firm Sanmina Corp. has reported revenue of $1.72 billion for the first fiscal quarter ended December 31, 2016, up from $1.67 billion in the prior quarter and $1.53 billion for the same period of fiscal 2016.

Key Tronic Posts $118.5M Revenue in Q2 FY 2017

For the second quarter of fiscal year 2017, Key Tronic reported total revenue of $118.5 million, up 2% from $116.4 million in the same period of fiscal year 2016. For the first six months of fiscal year 2017, total revenue was $235.7 million, compared to $242.6 million in the same period of fiscal year 2016.

Cirexx to Exhibit at SMTA Dallas 2017

Cirexx International will be exhibiting at the SMTA 2017 Dallas Expo & Tech Forum in Plano, Texas at the Plano Centre on March 7, 2017.

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Strategies for Addressing Flex Circuit Assembly Pain Points

by Stephen Las Marias
I-CONNECT007

In an interview with *SMT Magazine*, Steve Fraser, VP of Operations at Firstronic, discusses the challenges they face in flex circuit assembly and strategies to ensure the reliability of the products.

Stephen Las Marias: What do you think are the major challenges in flex-circuit assembly?

Steve Fraser: We are predominately working with rigid-flex circuit automotive lighting applications. One of the issues we are seeing is that while these boards used to be shipped in a rigid panel, they are increasingly coming in non-rigid panels. This is because LEDs tend to use metal backing rather than FR4. The cost of metal is high enough that to reduce material cost, panels are shipped in flex format. However, the tradeoff is that when this is done, the flex panels must be palletized. This drives added tooling cost since it requires 25–30 pallets to run product on an SMT line without impacting throughput. Post-SMT, panels/boards then require flat trays and carts for movement among production operations, which may or may not be compatible with a manufacturer's existing PCBA handling equipment.

An additional challenge is that the bonding material used to bond to the rigid portion is moisture sensitive, which means the product needs to be kept in sealed-in bags until ready for use in production. Typically, they must pass through the SMT process within four hours of opening to prevent unacceptable moisture absorption. Consequently, if you have serialization requirements, you have serialize product inline or run small batches. In lieu of this, pre-SMT baking is required which adds time and cost and is a non-value added process. Finally, we have some applications that have bend and form requirements for the rigid portions. We receive them flat, bend them first and then run them through the line formed, which increases the complexity of the required pallet.

Las Marias: What specific steps in a flexible circuit assembly process have the biggest effect on yields?

Steve Fraser

Fraser: First, it is important to ensure the board hasn't absorbed moisture prior to running through SMT process. Second, the pallet design must be appropriate for running the board through the SMT process and work with the test fixture. Third, it is important to develop a detailed handling plan that considers every step from when someone takes the board out of the out of the package through placing it in the finished goods package. Finally, finished goods packaging design needs to protect the product in shipment and be easy to load and unload without stressing solder joints.

Las Marias: How do assemblers address these challenges? What parameters should be considered?

Fraser: The reflow soldering process is straightforward. If you are running double-sided reflow, you really need to have your profiles dialed in. But for the most part, if you have good process in place, it isn't significantly more challenging.

Las Marias: How different is the flex circuit assembly from the standard PCB assembly, and what are the important factors to consider?

Fraser: Support and handling are more complex. In test, you need to design fixtures that will accommodate a carrier to lift the flex panel from the fixture without stressing it. Verifying stress and strain requirements at test is also critical.

Las Marias: What about the challenges with respect to flexible circuit materials?

Fraser: Moisture sensitivity can be an issue with the bonding material.

Las Marias: Do customers call out a specific brand name of material to use when dealing with flexible printed circuits?

Fraser: Yes, most of our customers specify material and board house.

Las Marias: What has the greatest impact on the quality of flexible circuit assemblies?

Fraser: When you are doing final assembly, you need to make sure that the board functions properly before beginning the mechanical assembly process and that the final mechanical assembly process doesn't damage it. The more a flex circuit is handled, the higher the probability of operator incurred defects or stress fractures that could cause failures in the field, so minimizing the possibility that a mechanical assembly step must be reworked is far more important than with a traditional PCBA.

Las Marias: In which end markets are you seeing increasing use of flexible circuits?

Fraser: In our case, exterior and interior automotive lighting.

Las Marias: What should OEMs consider when choosing an assembly partner for their flex circuit assemblies/projects?

Fraser: Does that partner have demonstrated capabilities in that application? Also, it is important to understand that less defects are likely to occur if the contract manufacturer does final assembly as compared to shipping the flex

circuits, because this final mechanical assembly provides a rigid structure to ship the flex board on and eliminates additional handling of packaging and unpackaging the PCBA. Additionally, doing it all in one place minimizes handling and over-processing, because if the product is shipped to a second facility, it must be packaged, retested and often repalletized for the next assembly step.

Las Marias: ***Are there new technologies out there that will significantly impact or benefit the flex circuit assembly process?***

Fraser: While not directly related only to flex, more automotive lighting applications are using LEDs and often these are mounted on flex or rigid flex because of packaging needs. Reflow ovens with vacuum process are beneficial in terms of pulling air pockets out of solder joint to eliminate voids. This level of defect of mitigation is good for both flex circuits and traditional PCBAs.

Las Marias: ***Thank you very much, Steve.***

Fraser: Thank you. **SMT**

Achieving Successful Flex Circuit Assemblies

by Stephen Las Marias
I-CONNECT007

Flexible circuits are increasingly being used in most end-markets amid the growing miniaturization trend and functionality needs of electronics products. "Flex circuits facilitate product miniaturization through 3D and that is a growing trend in most markets," says Yousef Heidari, vice president of engineering at EMS firm SigmaTron International.

Yousef Heidari

When it comes to assembly, the challenge varies based on the details of the all-flex or rigid-flex-rigid mechanical design, as well as the components that need to be assembled. The solder paste printing step is also one of the key challenging operations for designs that have multiple areas with fine-pitch components.

Heidari notes that there is no specific new equipment needed to address the challenges for typical flex circuit assemblies once the design details of handling the flex circuit during assembly have been worked out. The design must ensure that the different areas of the flex circuit get registered and are well supported.

Since the assemblies are moisture sensitive, one needs to ensure that the flex circuits and components are dry prior to going through the correct reflow process. He adds that they must be handled appropriately and baked prior to use. Handling is a concern throughout the assembly as inappropriate handling can cause delamination.

Do customers call out a specific brand name of material to use when dealing with flexible printed circuits? Heidari says they deal with a lot of mission critical products, and typically, those customers do have preferences in all aspects of defining the stack up material and details.

Overall, the design for the flex circuit assembly as well as the subsequent handling of the assembly before final product integration have the greatest impact on the quality of flexible circuit assemblies, according to Heidari, while the flex circuit panel design is the biggest contributor to yields.

For successful flex circuit assemblies, OEMs need to work closely with the design house, the fabricator, and the contract manufacturer, especially on the design for manufacturability, says Heidari. He stresses that having a good flex fabricator is also critical.

One Size Fits All?

by Michael Ford
MENTOR GRAPHICS CORP.

In the same way that we are not all driving the same car, have the same phones, or use the same SMT equipment in our factories, we are unlikely to all end up using a single smart solution or IoT technology. At the car rental counter, you can be confident that you will be able to drive whatever car is available; and in the same way, you should expect all of your factory technology to be interoperable. Choosing the best tool for the job differentiates the business and enhances competitiveness. Decisions on automation, IoT technologies, and software computerizations need to be based on merit because the choices vary considerably. Interoperability is the key for future-proofing, and this is not the time to be waiting for ultimate decisions while others are moving forward.

Humans–Cannot Live Without Them

Even in the wildest imagination of future smart factories, the reality is that humans remain in charge. We are the ones who will still make the fundamental decisions and choices about which technologies to use. We will have to wait I expect until Industry 5.0 to see factories that design, make, and configure themselves. That scenario may not be too far away once 3D printing technology really starts to evolve; but for the foreseeable future, Industry 4.0, which represents the computerized operation of the factory full of automated processes, is dependent on people.

Humans are quite variable entities. In spite of there being billions of us, we rarely see two people who look the same or dress the same. Because of this "human need" for differentiation, there are many variants in all of the stuff that we buy. For example, each car model can have thousands of variants for something that is just a mechanism for moving the fairly standard human form from one location to another. A distant potential relative of mine once thought


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that a single model in black should be all that we would need.

Many choices for any particular product also is common now in electronics, such as a smartphone or tablet. We carry these personal preferences with us wherever we go, including into our working lives. Ideas that successfully differentiate one operation against another create an immense amount of satisfaction. The need from humans for more personalized electronic products has led to an increasing number of product variations. Also, where once we saw electronics as a stand-alone industry, it is now a critical part of every other industry. As microelectronics move further into different aspects of our lives, new applications of electronics continue to add to the variation which, in some areas, appears to be increasing exponentially.

Intuition, innovation, ideas, and initiative—all of these words starting with "I" characterize qualities that we look for in engineers and managers. The simple fact that there is more than one factory in the world creates competitiveness. Humans are flexible, able to define and create factories that are appropriate for the product profiles that are being created, and for the human customers that they serve.

"Humans are flexible, able to define and create factories that are appropriate for the product profiles that are being created, and for the human customers that they serve."

Following this chain of flexibility, electronics assembly factories have to be flexible to cope with the many different products and variants and to respond to changes in customer delivery demands in the short-term, perhaps even daily in a perfect Industry 4.0 world. This is contrary, however, to the concept and nature of mass production. Because of mass production and associated economies of scale, we have been able to enjoy affordable products of any type. Now, it seems as though we are being pushed backward to the days when most goods were made on a bespoke basis. In this fast-moving, progressive, throw-away culture, the reality is that this is not practical. These are all the causes of the so-called revolution in manufacturing, and the solution is Industry 4.0. Smart Industry 4.0 factories have to be making products on a demand-driven basis but also need to operate in a mass production mode, albeit in a flexible way. This near impossible task cannot be managed by humans, so Industry 4.0 requires us to use computerization to take over the operational decision-making, to guide the products with their associated resources and dependencies dynamically, in real time.

Computerization Without Knowledge

We often hear the comment that there are "too many" providers of SMT and related equipment on the market, often citing lack of growth in the number of "shipped PCBs" or even an overall decline in recent years. This decline is a debatable measurement. I suspect that it comes from data at the PCB fabrication stage; however, it is never really explained. One modern fabricated PCB panel is normally split into a number of smaller PCB boards, just one of which is normally needed per finished product. The number of boards derived from each panel has increased rapidly in recent years as feature and materials sizes have diminished.

But if you take a look around yourself right now, you can see that the electronics industry is not shrinking; instead, there is growth in new applications for electronics. The simple "shipped PCBs" statistic hides a great deal of the detail, of that I am sure. It is like looking out the window to see what the weather is really like versus trusting the generalized weather report on TV, true especially here in the U.K. Such calculations and computerizations lack the accuracy, detail, and timeliness of hard data. Rather than using a purely market financial approach and saying that there are too many providers of equipment; if you take a real look at electronics manufacturing technology, you will see the range of specialist features and equipment that are applicable and necessary in the various aspects of the operation.

Although we may not be confident to always trust the weather report, or the statistics on the "health" of the electronics industry as a whole, factory shop-floor reporting, in most cases, is even worse. With a multitude of choices of equipment selection and the human element of understanding of what might be the best tool for the job, plus the seemingly unending marketing efforts from all of the companies concerned, it is no surprise that even a modest SMT factory operation features a wide variety of types, vendors, and models of equipment. Also, humans are responsible for production management, performance, quality management, supply chain, and various other disciplines that make up the factory. Each person in his or her role has a different expectation of what they want from data and interoperability on the shop floor.

"Each person in his or her role has a different expectation of what they want from data and interoperability on the shop floor."

People today in factories are making the transition from being happy to sit and look at the "weather report" to preferring to focus in on the actual detail, cross-referencing it with other data sources from around the factory with "big data" analysis. The core needs of manufacturing management change over time; again, because they are ultimately driven by humans. Computerizations such as those mandated by Industry 4.0 are today and always will be, created by humans, and so they will change and evolve as time goes by, at different times around the factory. The smart factory is not a static entity, any more than regular production is today.

The Practical Evolution of Being "Smart"

Interoperability is the single most important common factor in a smart, flexible factory. Data that describes events needs to be reliable and timely. Machines need to be able to communicate out data related to process and performance and to get information in about products and work orders, as well as feedback from other machines in the line, whether on a machine-to-machine basis or through a smart computerized function. For the deep analysis associated with evolving Industry 4.0 functions, the information requirement is something that also will evolve. It certainly will not be just a simple set of data like what we got with the development of legacy formats such as CAM-X. The importance of any communication standard is that it is open for use by any and all computerizations, not just a simple, basic dataset where more advanced information is contained in proprietary fields that prevent use by anyone other than the specific machine vendor.

Of course, choices for the data format used in a factory will continue to be available. Even the old CAM-X and its intended update from the IPC can work side by side with more open formats such as the Open Manufacturing Language (OML), by using gateways or adaptors in between. As we said, it is important to use the best tool for the job. If only simple information is required, then many choices will be available. OML, however, will continue to be at the forefront of manufacturing IoT technology, continuously supported by a peer group of end-users and vendors (www.omlcommunity.com), to ensure that the maximum value and opportunity can be obtained. We need to allow the human element to thrive on the shop floor and continue to define automation and smart Industry 4.0 computerizations that every factory will be using. **SMT**

Michael Ford is senior marketing development manager with Mentor Graphics Corporation Valor division. To read past columns, or to contact Ford, click here.

