Managing Time Delays, p. 24

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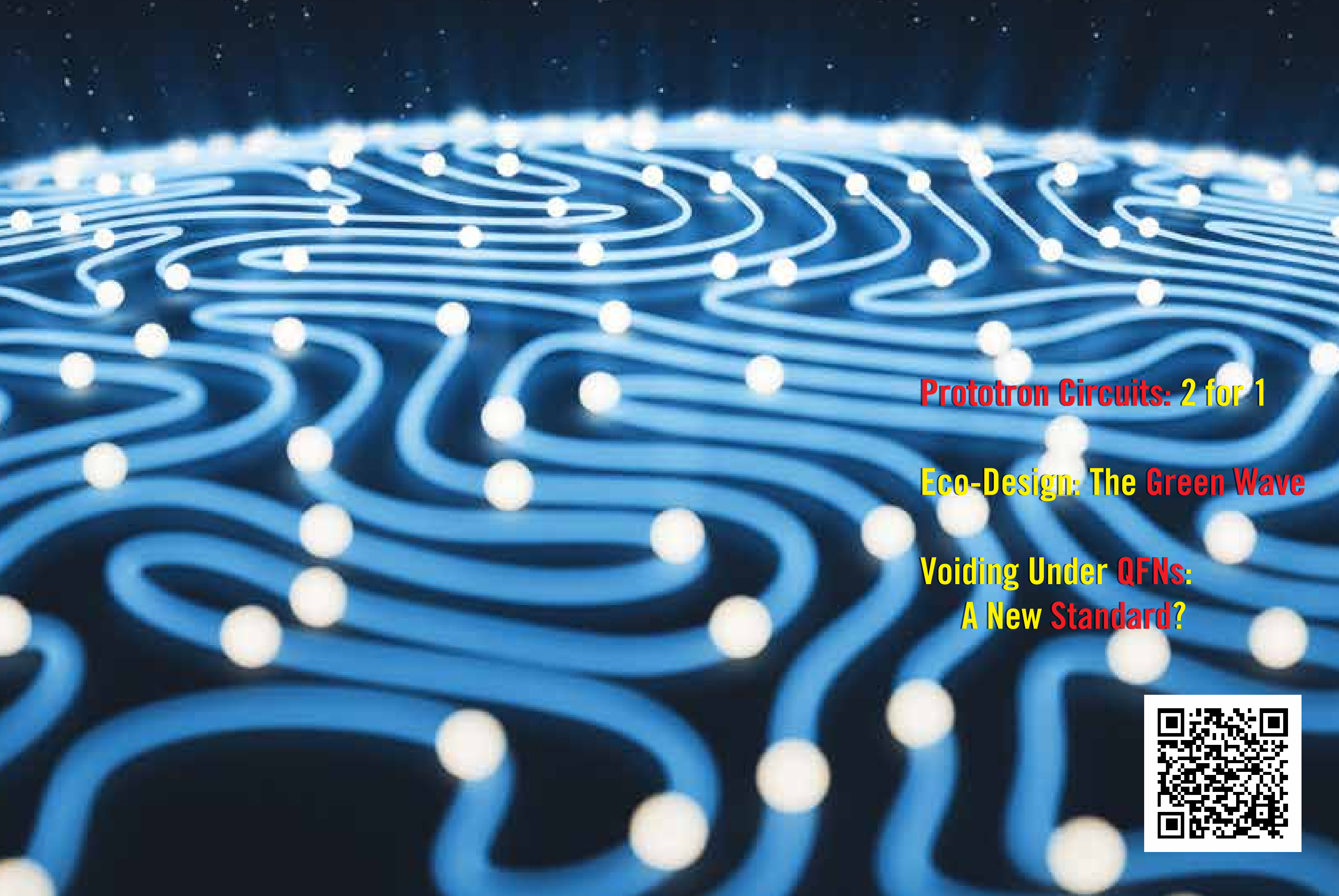

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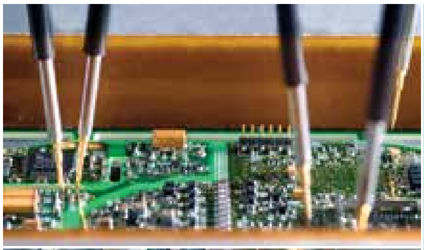
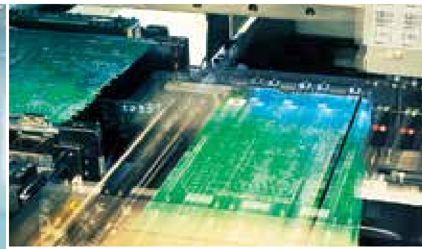
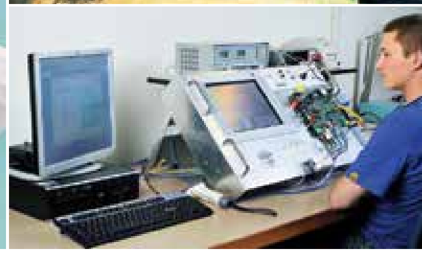
Grossenbacher Systeme AG



XJTAG® Boundary Scan Saves Valuable Time at Swiss Contract Manufacturer

"Time is precious for contract manufacturers, which is why Grossenbacher Systeme of St. Gallen in Switzerland chose XJTAG boundary scan to test customers' assemblies and program on-board devices. XJTAG's powerful features and intuitive user interface helped the company's engineers quickly become expert users after a short and effective hands-on introduction."

Grossenbacher Systeme, which is part of the Swiss Amalthea Group, provides high-quality manufacturing services to companies in sectors such as pharmaceuticals, food, medical technology, industrial automation, smart buildings, security, transportation, logistics and communications. The company has achieved ISO 13485 certification for producing medical devices, and has special expertise in user-interface design.

With capacity to place 70 million components per year, Grossenbacher has chosen XJTAG boundary scan to help minimise test cycle times, quickly program devices like microcontrollers and EEPROMs, and accelerate debugging and repair.

"Boundary scan is a powerful part of our test strategy, and can cut the time to identify errors caused by incorrect assembly or connections," explains Christoph Preisig, Team Leader, Test Engineering. "XJTAG has many features that help us create and run tests quickly and efficiently, and the user interface is easy to understand. After experiencing the introductory workshop, our engineers were soon up to speed."

XJTAG makes testing boards easier, with an intuitive user interface that guides the user through the test setup process. An advanced Connectivity Test, which also tests pull resistors and logic devices, is built-in and helps minimise the time between setting up and capturing test results. In addition, libraries of editable test scripts are available for many types of non-JTAG components including memory devices. These tests are written in a high-level programming language that makes them easy to understand and use.

"Creating boundary scan tests for our boards is straightforward, and allows us to deliver fast turnaround times for customers. Our engineers have become proficient very quickly, and the technical support provided by XJTAG's engineers is of a very high quality," continues Christoph Preisig. "The tools for use in production and repair environments are also easy to use, with powerful schematic and layout viewers that pinpoint fault locations."

XJTAG further accelerates production with special features for high-speed configuration of programmable devices like CPLDs and EEPROMs which can be used to assist in programming on-board flash. This technology minimises data on the boundary scan chain to eliminate conventional limitations and permit a huge increase in programming speed.

Another important feature, which is important to Grossenbacher's engineers, is the ability to control XJTAG boundary scan tests from a third-party test executive such as NI TestStand or custom-written windows applications. XJTAG can interoperate with a wide variety of other test equipment such as in-circuit test, functional test, flying-probe or inline inspection systems, either by being controlled by third party software or by using XJRunner, XJTAG's standalone production environment software, to control the third party equipment.

"XJTAG makes it easy for us to work the way we want to, either through built-in user interfaces like XJAnalyser or XJRunner, or integrated with our other test equipment," confirms Christoph Preisig. "Overall, XJTAG is easy to use, convenient, efficient and effective, and has quickly become popular with our engineers."

opinion

Christoph Preisig
Team Leader, Test Engineering
Grossenbacher Systeme

"XJTAG has many features that help us create and run tests quickly and efficiently, and the user interface is easy to understand. After experiencing the introductory workshop, our engineers were soon up to speed."

"The tools for use in production and repair environments are also easy to use, with powerful schematic and layout viewers that pinpoint fault locations."

"The technical support provided by XJTAG's engineers is of a very high quality."

"Overall, XJTAG is easy to use, convenient, efficient and effective, and has quickly become popular with our engineers."

Data Bank

Company	Grossenbacher Systeme AG Member of Amalthea Group
Nature of business	Full-service provider of Electronic Engineering and Manufacturing Services (EEMS)
Customers	Serving the Medical & Laboratory, Food & Pharma, Machinery & Industry, Building & Security, Transportation & Logistics, and Energy & Communications market sectors
Founded	1984
Employees	Approx. 150
Location	St. Gallen, Switzerland
Web site	www.gesys.ch

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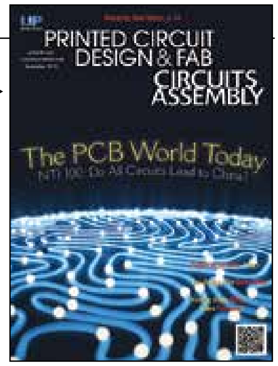

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MIKE BUETOW
EDITOR-IN-CHIEF

Circular Economy Regs Make My Head Spin

MANY "topical" conferences are not just good at answering questions, but they also open one's eyes to questions that have yet to be resolved.

The ITI/IPC 2019 Conference on Emerging & Critical Environmental Product Requirements is a perfect example. The two organizations caravanned across the US in June, bringing scores of environmentally conscious engineers and compliance officers up to date on the latest REACH and related regulations in the EU, UK and Asia.

What distinguishes REACH from almost any chemical safety regulation I can think of – including RoHS – is parties need to prove the safety of a substance before it's allowed on the market, and exemptions must be justified from both a risk point-of-view and a socio-economic point-of-view. Multiple independent technical committees, appointed by the Member States, make those assessments.

The latest efforts have lasered in on phthalates, also known as plasticizers. These chemicals are added to plastic to make it both stronger and more flexible, but perhaps are harmful to health. This would be an important addition to RoHS, as plastics are again under the public microscope for their near permanence and ubiquity in the environment. (Plastic bags were found this year by a manned sub at the bottom of the Mariana Trench.) A new environmental bill in the UK is working toward eliminating all avoidable plastic waste by 2042 and all avoidable waste by 2050. Estimates are 80% of the costs will be borne by producers. OEMs beware.

The one-day sessions gushed with the proverbial fire hydrant's worth of information. While the EU in particular is seen as trying to shorten the evaluation process, registration of a substance is not the end of the process. The European Chemicals Agency (ECHA) has a goal to increase compliance checks to 20% by 2027, from the current rate of 5%. If anything, scrutiny will intensify.

As an aside, if it feels like all the pressure on proving out substances is coming from outside the US, that's because it is. In the current regulatory environment in the US, any attempt to phase out chemicals for almost any reason has a snowball's chance in hell of succeeding. One attendee remarked it is probably better the US does not have its own rules, unless they were harmonized with those of other regions.

Speaking of harmonization, nine Asian nations now have versions of WEEE or RoHS. China's lead regulatory bodies, the State Administration for Market Regulation (SAMR) and the Ministry of Industry and Information Technology (MIIT), in May jointly issued the Implementation Measures for Conformity Assessment System, which stipulates conformity submissions are due within 30 days of a product's introduction to the market. The submission, which goes to a public website, can involve either a voluntary certification or a supplier's declaration of conformity. Come November, labels will be mandatory.

As is expected, goals and methods vary by nation. For instance, India seeks to reduce waste 10% per year, reaching a 70% decrease by 2024. Hong Kong has a disposal plan in effect, but as of June companies could only pay by check, not electronically.

All of this is part of the so-called circular economy. (For more on that, see the iNEMI article that starts on pg. 47.) Apropos, because my head was spinning with questions:

- Is the current goal of REACH to eliminate use of a substance or to eliminate human contact with a substance?
- Once a substance is on a list, is there any process for removing it?
- Should the US be involved in identifying and restricting chemicals of concern, or is it preferable to default to the EU? Which would be least disruptive to industry?
- Is there a strategy for harmonization across the US, EU, UK, Asia, etc.? If not, should there be?
- Are labels required for each end-product, or on every subsystem or component?
- One enforcement and compliance expert offered an example of a 20-person company that hired an additional worker to help the company stay in compliance. Is it financially feasible for small businesses to add staff just for compliance? Would it be better to outsource that function, and, if so, where would a company turn to do so?

I truly feel for the poor souls who are trying to keep up with it all.

mbuetow@upmediagroup.com
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P.S. See you this month at PCB West (pcbwest.com) at the Santa Clara Convention Center and SMTAI in Rosemont, IL (booth 1008).

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PCD&F People

Chin Poon appointed **SL Huang** president.

Insulectro named **Geraldine Arseneau** product manager-drill and business manager-Canada.

Ralph Morrison, author of a dozen books electronics engineering, passed away Aug. 2. He spent more than 50 years in the electronics industry and taught thousands of engineers about the fundamentals of voltage and currents.

TTM named **Dan Tozer** frontend engineering manager.

PCD&F Briefs

Amitron installed a **MicroCraft** E8M6151 flying probe tester at its facility in Chicago.

AT&S is investing 1 billion euros in a new plant in Chongqing in Southwest China.

Canadian Circuits has acquired an **Orbotech** Paragon 9800 LDI.

Downstream Technologies moved its headquarters to a new, larger facility in Marlborough, MA.

Eternal Technology named **International Electronic Components (IEC)** exclusive distributor for its dry film photoresist products in North America.

HannStar Board is acquiring a 24% stake in **Career Technology**, with the intention of developing 5G-related products, according to reports.

Iowa State engineers are using heat-free technology to print metal traces on flexible electronics.

iNEMI released four additional chapters from its 2019 Roadmap.

ITEQ and **Elite Material** are poised to embrace new business opportunities arising from the new server transmission architecture of PCIe Gen 4, according to industry sources.

Patchr and **Royal Circuits** have integrated their respective software systems to permit manufacturing once projects are completed in Patchr's platform.

Tech-Etch installed an **Atg** A5Neo flying probe tester.

Trackwise Designs released "The Engineers' Guide to Multilayer Flexible Printed Circuits (FPCs): Technologies and Applications," a white paper on FPCs, including limitless-length FPCs (https://tinyurl.com/y4d3w8r2). The fabricator also announced a collaboration agreement with **GKN Aerospace** to build the Type 8 Ice Protection System.

Bipartisan Legislation Introduced to Guard Against Foreign Threats to US Supply Chains

WASHINGTON – Citing the vital need for a secure US industrial base, US Senators Mike Crapo (R-ID) and Mark Warner (D-VA) have introduced bipartisan legislation to guard against attempts by the People's Republic of China and others to undermine US national security by exploiting and penetrating US supply chains.

The Manufacturing, Investment, and Controls Review for Computer Hardware, Intellectual Property and Supply (MicroChips) Act (S. 2316) would develop a national strategy to assess and prevent risks to critical US technologies.

"Actions by the People's Republic of China have contributed to an unfair and unsafe advantage in its technological race against the United States," said Sen. Crapo. "Through government investments and subsidies, as well as intellectual property theft of companies like Idaho's Micron, China aims to dominate a $1.5 trillion electronics industry, which creates serious, far-reaching threats to the supply chains that support the US government and military. The MicroChips Act would create a coordinated whole-of-government approach to identify and prevent these efforts and others aimed at undermining or interrupting the timely and secure provision of dual-use technologies vital to our national security."

"While there is broad recognition of the threats to our supply chain posed by China, we still lack a coordinated, whole-of-government strategy to defend ourselves," said Sen. Warner. "As a result, US companies lose billions of dollars to intellectual property theft every year, and counterfeit and compromised electronics in US military, government and critical civilian platforms give China potential backdoors to compromise these systems. We need a national strategy to unify efforts across the government to protect our supply chain and our national security."

Chinese companies export telecommunication technology equipment into software, hardware, and services used in the US, and reportedly hope to export 5G to the US that could potentially harm and expose both consumer and US military information.

Malicious chips or counterfeit parts could create backdoors enabling the monitoring or stealing of consumer data or cause broader system malfunctions. Even with high investments in cybersecurity, the US remains vulnerable to advanced cyberattackers like Russia and China.

A 2018 Government Accountability Office report stated, despite multiple warnings since the early 1990s, cybersecurity has not been a focus of weapon systems acquisitions within the military community. The Department of Defense's continuous acquisition of weapons systems without making security a key priority could potentially lead to loss of US IP and technological advantage of the US Armed Forces, contribute to unnecessary risks to human life and interfere with the ability of the Armed Forces to execute their missions.

The MicroChips Act would address China's practice of four major non-kinetic areas of warfare, including supply chain exploitation through supplying faulty software, hardware and components; cyber-physical attacks on US systems with real-time operating deadlines, such as missiles, aircraft and electrical grids; cyber-attacks on computer systems; and bad actors gaining sensitive information.

The act contains four sections with the following components: summarizes key findings of Congress regarding supply chain security; directs the Director of National Intelligence, DoD and other relevant agencies to develop a plan to increase supply chain intelligence within 180 days; establishes a National Supply Chain Security Center within the Office of the Director of National Intelligence to collect supply chain threat information and disseminate it to agencies with the authority to intervene; and makes funds available under the Defense Production Act for federal supply chain security enhancements.