SUPPORTIVE TOOLING:
The Magic Ingredient for Flex Circuit Assembly

Figure 1: Cathy Cox, process engineer, and John Mielke, supervisor for selective solder and wave solder, discuss the first time build manufacturing plan for a rigid-flex assembly in the SMT area of Saline Lectronics.

by Davina McDonnell
SALINE LECTRONICS

There is a circuit board assembly in almost every product with an on/off switch. Just sitting in your office, you are within arm's reach of at least four or five items with printed circuit board assemblies (PCBAs) inside of them—computer, calculator, phone, thermostat, digital clock, fitness band. And that's just within your office! Stepping out of work into daily life, you'll encounter products with PCBAs at every turn—there are countless circuit board assemblies in your car, in your home, in your doctor's office, at your local gym. Put simply, they are everywhere.

The proliferation of circuit board assemblies in so many different product types wouldn't be feasible without the use of rigid-flex and flex circuits. Could we appropriately put a rigid circuit board assembly into a small ankle monitor? Or a solar panel? Or a wearable infant safety device?

Flex circuits have changed the way product development engineers can design and package their electronic products. Flex applications have opened the doors for PCBAs to move out of square, box enclosures and fit into small, tight, even oddly shaped three-dimensional spaces that can withstand harsh vibration and multiple flex uses.

These thin, flexible circuits have completely revolutionized the use of PCBAs in certain applications. And while these flex assemblies may perform in the same way a traditional rigid PCBA does, they have their own set of assembly rules and manufacturing nuances.

"Flex circuit designs can make some things more painful for contract manufacturers," commented Dave Cusumano, VP of Engineering at Saline Lectronics. "We've come up with a variety of techniques to overcome specific flex circuit assembly hurdles."

Flex circuits don't play by the same rules as rigid applications in the assembly process—they're light, bendy, and can be heat sensitive. To ensure optimal quality and guarantee that the board will not be damaged while inside manufacturing equipment, a flex circuit must have strong support.

In most cases, depending on PCB size and how they are panelized, any PCB that is thinner than 0.032" requires a pallet for the assembly process. This will help to ensure that the board doesn't bend or get damaged during manufacturing. Pallet design is critical to appropriately support a flex assembly, and it's important to identify a supplier who understands the nuances of flex circuit behavior in different machines.

At Saline Lectronics, the manufacturing and engineering teams work closely with hardware vendors to design the ideal pallet for each specific flex assembly. In the case of double-sided flex circuits, Lectronics' process engineers build the perfect pallet to accommodate top and bottom configurations. This can be tricky depending on the differences between the two sides, but a single pallet design is far more cost effective.

Since flex circuits are so easily manipulated and extremely light, it can sometimes be difficult to ensure that they remain flat on the pallet. If the flex PCBA doesn't stay flat and fully supported under the component pads, the air cushion under the flex can act like a trampoline and cause components to bounce off during the placement process. To avoid this from happening, Lectronics' specifies a certain material that holds the flex circuit flat during the assembly process to guarantee that components are being placed appropriately.

"Pallets are the most important thing for flex circuit assembly," said Jason Sciberras, manufacturing manager at Lectronics. "Flex circuits are completely manufacturable if done right—design is right, panelization is right, and tooling is right. We've manufactured high-volume, complex rigid-flex assemblies with micro-BGAs, QFNs, and 0201s at 31,000 units per week. With the right support structure, it's easy to do."

Pallets also help to ensure that the flex assembly is presented to the machines at a consis-

Figure 2: Dylan Stringer, SMT operator, verifies the solder paste inspection results on a DEK Horizon 03iX SPI machine.

tent height. In the case of solder paste printing applications, it's crucial that the assembly is at a specific height for even distribution of paste. If the assembly doesn't enter the machine properly, the paste won't print correctly and gasketing issues can arise, which will cause manufacturing defects later in the assembly process.

In the case of SMT pick-and-place machines, the pallet for the flex circuit ensures that the assembly is also presented to those machines at the ideal height. High-speed SMT placement machines don't leave much room for error, so the flex assembly must be adequately prepared and supported for those fast placements.

Beyond tooling support, manufacturing engineers and technicians need to pay attention to the soldering heat applied to flex circuits. Since flex circuits are typically very thin, there's nowhere for the heat to go besides into the barrel, so thru-hole parts must be soldered at lower temperatures. Hand soldering a flex circuit can be challenging, and requires an experienced technician to utilize the perfect technique.

"When hand soldering a normal, rigid assembly you can touch the PCB for three to five seconds with a temperature range of 600–800°F," commented Cathy Cox, process engineer at Lectronics. "With certain flex circuits, you can only touch that board for one to two seconds at most, and the heat is much lower at about 580°F."

In the case of testing flex circuits, the same support and tooling rules apply. All flex circuits require appropriate backing to support the assembly during the testing process. In the case of flying probe testing, a special custom fixture should be developed to provide that support to the PCBA when it's being probed.

For in-circuit testing (ICT), a rigid backing is usually designed into the clamshell fixture. While this can add mechanical challenges for ICT development, it's needed to ensure safe testing of the flex circuit. Additionally, low force probes should be used to avoid any unnecessary damage to the flex's fragile surface.

"We also make special provisions to guarantee the orientation of flex circuits during the testing process," commented Tom Newman, test engineering manager at Lectronics. "Flex assemblies don't always have tooling holes to use as guides, so it's important to use a fixture or cut-out that the flex assembly can sit into perfectly."

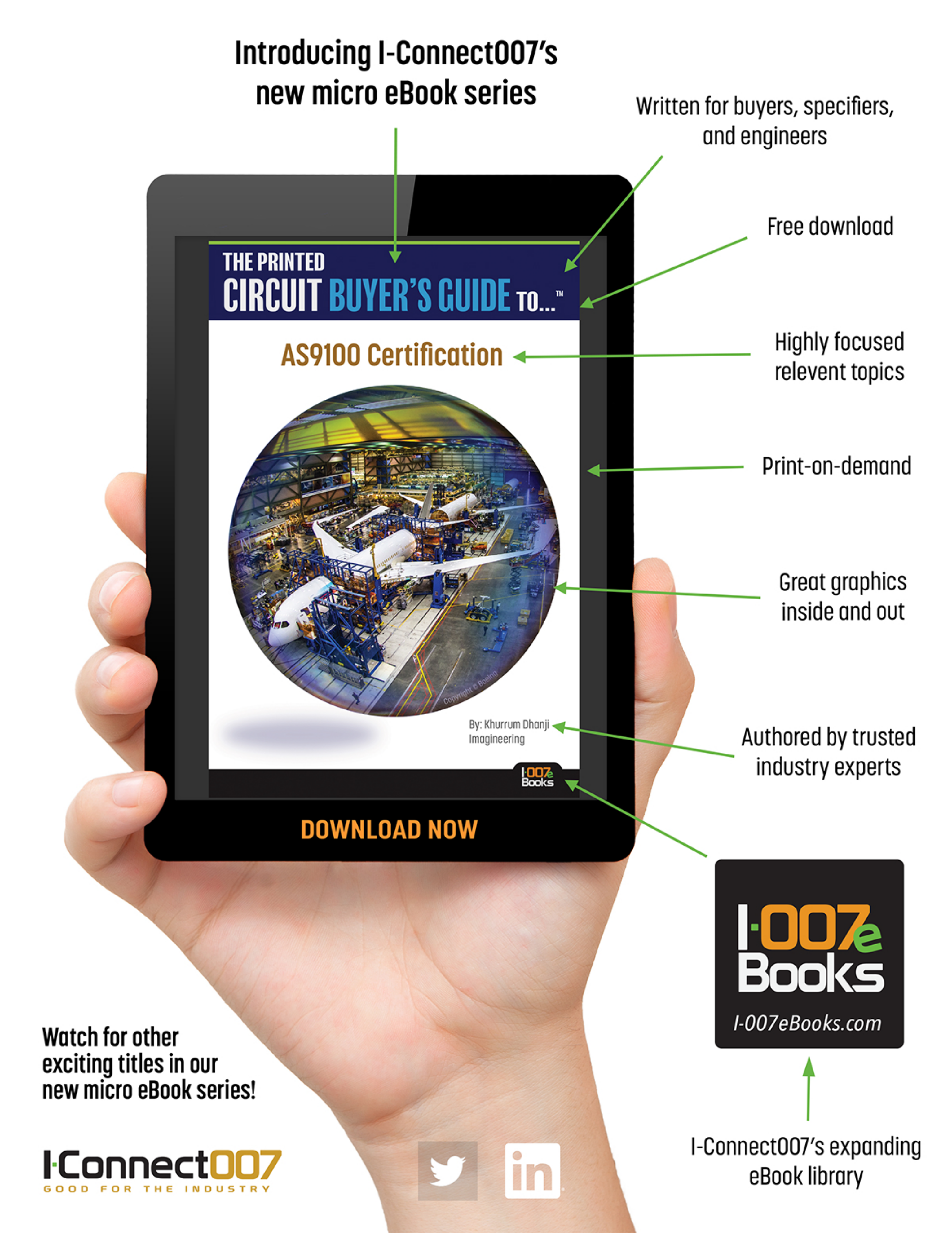
Traditionally it can also be difficult to access test points on flex assemblies. Without exposed thru-hole vias, test technicians have limited access to probe the assembly. Additionally, designing in appropriate test access points is sometimes overlooked with flex products. Electrical engineers should design in appropriate test points during the product development stage.

De-panelizing flex assemblies can also be tricky. In many cases the only option for depanelization is by hand, which can lead to poor quality control and repeatability issues in manufacturing. Laser de-panelizing is gaining popularity, and while much more precise than hand cutting, it's also a far more expensive solution. However, as laser cost continues to go down, these machines should become more commonplace.

Lectronics' engineering team works closely with bare board fabrication suppliers to optimize the array design and perimeter connections within the flex panels. They have specifically developed proprietary techniques to improve and optimize the de-panelization process where special tooling is no longer required.

As flex circuits continue to solve design constraints for space, heat, weight, and bend requirements in a variety of product applications, electronic manufacturing suppliers will develop new manufacturing parameters to assemble these flexible products. While flex circuits can be temperamental and play by their own rules at times, all these thin, fragile, bendy, heat-sensitive circuits really need is the right support system. **SMT**

Davina McDonnell is the director of marketing at Saline Lectronics. To read past columns, or to contact McDonnell, click here.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GOOD FOR THE INDUSTRY

Supply Lines Highlights

Reflections on 40 Years of Test and Measurement and What Lies Ahead

Dr. James Truchard, President, CEO, and cofounder of National Instruments, has penned his reflections on the last 40 years driving and leading some of the greatest progress and innovations the test and measurement industry has seen.

Nordson to Retain ACE Manufacturing, Service and Support in Spokane

Nordson Corp. has acquired ACE Production Technologies Inc. Founded in 2005 and employing a staff of approximately 50 people, ACE will operate as a new line of business within Nordson's Advanced Technology Systems segment. The engineering and manufacturing operations together with the customer support function of ACE will remain in Spokane Valley, Washington and will report to Peter Bierhuis, Vice President – Nordson Advanced Technology, Process Systems.

Electrolube's Phase Change Materials Offer Practical Alternatives to Thermal Greases

Electrolube has released two new phase change thermal management materials—the TPM350 and the TPM550—that offer high thermal conductivity, low phase change temperatures and low thermal resistance at the interface.

Ellsworth Adhesives Europe Adds Dymax SpeedMask 9-7001 to Lineup

Ellsworth Adhesives Europe is pleased to announce the addition of the new Dymax SpeedMask 9-7001 to its product range.

Super Dry Launches Network Compatibility for All Cabinets

Moisture specialist Super Dry has launched new networking solutions for all Dry Cabinets regardless of age or manufacturer, enabling traceability for even the least automated of moisture control processes.

PDR Americas Appoints MAN-TechSystems as Rep for Northern California

PDR Americas has appointed MAN-TechSystems as its manufacturers' representative in Northern California.

Kyzen Enters Sales Representative Agreement with EAP and Century Automation in Florida

Kyzen has entered into a sales representative agreement with Electronic Assembly Products (EAP) for the state of Florida. EAP's Mark Hendron will be teaming up with Century Automation's Joe Cormier to deliver outstanding service to Kyzen's customers throughout Florida.

Nordson Acquires InterSelect to Broaden Selective Soldering Capabilities

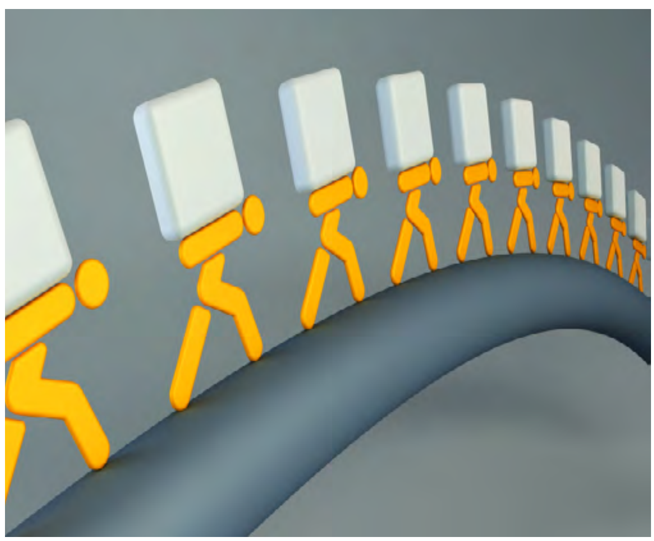
Nordson Corp. has acquired InterSelect GmbH, a German designer and manufacturer of selective soldering systems used in a variety of automotive, aerospace and industrial electronics assembly applications.

Mycronic Receives New Multiple Order for the MY600 Jet Printer

Mycronic AB has received an order for several MY600 Jet Printer systems from a new customer in Asia with a high-volume consumer application running 24-hour production.

Goepel electronic Achieves Record Sales in Anniversary Year

In 2016, Goepel electronic GmbH had the most successful financial year in its history by far, generating more that €35 million in sales in its 25th anniversary year.

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Rework and Repair on Flex Circuits

by Bob Wettermann
BEST INC.

Flex circuits are used in a variety of applications for the interconnection of conductors which need to be bent or exercised continuously. This interconnection technology has historically been used as a wire interconnection. There are a variety of versions of this type of circuit. One of them is the dual access flex circuit which is a single-sided flex circuit that is manufactured so that the conductive material can be accessed from both sides of the flex. A double-sided flex circuit is a circuit having two conductive layers, one on each side of the base layer within the circuit. Trace patterns, specific to your needs, can be created on both sides of the substrate film. They can be interconnected where desired with copper plated through-holes. A multilayer flex circuit combines several single-sided or double-sided circuits with complex interconnections, shielding and/or surface mounted technologies in a multilayer design. Rigid flex circuits combine the best of both rigid printed circuit boards and flexible circuits integrated. Circuits are typically interconnected between the rigid and flex circuits through plated through-holes.

There are a variety of benefits to the flex circuits. One of the major benefits of a flex assembly is the nearly error-free implementation of wiring in lieu of labor intensive hand wiring. They are also able to configured, unlike their rigid counterparts, as complex 3-dimensional configurations as they can be contorted in to a variety of shapes. As the name implies, the materials used in flex circuits can be bent back and forth numerous times meaning they can be used in in highly repetitive applications such as on print heads. When weight is an issue, flex circuits are a good alternative to rigid boards and wires as both the dielectric material and conductor runs are very thin.

Over the last several years the flex industry has seen a growth in demand. It is now a 10 billion WWD industry with growth rates in the 7–10% year range.

Figure 1: Rigid-flex circuit board assembly.

With this surge in usage of flex, the standards for rework (replacing devices while still meeting the initial specification and functionality) and repair (repairing the physical damage on a flex circuit) of these type of electronic interconnection circuits has not kept pace.

There are some rework challenges that come from the very nature of flex circuits. First of all, it is difficult to hold the flex circuit flat. The flexible nature of the Kapton or other base flex material, which makes it so attractive in the application, makes it challenging from a rework perspective. In order to retain the flatness of the assembly, it needs to be taped to be held down. In some cases, a vacuum fixture, a relatively pricey endeavor, is fabricated for flex circuit rework. When placing fine pitch components, the vacuum structure of such fixtures has a significant influence. If the vacuum is directly under some of the leads of a fine pitch component, there is a likelihood any vacuum will "pull" the flex into the hole, preventing the component from con-

tacting the flex circuit lead, thereby resulting in an electrical "open." For rework paste printing, co-planarity is a challenge when the stencil and surface to be printed are not coplanar. Therefore, paste print deposition using a syringe is often used instead. Sometimes, conductive epoxies are used in interconnecting devices to the flex material. While the curing temperature of these joining materials is much lower than the reflow temperature of more standard solder, it can make a mess. Even when the rework process is engineered properly, many times the limitation on rework is that the marginal cost of the assembly is far less than the burdened rework cost, making the scrap pile a more attractive economic alternative.

There are some advantages to reworking flex circuits from a process standpoint. The lower thermal mass compared to a rigid PCB shortens the duration time to reach liquidus when soldering to a flex board. This speeds up the rework process for replacement. In addition, many times this lowers the air temperature required from the hot air system thereby resulting in less potential component damage. The high temperature withstand properties of flex materials such as Kapton, Peek and high-temperature polyimide all give the flex rework process a larger process window.

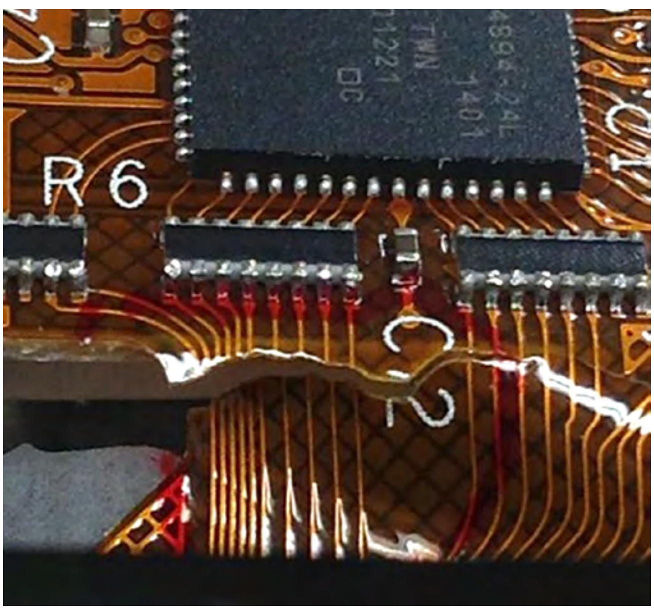


Figure 2: Ripped rigid-flex circuit.

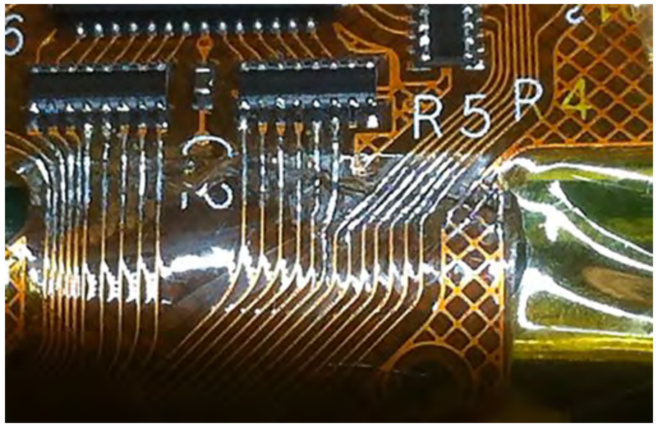


Figure 3: Repaired base Kapton material along with conductors.

In terms of industry standards for PCB repair, the IPC 7711/21 Repair and Modification of Printed Boards and Electronic Assemblies covers the rework and repair processes for flex circuits. Each of the processes in the standard are listed in terms of their applicability to flex rework or repair with an "F" in the upper right-hand part of the process documents under the "Board Type" section heading. There is even a flex-specific standard of conductor repair. Conductor repairs on flex is covered in procedure 7.1.1.

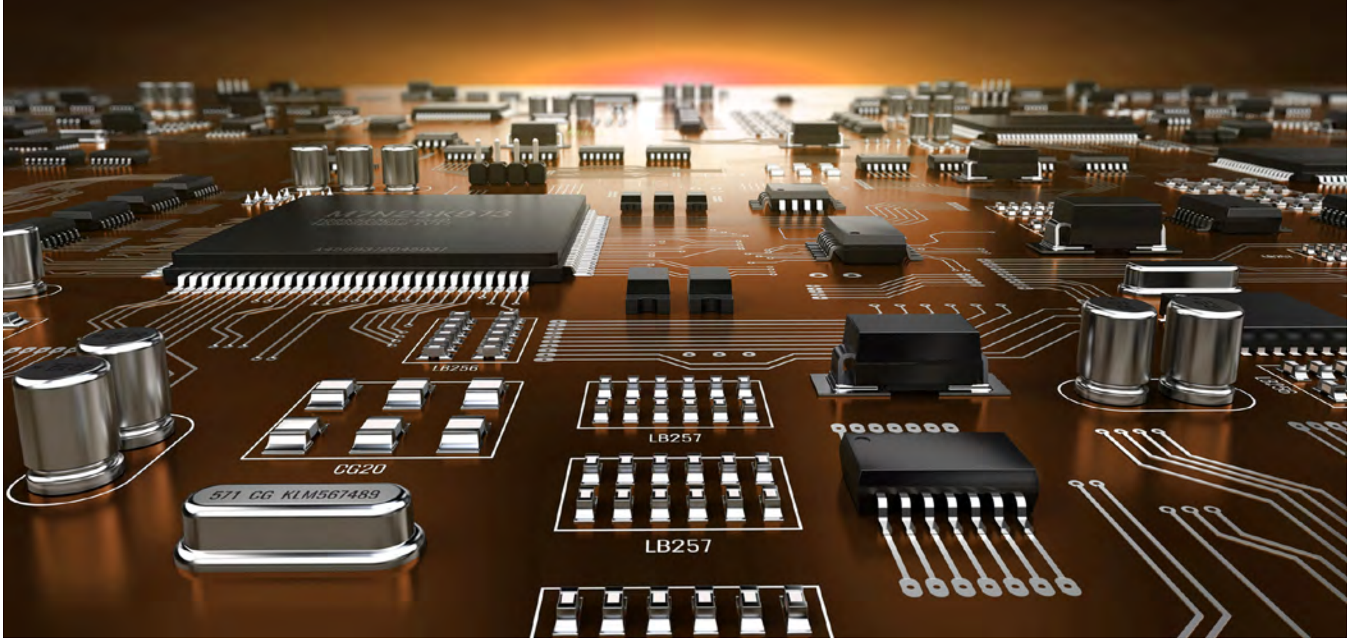
By way of an example of a conductor repair, Figure 2 illustrates a torn flex circuit as part of a rigid-flex board. The standard process found in IPC 7721 3.5.1 was used to repair the material. The conductor runs had a copper foil jumper installed to replace the damaged conductors and then they were soldered together for further rigidity. The outcome of this repair can be found in Figure 3.

Rework and repair of flex circuit assemblies is evolving and remains a challenge as the industry continues to adopt best practices from the rigid assembly world. **SMT**

Bob Wettermann is the principal of BEST Inc., a contract rework and repair facility in Chicago.

FEATURE INTERVIEW

JJS Stresses the Need for Baking Prior to Flex-Circuit Assembly



by Stephen Las Marias
I-CONNECT007

UK-based JJS Manufacturing is an EMS partner specializing in end-to-end procurement, manufacture (PCB assembly, box build, cabinet, electro-mechanical) and supply chain solutions. The company supplies complex, highly configurable, low-to-medium-volume industrial electronics products across a range of market sectors including industrial automation, process control, test and measurement, and laboratory technology.

Russell Poppe, director of technology, discusses with *SMT Magazine* the challenges when dealing with flex circuit assemblies and provides strategies to address them.

***Stephen Las Marias:** From your experience, what are the major challenges in flex-circuit assembly?*

Russell Poppe: From an assembly perspective, baking the flex circuits prior to manufacturing assembly is crucial as they can be susceptible to delamination. That said, baking any PCB prior to manufacturing is best practice and something we always do at JJS.

One of the biggest challenges in flex circuit assembly is making sure the circuits remain flat, particularly during the printing and pick-and-place processes. The parts of the circuit requiring SMT placement should have an FR4 stiffener designed in underneath; but it is also important to work with the PCB supplier up front. Getting the panelization right is important so that the boards don't bend when the parts are placed or when they pass through reflow. Panel design can be a challenge as flex circuits are often strange shapes! It might also be necessary to have a bespoke carrier or pallet to hold the flex circuits in place throughout the process; however, these carry additional costs—typically a few hundred pounds each.

***Las Marias:** What are the specific steps in a flexible circuit assembly process that have the biggest effect on yields?*

Poppe: Failure to bake the flex circuits prior to assembly can lead to delamination issues. If

panels are not kept flat during the pick and place process the SMT equipment can misplace components, leading to additional rework. Breaking out circuits from panels can also be an issue as often only thin layers of FR4 are used, which can lead to damage if handled incorrectly.


Russell Poppe

Las Marias: How should these challenges be addressed?

Poppe: We would recommend working closely with the PCB supplier and perhaps investing in bespoke pallets or carriers. If the design is stable and the volumes are high enough, then the initial cost of the pallets might make sense. If your policy is to run standard oven profiles, then it's likely that you will need to refine these—particularly if pallets are used as the oven profiles will vary significantly compared to a standard profile.

Las Marias: How different is the flex circuit assembly from the standard PCB assembly, and what are the important factors to consider?

Poppe: You could argue that the processes are very similar—providing you are already working to best practice! Care and attention should be given to panelization, circuits should be baked prior to assembly, and oven profiles should be tailored to suit the circuit being assembled. A robust NPI procedure should cover most of these points already.

Las Marias: Which end-applications are you seeing increasing use of flexible circuits?

Poppe: The demand for flex circuits in the sectors we serve—industrial electronics—is still relatively low. Clearly, there is much higher demand in automotive applications and consumer electronics, whether there is a significant increase in demand within the industrial sector remains to be seen.