Section two of the bill was included in the House-passed version of the Intelligence Authorization Act, and the Senate adopted section four of the bill through its version of the National Defense Authorization Act. – *CD*

We Navigate EMS Supply Chain Challenges Every Day

At SigmaTron International, we recognize that our electronics contract manufacturing customers want superior quality product where they need it, when they need it. While production is part of that equation, visibility into the supply chain and the ability to react to changing availability has become an even more critical element. Our knowledgeable supply chain team, proprietary real-time systems and logistics partners help ensure that customer requirements are consistently met.

SigmaTron's advantages include:

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- Robust systems for serialization, traceability and device history recordkeeping
- An experienced team capable of supporting your project's changing needs over time.

We've built our business around mid-to-high volume accounts who want Tier One caliber solutions, but truly customized service and responsiveness. All of our facilities are all registered to ISO 9001 and those building mission critical products are also registered to ISO 13485, IATF 16949 and/or AS9100D. You'll have access to global manufacturing options that support both nearshore and offshore strategies plus a trusted partner who truly values your business.

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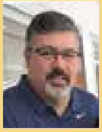


ACC Electronix promoted **Curt Williams** to president. Williams has 19 years' experience in EMS and was vice president of sales.

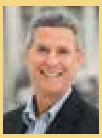
Benchmark Electronics named **Rob Crawford** chief revenue officer. He was vice president, global sales, Advanced Technology Solutions at Celestica, and previously held various leadership roles at QLogic, Quantum and Dell.

Data I/O named **Michael Tidwell** vice president of marketing and business development. He was previously head of marketing and business development at Sansa Security.

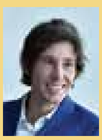
Dynamic EMS hired **Nicola Laird** for its purchasing department.

Green Circuits named **Nino Hardin** (left) regional sales manager for the Southwest region and **Kevin Kriss** (below, left) regional sales manager for the Southeast region.

H K Wentworth, parent company of Electrolube, appointed **Robert Crosby-Clarke** commercial director.



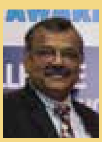
Identco announced **Chuck Horan** as director of sales, North America. He joined the company in 2016 as a global account manager and most recently was director, strategic accounts.



Inventec Performance Chemicals announced **Collin Whalen** as Northeast US regional sales manager.

Keysight named **Stacy Johnson** university program manager.

Lockheed Martin named **Kantesh Doss** senior member engineering staff.



Masterwork Electronics appointed **Bhawnesh Mathur** CEO. He was most recently president and CEO of Creation Technologies, and also was CEO of EPIC Technologies, EVP global supply chain at Sanmina-SCI, and chief supply chain officer at Arrow Electronics.

National Circuit Assembly appointed **Mark Cottam** vice president of sales and marketing. He has 30 years of senior

Good Chemistry: Atotech Acquires J-KEM

BERLIN – Atotech has acquired J-KEM International, a supplier of chemistries and processes for the printed circuit board and metal finishing industries. Terms of the transaction, which closed Aug. 1, were not disclosed.

Rosersberg, Sweden-based J-KEM's technology and customer relationships complement Atotech's product portfolio and will help expand addressable markets and drive future growth, Atotech said in a statement.

Atotech will maintain all existing services of J-KEM, while the latter's customers gain full access to Atotech's regional and global product development, production and technical support capabilities, including its material science and analytical services.

"We are thrilled to add J-KEM's strong products and technologies to Atotech," said Geoff Wild, chief executive, Atotech. "We see substantial opportunities to further grow our business with this set of new and excellent products. J-KEM brings a graphite process that gives superior performance, an accelerator-free system in collaboration with an EDTA electroless copper process, as well as a palladium-based direct metallization process. These additional capabilities will help expand our reach into exciting growth markets like flex-PCBs and exotic materials.

"This acquisition is representative of our strategy to drive growth and expand the scope of our technology so we can address a greater share of the market. We will continue to look for opportunities that make us a more important partner to our customers." – *MB*

Benchmark to Close 2 Sites, Lay Off 300 Workers

TEMPE, AZ – Benchmark Electronics will shutter assembly sites in San Jose and Guaymas, Mexico, by the end of next March and lay off about 3% of its global workforce.

Benchmark didn't specify how many positions would be cut, but based on the firm's fulltime headcount as of Dec. 31, the total would be about 315. The company also employs about 1,500 contract workers.

The two sites make up 4% of Benchmark's global footprint of about 4 million sq. ft.

The sites combined serve fewer than 20 customers and build products for a variety of end-markets. Customers are expected to be moved into other locations by the end of the first quarter 2020.

"We will consolidate many of these programs at the sites in other manufacturing locations in our network, which will in turn improve their asset utilization and efficiency," president and chief executive Jeff Benck said.

The EMS firm will take restructuring charges of $6 million to $8 million, of which $1 million to $2 million will occur in the current quarter.

Benchmark expects annualized savings of approximately $5 million once the site closures are completed.

The 79,000 sq. ft. San Jose site was formerly SMTEK, which was acquired by CTS Manufacturing Solutions in January 2005. It was acquired by Benchmark in October 2013.

The plant in Guaymas performs cable and wire harness assembly and electromechanical assembly. – *MB*

Flex to Incur Up to $320M in Restructuring Charges, Might Lay Off Thousands

SAN JOSE – Flex will take up to $265 million in charges over the next three quarters in part related to layoffs of an unspecified number of workers.

That's in addition to the $56 million in restructuring charges it booked in its fiscal first quarter ended Jun. 28. With potential additional costs in the range of $145

executive experience across multiple sectors, including manufacturing, technology and computer software.

Stentech named **Brent Nolan** vice president.

Universal Instruments named **Frank Silva** Western regional sales manager.

Zollner promoted **Manfred Amberger** to senior vice president, marketing and sales.

million to $265 million over the next nine months, the total restructuring charges could top $320 million in its current fiscal year.

Flex is making the moves in part due to the expected loss of Huawei as a customer. Huawei, which made up roughly 5% of Flex's quarterly revenue, was reportedly outraged when the EMS company held back shipments and raw materials to comply with US government edicts.

On a conference call with analysts, Flex CEO Revathi Advaithi acknowledged the company expects a "reduction in demand" from Huawei. "[A] well-publicized action by the US government and significant geopolitical uncertainty impacted our customer Huawei. These actions … led to a reduction in demand for products we assemble for them in China. And as a result of this, we're scaling down our Huawei-dedicated operations in China."

Separately, Reuters is reporting Flex could cut as many as 10,000 jobs in China, a result of the dispute with Huawei. Flex employs 50,000 workers in China. – *MB*

Flex Opens 4th India Assembly Site

CHENNAI, INDIA – Flex opened a 159,000 sq. ft. manufacturing facility here, its fourth in India.

"We are thrilled to celebrate the inauguration of our latest manufacturing facility in India that offers one-stop solutions ranging from engineering, manufacturing, and supply chain and logistics services to increase our customers' competitiveness and decrease time to market," said Richard Hopkins, senior vice president of operations at Flex. "This further reiterates our continued commitment toward the Government of India's Make in India vision and entrenches India's position as an important manufacturing base for Flex."

Flex has 10 other sites in India, providing manufacturing, after-market services and global business services. – *MB*

CA Briefs

AIM Solder opened a new full-line manufacturing facility in the Changxing district of Huzhou, Zhejiang Province, China.

AirBorn broke ground on a $3.7 million investment that will double its size in Pennsylvania and add up to 249 new jobs.

Apple will acquire the majority of **Intel's** smartphone modem business for $1 billion.

Arrow Electronics will close its plant in Windsor, CT, in mid-September.

AT&T is working with a product division of **Jabil** to accelerate retail automation using autonomous robots with 5G wireless networking capabilities.

BESTProto installed a **Mycronic** MY-300 pick-and-place line, its fourth.

Lindsay Goldberg, a New York private equity firm, will acquire a stake in **Creation Technologies** from **Birch Hill Equity Partners** and other equity holders for an undisclosed sum.

Epoch International installed a **Europlacer** EP710 screen printer and iineo+ placement platform, **Viscom** SPI and AOI, and **Heller** reflow oven at its EMS plant in Fremont, CA.

Fanuc Robotics America lost an appeal to import PCBs duty-free from China.

A **Foxconn** subsidiary has invested in a reported $8.9 billion in a new display plant in Guangdong province.

Foxconn and **Amazon** are coming under fire over labor conditions in a factory located in Hengyang, Hunan Province, China, after a report from the advocacy group **China Labor Watch**.

Fuji America named **Alphatek** sales representative in the Western US.

Huawei plans to build an $800 million plant in Sao Paulo, Brazil, over the next three years.

Jabil filed a lawsuit against **Essentium** and former staff members for the alleged theft of its TenX 3D printer design.

Konka, a leading Chinese home appliance company, is set to establish a JV with **HoHo**, an Egypt-based home appliance company, followed by an investment for the construction of a new factory.

Laserssel named as representatives **SW Systems Technology** for the Southwest US and Mexico and **Kurt Whitlock Associates** in Florida.

Lite-On Technology reportedly plans to sell its storage business consisting of SSD products, with **Toshiba Memory** being identified as a potential buyer, according to industry sources.

Motion Sensors installed an **Optical Control** OC-Scan CCX.3 x-ray component counter.

Northrop Grumman is seeking firms with expertise in printed circuit assembly to support what it calls a "major project" dealing with a US Air Force program to replace the Minuteman III ICBM missile system.

The **Plexus** Azteca manufacturing facility in Guadalajara, Mexico, achieved FDA approval to manufacture finished, Class III medical devices.

Quanta Dialysis Technologies selected **Benchmark Electronics** as production partner for the SC+ haemodialysis machine.

Sennheiser officially opened its new electronics assembly plant in Brașov, Romania.

TexMac appointed **Altrade** to represent and service **Takaya** systems in Brazil.

Unimicron and **Qisda** are among companies expanding in Taiwan after the Ministry of Economic Affairs approved their applications to participate in a government program to encourage investment.

University of Arkansas researchers are working to develop technology that will help protect electronic devices from high radiation.

Volex has acquired EMS firm **Servatron** for up to $28.5 million in cash and shares.

Z-Axis named **West-Tech** representative in Northeastern US and Canada.

EDITED BY CHELSEY DRYSDALE

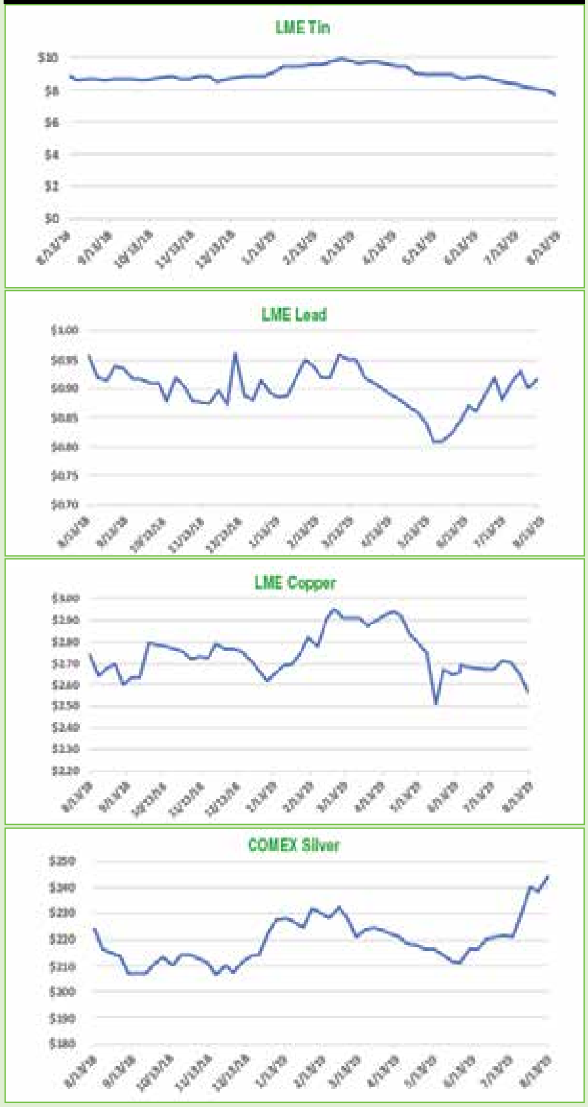
TOUGH DEFENSE

Trends in the electronics equipment market (shipments only).

	% CHANGE			
	APR.	**MAY**	**JUNE**	**YTD%**
Computers and electronics products	1.4	0.4	-0.7	5.3
Computers	0.4	-4.5	-6.1	-16.5
Storage devices	16.1	-5.6	-3.1	23.4
Other peripheral equipment	2.8	1.8	2.3	8.2
Nondefense communications equipment	1.3	-0.3	1.1	11.7
Defense communications equipment	-18.4	8.0	12.4	7.6
A/V equipment	5.8	7.7	-0.3	39.0
Components[1]	-1.4	0.7	2.3	2.5
Nondefense search and navigation equipment	0.9	-0.9	-1.7	3.9
Defense search and navigation equipment	2.2	-3.0	-1.6	3.1
Medical, measurement and control	2.2	-0.1	-2.3	2.5

[r]Revised. *Preliminary. [1]Includes semiconductors. Seasonally adjusted.
Source: U.S. Department of Commerce Census Bureau, Aug. 2, 2019

METALS INDEX



DRAM Sales to Decline 38% in 2019

SCOTTSDALE, AZ – Despite a 38% sales decline expected this year, the DRAM market is forecast to remain the largest of all IC product categories again in 2019, with sales of $62 billion, says IC Insights.

The DRAM market will account for 17% of total IC sales this year, according to the firm. By comparison, DRAM sales accounted for 23.6% of the total IC market in 2018.

The NAND flash market is forecast to slip from second to third position in the ranking, with total sales falling 32% to $40.6 billion in 2019. Taken together, the DRAM and NAND flash memory categories are forecast to account for 29% of the total $357.7 billion IC market this year, compared to 38% of the total IC market in 2018.

Hot Takes

- Worldwide sales of smartphones to end users will total 1.5 billion units in 2019, down 2.5%. (Gartner)
- The Brazilian electric-electronics industry has cut its 2019 production forecast to 2%, from 7% in the previous estimate. (Abinee)
- In 2018, worldwide contract manufacturing services market revenue increased 15%, resulting in combined EMS and ODM revenue of nearly $542 billion. (NVR)
- The worldwide tablet market declined 5% year-over-year during the second quarter as global shipments fell to 32.2 million units. (IDC)
- The wearables market will reach $50 billion 2019, more than double since 2014. (IDTechEx)
- Taiwanese PCB fabricators reported rigid exports grew 6.1% and flex exports fell 4.06% year-over-year in July. (TPCA)
- Worldwide semiconductor revenue is expected to decline 9.6% to $429 billion in 2019. (Gartner)

KEY COMPONENTS

Book-to-bills of various components/equipment.

	FEB.	**MAR.**	**APR.**	**MAY**	**JUNE**
Semiconductor equipment[1]	-22.7%	-24.9%	-28.5%	-23.6%[r]	-19%[p]
Semiconductors[2]	-10.6%	-13%	-13.7%	-14.8%[r]	-16.8%[p]
PCBs[3] (North America)	1.06	1.00	1.02	0.99	1.00
Computers/electronic products[4]	5.42	5.41	5.35	5.39[r]	5.44[p]

Sources: [1]SEMI, [2]SIA (3-month moving average growth), [3]IPC, [4]Census Bureau, [p]preliminary, [r]revised

US MANUFACTURING INDICES

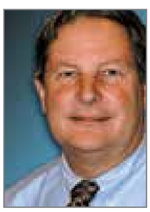
	MAR.	**APR.**	**MAY**	**JUNE**	**JULY**
PMI	55.3	52.8	52.1	51.7	51.2
New orders	57.4	51.7	52.7	50.0	50.8
Production	55.8	52.3	51.3	54.1	50.8
Inventories	51.8	52.9	50.9	49.1	49.5
Customer inventories	42.7	42.6	43.7	44.6	45.7
Backlogs	50.4	53.9	47.2	47.2	43.1

Sources: Institute for Supply Management, Aug. 1, 2019

The Skinny on Training in the Lean Organization

As the challenges of training evolve, so does the definition of lean.

PETER BIGELOW is president and CEO of IMI Inc. (imipcb.com); pbigelow@imipcb.com. His column appears monthly.



AN ORGANIZATION CANNOT become lean without tons of training.

Think about that oxymoron for a moment. It takes time to train, time that a lean organization cannot sacrifice. Training in this industry, which utilizes many varying yet intertwined processes, has traditionally taken the form of on-the-job training (OJT) versus a formal, classroom-style format. In any organization, especially a lean one, OJT is much easier to administrate and far less disruptive to employees and production than other types of training. In a service industry, even in support positions off the shop floor, it is much easier to take someone offline and plunk them down for formal training. In a lean manufacturing environment, however, excess resources in any given job function or department are rare. Hence, most training is integrated into the daily workflow as OJT.

But the type of training needed today is complicating this reliance on OJT. Owners or managers in manufacturing companies – regardless of industry – tell me the no. 1 issue they face is identifying, recruiting and hiring good employees. The subset to this challenge always mentioned by hiring managers includes themes along the lines of finding millennials who consistently show up for work; older people with skills or abilities; and anyone who is committed to a career versus a short-term job. Add language and legal status to the mix and hiring and retaining people – good people – becomes not just challenging, but almost impossible!

Increasingly, the type of training needed is changing and more time-intensive. For many these changing needs are far less intuitive. For older workers, learning to operate software-driven equipment that replaces an older electromechanical device (levers and knobs) can be time-consuming and daunting. Ditto for learning about cybersecurity, how to access encrypted, password-protected websites to gain access for, and then reply to, customer quotations, etc. For millennials who may have extensive computer, software and digital knowledge, learning to interact with different generations of people (without texting), being consistent in attendance and action so they can become a valued part of a team, or, for that matter, even knowing what exactly a true work team is, can be as intense as learning a foreign language. And speaking of language, harmonizing several foreign languages within a common work environment, especially in light of operating equipment, software and peer interactions, can challenge the most patient of us. Yet this is becoming the training norm.

Which makes OJT less viable when the subject matter to be taught is so generic, varied, and non-task-driven. Everyone in industry who relies on an older, soon-to-retire workforce, especially ours with its range of specific processes utilizing a mix of legacy and state-of-the-art equipment, needs to rethink training. That means rethinking not only how training should be conducted, but also what training is needed by which generation, level of experience, or tenure of employee.

OJT does not lend itself to instructing many of the needs we now must master. When so many need to learn how to manipulate a new software program, or master online tools to manage the onslaught of passwords, or become familiar with a new regulation or standard, it is best to commit the time and resources to train employees in a more formal classroom or online setting. Employees need to become comfortable learning in varied environments, including their workstation, machine, cubicle or even home.

The expectation of responsibility by employees, like training needs, may require a similar shift in thought within the electronics industry. In many other industries, employees are required to spend personal time taking assigned training courses to stay current on processes, equipment, and regulations that impact their work. Performance reviews and compensation are often tied to the employee's completion and mastery of content, demonstrated by passing quizzes after each training segment. Our industry may need to adopt the same expectations *and* commit to investing in content and courses critical for success.

Online courses are currently available in many areas, from safety through quality analysis to specific administrative and operational process skills. Software and digital overviews and deep dives in training are available to assist employees transitioning from the electromechanical world to the digital age. Courses for certification to standards, as well as basic skills in how to interact with peers, are also well-suited to online training. The challenge for managers is to identify what is needed in the organization and by whom, and then overlay the available courses and optimal delivery methodology. All this is a paradigm shift from the familiar and much less disruptive training environment we are accustomed to with OJT.

Given all that, how does training contribute to a lean business environment, especially given the dynamic our industry now faces? As training needs and delivery methodology change, so too does the concept of lean. How employees interact with machinery, people and now even robotics is rapidly evolving. Knowledge that allows independence of action is increasingly more important. The days of a work cell being made up only of humans is giving way to smart machinery, requiring workers with programming skills, not just operations abilities. The definition of lean may soon have more to do with how thoroughly a person masters a piece of equipment, rather than how many different pieces of equipment they master. ❑

It's Time to Bypass the PCB Broker

It's adding unnecessary costs to your supply chain.

WANT A MORE robust and cost-effective supply chain? Shrink it. Remove the expensive middleman. You don't need to pay a PCB broker a 20 to 40% markup to, basically, relay information from you to overseas vendors.

The truth is the PCB broker business model – where companies buy printed circuit boards from an overseas manufacturer and then resell them to a customer – is outdated. And it's adding unnecessary costs to your supply chain.

Years ago, brokers were small operations, with perhaps three to five people. And at one time, they did provide a valuable service to their customers, offering lower prices on boards made overseas, while handling all the details of procurement from foreign vendors in what was often a challenging PCB buying cycle.

For a couple of decades, brokers and customers had a symbiotic relationship that served the industry well.

But that's no longer the case.

Today's dedicated brokers are typically multimillion-dollar businesses, dependent on a collection of board houses, requiring large and costly staffs to maintain their operations. They have become a business within a business. What was once value-added is now an unnecessary expense to PCB buyers.

Interestingly, the not-so-dedicated brokers, those domestic PCB manufacturers that buy and resell finished PCBs to supplement their sales, may not be getting boards directly from an overseas factory. It is not uncommon for them to buy boards through other domestic brokers, adding another layer of expense. So instead of the typical customer-broker-overseas manufacturer supply chain, it is customer-broker-broker-overseas manufacturer.

Any business that survives is ultimately cyclical. Board distribution is not immune. But the broker model has remained stagnant.

Brokers still do the same things they did 20 years ago. They receive CAD files, sanitize them, then send them off to vendors. They get a quote and rebrand that quote for the customer. They have product shipped to a centralized warehouse in the West, where they reinspect the product (usually) before reboxing or rebranding the shipment to the customer.

This is an inefficient system. Most, if not all, these activities can be handled more cost-effectively by the manufacturer.

Today, good offshore manufacturers have the industry-prerequisite certifications and registrations, communicate well, make quality product, warehouse inventory to meet changing production needs, and have service centers near customers.

Why can't a customer send CAD files directly to a manufacturer? Communication from offshore vendors is much better than it was 10 years ago, and technology has made it even easier. A customer can send CAD files, request a quote, and get a timely response just as easily as a broker.

Why must another entity be involved to ensure PCB quality? If there is a need for a second "Western" inspection, then why is that broker's particular vendor used?

The typical broker will tout its service, quality and years of experience, but will tell you next to nothing about the actual board vendor. Quality of goods shipped from the other side of the world is a genuine concern. But what are we talking about here? Class 3 or just standard fare? More than 95% of the PCBs built are not going into missiles or airplanes.

And it's not the first rodeo for offshore vendors. They've built thousands of part numbers; their engineering and quality staffs have become much better. In fact, Chinese universities offer degrees in PCB manufacturing, as opposed to the inconsistent, learn-on-the-job system of PCB training in the West.

Why can't an offshore PCB manufacturer offer terms – the same terms offered to a broker – directly to customers? Many overseas manufacturers want to directly deal with customers, as made clear by the volume of emails received by PCB buyers every day from these vendors.

And it is easier than ever for customer quality departments to vet overseas manufacturers and confirm customer testimonials.

So, why shouldn't PCB buyers go direct?

Full disclosure: Many may remember I was a strong proponent of the PCB broker model. When I started in this industry 25 years ago, offshore manufacture of high-mix, low-to-medium volume PCB orders was still in its infancy. Using a broker back then made sense. And for some board customers, the services brokers provide may still be worth it.

But in this highly competitive industry, dropping a costly link in your supply chain could make a real difference to the bottom line.

PCB brokers carved out a useful niche at a time when the industry needed them. Now they are, for the most part, a relic that leads to bloated board pricing.

It's time for PCB buyers to work directly with offshore vendors and bypass the broker. ❑

GREG PAPANDREW has more than 25 years' experience selling PCBs directly for various fabricators and as founder of a leading distributor. He is cofounder of Better Board Buyer and will be speaking at PCB West in September; greg@boardbuying.com.

Assembly Data and Documentation Process Overview, Part II

Prepping the data for placement and soldering.

IN PART ONE of this two-part series on assembly data and documentation, we discussed how data drive the assembly package and listed several items needed for it to be complete. Understanding this and the manufacturing process will help users make sound design decisions. This column provides a deeper dive into each step of this process.

Programming the placement machinery. Once the parts (including the PCB panels) are purchased, the automated assembly process can begin. Data required for this phase of the manufacturing process are taken from a few valuable sources. For the manufacturing engineer, the bill of materials (BoM) provides a limited view of the requirements. Along with the BoM output, the designer has hopefully provided an intelligent data format file for the design. With this information, the manufacturing engineer can get a good look at the design intent and begin planning the order of manufacturing operations.

The provision of x, y placement data output from the design database is invaluable to the process. Sometimes referred to as a "pick-and-place" file, the data can be fed into process programming to help select the proper tape reel and define the nominal location and rotation for each SMT part that will be automatically soldered to the board.

If there are SMT parts on both sides of the board, the placement file will indicate this, and the placement parameters will be divided into two operations (called first pass and second pass) to place and solder SMT parts to their respective sides.

All remaining through-hole parts which are not to be run in the reflow oven process will be designated for secondary solder processing. This can be performed manually by a soldering technician or by two other common automated processes: wave soldering and selective soldering.

Assemblers widely use wave soldering to make solder joints on the side of the PCB from which the through-hole pins protrude. The best-case condition for wave soldering is when all the parts are mounted on the topside of the PCB. Only the through-hole pins needing solder and the secondary side of the PCB should meet the solder wave (FIGURE 1).

When SMT exists on both sides of a mixed technology PCB, it is far more common to process both sides of the PCB SMT passes in the reflow oven. Then, the assembler selectively solders the remaining through-hole parts on the assembly.

Selective solder machinery can make accurate solder joints on through-hole component pins by positioning a small fountain of solder underneath the selected pin and automatically raising the fountain cup to a height to make the solder joint (FIGURE 2). The process is highly accurate but is not considered "speedy" due to the nature of the single solder fountain head.

Many important decisions must be made regarding solder processing before a board begins to roll down the assembly line. Although the assembler has many options to address the manufacturing challenges, the PCB design engineer's goal should be to communicate with the manufacturing engineering stakeholder. Seek out design solutions to reduce these multiple process requirements as much as possible; that's just good DfM.

Automated placement. After solder paste is applied, the panel moves onto the placement line. The panel is designed to include rails, which not only provide stability to the panel structure, but support the panel on the conveyer as the panel is moved into position for automated placement. The pick-and place machine optically calculates the exact position and rotation of the panel. The PCB designer provides the coordinate starting point of the panel via the placement file,

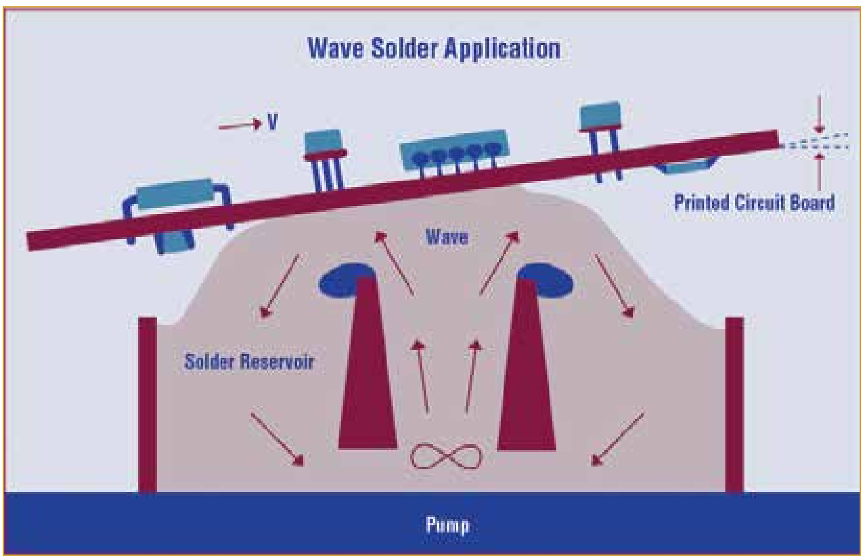


FIGURE 1. Wave solder application process.

This excerpt of *The Hitchhiker's Guide to PCB Design* was written by EMA DESIGN AUTOMATION WITH PATRICK DAVIS of RocketEMS. Download to learn more about PCB design stakeholders and real-world, actionable PCB design tips from industry experts (go.ema-eda.com/pcbguide).

permitting the machine to place components on the panel with lightning speed.

Moving through the reflow oven. Once all the parts are placed on the side to be assembled, the panel moves along the conveyor into the reflow oven, where the assembly is heated, the solder melted, and solder joints formed.

A few variables must come together well for solder joints to be in spec:

- The footprint land geometry must be designed properly with enough toe and heal and side extension to permit a perfect solder fillet. (See IPC-7351 for more information.)
- The optimal amount of solder paste must have been applied to the land by accurately calculating the stencil opening in relation to the stencil thickness and the type of solder used on the PCB.
- The oven's thermal profile (or heat zones) must be optimized so the PCB and components receive the proper thermal ramp, soak and cooling times to permit the solder to flow and solidify properly.

Second operation assembly processing. As mentioned, parts not suitable for reflow must be processed using different manufacturing practices. It is usually up to the manufacturing engineer to determine how these remaining components will be soldered. The PCB assembly drawing the designer provides should specify the components be "soldered" without being specific as to how. This is for manufacturing flexibility. Some through-hole parts must be addressed specially with alternative soldering processes such as wave and selective soldering, but many other types of assembly actions are required on the PCBA after all the parts are soldered. It is important for these second-op conditions to be carefully considered by the PCB designer during the layout phase, hopefully in collaboration with the manufacturing engineering stakeholder. Ultimately, it is up to the design and engineering stakeholders to define the performance requirements of the product. Ideally, it is left to the manufacturer to decide how to accomplish them.

Assembly test. Once all the assembly operations and processes have been run, verification must take place for the PCB assembly to be validated for performance. This is the point where all the frontend investment of time and expense to add test points and create fixtures and software mentioned in our column on design for test is going to pay off. If everything has gone according to plan, the PCBAs are taken from the line and placed into the assembly test fixture. There is a program to check for continuity between parts to ensure all the soldering and placement has gone smoothly. Functionality checks will supply power to light LEDs and run displays. The test engineers have collaborated with the PCB design engineer to make certain every function of the PCBA is tested and performs within specifications.

If a problem is found, such as a mislocated part or even an incorrect part, the board can be set aside for rework. After rework, the board will have to run through the entire assembly test process again to ensure complete conformance.

Final inspection (IPC-A-610). A few assembly notes may be deemed necessary on an assembly drawing. Adding a simple note, "Acceptance criteria per IPC-A-610," says all the right things to the final inspection department. The pictorial, easy-to-read specification covers conditions of every basic process the PCBA will have been exposed to during its journey through the assembly shop.

IPC-A-610 and the many other specifications utilized to compare manufactured hardware with conforming or nonconforming criteria are invaluable guidelines for final assembly test technicians to measure how each stakeholder has done their job. Once all the solder joints and parts are inspected, and the PCBA has passed burn-in testing, the manufacturing process is complete, and the PCBA is ready to be shipped.

Conclusion. Within the PCB assembly process or any PCB-related process, tens of thousands of things can go wrong. The fully engaged stakeholder knows the processes inside and out and has learned from each assembly, each cycle, and has made the required adjustments. So must the PCB design engineer. Data and documentation created by the PCB design engineer on the frontend must be clean: garbage in equals garbage out.

Every topic and character description throughout this series illustrates a relative interconnectivity between stakeholder responsibilities and the design manufacturing and assembly processes. It is the hope of all the contributors of this series that its message of collaboration, communication, and understanding will serve the designer well, as they assume an influential role as the hub of the entire design and manufacturing process for the PCBA. Learn from your assembly manufacturing colleagues to incorporate the tangible causes of success into your own PCB design process. ❑

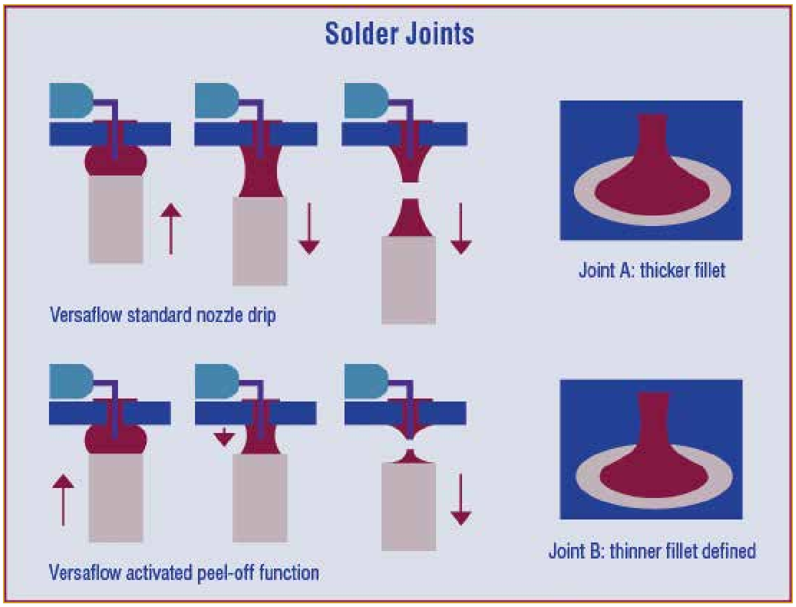


FIGURE 2. Example of how the selective solder process works.