Las Marias: When choosing an assembly partner for flex circuit assemblies/projects, what are the top things to consider?

Poppe: Robust NPI process; good material handling and preconditioning process prior to assembly (i.e., baking and dry storage; ensuring the manufacturer that you partner with is the right fit—that is, do they have demonstrable experience in producing similar products and flex circuits?) and design for manufacture support on PCBA.

Las Marias: Thank you, Russell.

Poppe: Thank you. **SMT**

Real Time with...IPC: Alpha Discusses Improving LED Reliability Issues

At the recent IPC APEX EXPO 2017 in San Diego, California, Steve Godber, LED Commercial Manager at Alpha Assembly Solutions, discusses with I-Connect007's Stephen Las Marias the reliability and voiding challenges in the LED market, and how the company is helping their customers address these issues through their solder technologies.

Watch The Interview Here

Electronics Industry News
Market Highlights

Internet of Things Market in Central and Eastern Europe to Boom Through 2020

According to a new update to the Worldwide Semiannual Internet of Things Spending Guide from IDC, IoT revenues in the Central and Eastern Europe region will post a CAGR of 21.5% over the 2016-2020 forecast period, reaching $24 billion in 2020.

Global Commercial Avionics Systems Market Posts Revenue of $25.34B in 2016

Transparency Market Research forecasts the global commercial avionics systems market to take advantage of the rising investments and adoption of leading-edge technologies to register a CAGR of 3.5% between 2016 and 2024. By the end of the forecast period, the global market is expected to reach $31.07 billion.

Worldwide Sales of Smartphones Grew 7% in Q4 2016

Global sales of smartphones to end users totaled 432 million units in the fourth quarter of 2016, a 7 percent increase over the fourth quarter of 2015, according to Gartner Inc. The fourth quarter of 2016 saw Apple leapfrog past Samsung to secure the No. 1 global smartphone vendor position.

Over 69 Million Automotive LiDAR Sensors Will Ship in 2026

ABI Research forecasts more than 69 million automotive LiDAR sensors will ship in 2026, fueled by declining hardware costs and the need to equip vehicles with multiple sensors to ensure 360-degree coverage.

Top 3 Chinese Smartphone Vendors Grab Nearly Half of China's Market in 2016

According to the latest IDC Quarterly Mobile Phone Tracker, the smartphone market in China saw a 19% YoY growth and 17% QoQ growth in the fourth quarter of 2016. For the full year of 2016, the market grew by 9%, with top Chinese smartphone vendors taking up a larger share of the market.

Apple Tops Samsung in Q4 to Close Out a Roller Coaster Year for the Smartphone Market

According to preliminary data from the IDC Worldwide Quarterly Mobile Phone Tracker, smartphone vendors shipped a total of 428.5 million units during the fourth quarter of 2016, resulting in 6.9% growth when compared to the 400.7 million units shipped in the final quarter of 2015.

Latest Report on Top 10 Sensors

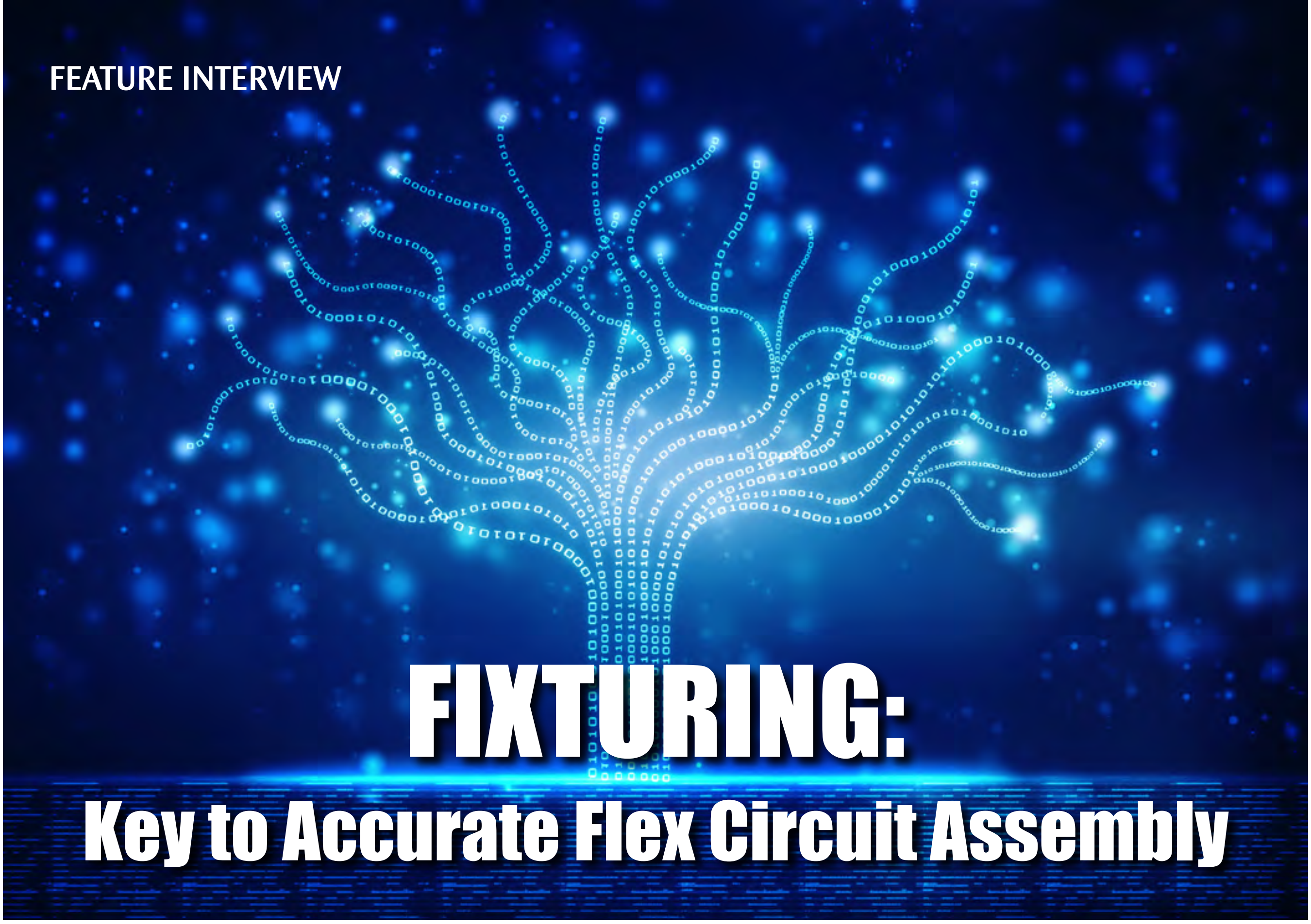
According to MarketsandMarkets, the global sensors market is expected to grow at a significant rate between 2016 and 2022, mainly driven by the increasing advancement toward smaller, smarter, and cheaper sensors; miniaturization trend in sensors; advent of platforms such as IoT, AR, and M2M; and growing trend toward smart living among end users.

Global Semiconductor Revenue Forecast to Grow 7.2% in 2017

The worldwide semiconductor revenue is forecast to reach $364.1 billion in 2017, an increase of 7.2% from 2016, according to Gartner Inc. This represents a complete turnaround for the semiconductor industry as the market experienced 1.5% growth in 2016.

IDC Predicts 3D Printing Will Hit Mainstream Market in Asia Pacific in 2018

With supportive government policies and continuous drive from countries like China, South Korea and India, IDC predicts that 3D printing will eventually become a mainstream market in Asia Pacific excluding Japan (APeJ) in 2018.



FIXTURING:
Key to Accurate Flex Circuit Assembly

by Stephen Las Marias
I-CONNECT007

Adrian Nishimoto, operation manager at Spectrum Assembly Inc. (SAI), talks about the critical factors to consider during flex circuit assembly, such as fixturing and accurate thermal profiling. He also mentions why jet printers are suitable for use in assembling flex circuits.

***Stephen Las Marias:** What do you think are the major challenges in flex circuit assembly?*

Adrian Nishimoto: Helping our customers realize that fixturing is an integral part of successfully building flex circuits. We need good 3D Solidworks files, CAD or Gerber data to design carriers able to provide a rigid surface as the flex circuits go through stencil printing, pick-and-place and reflow. In some cases, we also use specialized carriers for aqueous wash system.

Adrian Nishimoto

***Las Marias:** Please talk about specific steps in the flexible circuit assembly process that have the biggest effect on yields.*

Nishimoto: Having tooling holes that keep the flex substrate rigid in a fixture during stencil printing and pick-and-place ensures better solder paste accuracy and component placement accuracy. The goal is to keep it flat and keep it from moving during these processes. The carrier is also critical if you have any type of conveyor system handling PCBAs in production.

***Las Marias:** How do you address these challenges? Does the process require different parameters?*

Nishimoto: In addition to the fixturing considerations we've mentioned, accurate thermal profiling is also necessary. The carrier's thermal mass impact—the ability to absorb and store heat—needs to be taken into consideration. We do have our suppliers drill material out of the carrier to make them more web-like and less of a heatsink. That said, there isn't a one-size-fits-all solution to profiling because flex circuits come in all size ranges and that changes the optimum profile.

***Las Marias:** How does flex circuit assembly differ from standard PCB assembly?*

Nishimoto: Because the material is flexible, all secondary operations need to use extra care in processing. If there are ceramic capacitors or other large ICs, it becomes important to make sure that the substrate is not flexed in handling because that will damage the solder joint.

***Las Marias:** What about the challenges with respect to flexible circuit materials?*

Nishimoto: We don't see any challenges as long as we can create a fixture to keep it rigid.

***Las Marias:** Do customers call out a specific brand name of material to use when dealing with flexible printed circuits?*

Nishimoto: There is no specific brand name of material called out. In some cases, the substrate is exotic, but most are polyimide materials. Some customers specify the supplier on the approved vendor list, but in many cases, they depend on us to identify suppliers and give them choices to qualify that meet their requirements in terms of material performance and lead-time.

***Las Marias:** Which practice has the greatest impact on the quality of flexible circuit assemblies?*

Nishimoto: Following industry-standard best practices in initial design and layout. Since flex circuits are folded up and put in tight enclosures, it is important to reduce points of failure, such as the location of points of interconnect. For example, a really long connector may require a rigid flex design, which uses stiffener rather than a 100% flex design.

***Las Marias:** In which end markets are you seeing increasing use of flexible circuits?*

Nishimoto: Primarily, we are seeing them in medical and consumer applications.

***Las Marias:** What are the key things for OEMs to consider when choosing an assembly partner for flexible circuit assemblies/projects?*

Nishimoto: First is prior experience with flex circuit assembly. Then, they should have a good relationship with one or more board carrier fabricators. Lastly, they should have an expertise in thermal profiling in reflow and strong discipline in work-in-process handling practices.

***Las Marias:** Are there new technologies out there that will significantly impact or benefit the flexible circuit assembly process?*

Nishimoto: When you have rigid-flex combinations or stiffeners in use, you have two different heights—which makes it impossible to screen print without specialized fixturing. Paste jet printers like the MY500 we use are more adjustable and do not have that constraint because it allows us to tailor the amount of solder on individual components without the use of a stencil.

***Las Marias:** Thank you, Adrian.*

Nishimoto: Thank you. **SMT**

Real Time with...IPC: BEST Talks Rework Challenges and Opportunities

Bob Wettermann, president of BEST Inc., talks with I-Connect007 Editor Stephen Las Marias about the challenges in rework, and how his company is helping their customers address these problems. He also discusses his paper presentation at the technical proceedings at IPC APEX EXPO 2017.

Watch The Interview Here

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A New Organizational Model Using Logic, Cost-Effectiveness and Customer Service, Part 4

by Tom Borkes
THE JEFFERSON PROJECT

This month we complete our analysis of labor cost reduction in electronic product assembly. A new organizational model is proposed to replace the traditional burdensome one that has in most cases been taken for granted in our industry.