PCB WEST 2019
Conference & Exhibition

WHO'S EXHIBITING

Accurate Circuit Engineering
Aculon, Inc.
Advanced Assembly
Advanced Circuits
AGC Nelco America Inc.
All Flex Flexible Circuits & Heaters
Altium, Inc.
American Standard Circuits, Inc.
APCT
Aspocomp PCB Technology
Asteelflash
Autodesk EAGLE
Bay Area Circuits, Inc.
Beta LAYOUT
Bittele Electronics Inc.
Bowman XRF
Cactus Materials/GTS Flexible Materials
Cadence Design Systems
Cicor Group
Clear Blue Engineering
CML USA Corp.
Cofan USA Inc.
Creation Technologies
dalTools
Dino-Lite Scopes (Big C)
DownStream Technologies, Inc.
DuPont
DYCONEX AG
Dynamic Electronics Co., Ltd.
ECI Technology Group
Elgris Technologies, Inc.
Elsyca
Eltek
EM Solutions Inc.
EMA Design Automation
EnviroSense, Inc.
Fischer Technology, Inc.
Flex Interconnect Technologies
Flexible Circuit Technologies
FootPrintKu PalPilot
Freedom CAD Services, Inc.
FTG-Firan Technology Group
GS Swiss PCB AG
HSIO Technologies
ICAPE Group
Imagineering, Inc.
Insulectro
INTERXSOFT
IPC-2581 Consortium
Isola
JetPCB Web LLC
Kyocera International, Inc.
Leader Tech, Inc.
LPKF Laser & Electronics
Mentor, A Siemens Business
MicroConnex
Minco Products, Inc.
Multek Technologies, Inc.
MV Circuit Technology Co., Ltd.
MVINIX Corporation
Oak-Mitsui Technologies
Ohmega Technologies, Inc.
Oki Printed Circuits Co., Ltd.
Optiprint AG
P4Q USA, Inc.
Panasonic Electronic Materials
Polar Instruments, Inc.
Polliwog Corporation
Polyonics
Printed Circuits
Prototron Circuits
Pulsonix PCB Design Software
Quadcept
Risho
Rogers Corporation
Royal Circuits
San Diego PCB Design
San-ei Kagaku Co., Ltd.
Sanmina Corporation
Screaming Circuits
SEP Co., Ltd.
Shenzhen Danyu Electronics Co. Ltd.
Shenzhen Kinwong Electronic Co., Ltd.
Shenzhen Leadsintec Technology Co., Ltd
Shenzhen Sprint Circuits Co., Ltd.
Sierra Circuits, Inc.
SOMACIS
Summit Interconnect
Sunshine Global Circuits
Sunstone Circuits
SVTronics, Inc.
Tempo Automation
Tessolve
Ticer Technologies
Ultra Librarian
Varioprint AG
Ventec International Group
Victory Giant Technology (Huizhou) Co., Ltd.
Vision Circuit Technologies Inc.
VYCOM Global Sources Ltd.
Wuzhu Technology (Hong Kong) Limited
Zuken USA Inc.

Managing Time Delays

How to calculate trace length from time delay value for high-speed signals.

TO KEEP A good high-speed signal quality from driver to receiver on a PCB is not an easy task for designers. One of the most challenging issues is managing the propagation delay and relative time delay mismatches. To manage the time delays, we need to know how to calculate trace length from time delay value in order to implement the PCB trace routing accordingly. Let me take you through the process.

Calculating signal speed. According to physics, electromagnetic signals travel in a vacuum or through the air at the same speed as light, which is:

$Vc = 3 \times 10^8$M/sec = 186,000 miles/sec = 11.8 in/ns

A signal travels on a PCB transmission line at a slower speed, affected by the dielectric constant (Er) of the PCB material. The transmission line structure also affects the signal speed.

There are two general PCB trace structures*: stripline and microstrip (**FIGURE 1**).

The formulas for calculating the signal speed on a PCB are given below:

Signal speed on striplines: $$V_{p\,(inner)} \approx \frac{Vc}{\sqrt{Er}} \approx \frac{11.8\ in/ns}{\sqrt{Er}} \qquad (1a)$$

Signal speed on microstrips: $$V_{p\,(outer)} \approx \frac{Vc}{\sqrt{Er_{eff}}} \approx \frac{11.8\ in/ns}{\sqrt{Er_{eff}}} \qquad (1b)$$

where

- *Vc* is the velocity of light in a vacuum or through the air
- *Er* is the dielectric constant of the PCB material
- Er_{eff} is the effective dielectric constant for microstrips; its value lies between 1 and *Er* and is approximately given by:

$$Er_{eff} \approx (0.64\,Er + 0.36) \qquad (1c)$$

With those formulas, we know the speed of signals on a PCB is less than the signal speed through the air. If *Er*≈4 (as with FR-4 material types), then the speed of signals on a stripline is half that of the speed through the air; i.e., it is about 6 in/ns.

Calculating propagation delay (tpd). The propagation delay is the time a signal takes to propagate over a unit length of the transmission line. Here is how we can calculate the propagation delay from the trace length and vice versa:

$$t_{pd} = \frac{1}{V} \qquad (2a)$$

where

- *V* is the signal speed in the transmission line.

In a vacuum or through the air, it equals 85 picoseconds/inch (ps/in).

On PCB transmission lines, the propagation delay is given by:

$$t_{pd} \approx 85\sqrt{Er}\ ps/in \text{ in striplines} \qquad (2b)$$

$$t_{pd} \approx 85\sqrt{Er_{eff}}\ ps/in \text{ in microstrips} \qquad (2c)$$

Case Study

To comply with JEDEC specifications, the maximum skew among all signals shall be less than +/-2.5% of the clock period driven by the memory controller. All the signals of SDRAM are directly or indirectly referenced to the clock.

In the example below, the normal FR-4 material with Dk of 4 is used on the PCB with a differential clock rate of 1.2GHz (i.e., 833ps clock period).

Question: What is the maximum skew of the trace length for all the signals?

continued on pg. 46

LANCE WANG is a solutions architect at Zuken (zuken.com) lance.wang@zukenusa.com.

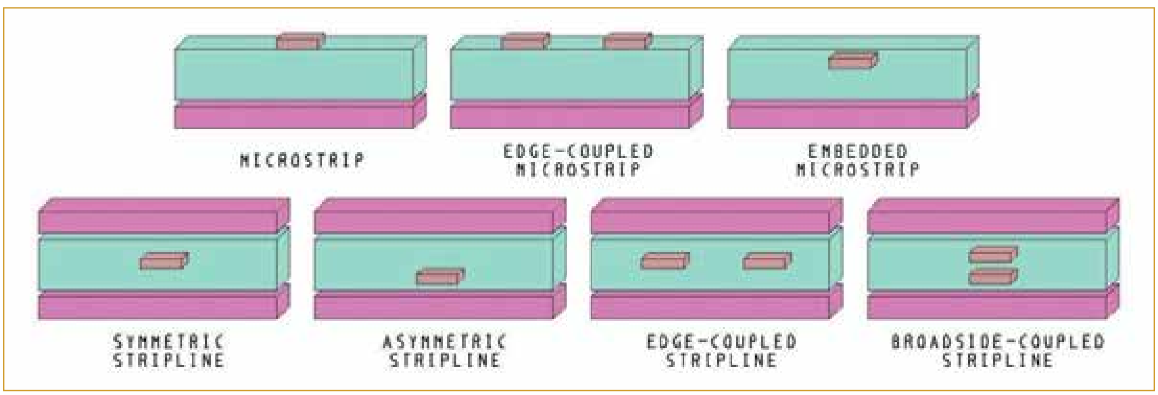


FIGURE 1. Sample striplines and microstrips.

The Digital Route: From EMI to RF

The latest reports from the local chapters.

STEPHEN (STEPH) CHAVEZ is a member of the IPC Designers Council Executive Board and chairman of the communications subcommittee; stephen@eptac.com.

WE'RE ONTO THE second half of the year now, and we've seen a lot of activities within our local Designers Council (DC) Chapters, including a few international chapters. It's great to see and hear about the continued activities from professional development to knowledge sharing and networking taking place at various industry events. Here is a snapshot of what has taken place so far from several of our active chapters.

If you are involved in discussions about industry content regarding PCB design, fabrication or assembly, whether it is in a small or large group, but you are not part of IPC, then I highly recommend you contact me so I can assist you in joining the IPC collective. It's free and well worth it! And if you are an industry veteran with much experience, yet not active in IPC, or simply a college student starting your career, this is a great group to join and get plugged in. I hope to hear from those who are not part of IPC, especially within a DC chapter.

Silicon Valley Chapter

Chapter leader: Bob McCreight

Around 32 people attended our third quarter meeting on Jul. 25. Many thanks to Altium, Amazon, and the guest speakers. To start the meeting, we were treated to a nice greeting from Umar Shah and Charles Rusch from Amazon Lab126. Then we went around the room, and each attendee introduced themselves. It was nice to put faces with names. Stephen Golemme followed with a quick presentation about the IPC-2231 standards committee. Next, Judy Warner talked about Altium-Live 2019 and her OnTrack podcast.

The feature presentation by Vincent Himpe of Tesla was well received and sparked some lively discussion. His talk, What's in a Name: Making Sure There Is No Ambiguity When Exchanging Data, explored several key items. He touched on schematic symbols, reference designators, footprints, net names, component values and file names.

Our next meeting will be Oct. 24 in San Jose. Zuken will host, and PalPilot will sponsor lunch.

Scott Nuance from Optimum Design Associates will present Best Practices for RF and Mixed Technology PCB Design. I will set up the invitation in a few weeks, so for now, save the date.

Cascade Chapter (Seattle)

Chapter leader: Tim Mullin

In addition to my role as the Cascade Chapter president, other board members include Paul Brendt (VP), Jerome Larez (treasurer), Aubrey Moore (secretary), Cherie Litson (education chairperson) and Cory Grunwald (webmaster).

Held at the Lake Washington Institute of Technology, we had our first quarter meeting in April. Aerotek sponsored dinner, and speakers included Cherie Litson, Tim Mullin, and Jerome Larez. The roundtable discussion covered three topics: cutting-edge technologies, IPC standards, and materials and processes. Held in June, Mentor was the dinner sponsor for the second quarter meeting, and the guest speaker was Robert Hanson, who discussed Achieving Signal Integrity and Meeting EMI Radiation Requirements.

The speakers and topics are still to be determined, but our third quarter meeting will be held on Sept. 18, and the fourth quarter meeting will be Dec. 4, both at the Lake Washington Institute of Technology. Mark your calendars!

Research Triangle Park (RTP) Chapter

Chapter leader: Tony Cosentino

The Research Triangle Park (RTP) Chapter supports the Raleigh-Durham (NC) area. We held our first meeting at the end of January, including an election for the new slate of leaders: myself as president, Randy Faucette (VP), Steve Trasatto (treasurer), Ian Jackson (secretary), and Lance Olive (membership). Hosted by Protolabs in Morrisville, NC, the guest speaker was Eric Utley, applications engineer at Protolabs, who spoke on 3D Printing: Beyond Prototyping. The 24 attendees also toured the Protolabs facility.

Our March meeting included 20 attendees and was hosted by CertifiGroup in Cary, North Carolina. Josh Hunt, field service manager at CertifiGroup, addressed Environmental Testing for Reliability of Products and Components. There was also a site tour of the CertifiGroup facility.

In June, there were 25 attendees. Ian Jackson, the elected secretary, dropped out of office due to workload issues, and the position is open and being backfilled by Steve Trasatto, the current treasurer. Hosted by Ixia, a Keysight Business, in Morrisville, guest speakers Shruthi Soora and Dr. Mike Barts from the Wireless Research Center addressed PCB Antenna Considerations from Concept to Certification.

July and August served as a summer break for the chapter, and the date and details for the September meeting will be announced soon. In addition, PCB Carolina 2019 is approaching and will be held Nov. 13 at the McKimmon Center at North Carolina State University in Raleigh. It's free to all attendees and includes a keynote and 16 technical sessions.

San Diego Chapter

Chapter Leader: Luke Hausherr

Our last meeting was held at the Del Mar Electronics show with around 35 attendees. Altium paid for everybody's lunch. I made my debut as the new chapter president since Bob Griffith has retired. I gave a short speech thanking the community for their support and explained my objectives to increase membership. John Carney from Cadence is now the secretary, and Judy Warner from Altium joins the team as education chair.

Gerry Partida, director of engineering for Summit Interconnect in Anaheim, spoke on CAD to PCB: Your Data and What I Actually Do with It. His presentation provided a great overview in understanding the input and data review process of your design data in frontend engineering departments at PCB fabrication companies. We then had a raffle in which we gave away a bunch of vendor- and chapter-sponsored items.

Our next meeting will be held at San Diego PCB in September. Jeffrey Jenkins, PCB chief technologist at L3 Communications, will give a presentation about conformal coating: what it is and why to use it.

Orange County Chapter, CA

Chapter Leader: Scott McCurdy

We had our latest "lunch 'n learn" chapter meeting on Jul. 18 at JT Schmid's Restaurant banquet room in Anaheim. We had a very well-attended event with 68 designers and PCB professionals in the audience. The topic was How Fabrication Processes Determine DFM Guidelines, presented by Julie Ellis, field applications engineer at TTM Technologies. She gave a detailed look at fabrication realities to help designers understand capabilities and tradeoffs. It was very educational and generated a lot of questions from the audience.

I wish to thank Altium for sponsoring much of the lunch cost of the meeting and for providing a three-day pass to their upcoming AltiumLive event in San Diego as one of our door prizes. PCB Libraries provided a generous grand prize for a one-year cloud license of their full-featured PCB Library Expert Enterprise tool. Mentor and Freedom CAD Services also donated other raffle prizes.

International Chapters

Our international chapters continue to be very active, two of which have been showcased in recent columns. Luis Saracho leads the Monterrey Chapter, and Robert Ivan Villalba Gonzalez heads the Sonora Chapter.

IPC CID/CID+ Certification Success

BY STEPHEN V. CHAVEZ, MIT, CID+

We continue to have successful IPC CID and CID+ certification classes to date, resulting in many new and seasoned engineers and designers successfully achieving their certifications. Congratulations to all who have recently achieved their new IPC CDI/CDI+ certification! Welcome to the family!

In the next section, you will find the remaining training sessions, as well as upcoming PCB design events.

2019 Training and Certification Schedule

IPC Certified Interconnect Designer (CID)

- September 19–22: Schaumburg, IL
- October 8-11: Carmel, IN
- October 21–24: Anaheim, CA
- November 2–5: Raleigh, NC
- November 5–8: Dallas, TX

IPC Advanced Certified Interconnect Designer CID+

- September 10–13: Kirkland, WA
- September 17–20: Schaumburg, IL
- October 21–24: Anaheim, CA
- November 2–5: Raleigh, NC
- December 3–6: Manchester, NH

PCB Design Events

PCB West 2019

- September 9–11: Santa Clara, CA

AltiumLive 2019

- October 9–11: San Diego, CA

PCB Carolina 2019

- November 13: Raleigh, NC □

How to Avoid Getting Totally Skewed, Part Three

Mitigation techniques and costs of designing around glass-weave skew.

Au: This column is a comprehensive follow-on to the July column introduction on glass-weave skew and the discussion in August of various mitigation strategies. With some overlap, these may be read together or independently.

IN JULY, I introduced glass-weave skew causes and when or why a hardware designer might care. In Part Two, I discussed various mitigation techniques and cost. Here, I'll do a deeper dive into the impact of glass styles on precipitating or mitigating skew. Part Four will cover dual-ply and low-Dk glass.

While glass-weave skew (GWS) is a real problem, it's hard to characterize because it is statistical in nature. What is the chance one line in a pair will see a different dielectric constant than the other? It depends on the pitch of the lines, the length of the lines, the laminate composition, and the relative chance alignment of the glass bundles under the two lines. Not to say it's the best way to mitigate glass-weave skew, but glass-style selection provides the least expensive way to mitigate the "fiber-weave effect," as it's often called.

The standard. Before we go into the pros, cons and differences between different glass styles as they relate to glass-weave skew, we need to start with concrete definitions and specifications that you can hang your hat on – things that the industry as a whole has already agreed on.

IPC-4412B, *Finished Fabric Woven from "E" Glass for Printed Boards*, lists 86 different glass styles and their properties. In practice, I've only seen 20 of these in use for laminate-vendor construction tables and actual circuit boards. The list is shown in TABLE 1.

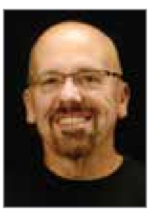
The availability column needs to be considered, to avoid what I call "unicorn constructions." If a particular construction isn't readily available at your preferred fabricator, and it also happens to be a "2" for availability in Table 1, there will be lead-time issues.

Not covered in the table or in IPC-4412B are data in the x-y direction, parallel to the glass, that would potentially impact glass-weave skew. We'll discuss some of these factors below.