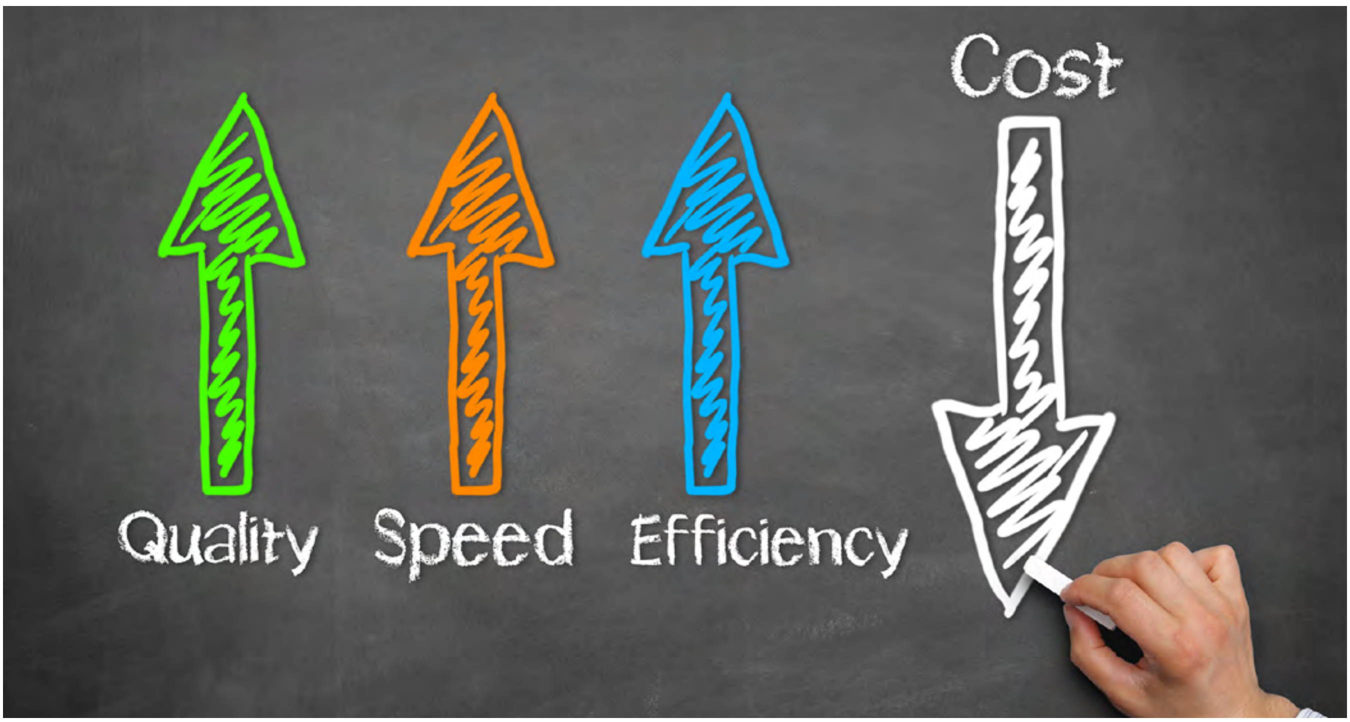
For years, many of us in high labor-rate regions of the globe have jumped on the bandwagon, claiming that moving product assembly and test to geographic areas of inexpensive labor was the only way to compete.

We've heard the management plea shouted from the rooftops in high direct labor-rate companies, "We will always assemble prototype and preproduction quantities here, but high-volume production is lost forever to sources with low labor rates."

What's Wrong with this Picture?

Think about it: Based solely on labor costs, if everything else is equal, in what arena should a high labor-rate assembler compete more effectively—low volume or high volume? Since start-up costs, process development, line set-up, assembly and test tooling and fixture expenses and recurring production support are all amortized over larger numbers in volume production, the price per production unit is less. So, high volume assembly should be more competitive with a high labor rate direct labor workforce.

After several decades of producing products remotely, the total cost and impact of producing products on a distant shore is being fully realized. Many in management, in their infinite wisdom, initially jumped on the low labor rate bandwagon, are starting to pull back on the bandwagon's reins and say, "Whoa!" Some, who actually know what their products cost to assemble locally, and can develop and maintain a statistically capable process, have begun to jump off the bandwagon. It seems the picture of low costs, protected intellectual property



(IP), reliable deliveries and high product quality that was envisioned as the company's Mona Lisa masterpiece has turned out to be more like a painting of dogs playing poker[1].

The Labor Cost Pie

The two principal ingredients that are baked into the product assembly cost pie are labor and material. All costs that a company incurs can be placed in one of these two ingredient containers. Historically, in most cases, the labor cost slice is only 10–30% of the entire pie.

Considering high labor-rate regions of the world should be MORE competitive in high volume production, it's fair to challenge the long-held premise about high direct labor rates being the root cause of needing to assemble volume production off shore. In addition, remember direct labor is only a percentage of the total labor cost, which itself is only 10–30% of the total product cost! Let's continue to drill down and examine more closely what has really been going on.

The Direct Labor Rate Disparity Defense

Labor rate disparity has been a convenient excuse for moving production out of high labor-rate areas, but there are other factors that have had more of an impact on the competitive landscape and, perhaps, come closer to the root cause (choose as many factors as applicable in your environment).

1. High assembly yield loss causing labor costs in high labor-rate operations to balloon due to expensive rework. (Not an issue in low labor rate regions where rework labor costs can diminish the effect of poor process development and control.)
2. High indirect and general and administrative labor costs that must be absorbed and greatly inflate the labor sell rate.
3. Material cost differences—a potentially big issue. This is especially true for tier 3, 4 and 5 operations that don't have facilities in low labor-rate locations with a central procurement activity to leverage volume production and local favorable material pricing[2].
4. Government policy such as corporate tax, tariffs and regulation that affects the cost of doing business.

Some of these factors are controllable (e.g., Factors 1 and 2), and some are not (e.g., Factors 3 and 4).

Who Says You Can Never Go Home Again?

A re-shoring initiative is underway in some high labor-rate regions. There are several reasons. One reason is that for about 10 years the true cost of offshoring electronic product assembly has been slowly but relentlessly hitting the original product developer (OPD) and electronic manufacturing service (EMS) providers' books.

The accountants have said, "Maybe we should look at this offshoring stuff a little more closely." But in many cases the die has been cast; the money to create the additional organization needed to manage and deal with operations halfway around the world has been spent. Too many in management have their reputations and egos to worry about. Remember, there is a good reason for moving production offshore: the desire to sell products into a huge "local" market. Unfortunately, the underlying, unspoken motivation to move production was often some combination of the four factors listed above, and not driven by the desire to expand product exposure into new markets. The labor-rate disparity provided cover.

The Uncontrollable Parts: Factor 4

In the United States, we now have a new administration that is seasoned in the art of the deal. The good news is that we now have leadership that at least understands business. The bad news is that they are still subjected to the politics that can trump logic and shape an economic policy that is not in the best interest of the country[3].

The way out of this mess is to have leadership at the national level that focuses on making the economic opportunity pie bigger, and not one that is consumed with making the size of the slices equal. The promise of this country has never been equal results, but the freedom to pursue individual happiness—in whatever way happiness is defined by the individual.

The Uncontrollable Parts: Factor 3

Material cost differences between high and low labor rate regions of product assembly activity should not be ignored, especially when considering that material cost normally accounts for 70–90% of the total product cost pie. There should be near parity in material pricing as a function of where the material is purchased. There is not. The details of this factor are complex in nature and will be discussed in detail over the next several columns.

The Controllable Parts: Factor 1

We have addressed this topic in previous SMT Magazine columns. To summarize: The need to apply expensive direct labor to "touch-up" and rework assemblies is a function of poor test yields. This result is a function of one of two conditions:

A. A statistically incapable assembly process where naturally occurring process variation exceeds the upper or lower specification limits of the process, or
B. A process acted on by an assignable cause that has led to the process going out of control.

About 91% first pass in-circuit test yield may have been acceptable before the advent of inexpensive labor sources. However, to successfully compete in today's competitive environment, yields of 99.6% are typically needed. This assembly yield not only greatly reduces rework labor content, but also removes the need for 100% ICT[4].

The Controllable Parts: Factor 2

The subject of this and the previous three *Jumping off the Bandwagon* columns has been to establish an organizational model that significantly reduces all labor that cannot be categorized as "direct" (i.e., labor that is not attributable to the actual assembly of a product). There are several papers that address this topic as well[5].

Reducing labor cost by reducing labor content through automation brings with it the ability to absorb less non-direct labor costs.

In any case, when a company's indirect labor costs begin to amount to one, two, or more times the direct labor cost, the labor sell rate becomes non-competitive. These indirect costs are a result of the traditional hierarchical nature that has characterized the organizational structure of most business models.

Two Caveats Associated with Reducing Labor Cost Through Reducing Labor Content

So, while reducing labor cost by reducing labor content by automating traditionally labor intensive processes instead of relentlessly seeking low labor rate assembly sources is a good competitive strategy, it come with two important caveats:

1. A highly skilled workforce that can develop and maintain the new automated processes is necessary. Unfortunately, this requirement for a highly technical engineering workforce requires skills that our educational system currently cannot provide. The constant theme throughout these columns has been the absolute necessity of rethinking and overhauling the way we educate for our industry.[6]
2. A new organizational model that minimizes all non-direct labor costs (controllable factor 2) is required. We have spent the past three months in this space drilling down into these costs. The conclusion: If we want to reduce labor cost by reducing labor content instead of eternally searching the globe for the lowest labor rates, a reduction in direct labor hours must be accompanied by a reduction in

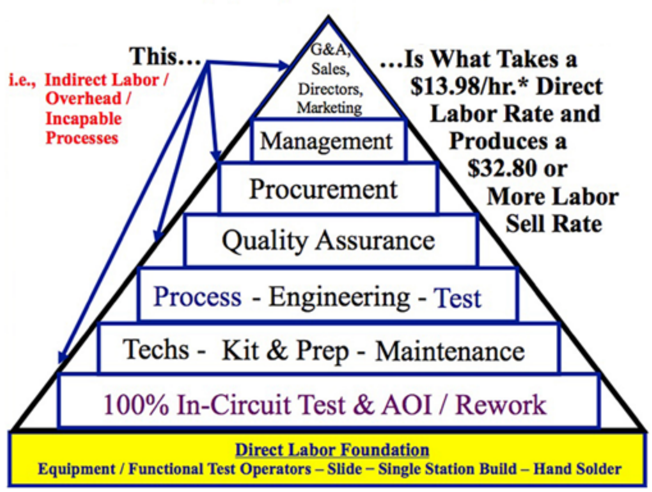


Figure 1: The traditional hierarchical organizational model is laden with non-direct labor costs.

the non-direct labor costs that the direct labor must to absorb.

The New Organizational Model

The traditional hierarchical organizational model is laden with non-direct labor costs (Figure 1). Figures 2 and 3 represent two of the 22 organization charts for a typical tier 1 or 2 hierarchical business structure. All of the personnel costs represented on the charts are G&A (general and administrative) and must be absorbed by direct labor to form a labor sell rate.

The new model replaces the traditional model with just two groups: Self-managed product teams and a leadership team.

1. The Product Team: a small, self-managed, multi-skilled group of engineers that directly

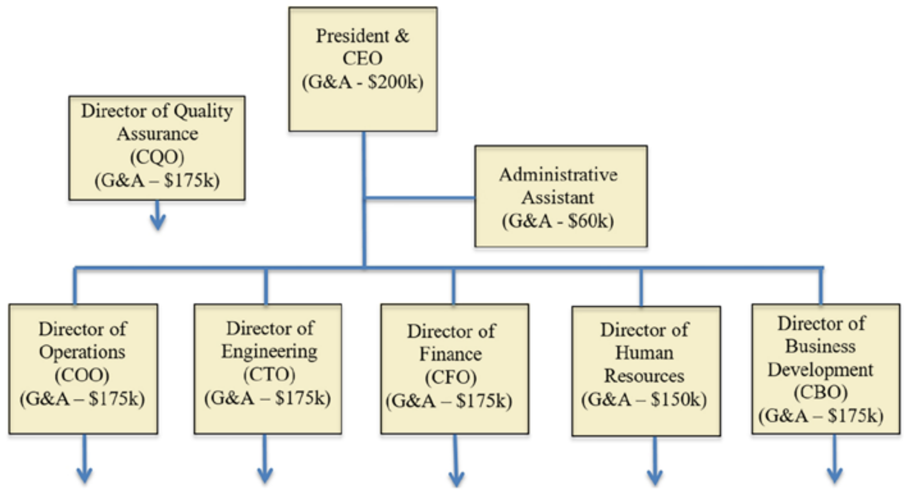


Figure 2: Typical top level hierarchical organization chart (Cost category: Salary/year).

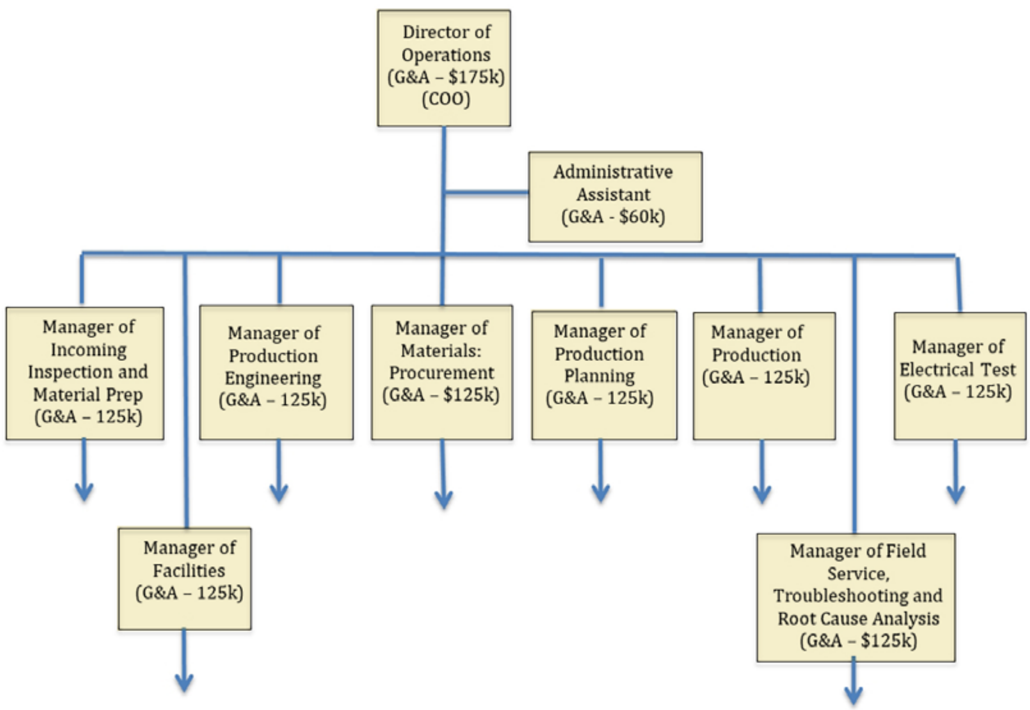


Figure 3: Typical operational hierarchical organization chart (Cost category: Salary/year).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and comprehensively plan, develop, assemble, test, interact with customers and manage all aspects of product production.