TABLE 1. Yarn Counts, Glass Thickness and Relative Availability for 20 of the 86 Glass Styles Listed in IPC-4412B, Appendix II

STYLE	"FABRIC COUNT WARP X FILL (PER INCH)"	"GLASS THICKNESS (MILS) (REFERENCE ONLY)"	AVAILABILITY
1017	95 x 95	0.53	2
1015	96 x 96	0.59	2
1027	75 x 75	0.75	2
1035	66 x 68	1.1	2
1037	70 X 73	1.1	2
106	56 x 56	1.3	1
1067	70 X 70	1.4	2
1078	54 x 54	1.7	1
1065	56 x 56	2.1	2
1080	60 x 47	2.1	1
2113	60 x 56	3.1	1
2112	40 x 39	3.2	2
3113	51 x 30	3.2	2
2313	60 x 64	3.3	1
3313	60 x 62	3.3	1
2116	60 x 58	3.7	1
1504	60 x 50	4.9	1
7628	44 x 31	6.8	1
7629	44 x 34	7.1	1
7652	32 x 32	8.7	2
Source: IPC-4421B			
1 = more available			

BILL HARGIN has more than 20 years' experience in PCB design software and materials. He is director of everything at Z-zero (z-zero.com); billh@z-zero.com. He is speaking at PCB West in September.



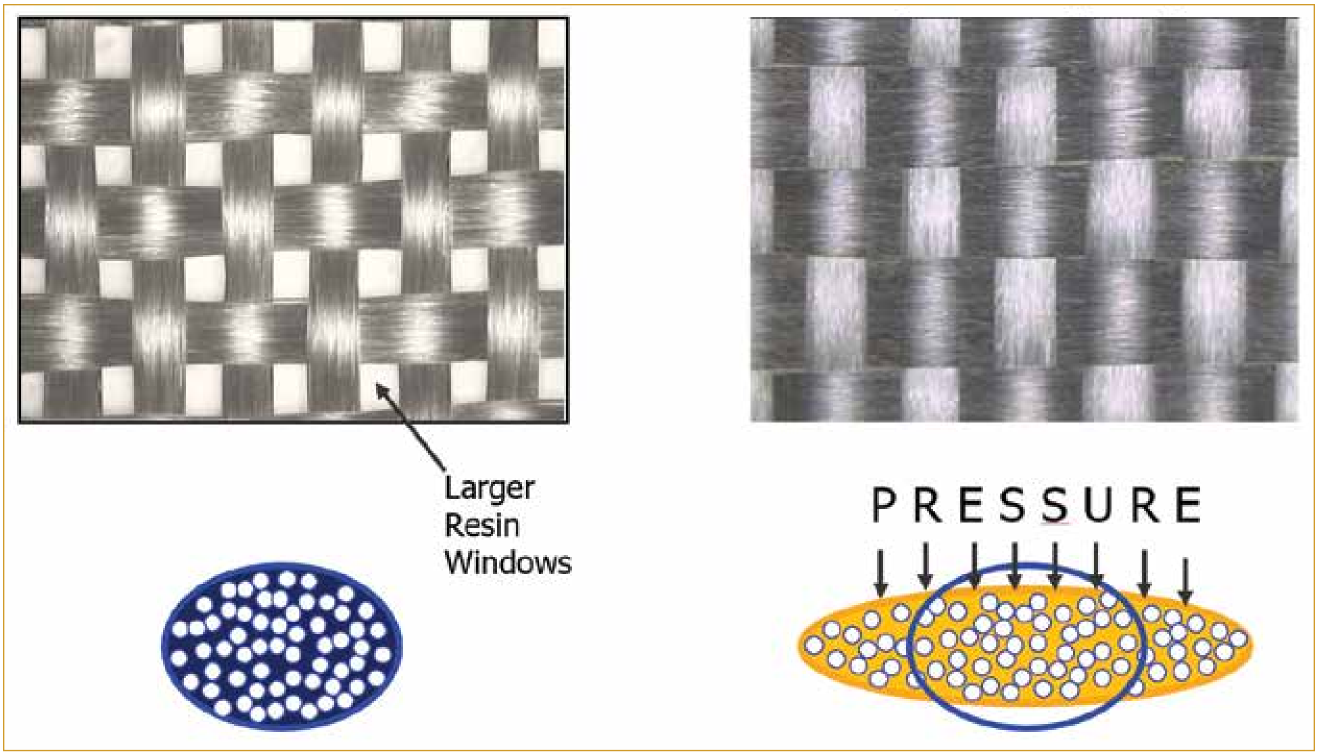


FIGURE 1. Standard glass is shown on the left, with a relatively round yarn cross-section, while mechanically-spread glass – the result of pressure from water jets, typically – is shown on the right.

Preventing glass-weave skew. Last month, in Part 2 of this series, I outlined a list of skew-control techniques, roughly ranked in ascending order of cost in manufacturing:

1. Choose a glass style that minimizes resin windows.
2. Choose a glass style with a "square weave" (equal number of yarn strands in the weave and fill directions).
3. Route each member of the pair at the same pitch as the glass fibers.
4. Align trace direction to the fill/weft.
5. Use mechanically spread glass.
6. Dual-ply glass
7. Half weave pitch jog – halfway down the trace
8. Zigzag routing of differential pairs at a 10° angle to the weave
9. Build each PCB with the artwork rotated at a 10° angle to the panel and weave.
10. Use glass with a lower dielectric constant (closer to the resin Dk).

Numbers 1, 2, 3 and 5 will be discussed in more detail here.

Spread, mechanically spread, or flat? "Spread" glass or "flat" glass are common means of mitigating glass-weave skew. Mechanically spreading or flattening the glass fabric provides several benefits:

- Initially, "flat" glass emerged as a methodology for improving the uniformity of the laser-drilling process.
- Flattened glass also helps mitigate glass-weave skew.
- Improved resin distribution.

Some vendors say spread vs. flat glasses are different, but there's no consensus on what the differences are. In both cases, glass fabric is pressed in the z direction, either with water jets or rollers.

While it's been discussed at length, IPC does not have an agreed-upon definition of what we refer to as "spread" glass, one of the means for mitigating glass-weave skew that we'll address in more detail below. Isola has one definition; Nanya has another; and Nittobo, Asahi or Taiwan Glass have their own as well.

Methods for Characterizing Glass Fabric

Two methods for gauging or quantifying the relative performance of various glass fabric constructions as it relates to glass-weave skew have been proposed to the IPC-4412 task group. Glass manufacturers and committee members are split roughly 50/50 on the two methods.

Air permeability. The ASTM 737-96 test method covers the measurement of the air permeability of textile fabrics,

TABLE 2. Air Permeability and Glass Coverage Test Results for Glasses from Nan Ya Plastics

	1015	106	1027	1037	1080	1067	2112	1078	1086	2116	2113	3313
Air Permeability	126	113	100	78.1	57.1	52.4	39.1	38.1	31.8	23.8	23.2	19.2
% Coverage	89%	93%	92%	95%	95%	96%	97%	98%	98%	97%	98%	98%

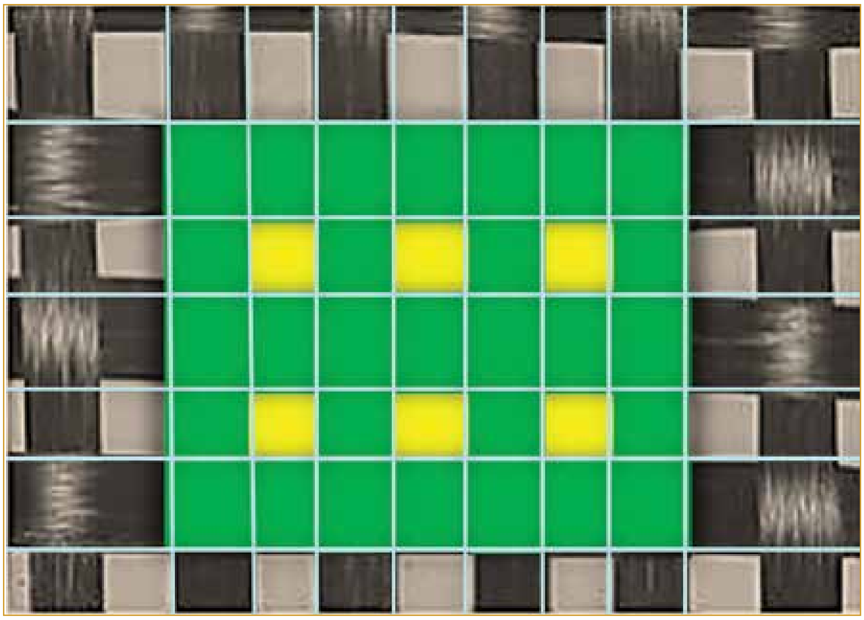


FIGURE 2. Optical measurement images are used to determine glass coverage percentage (green) vs. resin coverage (yellow).

the rate of airflow passing perpendicularly through a known area under a prescribed air pressure differential between the two surfaces of a material. This test is used for woven fabrics and airbag fabrics, for example. Results are generally expressed in SI units as $cm^3/s/cm^2$ and in inch-pound units as $ft^3/min/ft^2$. Lower air permeability results signify more fabric coverage (high Dk) and smaller air gaps (lower Dk "resin windows"). The best glass styles for mitigating glass-weave skew are those with the lowest air permeability.

TABLE 2 shows air permeability test results for Nan Ya glass, the market-share leader in electrical-grade glass fabric that's used by many copper-clad laminate manufacturers in Asia, along with glass-coverage area, discussed in more detail below. (Note: All Nan Ya glass is mechanically spread.)

Optical measurement of % coverage. This method employs an optical microscope, digital camera and digital-image analysis software to assess the glass-coverage area versus the air gap area. Results are usually reported as percentages.

FIGURE 2 shows how optical-measurement images are used to determine glass-coverage percentage (green) vs. resin coverage (yellow). Ideally, for mitigating glass-weave skew, we would want the glass coverage percentage (green) to be as high as possible. Some will say the smaller resin windows are a problem for proper resin encapsulation, and that's a legitimate concern, but modern laminates and high-layer-count circuit-board fabricators have learned to work around narrower resin-flow paths. Higher glass coverage means there's a higher probability two halves of a differential pair will "see" the same or similar Dk environment along the signal paths, all other things being equal.

Horizontal and vertical lines in the image emphasize that glass yarn wanders a bit in practice.

The graph in FIGURE 3 correlates these two measures by glass style, incorporating the results of Table 2. The vertical axis is air permeability, and the horizontal axis represents glass coverage (%). Glass styles that would be better for glass-weave skew mitigation are shown to the bottom right. These constructions have low air permeability values and relatively smaller resin windows.

A couple of things are important to note here. First, these results are for single-ply glass constructions. While dual-ply glass costs a bit more than single-ply glass for the same dielectric thickness, dual-ply glass – or more generally, multi-ply glass – turns out to be an extremely effective way to mitigate glass-weave skew. Second, it's important when looking at the graph to compare single-ply glass styles that tend to be used for the same dielectric thicknesses. In this respect, 106 glass should be compared to 1067 glass, rather than 2116 or 3313 glass, for example. Groupings by core thickness are shown in yellow in **Figure 3**. According to these data, thicker single-ply glasses are consistently better than thinner single-ply glasses.

For similar core thicknesses, you can see 1067 glass is better than 106 for a 2.0-mil core. For a 2.5-mil core, 1078 glass is better than 1080. For 3 mil cores, 1086 would be considerably better than 1080. For 3.5 to 5.0 mil cores, there's a good bit of consistency between 2116, 2113, 1078, 1086, and 3313 single-ply glass styles. We can't say for sure these relationships hold for other glass manufacturers, but it's an interesting starting point for follow-on analysis and comparisons and for making initial tradeoffs while performing stackup design.

Square weaves. Some designers and PCB fabricators prefer "square weaves" over the alternative. A weave is informally classified as being "square" when it has an equal yarn count in the warp and fill directions. (See Table 1.) The concept is tied to the fact that square weaves have the same pitch in both directions as well. For this reason, if the design team is interested in matching the differential pair pitch to the glass pitch, it's possible to do so without worrying about how the board is oriented ("laid up") on the manufacturing panel. (See Part 2 for more details on panelization.)

Conclusion. It gets more complicated when laminate manufacturers get glass from different sources, as many do. Who's tracking where the glass came from, as well as the glass characteristics in the x-y direction? At what frequency should you care? (See Table 1.) This is something I'll expand on in a later column.

Here, we addressed glass-based mitigation techniques (i.e., 1, 2, and 5 from my list of 10 mitigation strategies), but there's more to cover, including dual- or multi-ply glass, low-Dk glass, techniques in combination, and expanding on some of the different

offerings from various laminate vendors. These will be covered in Part 4 of this series, where we'll hopefully tie this all together.

I'm interested in hearing comments if this article rang a bell, or download the evaluation software that includes a tutorial for mitigating glass-weave skew from z-zero.com. ❑

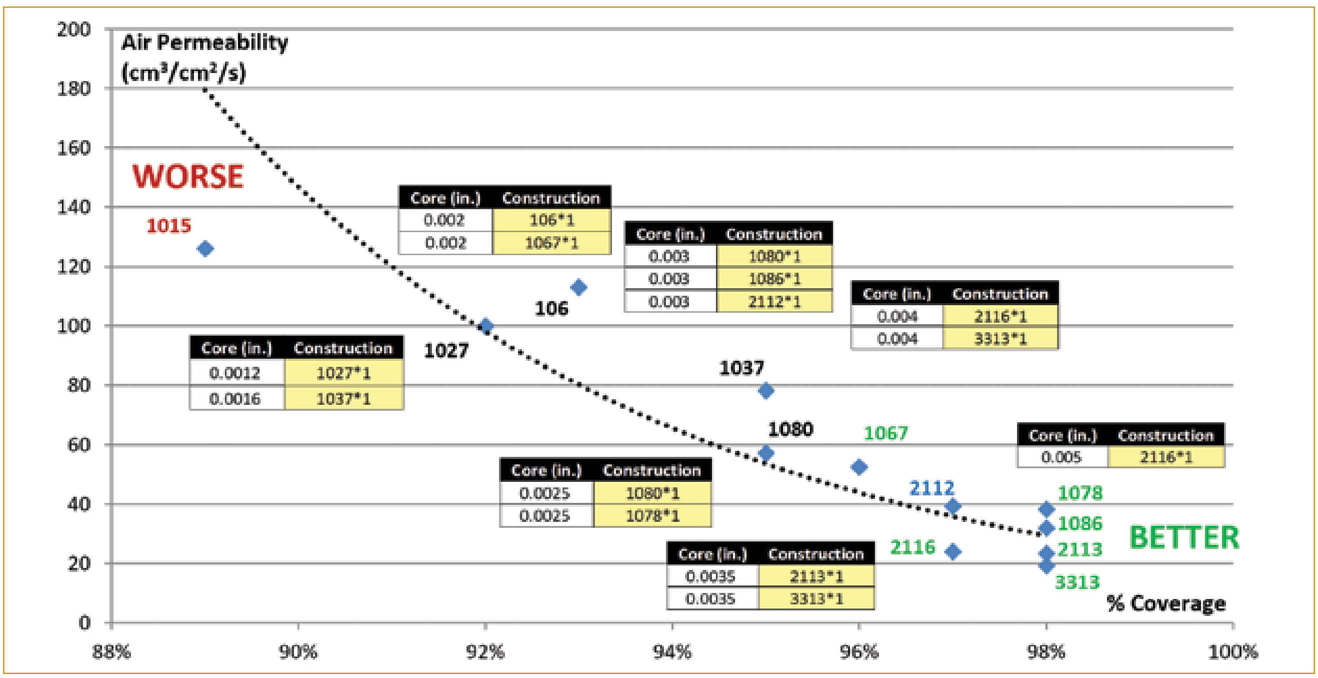


FIGURE 3. Air permeability and glass coverage test results for single-ply glasses from Nan Ya Plastics.

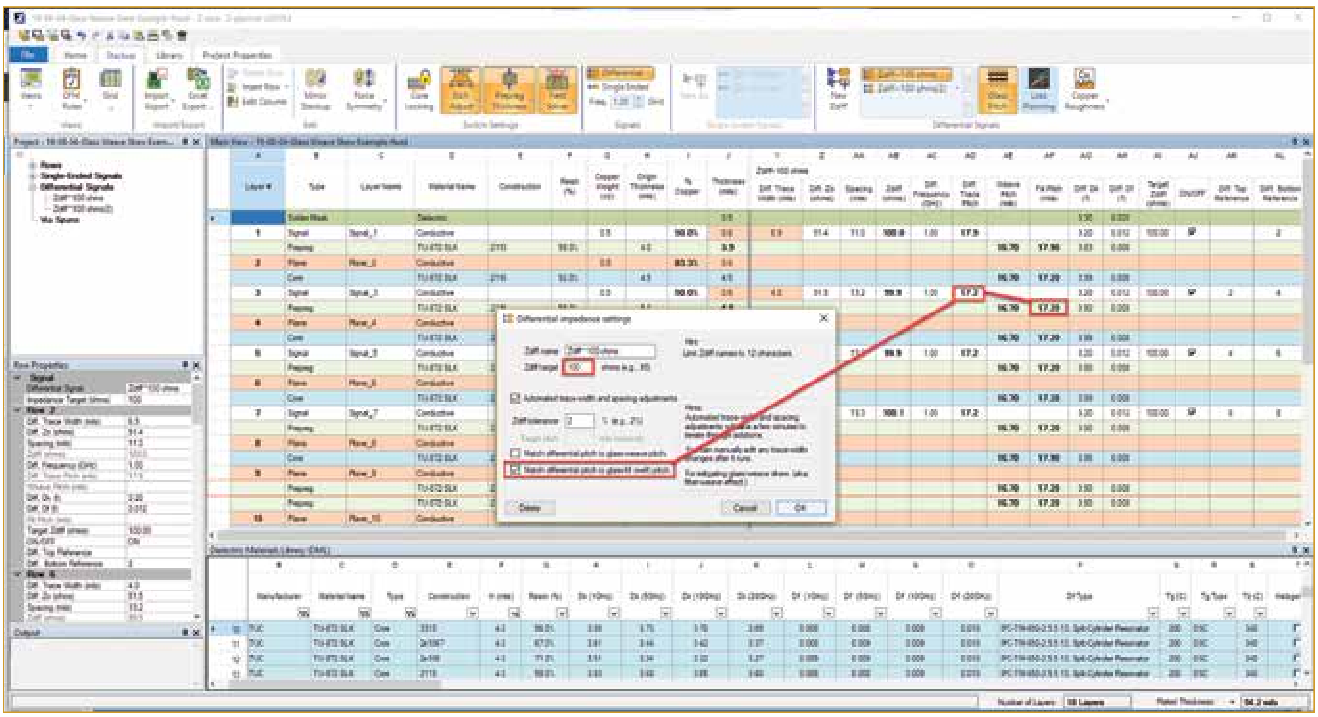


FIGURE 4. Differential-impedance targets were achieved while matching differential pitch to the adjacent glass-fill pitch. (Shown with Z-zero Z-planner.)

Will Self-Driving Vehicles Sharpen Our Focus on Reliability?

The nature of ADAS could revive CAF fears.

IN A PREVIOUS column, I enthused about the prospects for 5G to transform lives for the better, supporting new services that take advantage of ultra-reliable low-latency communication (URLLC) and capacity for massive machine-type communications, or mMTC. One place the impact of 5G will be felt is on the road, where machines will assume the entire decision-making from humans.

Leveraging 5G's guaranteed latency below 1ms for effective real-time performance, the prospects for mission-critical V2X vehicle-to-everything communication can become real. Vehicle-to-infrastructure interactions with smart signs should result in smoother, safer journeys, and vehicle-to-vehicle connections that share information about presence and position should avert huge numbers of "sorry, I didn't see you" accidents. Of course, it will take time for smart infrastructure to evolve and for V2X-equipped cars to enter the market. But it's quite clear, even now, that cars are destined no longer to be islands. Ultimately, it's a matter of when, not if, our road journeys come to be handled by fully self-driving vehicles.

There are still many technical hurdles to overcome, as well as legal issues, not to mention cultural obstacles. On the other hand, we can gain tremendous benefits by separating the privilege of personal mobility from the burden of car ownership. Cost-effective services delivered on a pay-per-use basis can extend access to groups excluded by current models based on vehicle ownership, such as those on low incomes or allowing the elderly to lead independent and active lifestyles into later stages of life than ever before. As we age, I suspect that more of us will tune into the benefits of being able to summon a self-driving vehicle whenever we need, be it to get somewhere or just for a change of scenery.

Parking is another problem that will become much easier to deal with. Self-driving cars will move from one job to the next, no stopping or waiting. Towns will no longer need to devote precious real estate to vast parking areas or commit resources to collecting payments and monitoring proper usage. Homeowners could utilize driveway and garage space for other purposes. We can all enjoy the prospect of residential streets no longer lined by parked cars.

This all has implications for the self-driving vehicles themselves. They obviously need to become far more intelligent, and nonstop motion will place a much greater load on components and systems than most conventional privately-owned vehicles would experience, resulting in faster wear-out and shorter lifetime.

We will also need to consider how to maintain them during their operational life. These "servers on wheels" will quickly become outdated, embodying standards that will become eclipsed and obsolete in a short timeframe after manufacture. Ensuring compatibility between infrastructure upgrades and multiple generations of vehicles could be a challenge. Together, compatibility issues and high duty cycles may require important on-board electronic equipment – particularly modules associated with machine vision and off-vehicle communications – to be renewed and upgraded at specific intervals, much like consumable items such as tires or engine drivebelts are today. On the other hand, cars may simply become consumables to be discarded in favor of a new and more up-to-date model, just as we now move easily from one mobile phone to the next at the end of each contract.

Either way, the primary onboard systems and safety systems must operate continuously and must be 100% reliable. Reliability is a multifaceted issue in such a complex interconnected environment comprising vehicles' on-board systems, cellular networks, data-center servers, and more. On-board the vehicle, high operating temperatures, frequent temperature cycling, shock and vibration, and electromigration are all issues that challenge reliability. As these systems become increasingly mission-critical, electronic manufacturers and materials suppliers need to understand the various deterioration mechanisms and effective techniques for dealing with them.

At the substrate level, where I feel most qualified to comment, conductive anodic filament (CAF) formation is a key factor in the degradation of the PCBs that provide the underpinnings for every vehicle's on-board systems. The ingredients for CAF include the presence of charge carriers, voltage bias and moisture; a recipe we can guarantee in any automotive operating environment. Initially aided by degradation of the dielectric over time, due to the presence of impurities in the material, electrochemical action drives ion migration that eventually causes short circuits, leading to electrical failure.

Mitigating the risk of CAF requires controls at all stages of manufacture. Ventec has developed optimized treating processes to ensure complete wetting of the glass fabric with the resin to ensure an optimum chemical bond. Current research is targeting CAF-formation resistance of low-loss materials for automotive use at high data rates. Industry bodies are also active; the High-Density Packaging User Group (HDPUG) is moving to increase industry understanding of the issue and suggest processes and practices to mitigate the risks.

Material suppliers should support initiatives such as these and take part in industry testing programs, compare products with those of peers, and work with OEMs to develop effective countermeasures and position new products properly in the market. ❑

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5G BUILD-OUT Will Speed PCB Fabricators' Gains

After years of taking a backseat to mobile device fabs, multilayer manufacturers stand to reap the rewards. by DR. HAYAO NAKAHARA

There is an ongoing changing of the guard when it comes to drivers of the PCB industry. Mobile and PC-related end-products are slowly giving way to the emerging 5G infrastructure. This swing is just beginning to impact the NTI-100 list of the world's largest fabricators, but it's only one of the new trends seen as we collected and analyzed this year's data. Another interesting development: A pair of fabricators from the US and Europe have come to dominate their respective "home" regions.

This year's NTI-100 report is the 22nd in the "top fabricator" series since the author started in 1998. (The "100" refers not to the number of companies ranked but rather the entities with $100 million or more in PCB revenue in the last calendar year.) As more Chinese PCB fabricators achieve sales revenues of $100 million or more, many privately owned, it is becoming extremely difficult to get accurate data. Without the help of CPCA, this work would have been impossible. The author would like to express his gratitude to Angela Chen of CPCA, who collected valuable data. Although the data have some flaws, they are no fault of CPCA.

Some fabricators may have been missed, and others should not be on the list. There are more than 2,400 PCB fabricators in the world, half in China, and many Chinese fabricators are elusive and hard to get data from. Nevertheless, as usual, any errors are strictly the responsibility of the author. His confidence level in the data's accuracy continues to decline every year, and if we were to put a number on it, it may now be 95%. He asks readers to be open-minded and tolerant of any errors.

Exchangerate.com shows 268 days of exchange rates for each currency (excluding Saturdays and Sundays). The author added exchange rates of 268 days and divided by 268 to obtain the above average currency exchange rates (TABLE 1).

Assumptions

1. It is very difficult to prorate portions of revenues of acquired fabricators and incorporate those portions into the revenues of the acquirer. So, regardless of the purchase or merger date, all transactions are assumed to have taken place Jan. 1. A good example is the case of MFlex, owned by DongShan Precision of China, which bought Multek on Dec. 1, 2018. The full-year revenue of Multek is added to MFlex's totals, despite the acquisition late in the year.
2. The PCB business of some fabricators belonging to larger, diversified companies is not reported separately; for example, Sanmina. Publicly held Japanese

TABLE 1. Average Exchange Rates Used to Convert Local Currencies to USD

CURRENCY	2014	2015	2016	2017	2018
China yuan (RMB)	6.158	6.284	6.634	6.758	6.616
Japan yen	105.86	121.06	107.84	112.93	110.44
Taiwan NTD	31.855	31.777	32.25	30.44	30.16
S. Korea won	1,053.58	1,132.33	1,160.80	1,130.59	1100.8
Thailand baht	32.482	34.253	35.290	33.92	32.32
Singapore dollar	1.276	1.375	1.440	1.334	1.349
Malaysia ringgit	3.270	4.120	4.100	4.32	4.035
Vietnam dong	21,137.07	21,920.68	22,763.00	22,721.03	23,001.08
Philippines peso	44.399	44.520	47.300	50.44	52.7
Indonesia rupiah	12,671.31	13,749.27	13,320.00	13,440.00	14,236.00
Canada dollar	1.104	1.279	0.997	1.297	1.296
India rupee	61.007	64.235	67.800	64.87	68.43
Mexico peso	13.306	15.792	19.05	18.95	19.00
Russia ruble	38.512	61.195	57.4	58.31	62.78
Swiss franc	0.915	0.962	0.997	0.98	1.022
UK pound	0.606	0.655	0.74031	0.81	0.75
Euro	0.754	0.902	0.904	0.886	0.844

Source: Exchangerates.com

fabricators report PCB revenues separately, with two exceptions: Kyocera and Murata. The author could not get separate PCB revenues from Kyocera or Murata. Thus, the calculated estimates of the PCB revenues of these fabricators are based on the data he could obtain.

3. Many PCB fabricators are now engaged in assembly as well. Separating the bare-board portion from the total will inevitably introduce errors. As in the past few NTI-100 reports, the author chose not to separate assembly values (components and labor costs), although estimates could be made. All flexible printed circuits (FPCs) delivered to Apple are assembled by the respective fabricators prior to delivery. The bare board value of "assembled FPCs" is said to be about 40 to 60% of the total. However, more than 20 FPCs and rigid-flex boards are used in the iPhone X, and the bare board values depend on which models FPC fabricators supply to Apple (ZDT, Flexium, Career, Nippon Mektron, Fujikura, Sumitomo Denko, SEMCO, BH Flex, etc.). The bare board values of these fabricators' revenues may be only 50% of the total shown.

4. Some PCB fabricators' revenues include subcontracted or brokered board sales (i.e., purchases for resale). Here again, it is impossible to know the accurate resale values for all the PCB fabricators on the list. Therefore, it is assumed the list includes an undisclosed percentage of resale revenues.

In defense of the work and inherent uncertainty, the author advises readers to be content with this work and view the list only as a reference.

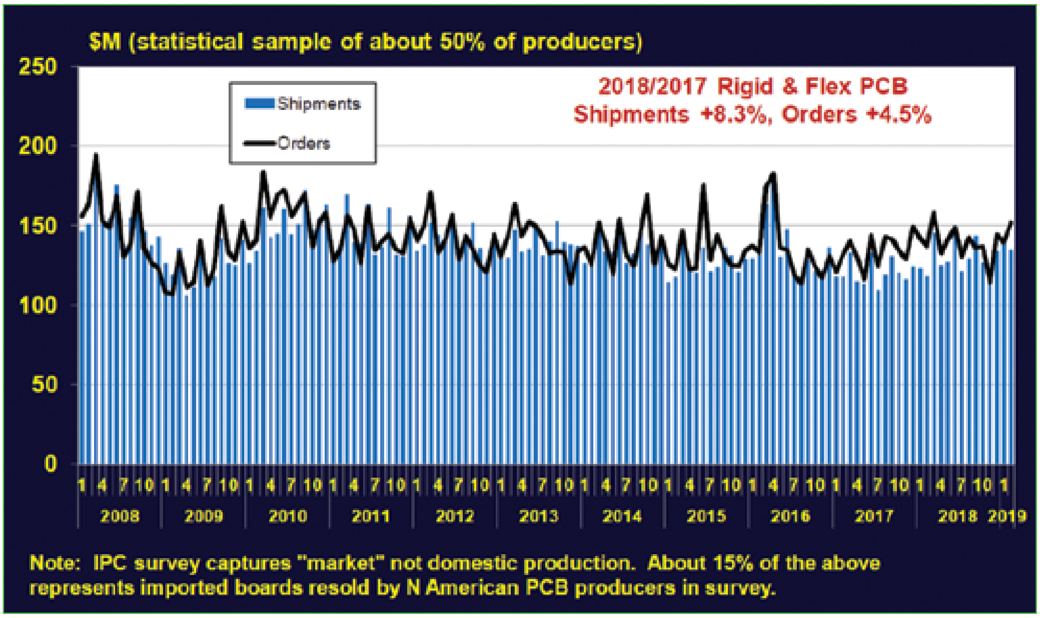

FIGURE 1. North American rigid and flexible PCB shipments and orders. (Source: Custer Consulting)

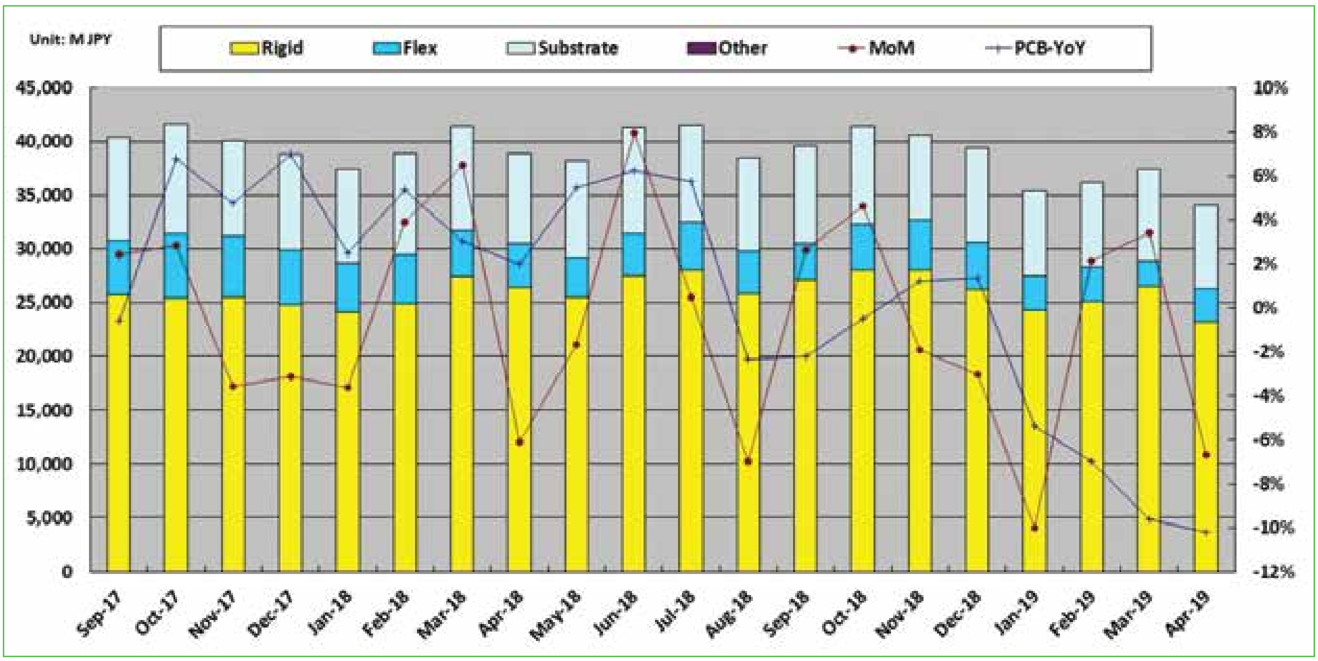

FIGURE 2. Japan monthly PCB production value. (Source: CPCA summary based on JPCA data)

Analysis

The number of entries (fabricators with revenue ≥$100 million) increased to 117 in 2018 from 115 in 2017 (**TABLE 2**). However, several fabricators "disappeared" last year because they were purchased and are included here with their new owners. Multek is under MFlex. Elna is under HannStar Board. (The actual owner is GBM, a sister company of HannStar Board, both belonging to PSA/Passive Systems Alliance.) Eastern is now part of South Korean fabricator Simmtech. NBC should not have been included last year; its entire revenue was counted as PCB-related, when in fact PCB makes up just 60% of overall sales.

Taiwan is the king of PCBs. China continues growing, and Japan continues to slip, despite an increase in its total revenue. The growth of Taiwan and China, respectively, is faster than that of Japan (**TABLE 3**).

Taiwan gained one entry from 2017. China gained three. Japan lost three. (Mitsubishi Gas Chemical/Taihong Circuit Industry is now under Taiwan.) There were no changes to South Korea and the US. Europe gained one, and the S.E.A. also gained one. QDOS finally made it!

Revenues of top Japanese and South Korean fabricators lost a few percentage points, but all other regions gained (**TABLE 4**). The top 117 fabricators grew 6.5% from 2017 to 2018, in line with the world PCB output in 2018. (Worldwide growth was 5.6%.) Larger fabricators' growth was larger by about 1%.

Japan's decline is due mainly to weaker sales to Apple by Nippon Mektron and Sumitomo Denko, offset in part by strong gains by CMK and Meiko in automotive PCBs. South Korea's drop is due to Interflex's loss of Apple business (under Young Poong Group). Apple is problematic for PCB fabricators, despite its huge PCB purchases. Taiwan's Career Tech had problems with Apple as well.