2. The Leadership Team: a group that effectively works for the product teams by serving an enabling function:

a. They ensure the product team has all the tools they need to be successful.

b. They form the product team with personnel who have the required skill sets.

c. They provide a check and balance on the product team's performance and decision-making.

d. They serve an arbitration function if the product team can't resolve an issue internally.

The relationship between the product and leadership teams is symbolically represented below by Figures 4 and 5.

As summarized in last month's column, the following has been concluded:

1. Automation is the counterweight to low labor rates. High labor-rate environments can compete by reducing labor content through automation.

2. In this automated environment, the workforce needs to be transformed from many low paid direct personnel to a few high paid engineers with the ability to develop and maintain the automated processes.

3. This new workforce must be cross-disciplined, with each member having multiple skill sets and the versatility to multitask and wear whatever hat is necessary at a particular point in time. They will be focused on the products they are assembling, not the departments from whence they once resided.

4. What must accompany this workforce transformation is a transformation in the company's organizational model. The reduction in labor content must be accompanied by a corresponding reduction in indirect and overhead cost since there is less direct labor to absorb these costs.

5. This new organizational model is a structural disruption from the traditional hierarchical form of power pyramid.

6. What is needed for the new workforce requirements and new organizational structure is a new approach to education.

We now add to this list assembly yields of 99.6%+ and details of the new organizational model, both discussed above.

Figure 4: The new organization model: The product team and a leadership team.

Figure 5: The new organization model: The product team of "super engineers" and a leadership team that serves as a project team enabler and a check and balance.

This new strategy and model has been analyzed and demonstrated to be less expensive than a typical low labor-rate model[7].

Next time we'll begin our treatment of material costs.

Hey, what do YOU say? I'd like to hear your thoughts and experiences. **SMT**

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Tom Borkes is the founder of the Jefferson Project and the forthcoming Jefferson Institute of Technology. To read past columns or to contact Borkes, click here.

Metcal Brings Big Science and High Reliability to Hand Soldering

Recently, Judy Warner met with Metcal's Product Support Engineer Robert Roush to discuss their patented hand-soldering technology unveiled at this year's IPC APEX EXPO, in San Diego, California.

Robert Roush

The new technology, called Connection Validation (CV), provides real-time feedback to the operator and indicates whether they've successfully achieved a "good" solder joint, or if there's been some fault during the soldering process.

When Metcal first introduced SmartHeat, customers achieved a new level of process control within their hand soldering operations, which is historically the weakest link. Now with CV, Metcal offer control not only of the tip temperature, but also solder joint quality itself. According to the company, it's the most innovative advancement in soldering technology in almost 30 years and represents a quantum shift in process control—particularly in the prototyping and production of automotive, aerospace, military, medical devices, and other products with zero risk tolerance.

CV was the centerpiece of Metcal's newly designed booth at IPC APEX EXPO 2017. "We did live demos, and walked people through exactly how this technology works. We had multiple stations where people came up and experienced the technology live," said Roush.

The company has also developed a technical white paper, "Risk Mitigation in Hand Soldering," which is clearly at the crux of what its new product addresses. (The white paper can be downloaded here.)

The technology sounds like a real game-changer, from a reliability and process control standpoint, and promises to bring a new level of science and control to the world of hand-soldering.

Read The Interview Here.

Flex-Circuit Assembly Success Hinges on MSL Control and Panelization

by Stephen Las Marias
I-CONNECT007

Screaming Circuits, a division of EMS firm Milwaukee Electronics, specializes in building short-run, one-off, and prototype PCB assembly, with rapid turn times and instant online quoting and ordering.

Mike Galloway, technical team supervisor at Screaming Circuits, discusses with *SMT Magazine* the biggest challenges when it comes to assembling flex circuits, the critical factors affecting yields, and the key considerations for OEMs when selecting contract manufacturing partner for their flex circuit assemblies.

***Stephen Las Marias:** Mike, what are the major challenges in flex circuit assembly?*

Mike Galloway: We have found that you need to control moisture sensitivity level (MSL). We are treating them as MSL 5. We are baking them on receipt and sealing them in moisture sensitive packaging. If top and bottom side assembly will have a time gap of several hours, we will reseal them during the production process.

***Las Marias:** What specific steps in a flexible circuit assembly process have the biggest effect on yields?*

Galloway: We find panelization is critical. The contract manufacturer and design team need to discuss the depanelization strategy and make sure the proper tools are specified. It is also important that the layout uses appropriate clearances on edges that will be cut or routed.

***Las Marias:** How should these challenges be addressed?*

Galloway: Typically, flex boards are not square. We need to hold them flat and provide them with adequate support. We typically fixture with FR4 and use double-sided kapton tape to hold it down for most situations. When the application warrants it, we go to a fixture house and have custom fixtures with tooling pins made.

***Las Marias:** How different is the flex circuit assembly from the standard PCB assembly?*


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Galloway: We are starting to see people put BGAs on flex. We've even seen chip scale BGA packages on flex. Just because you can do something doesn't mean you should do it. A rigid-flex may be more appropriate in these cases. While flex circuits require specialized handling during manufacturing, the real concern would be robustness in the field since flexing of the material during transport or use of the product could result in degradation of solder joints.

Mike Galloway

Las Marias: What about the challenges with respect to flexible circuit materials?

Galloway: We have had limited issues with different flex materials. The suppliers we use are experts in the field and we have discussions with them on best ways to process specific substrates.

Las Marias: What has the greatest impact on the quality of flexible circuit assemblies?

Galloway: The support factor in processing. Tooling must keep the flex circuit flat and immovable.

Las Marias: In which end markets are you seeing increasing use of flexible circuits?

Galloway: We are seeing across the board: consumer applications, industrial equipment and medical. We aren't seeing it defense applications.

Las Marias: What should OEMs consider when choosing an assembly partner for their flex circuit assembly?

Galloway: Have an open dialogue with the contract manufacturers you are considering to see how comfortable they are with flex circuit assembly and what their experience and capabilities are. Make sure more sensitive components such as BGAs are on a rigid portion of the flex. Also, make sure fiducials are in the design. We've seen a growing trend of designers leaving out fiducials. They are critical to accurate component placement on any substrate. The fiducials can be placed on the rigid, flex or the panel. This is an area where contract manufacturers may have individual placement preferences so having open dialog during the layout process is important.

Las Marias: Do you have any final comments?

Galloway: Flex may seem exotic, but with a little extra care can be a reliable way to get electronics into highly mechanically-constrained environments. Following a few guidelines and talking with your manufacturer will help to take the mystery and risk out of using flex circuits.

Las Marias: Thank you very much, Mike.

Galloway: Thank you. **SMT**

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Prodrive Technologies: 4.0 in Action

by Rich Heimsch
SUPER DRY-TOTECH EU

Headquartered in Eindhoven, Netherlands, Prodrive Technologies is a global provider of world-class technical products, systems, and automation solutions. From servo drives to automated guided vehicles (AGVs), Prodrive builds it, and creating their own factory of the future has been a significant part of their success.

At a time when numerous companies around them chose to move their manufacturing to lower cost geographies, Prodrive decided instead to develop and integrate automation solutions for the production of their high mix, low to high volume products. With a strong focus on quality, flexibility, and productivity, they have proven to possess a globally competitive production environment—located in Western Europe. From the moment Prodrive Technologies started with in-house production, they viewed automation in an unconventional way. Working in a dynamic industry and producing over a thousand different products every year demands flexible automation. They believe that critical focus for successful automation must be trained upon the processes and not the products. With this philosophy, over a thousand different products are being handled by the same automated processes.

Creating their own systems that support or improve the production processes is one of Prodrive Technologies' core competences. The Prodrive Technologies AGVs are a good example of an in-house development, taking care of the intelligent transport of components and products. The AGVs are not only used to optimize their internal processes, but are now also available for outside sale. Prodrive Technologies is a fast-growing company with a high diversity in products, which makes flexibility in transport essential. After an extensive market research, Prodrive Technologies decided to develop their own AGVs that actually provide the flexible and intelligent transport needed. Taking care of the transport, the

Figure 1: Prodrive Technologies' AGVs navigate without supporting infrastructure through the factory, finding their way from pick-up locations to drop-off locations.

AGVs increase Prodrive Technologies' productivity and enable 24/7 production without human interference. They navigate without supporting infrastructure through the factory, finding their way from pick-up locations to drop-off locations.

In this age, smart minded companies continuously search for flexible automation and digitalization of their processes. Track and trace become essential parts of every automation process. Industry 4.0 is a good example of an initiative that helps companies getting ready for the next industrial revolution, focusing on flexible automation, digitalization, and track and tracing throughout the whole supply chain. Embracing these ideas in such a way has enabled manufacturing in Europe be globally competitive and significant amounts of manual labor redeployed. Prodrive developed a components logistic process for printed circuit board assembly that is completely automated and digitized and had increased their productivity enormously.

The Component Tape Flow

Every electronics manufacturer deals with large numbers of components used in the production process. These components are placed on component tapes that can be used by the pick and place machines for PCB assembly. Current technology has advanced such that this flow of component tapes is fully automated, from inbound to the moment they are ready to be loaded onto the pick and place machines. Even more important, processes are set up in a way that provides complete tracking and tracing of the components at all times, eliminating manual handling and reducing errors.

This automated process is set-up as follows. All incoming reels are handed to a robot that is able to automatically recognize tapes using vision technology. With 3D vision, it recognizes specific characteristics of the reels and scans the unique barcode. The reel gets a unique serial number and the component information is automatically logged into the ERP system. Placed in a standardized carrier, they are ready to be transported to storage locations. For the most efficient process, multiple trays are stacked by a robot cells. Automated guided vehicles (AGV) were chosen for transportation because they are systems that take care of transportation in both an automated and autonomous way.

AGVs deliver reels or trays to the central, robotically manned "warehouse." This warehouse is environmentally controlled for both humidity and temperature, enabling the intricate management of all moisture sensitive components. The component tapes are being delivered by the AGVs to selected entry points. Reels are identified and the type and floor life (both exposed and remaining) are immediately known. Five-axis robots then place each reel into a best fit location. Best fit not only physically, but with respect to the components' MSL and floor life exposure, which may mean <5% rH or an elevated temperature low rH area for floor life reset.

When a reel is needed for production, it will be automatically located, selected and handed out to the operator, who puts it into a feeder that is used to place the tapes in the aforementioned AGVs. Feeder carriers are specially designed to increase the tracking and tracing of components throughout the logistic process. Every slot of the feeder carrier has an own identity and is connected with the manufacturing execution system (MES). Using the location information in an intelligent way for smart scheduling and assignment of the slots, the operator handling time and the margin of error with tapes and feeders is reduced substantially. Having supporting systems like the feeder carrier also prevents loss of tapes which causes searching time and mistakes like placing the wrong tape on the machines.

The final step before PCB assembly is placing the feeders with the tapes into the pick and place machines. The process has reduced manual handling to only two steps, the remainder is completely automatic.

The Benefits

During the whole process, there is real-time insight of component locations and production process status. Using real-time information to prepare future production batches not only gives a huge productivity increase, it also helps reducing product lead times and increases flexibility. The margin of error is being eliminated by a real-time control of the MES and ERP. By continuously investing in intelligent automation and productivity, the setup of this process is a real-world example of how to build the factory of the future. **SMT**

Rich Heimsch is a director at Protean Inbound and for Super Dry-Totech EU in the Americas. To read past columns or to contact Heimsch, click here.

Evaluating a PCB Assembler

by Dora Yang
PCBCART

When it comes to technology and quality, an SMT assembler's capabilities will be reflected when you go through the key elements in the SMT process. This article provides key points to consider in evaluating a PCB assembler, which allows you to test whether your circuit boards assembled in that factory conform to your required standard.

Among the key elements in evaluating SMT quality are solder paste printing quality, reflow quality, how to avoid misplacement of components, how to avoid manual placement, capabilities on stencil thickness calculation and modification, size of aperture, up-to-date equipment or instrument. Of these elements, the quality control of solder paste printing is the most critical. If solder paste is badly printed, your circuit boards are incontrovertibly in low quality, whether component mounting is accurately completed and reflow temperature is suitably modified. After all, non-standard amount of printed solder paste is closely associated with quality of soldering.

In terms of the other elements, the accuracy of the surface mounter has already achieved the required level and reflow temperature curves have been determined in advance, therefore few modifications are needed.

To evaluate solder paste printing capability, there are two aspects to consider: solder paste quality administration capability and solder paste printing capability.