An interesting observation can be made about North America (read: US and Canada) and Europe. The total North American output in 2018 is estimated at about $5.2 billion, a figure that includes the overseas output of roughly $2 billion by TTM Technologies, Sanmina and Amphenol, with no more contributions from MFlex and Multek. Thus, TTM's revenue accounts for 55% of all North American fabricators' output.

AT&S's China output from two facilities (Shanghai and Chongqing) was $1 billion. Its Indian and South Korean output is an estimated $120 million. So, including its overseas output, the total AT&S output accounts for 36% of the total Europe-based fabricators' output (≈$3.4 billion, domestic and overseas) (**TABLE 5**).

The aggregate Top 117 output ($62 billion) accounts for 83% of the global output ($74.5 billion) in 2018. It has been said that, in general,

TABLE 2. NTI-100 World Top PCB Fabricators by Revenue, 2018

RANK	COMPANY	NATIONALITY	2017	2018	GROWTH
1	ZD Tech*	Taiwan	3,608	3,929	8.9%
2	TTM Technologies	US	2,659	2,847	7.1%
3	Nippon Mektron*	Japan	3,283	2,704	-17.6%
4	Unimicron	Taiwan	2,155	2,513	16.6%
5	Tripod	Taiwan	1,519	1,728	13.8%
6	Mflex (DSBJ)*	China	966	1,725	78.6%
7	Compeq	Taiwan	1,789	1,685	-5.8%
8	HannStar	Taiwan	1,314	1,435	9.2%
9	Samsung E-M	S. Korea	1,279	1,348	5.4%
10	KB Chem. PCB Group	China	1,040	1,237	18.9%
11	AT&S	Austria	1,175	1,218	3.6%
12	Young Poong Group*	S. Korea	1,746	1,217	-30.3%
13	Fujikura*	Japan	1,138	1,155	1.5%
14	Shennan Circuit	China	860	1,152	40%
15	Meiko	Japan	986	1,081	9.6%
16	Ibiden	Japan	1,051	1,054	0.3%
17	Wus Group	Taiwan	880	1,016	15.4%
18	Nanya PCB	Taiwan	883	956	8.3%
19	Simmtech	S. Korea	738	916	24.1%
20	Flexium*	Taiwan	857	888	3.6%
21	Daeduck Group	S. Korea	858	885	3.1%
22	Sumitomo Denko*	Japan	908	820	-9.7%
23	CMK	Japan	789	820	3.9%
24	LG Innotek	S. Korea	789	807	2.3%
25	Kinsus	Taiwan	740	787	6.3%
26	T.P.T.	Taiwan	746	765	2.5%
27	Kinwong	China	665	755	13.5%
28	BH Flex*	S. Korea	628	698	11.1%
29	Gold Circuit	Taiwan	637	683	6.8%
30	Shinko Denki	Japan	708	683	-3.5%
31	Chin Poon	Taiwan	788	670	-15%
32	Unitech	Taiwan	602	648	7.6%
33	Murata*	Japan	450	600	33.3%
34	Shenzhen Suntak	China	467	553	18.4%
35	Kyocera PCB	Japan	540	545	9%
36	Shenzhen Fast Print	China	497	525	5.6%
37	Career*	Taiwan	429	515	20%
38	Victory Giant	China	369	501	35.8%
39	SI Flex*	S. Korea	528	500	-5.3%
40	Isu-Petasys	S. Korea	483	497	2.9%
41	Ellington	China	496	489	-1.4%
42	Dynamic	Taiwan	385	432	12.2%
43	KCE Electronics	Thailand	426	418	-1.9%
44	Kyoden	Japan	398	401	0.7%
45	Wuzhou	China	336	386	14.9%
46	Founder Tech.	China	389	383	-1.5%

RANK	COMPANY	NATIONALITY	2017	2018	CHANGE
47	Hitachi Chemical	Japan	381	375	-1.6%
48	CCTC	China	349	372	6.6%
49	APEX	Taiwan	345	370	7.2%
50	Nitto Denko*	Japan	382	362	-5.2%
51	Xiamen Hongxin	China	224	341	40%
52	Aoshikan	China	263	338	28.5%
53	Gul Technologies	Singapore	260	338	30%
54	Olympic	China	285	330	15.8%
55	DG Shengyi Electronics	China	285	320	12.3%
56	Guangdong Xinda	China	306	300	-2%
57	Sanmina	US	330	300	-9.1%
58	APCB	Taiwan	290	296	2.1%
59	Bomin	China	266	295	10.9%
60	Redboard	China	283	293	3.5%
61	DAP	S. Korea	269	290	7.8%
62	CEE PCB	China	163	263	61.3%
63	ASE	Taiwan	280	260	-7.1%
64	Shirai Denshi	Japan	259	260	0%
65	Sun & Lynn	China	244	260	6.6%
66	Boardtek	Taiwan	227	252	11%
67	AbonMax (Palwonn)	Taiwan	230	250	8.7%
68	BYD	China	167	250	49.7%
69	Ichia*	Taiwan	238	240	0.8%
70	MFS*	Singapore	186	238	28%
71	Fujitsu	Japan	226	230	1.3%
72	Guangdong Chaohua	China	218	210	-3.7%
73	Kunshan Huaxing	China	202	204	1%
74	SDG Precision Tech.	China	117	201	71.8%
75	SEMCO	S. Korea	199	200	0%
76	Kyosha	Japan	193	191	-1%
77	Somacis	Italy	181	187	3.3%
78	Delton	China	155	185	19.3%
79	AKM*	China	170	185	8.8%
80	Onpress	China	177	182	2.8%
81	KSG	Germany	154	182	5.2%
82	Lead-Tech	China	146	181	27%
83	Liang Dar	Taiwan	175	180	2.8%
84	Circuitronix	China	175	180	2.8%
85	Ji'An Mankun	China	154	180	3.9%
86	Zhuhai Kingsun PCB	China	124	173	39.4%
87	Shenzhen Sunshine	China	160	171	6.9%
88	Guangzhou Kingshine	China	171	171	0%
89	GZ Junya (Champion Asia)	China	149	169	13.4%
90	Guangzhou GCI	China	148	168	13.5%
91	Daisho Denshi	Japan	164	166	1.2%
92	Würth Elektronik	Germany	158	166	5.1%

TABLE 2. NTI-100 World Top PCB Fabricators by Revenue, 2018 (cont.)

RANK	COMPANY	NATIONALITY	2017	2018	GROWTH
93	OKI PCB Group	Japan	150	164	9.3%
94	New Flex*	S. Korea	137	164	19.7%
95	3Win Group	China	150	160	6.7%
96	Huading Group	China	149	154	3.3%
97	Schweizer	Germany	138	148	7.2%
98	Changzhou Haihong	China	144	145	0%
99	SZ Jove Enterprise	China	138	144	4.3%
100	Hyunwoo	S. Korea	125	141	12.8%
101	Jiangsu Suhan	China	131	141	7.6%
102	Amphenol PCB Div	US	130	140	7.7%
103	Mutual Tech	Taiwan	104	139	33.6%
104	Kunshan Wanzhen PCB	China	135	137	1.5%
105	Plotech	Taiwan	128	133	3.9%
106	Yamamoto Mfg.	Japan	143	125	-12.8%
107	Netron Soft Tech*	China	123	122	0%
108	Kunshan Hua Zhu	China	119	119	0%
109	Zhuhai Topsun Elec.	China	116	116	0%
110	Suzhou Forein FPC*	China	94	111	18.1%
111	HT Circuits	China	112	110	-1.8%
112	CHPT (中華精測)	China	103	109	5.8%
113	Benlinda PCB	China	94	104	8.5%
114	Dongguang Honyuen	China	91	103	13.2%
115	HT (HeTon) Electronics	China	105	103	-1.9%
116	QDOS*	Malaysia	90	103	14.4%
117	Brain Power	Taiwan	112	101	-9.8%
	Top 117 Total		**58,266**	**62,061**	**6.5%**

In US$ millions. Source: N.T. Information Ltd.

*Major products are FPC

20% of the companies in an industry account for 80% of the sales. Considering approximately 2,400 fabricators operate globally, 117 fabricators constitute less than 5% of the total. So, for the PCB industry, 5% of the fabricators are responsible for 80% of the output.

The "domestic" PCB production of once-mighty North America, Japan and Europe has now sunk to the bottom. Their growth comes from overseas plants. The US-China trade war will not affect this pattern insofar as PCB production is concerned. No idiots will bring their overseas PCB production back home, at least in this author's lifetime.

Japan's investment in China is finished, and its expansion in Thailand is dormant, except at CMK Thailand.

TABLE 3. Summary of NTI-100 2018 by Region

REGION	NUMBER OF ENTRIES		TOP MAKER OUTPUT		2018/2017	2018 SHARE
	2017	2018	2017	2018	Growth	
Taiwan	25	26	19,564	20,980	7.23%	33.8%
China	46	49	12,907	15,418	19.33%	24.8%
Japan	21	18	12,149	11,736	-3.4%	18.9%
S. Korea	12	12	7,779	7,663	-1.5%	12.3%
US	4	4	3,119	3,287	3.1%	5.3%
Europe	4	5	1,806	1,901	5.3%	3.1%
S.E.A.	3	4	962	1,097	14%	1.8%
Total	**115**	**118**	**58,286**	**62,082**	**6.5%**	**100%**

In US$ million. Source: N.T. Information Ltd.

TABLE 4. World PCB Production by Region*

REGION	2017	2018	YOY	2019F	YOY
America	3,037	3,158	4.0%	3,174	0.5%
Germany	960	994	3.5%	939	-6%
Other Europe	1,385	1,257	1.2%	1,270	1%
Africa & Middle East	142	143	0.0%	145	1.4%
WEST TOTAL	**5,524**	**5,552**	**3.1%**	**5,528**	**0.4%**
China	37,200	40,510	8.9%	39,880	-1.5%
Taiwan	7,685	7,780	1.2%	7,690	-1.2%
S. Korea	7,215	7,515	4.1%	7,214	-4%
Japan	5,625	5,654	0.5%	5,796	-1.2%
Thailand	2,980	3,132	5.1%	3,160	0.9%
Vietnam	2,620	2,704	3.2%	2,905	3.7%
Other Asia	1,738	1,668	-4.0%	1,700	1.9%
ASIA TOTAL	**65,063**	**68,963**	**6.0%**	**68,345**	**-0.9%**
WORLD TOTAL	**70,587**	**74,515**	**5.6%**	**73,873**	**-0.9%**

In US$ million. Source: N.T. Information Ltd.

* Production includes assembly operations, particuarly FPC.

Investment is now concentrated in Vietnam. However, Ibiden and Shinko Electric are investing more than $1 billion combined to cope with demand for high-end chip substrates from Intel, their collective customer which is expanding dramatically in Oregon and Israel. This may change Japan's domestic picture in a few years.

European PCB fabricators do invest a few dollars, not for capacity expansion but more for accommodating new technologies.

A similar phenomenon is taking place in South Korea, and to a lesser degree, Taiwan. (Sixty percent of Taiwan's PCB production is made in China, 5% in Thailand, and 35% in Taiwan). As Samsung Electronics continues to shift smartphone production to Vietnam, many South Korean FPC fabricators followed the OEM to the Hanoi area: 10 so far, with more to follow.

FIGURE 3. PCB fabricator investments in China in past decade.

The author visits China three to four times a year and makes plant tours of about 60 PCB fabricators, Chinese and foreign. Some of their new plants and expansions are huge! So many new plants have been constructed in the past few years, and expansion continues, albeit more cautiously since the start of the US-China trade war. The author is aware of at least 35 to 40 gigantic new plants that are under construction in China.

Waste regulations are getting tougher in China, particularly "PCB-infested" areas such as Shenzhen and Shanghai Belt. Fabricators that cannot meet government regulations in these areas go out of business. Those that have resources to build new plants choose north of Yangtze River (Nantong, Yancheng, etc.), Hubei province (Huangshi in particular), Jiangxi province (the favorite place for Shenzhen-based fabricators because of its proximity to Shenzhen), and Zhuhai (FIGURE 3).

In a few years, when all these investments start producing PCBs, the Chinese output may account for more than 70% of the global production, including foreign transplants, mostly Taiwanese. More Chinese fabricators will occupy higher positions on the NTI-100 list, and more Chinese fabricators will achieve revenues ≥$100 million per year.

The author is tiring of this work because it is getting harder to collect data, but he hopes to continue this project to see how Chinese PCB fabricators will grow.

In the 2019~20 period, high-layer count MLB fabricators will gain, thanks to 5G communication infrastructure installations. 2019 is considered a starting point for 5G, and as we enter 2020, demand for base stations, routers, servers, antennas and other equipment will increase. PCB fabricators that can supply to such demands in volume will grow by leaps and bounds.

Automotive unit shipments experienced a hiccup in 2018, and at this moment 2019 does not seem to have brought much improvement. EV shipments are growing at 50% annually, but its share of the total shipment of 95 million to 96 million cars per year expected in 2019 is still less than 3%. "Semi" autonomous cars will start showing up on public roads in 2020, not for testing but for carrying passengers. (We say "semi" because the level of autonomy will be level 3 or 4, at best.) It will take a few more years before we see fully autonomous cars without steering, brakes and

TABLE 5. Europe PCB Output, 2012-18

	2012	2013	2014	2015	2016	2017	2018
Revenues*	1.846	1.807	1.831	1.815	1.747	1.833	1.921
Staff	16.935	16.546	16.432	16.491	15.902	16.015	16.587

*In euros millions Source: Data4PCB/Michael Gasch

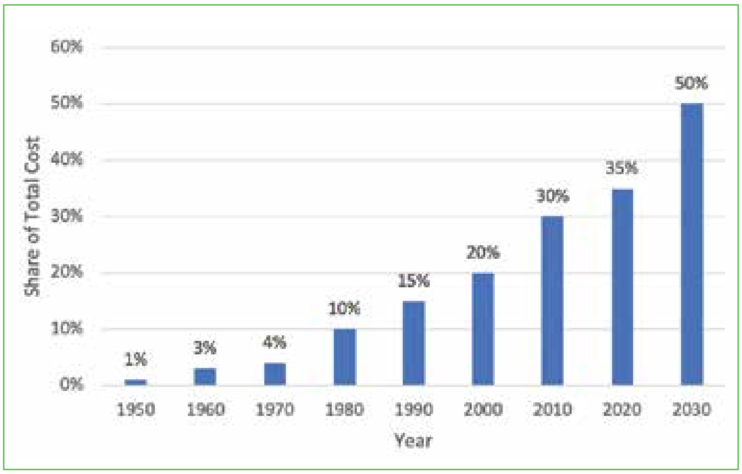

FIGURE 4. Automotive electronics cost as a percentage of total car cost worldwide, 1950 to 2030.

accelerator pedals (level 5) running on the roads. But, the electronic content of the car is expected to increase continuously (FIGURE 4). Therefore, automotive PCB fabricators will perform better, despite eroding selling prices of PCBs for automotive applications. Japanese and Taiwanese fabricators dominate automotive PCB production (TABLE 6).

High-layer count MLB FABRICATORS WILL MAKE GAINS, THANKS TO 5G INFRASTRUCTURE INSTALLATIONS.

PC shipments had a surprise rise in the second quarter, despite pessimistic forecasts (TABLE 7). According to the Gartner research firm, OEMs sought to ship as many units as possible before higher tariffs were imposed. PC motherboard suppliers are singing happier notes at this moment, although the long-term prospects are still not so bright (TABLE 8).

In conclusion, this year's winners will be those that cater to 5G infrastructure, automotive electronics, IC substrates, and, still, smartphones (absorbing 20+% of all PCBs despite its slow growth). Gains from other industries will be infinitesimal. ▫

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TABLE 6. World Top 20 Automotive PCB Fabricators, 2018

RANK	FABRICATOR	NATIONALITY	TOTAL REVENUE	AUTOMOTIVE PCB
1	CMK Corp.	Japan	820	628
2	TTM Technologies	US	2,847	572
3	Nippon Mektron	Japan	2,704	560
4	Meiko Electronics	Japan	1,081	508
5	Chin Poon Industrial	Taiwan	670	470
6	Kingboard Chem GRP	China	1,250	370
7	Tripod Technology	Taiwan	1,728	351
8	KCE Electronics	Thailand	420	335
9	AT&S	Austria	1,218	275
10	PCA PCB Group	Taiwan	1,435	220
11	Wus Group	Taiwan	1,016	200
12	Unitech PCB	Taiwan	648	190
13	Dynamic Electronics	Taiwan	432	180
14	Unimicron	Taiwan	2,513	170
15	Kinwong	China	755	150
16	Gul Technology	Singapore	338	118
17	Kyoden	Japan	401	116
18	Nanya PCB	Taiwan	956	116
19	CCTC	China	368	114
20	Olympic PCB	China	330	111
	Top 20 Total		**21,930**	**5,754**

In $US millions   Source: N.T. Information Ltd., May 2019

*GBM+Elna+HannStar Board, mainly the former two

TABLE 7. Worldwide Device Shipments by Device Type, 2018-2021

DEVICE TYPE	2018	2019	2020	2021
Traditional PCs (desk-based and notebook)	195,317	189,472	182,823	175,058
Ultramobiles (premium)	64,471	68,869	74,432	79,871
Total PC market	**259,787**	**258,341**	**257,255**	**254,929**
Ultramobiles (basic and utility)	149,561	147,963	145,811	143,707
Computing device market	**409,348**	**406,304**	**403,066**	**398,636**
Mobile phones	1,811,922	1,802,394	1,824,628	1,798,356
Total device market	**2,221,270**	**2,208,697**	**2,227,694**	**2,196,992**

In millions of units. Source: Gartner

TABLE 8. Top 5 PC Shipment OEMs, Q2 2019

COMPANY	2Q19 SHIPMENTS	2Q19 MARKET SHARE	2Q18 SHIPMENTS	2Q18 MARKET SHARE	2Q19/2Q18 GROWTH
Lenovo	16,254	25.1%	13,750	22.2%	18.2%
HP	15,356	23.7%	14,880	24%	3.2%
Dell	11,606	17.9%	11,255	18.2%	3.1%
Acer	4,288	6.6%	4,363	7%	-1.7%
Apple	4,077	6.3%	3,722	6%	9.6%
Others	13,276	20.5%	13,961	22.5%	-4.9%
Total	**64,858**	**100%**	**61,931**	**100%**	**4.7%**

Source: IDC

PROTOTRON CIRCUITS:
2 Sites, 1 Vision

The West Coast-based fabricator is turning boards up to 30-layers as fast as they get them. **by CHELSEY DRYSDALE**

Sometimes two are better than one.