Solder Paste Quality Administration

High-quality solder paste relies on its brand and freshness degree. The freshness degree of solder paste has to be tracked starting from the time of warming up, to jar opening and stirring. Different manufacturers conform to different regulations stipulating that solder paste has to be used up within a certain period of time, otherwise it will oxidize and lead to insufficient soldering in the reflow process. Furthermore, significant administration has to be implemented on solder pastes applied in stencil.

Solder paste is recommended to be stored in low-

temperature storage to maintain its activity, and warming up (generally more than four hours) is required prior to application to prevent its temperature from being incompatible with room temperature. When the temperature varies dramatically, water drop will be generated on the surface of the solder paste, leading to splashing during high-temperature reflow.

In addition, you should also consider issues such as how the solder paste applied in stencil will be processed, how the solder paste is timed, and how the solder paste that has been applied in original stencil will be administered and controlled when the stencil is modified.

"Another item that needs to be carefully studied is the time when the first batch of solder is warmed up, especially for PCB assemblers that don't run 24 hours a day."

Another item that needs to be carefully studied is the time when the first batch of solder is warmed up, especially for PCB assemblers that don't run 24 hours a day. As the SMT line starts working only when the solder paste is completely warmed up, some manufacturing houses will run warm-up about four hours earlier, or even one day earlier, to save time and improve the efficiency of the SMT lines. It's necessary to know that the solder paste quality will be greatly decreased if the warming-up procedure took place one day before application. In practice, professional PCB assemblers will surely scrap the solder paste if the warm-up happened over 12 hours before application.

Solder Paste Printing Capability

In terms of solder paste printing capability inspection, PCBs containing fine pitch (0.4 mm or 0.5 mm) BGAs should be selected for inspection. Repeating solder paste printing should be implemented on the same piece of PCB for five to ten times. Each printing result should be inspected under a microscope to see whether issues like bridging or displacement occur.

An SMT manufacturer with a solder paste inspection (SPI) equipment can also measure the solder paste amount or volume.

Stencil cleaning is also another element affecting the quality of solder paste printing. As solder paste leakage tends to be caused by long-term printing, leading to bridging, the stencil should be cleaned with non-dust cloth or with an ultrasonic wave to avoid hole blocking issue.

Solder paste quality administration and solder paste printing capability are the main focus of SMT process inspection. Of course, genuine solder paste printing technique contains far more items that'll be summarized into the following aspects:

a. Solder paste: Solder paste is mainly composed of tin powder (metal alloy powder including Sn, Ag, Cu, Bi) and flux, whose volume ratios account for 50%, respectively. It's necessary to select a type of suitable solder paste compatible with the requirements of your products. Furthermore, tin powder can be rated with different numbers. The larger the number is, the smaller the particle is. Generally, No. 3 tin powder is used for SMT while No. 4 tin powder is applied for fine pitch or small soldering pad mounting.

b. Stencil: Steel is usually used as a stencil material. Apertures of steel are generated generally based on three leading different methods: etching, laser cutting and electrotyping. In terms of products with fine pitch ICs, laser cut stencil is suggested since aperture wall through laser cutting is more accurate and neat. In spite of excellent performance of electrotyping stencils, they have limited effect and the price is relatively high.

Stencil thickness and size of aperture greatly influence both the solder paste printing and reflow quality. According to principles, the key administration point lies in tin volume, in that

the amount of solder paste has to be compatible with the final required soldering amount. In theory, the smaller the SMD component is, the thicker the stencil has to be. However, keep in mind that the thinner the solder paste is, the more difficult it is to control the tin amount. Basically, the thickness of an ordinary stencil is within the range from 0.12 mm to 0.15 mm. When it comes to fine pitch components (0201 or 01005), a stencil with thickness of 0.1 mm below is needed.

Silkscreen Printing Parameter Setting and Modification

a. Scraping blade pressure: A slight modification of scraping blade pressure leads to tremendous influence on solder paste printing. If blade pressure is too low, the solder paste will fail to fall at the bottom of stencil aperture and to be effectively transferred to the pad. If blade pressure is too high, the solder paste will be too thin or the stencils will even be damaged. The optimal condition is that the solder paste is scrapped from the surface of stencil totally.

b. Printing thickness: Printing thickness largely relies on the thickness of the stencil. A slight modification of solder paste printing thickness can be obtained through blade speed modification and blade pressure. Suitable reduction of printing speed of blade also leads to increasing of solder paste amount on PCB.

c. Stencil cleaning: In solder paste printing, the stencil should be cleaned after every 10 units of PCBs have been successfully printed in order to eliminate deposits at the bottom of stencils and pervasive solder paste. Generally, alcohol without water is applied as a cleaning agent.

To obtain genuinely high SMT quality, investigation and analysis have to be carried out on each manufacturing link and key elements so that effective control methods can be captured. In the SMT assembly process, solder paste printing is the most critical. As long as reasonable parameters are set and corresponding laws between them are mastered, high-quality solder paste printing can be achieved. **SMT**

Dora Yang is a technical engineer from PCBCart, a China-based prototype and middle-volume PCB assembly service provider.

IPC APEX EXPO 2017 Coverage with I-Connect007

Didn't make it to IPC APEX EXPO 2017? We've got it covered for you.

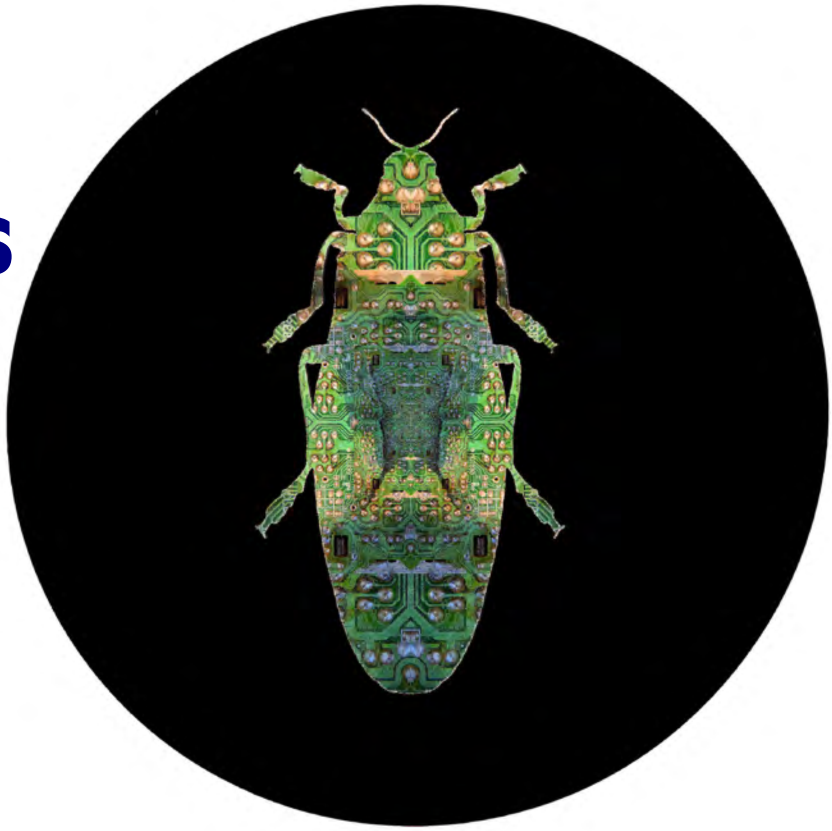
During IPC APEX EXPO 2017, we at I-Connect007 featured a state-of-the art micro studio, where over 70 RealTimewith…IPC interviews were conducted.

See the opening ceremony, hear from suppliers on their new products, learn more about the HDP Users Group, and don't miss the videos by IPC President John Mitchell and his staff.

We also created a time-lapse video, which is made up of more than 50,000 photos taken from the event setup to closing. We are sure you will find this very entertaining. The video is about seven minutes in length…which is not bad considering you're watching a three-day event!

So, get all of your post-show coverage, including in-depth interviews and the event photo gallery, by visiting our RealTimewith…IPC APEX EXPO 2017 site now!

Miniature Components on PCBs Requires Flexible Cleaning Methods



by Michael Jones, MICROCARE CORP.,
and Sally Stone, HART MARKETING

Most people are not good at predicting the future, but here's one forecast that's certain: Electronics are going to get smaller, smarter, denser, and hotter. This puts more computing power and snappy features into the mobile devices we all love, which is a good thing. But it also puts pressure on PCB manufacturers as they deploy ever more complex miniature components with ever tighter tolerances.

Smaller, more densely populated circuit boards make the issue of managing faults, quality and product longevity highly challenging. This is why so many companies consider their PCB cleaning as a mission-critical process. If the cleaning is not effective the device simply will not function reliably for the required life of the product.

Manufacturers also need a cleaning process that's flexible, because today's components won't be used in next year's designs. Speed is important, but so is the ability to clean new shapes or unusual contamination. A large, rigid, inflexible cleaning process may be very cost-effective today, but how will it handle the parts and fluxes five years from now?

To future-proof any investment in cleaning, a company needs to understand the complexities of cleaning. But that's truly difficult because the trade-offs are not always obvious; many diverse factors crowd the equation. So the question is, which critical cleaning process takes into account all the important requirements, whilst still cleaning components today and tomorrow? The answer, in my mind, is solvent cleaning.

A Time for Change

At the turn of the century, the trend in cleaning leaned towards the use of water-based products. Water was cheap, the boards were big and the stand-offs high. The cleaning systems grew to enormous size, able to spit out hundreds or even thousands of clean PCBs an hour.

But as the dinosaurs found, bigger may not always be better. Aqueous cleaning may no longer be optimal simply because the systems are so large and complex, which ossifies them. Companies with rigid cleaning processes have difficulty adapting to new component designs and new contaminates. They run the risk of being left behind, especially as smaller components are making cleaning processes increasingly more difficult to implement. Many manufacturers now are opting for solvent cleaning be-

cause they find it to be more effective, flexible, and less expensive.

Here's the essence of vapor degreasing: It is a closed-loop system with few moving parts that inherently recycles the solvent. This keeps costs down and through-put up. In particular, vapor degreasing offers excellent performance when cleaning miniature components.

In the simplest configuration, a vapor degreaser consists of a top-loading cleaning machine composed of two chambers. The first chamber is called the boil sump and the second chamber is the rinse sump. Both chambers are filled with a special nonflammable cleaning fluid that boils near room temperature.

In the boil sump, the solvent is heated and immersed parts are cleaned in the roiling fluid. The heat also generates vapor (e.g., steam from the solvent). The vapors rise inside the machine until they are captured by refrigerated coils that encircle the perimeter of the system. The refrigeration condenses the vapors back to the liquid state. This pure, clean distillate liquid is channeled into the rinse chamber which eventually overflows back into the boil sump.

Without any air knives, blowers or dryers, the parts come out clean, dry, spot-free and immediately ready for further processing. Depending on the process requirements, vapor degreasing can handle the largest parts, the highest volumes and the most challenging shapes.

A few simple additional features can make this simple system even more flexible. An automated hoist can move the dirty parts through the cleaning system. Ultrasonics can enhance cleaning and ensure residue-free results. The sumps can be fitted with filtration systems to remove insoluble contamination

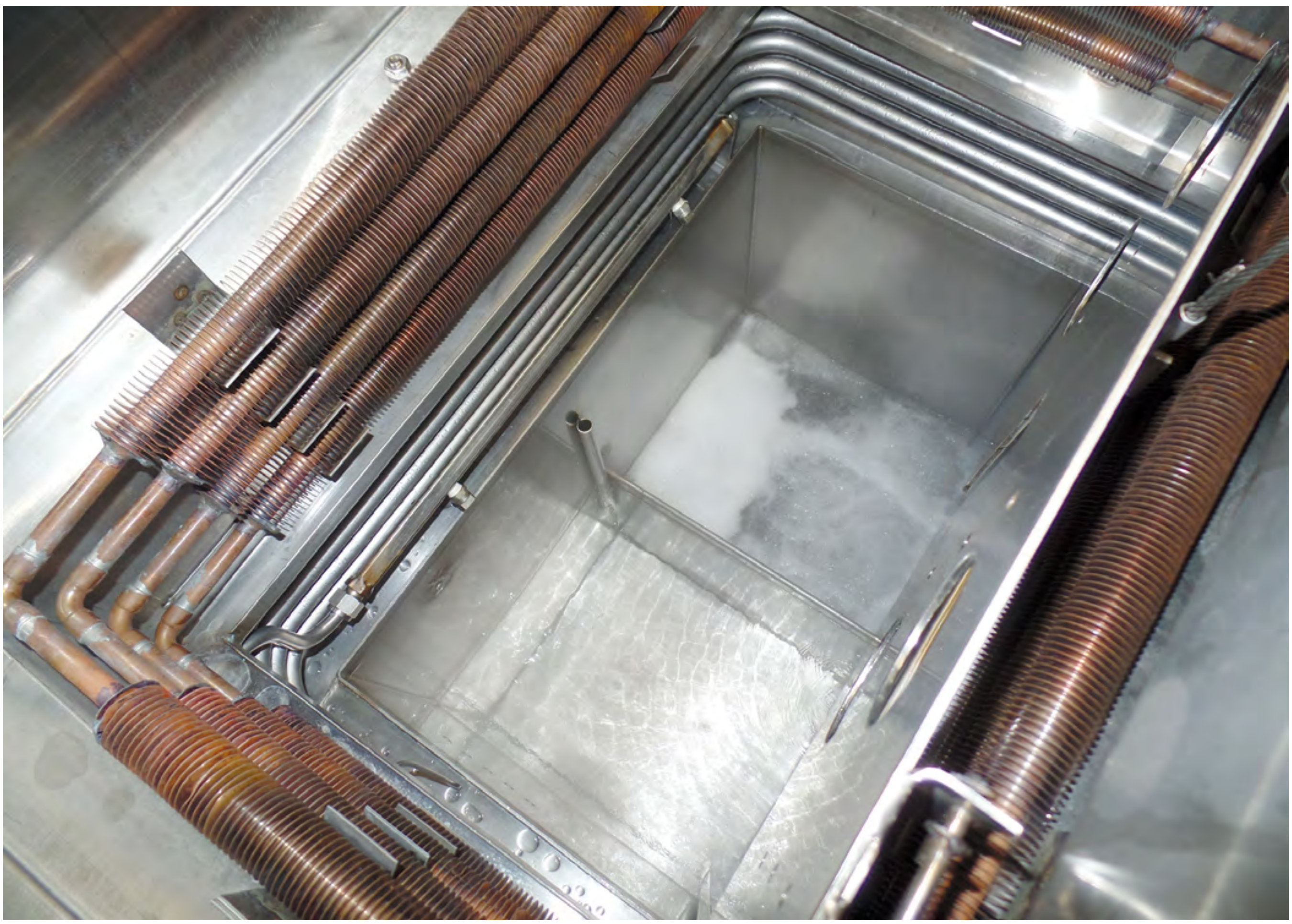


Figure 1: Vapor degreasing.

(particulate). "Super heat" and external distillation are also money-saving, performance-enhancing choices. These systems are easily programmable and allow for excellent repeatability. Companies can pick and choose to tailor their equipment and processes to their PCBs and budgets.

Vapor Degreasing Advantages

In comparison to aqueous systems, the advantages of vapor degreasing are clear. The systems are very easy to use, highly efficient, smaller in footprint, and lower in overall capital and operating costs. Let's look and see how these benefits are delivered.

First, solvent cleaning leverages the chemical properties of the cleaning fluid, rather than fighting against those characteristics. Low-boiling solvents have a much lower surface tension and viscosity than water, so they easily clean even under the smallest of parts. Most vapor degreasing fluids are also very heavy and dense, typically 20–40% heavier than water, which aids in dislodging particulate from components. Because the solvent is tailored for the application, delicate parts are easily cleaned and dried. It is possible to combine all these factors into a "wetting index" that permits apple-to-apple comparisons (Chart 1).

Another advantage is the cleaning fluid boils at a low temperature (usually slightly above room temperature), so heating the cleaning fluid uses very little electricity. In comparison to an aqueous cleaner, a vapor degreaser of comparable capacity will use about 1/6th the electrical power. Since burning fossil fuels to generate electricity is one of the primary sources of carbon in the atmosphere, an energy efficient-cleaning system is highly attractive.

An unexpected cost savings stems from the fact the solvents, unlike aqueous saponifiers and surfactants, can be re-used indefinitely. This is because a vapor degreaser is a recycling system. While aqueous cleaning dump the cleaning fluids after a single use, the re-usability of solvent cleaning makes the choice extremely cost-effective.

These machines, when properly designed, equipped and configured, outperform the cleaning efficiency of any other cleaning technology.

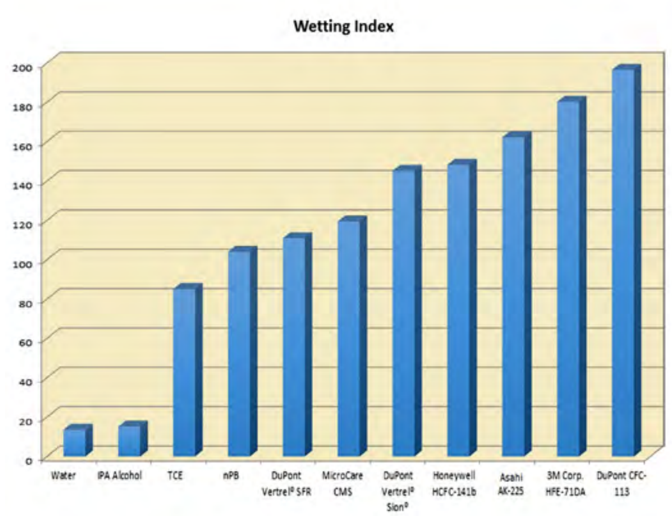


Chart 1: Wetting index comparison between different solvent cleaning solutions.

Water—Not as Green as You Think

Aqueous cleaning is the most common alternative to solvent cleaning. Experience has proven that it can work well in non-critical applications because water cleaning uses the kinetic energy of pumps and sprays to "power-wash" contamination from surfaces. But as parts become smaller and the stand-offs tighter, the performance of aqueous systems suffer.

There are a number of reasons why the ostensible advantages of water cleaning do not always materialize as expected.

First, clean water does not come straight from the tap. Water needs to be pre-treated to be acceptable to ensure there are no trace materials, minerals or pre-existing bioburden that would compromise the cleaning process. Next, expensive cleaning fluids need to be added to the water to reduce the surface tension so the water can clean effectively. Lastly, substantial expertise is required to monitor the cleaning fluid (such as the pH) so extra people, consumables and services are required. In contrast, solvents come ready-to-use, require no mixing and can be used indefinitely.

Aqueous cleaning processes operate horizontally and contain many moving parts, including conveyors, pumps, air knives and heaters. These machines and their support systems have an enormously larger footprint than a vapor degreaser, requiring more overall space in the factory floor. Vapor degreasing systems, in contrast, work vertically, and require little space and less energy than aqueous systems.

The small, delicate parts used in PCBs can be a challenge to clean in an aqueous system. Due to the chemical characteristics of a water molecule, water often cannot get into the tightest spaces or smallest apertures. This means those hard-to-reach locations are not wetted and—as cleaning experts all understand—if you cannot wet, you cannot clean. Chart 1 compares the wetting abilities of water to a variety of popular solvents.

Big aqueous cleaning systems also have a much slower through-put than a vapor degreaser. I have personally seen 15-meter long aqueous systems using 45-minute cycle times, while a vapor degreaser typically cleans a basket of PCBs in 8–10 minutes.

Energy is a big issue today. Aqueous systems require high temperatures to be effective, more energy to dry the parts after cleaning, and still more energy to treat the water after use. Soggy aqueous systems also inject humidity into the atmosphere of the workspace, requiring more electricity to cool and dehumidify, but it requires an enormous amount of energy to heat water. As noted above, aqueous cleaners generally will consume at least six times more energy than a vapor degreaser cleaning the same quantity of parts.

Filtration is also problematic with water-based cleaning systems because water does not easily traverse 2 or 3 micron filters. The only way to deliver micron-grade filtration is with big, energy-hungry pumps to force the water through the filter.

Also, the rinsing and drying process is much more complex. Blowers or heated dryers often are used to reach nooks and crannies, and even then, spotting or corrosion can be a problem. These blowers and heated dryers also require additional energy to operate.

Finally, bioburden, which forms when assembled devices come in contact with residual organic materials, can be a problem with aqueous systems, but not with solvent-based systems. For a medical device manufacturer that has had to re-clean, re-package or scrap devices that have been affected by bioburden, the vapor degreaser system can offer significant savings in time and money.

To sum it all up, not only does solvent cleaning offer an environmental benefit, it is also a cost savings for almost every manufacturer.

Innovative Solvents and the Environment

Today's modern solvents meet strict environmental standards. They are all completely ozone-safe, for example. They meet Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) requirements, are TSCA registered and some of the newest choices have virtually no global warming impact. These innovative new solvents available on the market are not only gentle on the planet, but also deliver consistent and reliable cleaning with the lowest overall costs.

Cleaning trials should be a prerequisite before making choosing a cleaning method. Tests usually involve collecting a standardized sample of contaminated parts and sending them to the chemical company's lab. Any quality vendor should be willing and able to perform a modest amount of testing. The vendor should provide a detailed written report and often will perform these services free of charge.

The continued miniaturization of components is making critical cleaning of PCBs a challenge. In general, the need get the job done right, while protecting people and the environment, and the incessant pressure to reduce costs combine to make solvent cleaning a very attractive option. The companies who choose the most versatile, flexible, low-risk option that meets all the critical cleaning requirements are the winners, and the way to come out on top is through selecting solvent cleaning using a vapor degreasing process. **SMT**

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Sally Stone is a technical specialist at Hart Marketing.

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Recent Highlights from SMT007

1 Help Wanted! Our 2017 Industry Hiring Survey

This month we conducted an industry survey on plans for hiring during the year. We started by simply asking, "Do you plan to hire additional people this year?" More than half of the respondents answered yes—which we take as an optimistic sign that our industry plans to expand in 2017.

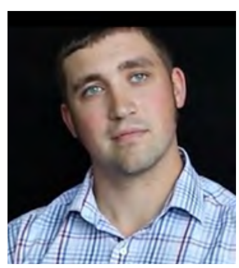
2 Millennials in Manufacturing: Mya Walton – The Millennials' Advantage in Manufacturing

Mya Walton, associate coordinator in the test department at Saline Lectronics, talks about how working in the manufacturing industry opened up a new world of possibilities for her, and how it feels to be creating products that help other people, such as heart monitors and black boxes.

3 Enics Acquires PKC Electronics

Enics has acquired PKC Electronics, including its factories in Raahe, Finland and Suzhou, China. Both factories are providing services in testing, power solutions and design and manufacturing services in electronics, mechanics, software and test systems design.

4 Millennials in Manufacturing: Tom Scales – Manufacturing from an IT Perspective



Tom Scales, IT manager at Saline Lectronics, talks about loyalty, work ethics, motivation, leadership, his greatest challenges from an IT perspective, and what he thinks the manufacturing industry should be doing when it comes to attracting more millennials to join this field.

5 Millennials in Manufacturing: Zach Tondreau – Motivating Millennials

Our last millennial to be featured in this series is Zach Tondreau, the conformal coat lead at Saline Lectronics. He talks about motivation, and how the younger generation can be attracted to join the manufacturing community.

6 What to Look for When Auditing an Electronics Manufacturing Facility

Although a large amount of research can be carried out online when selecting an EMS partner, the only real way to satisfy an OEM whether an EMS provider will be a good fit or not is to meet the team and audit their processes. This article lists the approach many OEMs take and highlight some of the key questions they ask.

7 RoHS Exemptions Unlikely to Be Published Before Fall 2017

The EU Commission and Member States continue to meet to discuss the disposition of RoHS exemption renewal requests submitted by industry in January 2015.

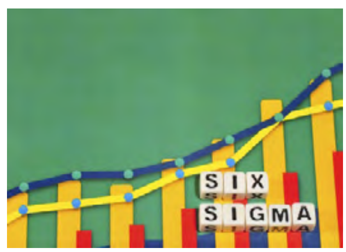
8 Real Time with...IPC 2017 Videos Now Available for Viewing

Over 70 video interviews from the IPC APEX EXPO 2017 show in San Diego, California are now available for viewing.

9 MC Assembly Demonstrates Its Success with Lean Manufacturing

EMS firm MC Assembly recently presented its lean manufacturing journey during Neptune Technology Group's annual supplier symposium, an annual event where key suppliers of Neptune Technology Group gather to review the achievements and goals for the coming year.

10 Six Sigma: What is it and How is it Used in Electronics Manufacturing?



Six Sigma is a defined, data-driven methodology aimed at process improvement and consistent output in manufacturing. This article discusses how it is used in electronics manufacturing, and the benefits it offers companies that have implemented it.

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Events

For IPC's Calendar of Events, click here.

For the SMTA Calendar of Events, click here.

For the iNEMI Calendar, click here.

For a complete listing, check out SMT Magazine's full events calendar here.

China International PCB & Assembly Show (CPCA)
March 7–9, 2017
Shanghai, China

NEPCON China 2017
April 25–27, 2017
Shanghai, China

The 14th Electronic Circuits World Convention
April 25–27, 2017
Goyang City, South Korea

KPCA Show 2017
April 25–27, 2017
Goyang City, South Korea

IPC Reliability Forum: Manufacturing High Performance Products
April 26–27, 2017
Chicago, Illinois, USA

IMPACT Washington D.C. 2017
May 1–3, 2017
Washington D.C., USA

Thailand PCB Expo 2017
May 11–13, 2017
Bangkok, Thailand

SMT Hybrid Packaging
May 16–18, 2017
Nuremberg, Germany

JPCA Show 2017
June 7–9, 2017
Tokyo, Japan

IPC Reliability Forum: Emerging Technologies
June 27–28, 2017
Düsseldorf, Germany

SMTA International 2017 Conference and Exhibition
September 17–21, 2017
Rosemont, Illinois, USA

electronicAsia
October 13–16, 2017
Hong Kong

productronica 2017
November 14–17, 2017
Munich, Germany

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Coming Soon to *SMT Magazine:*

APRIL:
Soldering
This month focuses on the soldering process challenges and strategies.

MAY:
Help Wanted!
This issue will look into the challenge of finding, hiring, and retaining the right talent in the electronics assembly industry.