Take Prototron Circuits. The 30-plus-years-old board fabricator operates two factories in the Western US, and while they are hours apart by air, insofar as how the company sees them, they might as well be on the same campus.

In May, PCD&F visited the printed circuit board fabricator at its facility in Redmond, WA. The plant, which doubles as the company headquarters, is about 1,500 miles northwest of its other site in Tucson, AZ. But in the minds of the staff, the two plants act as complementary standalone facilities, serving thousands of customers each year.

"They do things we don't do, and we do things they don't do," said Mark Thompson, engineering support, who gave the factory tour. He and Lee Salazar, Western Washington sales, answered questions before walking PCD&F staff through the 25,000 sq. ft. plant. (The Tucson facility is 20,000 square feet.)

Prototron's origins date to 1987, when it was launched by a local engineer named Dave Ryder. While sales have grown organically through the years, the company has also made timely acquisitions. In 1997, Prototron acquired Cir-Quick – Ryder's former employer – giving it its current manufacturing space. Two years later, it bought Tucson-based Southwest Circuits, adding a mil-spec capability and extensive specialty material expertise to its offerings.

FIGURE 1. The yellow room at Prototron Circuits features a Maskless Lithography direct imager and Opti-Beam dry-film exposer.

Tucson has 45 staff members and can make aerospace flight boards, while Redmond has 52 employees and builds hybrid and high-layer-count boards. Redmond can do immersion gold/HASL, while Tucson does hard gold for PCIE connectors. Redmond also builds aerospace engineering prototypes.

Both plants are ISO certified; Tucson also has AS9100D registration. Equipment sets are "essentially the same" in both plants. Redmond can build 3 mil lines/spaces on 0.25 oz. foil, while Tucson can do 4/4.

Smaller Products …

Prototron says its model relies on keeping up with customer requests. One such example: via-in-pad, which Prototron fills with epoxy.

"We train customers to give us the right packages and ask the right questions," Thompson noted. "We have a customer special requirements database for the hot buttons of each customer."

That database includes all sorts of unique customer requirements, from using antistatic bags for shipping to building to IPC Class 3 performance specifications for plating only.

According to Thompson, "everything is getting smaller." Prototron can mechanically drill holes down to diameters of 0.0059". Laser drilling is outsourced offshore.

The company's biggest technology concern is "making sure controlled impedances are correct," he added.

"They are usually very high: around 4.5. At four or five mil trace, Dk is considerably lower than what's on a customer's PDF file," said Thompson.

They added, "We only do film for solder mask and IDs. Most shops don't use phototools anymore."

Production bottlenecks are typically in plating and electrical test. It used to be drilling, but investment in new Schmoll machines ramped drilling speeds five to six times over the old machines. Prototron also recently added an epoxy via fill machine.

Prototron Circuits accepts IPC-2581 and ODB++ files. It prefers ODB++ because it "won't have any missing netlists." IPC-2581 "includes all image formats. Fabricators have to compare them. ODB++ is a whole lot easier."

…and a Shrinking Supply Base

From a business perspective, the seemingly constant shrinking of the number of suppliers weighs on Prototron. When asked about the firm's biggest business concern, they said the health of the industry, noting large shops are "swallowing" smaller ones. Moreover, the larger fabs aren't "servicing the small [OEMs] for prototypes."

For its part, Prototron sees a business opportunity. Prototypes are its business, and it does "as much as possible." It can turn 16-layer boards in 24 hours, and 30-layer boards in three days.

In Redmond alone, Prototron has more than 5,000 customers, and no single customer makes up more than 10% of its business. Much of its business comes from the vibrant EMS community. (See a related article on Applied Technical Services, July 2019.)

"We have contracts with *all* the local assemblers and contract manufacturers," Thompson said. "We do everything based on local customer need, not buzzwords."

That approach is strained at times. For instance, when material lead times get extended, smaller shops like Prototron must plan creatively. Recently, for instance, a major supplier of specialty material pushed its lead times to five weeks. "If a customer has a three-day turnaround, that's a problem. This is pervasive, even for large shops," the firm told PCD&F.

Prototron has an extensive CAM worksheet that inside sales fills out; these are the instructions for the CAM operator. There are three dedicated CAM stations. It uses Frontline Valor CAM software and Polar SI 8000 software. The field solver has hundreds of different models, including broad-side structures. Engineers can put in numbers for all 26 processes.

The company uses Frontline Genesis 2000 software to create a preview database and work order number. Here, it can import files such as ODB++. Insight PCB, also from Frontline, performs pre-CAM functions, including some design rule checks and analyses. This process allows sales to quote properly and saves time, Thompson said.

CAM operators perform drill compensations to account for known loss in the etcher, etch compensations, and scale factors. "The thinner the core, the higher the scale factor," Thompson said.

The Redmond plant is straightforward, with conventional processes for imaging, develop/etch/strip, and lamination, drilling, a vertical plating acid copper bath, and post-etch punch. Both sites handle a variety of materials, including polyimide, with Tucson some aluminum-backed flavors. Prototron handles a "considerable amount" of 2.5 mil cores, which it processes in 12 x 18" and 18 x 24" panel sizes.

Prototron boasts three types of imaging: an Accuprint AP30 5000 Power Plus, one of the oldest machines on the floor; the newer DI machine for maskless lithography, which it uses 85 to 90% of the time; and an Opti-Beam dry-film exposure unit. Prototron uses it for solder mask prior to developing. Direct imaging is used for circuit layers. Next up is the purchase of an ultrasonic cleaner.

Prototron performs visual inspection of innerlayer cores to check lines and spaces and uses AOI to look for shorts and opens. If a defect is found at AOI, it is reprinted until it passes, Thompson said.

In the lamination layup area, operators process up to 32 different boards at a time. Separate machines are used for hot and cold press. Extended cool downs are used to eliminate bow and twist.

The new Schmoll Multi-X Axis drill has a wide range of tool sizes available. It uses laser blocks to determine – as Thompson colloquially said, "Yeah, I like that bit" – and then drills it. "It's six times faster than the old machine." The linear drive has 10-ton granite blocks underneath to keep the machine in place.

"Ten years ago, this was a bottleneck. We can now drill faster than plating."

The solder mask area contains an ITC Intercircuit epoxy fill machine. Holes are filled completely with epoxy by means of a hydro-squeegee, then plated to encapsulate them. The specific size range is 0.008" to 0.020". Later, the boards are lightly scrubbed before coating with a DP 1000 automatic flood coater: 1 mil over glass/half a mil over copper.

Next up: the tack cure oven, followed by liquid photoimageable imaging. Ovens are at full bake with a potassium carbonate solution, and then the boards are surface-finished. Prototron offers LPI solder mask, NiAu and ENIG finishes, and even HASL. ("There are still folks who want it," Thompson said.)

For signal integrity, a standard set of six questions are asked, plus two additional questions:

- Are all the structures in free space? (Any coplanar coupling?)
- What's the color of the mask? (For example, white for LED applications is two times the thickness – and almost double the dielectric constant.)

Redmond has three Microcraft Emma flying probe testers for electrical test. The machines can correct for z-axis contraction.

In a dry lab, Polar software is used to test for ionic contamination.

Prototron Circuits is affiliated with local universities, as well as universities across the country. Thompson guest lectures for engineering students and provides those same lectures for customers. One such company is Monsoon Solutions, which he visits five times per year to educate employees.

"Monsoon can order one- to three-day turns for board designers," he said. "We can get any of their impedances to work."

When it comes to demand, Prototron is fortunate, having the benefit of the aerospace industry. Work comes in "all year round (because) launch times don't coincide with budget releases two times per year. Demand will always continue."

The two shops may be miles apart, but the vision of CEO Ryder is instilled and prominent in both. As Russ Adams, national sales manager, said, "Prototron is known for service, reliability, on-time delivery, integrity and knowledgeable customer support. That goes for both facilities. We both live by the same principles." ❑

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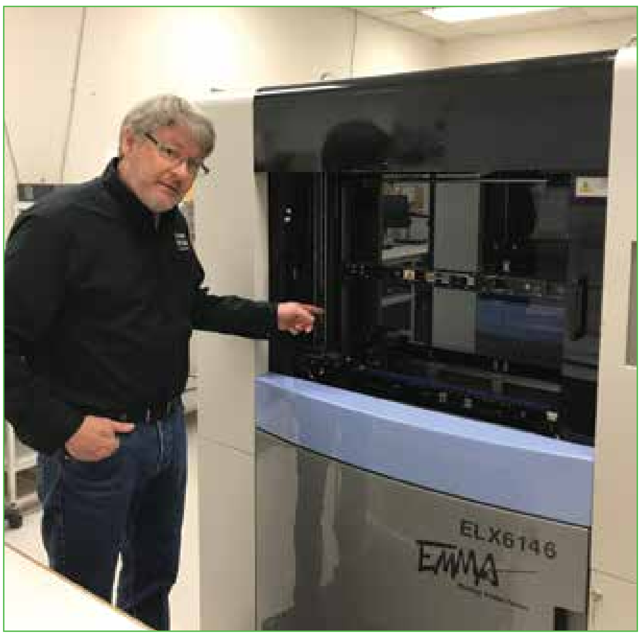

FIGURE 2. Mark Thompson shows Prototron's flying probe tester.

Designer's Notebook continued from pg. 24

Answer: Max skew in time delay = +/-2.5% of the 833ps clock period = 20.825ps FR-4 $Er \approx 4$, $Er_{eff} \approx 2.92$.

So, for striplines, the maximum skew should be less than +/-(20.825/(85*SQT(4)) = +/-0.1225 in = +/-122.5 mil.

For microstrips, the maximum skew should be less than +/-(20.825/(85*SQT(2.92)) = +/-0.1433 in = +/-143.3 mil.

*Note: Different microstrip and stripline structures will affect the signal speed, but only slightly.

Keep this in mind the next time you calculate trace lengths. It should make the job a little easier. ❑

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Market Forces and Regulations Converge on ECO-DESIGN

Cost savings, boosted by European Commission initiatives, drive product designers to implement eco-design. by PAMELA J. GORDON

Ed.: This is the first of an occasional series by the authors of the 2019 iNEMI Roadmap. This information is excerpted from the roadmap, available from iNEMI (inemi.org/2019-roadmap-overview).

A common misconception is that eco-design adds costs to products. In fact, nearly every eco-design principle reduces product costs. The growing demand for more environmentally sustainable products, coupled with increasing regulatory restrictions, is motivating electronics manufacturers to leverage eco-design principles and the circular economy model to simultaneously build business value, decrease product costs and mitigate harm to the environment and society. Progress in eco-design since the 2017 *iNEMI Roadmap* has been driven largely by upcoming requirements from regulatory bodies and competition-driven initiatives; the latter stems from stakeholders' increasing awareness of the toxicity, CO_2 emissions, social inequities, and costs attached to many materials in the extraction, manufacturing, transportation, use and post-use phases.

The European Commission (EC) remains the most active driver of regulatory eco-design requirements, especially in removing hazardous substances from products and in creating mandates for new standards related to the circular economy. For instance, the electronics industry is actively removing four phthalate substances in advance of RoHS restrictions that take effect starting in 2019. Also, in early 2018, the EC launched its next round of substance reviews for possible restriction in electronic products.

Moreover, 10 European standards to enable future initiatives and regulations on the circular economy are in the final stages of development. These standards address definitions, requirements and methods for product durability; ability to remanufacture as well as to repair, reuse, and upgrade; recyclability and recoverability; and a proportion of reused components and recycled material. (According to the Ellen MacArthur Foundation, the circular economy

TABLE 1. Anticipated Changes to, and Impacts from, Future Regulations

DESIGN CATEGORY	CURRENT STANDARDS AND/OR REGULATIONS THAT ADDRESS THIS DESIGN CATEGORY
Material selection	Partially addressed by IEC TR 62824:2016 Guidance on material efficiency considerations in environmentally conscious design of electrical and electronic products
Ecolabels: most programs and standards require use of recyclable materials; many standards in N.A. and Europe require use of recycled plastic and fiber materials (e.g., IEEE 1680.x, UL110, NSF 426, Blue Angel, TCO)	EU Commission mandate to develop circular economy and critical raw materials (CRM) standards will lead to new regulations
Material identification	ISO, IPC and other standards for labeling; material declaration (with material classes) for additional details
Ecolabel standards already require many plastic parts to be labeled	EU Commission mandate to develop circular economy and CRM standards will lead to new regulations that may be more prescriptive
Material restrictions	RoHS, REACH and similar regulations restricting materials in electrical and electronic products
Manufacturing and assembly	IPC and other industry organizations have long produced standards for manufacturing and assembly quality; focus on eco-design at these stages has been lagging

Source: Sustainable Electronics chapter of the 2019 iNEMI Roadmap is a way to design, make and use things within planetary boundaries, by designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.)

Finally, the desire to leverage recycled materials for new product manufacturing is calling for the elimination of all hazardous substances from products.

Concurrently, a burgeoning number of product companies are implementing voluntary eco-design initiatives – sometimes to earn eco-labels including EPEAT, and sometimes to achieve business value through product-and-process innovations.

The competitive pressure comes from increasing education of, and demands for, responsibility by a broad range of stakeholders, including leading manufacturers, purchasers, governments, NGOs and the experiences from reuse and recycling service providers. Some of the most recent initiatives include increases in these areas:

- Proactive identification/elimination of hazardous substances and the use of alternative assessment methods to evaluate substitute materials and chemicals.
- Requirements for recycled content in plastic materials.
- Closed-loop recycling of plastic materials for use in similar products.
- Push of eco-design requirements into the supply chain, which can be supported by standards.
- Corporate social responsibility and responsible sourcing of materials and services.
- Energy management, including product energy efficiency and use of renewable energy by manufacturers and suppliers.
- Flexibility to reuse and repair products.

To mitigate economic, environmental, and social issues present today and expected to intensify during the next 10 years, the global electronics industry must incorporate eco-design principles throughout product and package development, supply chains, manufacturing, logistics, use-phase, and post-use value retention.

Looking forward to the next 10 years, the roadmap anticipates changes to, and impacts from, regulations and standards relative to eco-design, summarized in **TABLE 1**. ▫

This excerpt from the 2019 iNEMI Roadmap is based on the Eco-Design section of the Sustainable Electronics chapter, chaired by **PAMELA J. GORDON**, director of partnerships for Presidio Graduate School.

Is Your CONTACT CLEANER Compatible with Today's Complex Electronics?

Some cleaners are speedy and effective but can attack plastic components. by **EMILY PECK**

With modern electronics getting smaller and more complex, finding a reliable cleaning method that is both effective and compatible with the different materials of electrical equipment can be difficult. The smallest contaminant can form a barrier between contacts and parts, or initiate dendritic growth, affecting the device's efficiency and performance. This is why cleaning plays an important role in guaranteeing the quality of electronics equipment coming off the production line.

Contact cleaners are widely used in the industry due to ease of use and convenience. They clear particulate and oil residues from hard-to-reach places and refresh electrical connectivity on switches, relays, potentiometers and other devices. They safely rinse grit from hot motors and dust from inside electromechanical relays and keyboards. They are also effective in removing contaminants from hard-to-reach areas on connectors, cable harnesses, tuners, power supplies, encoders, distribution panels, junction boxes and switching devices.

The perfect contact cleaner should be nonflammable, noncorrosive and have strong dielectric properties. Ideally, it could even be sprayed on energized electrical circuits without concern. The cleaning agent must be safe for use on all component materials without risk of damaging delicate parts. These features may be the ultimate contact cleaning combination, but some electronics manufacturers may not be taking time to check the cleaners used are up to the job and compatible with electronic components.

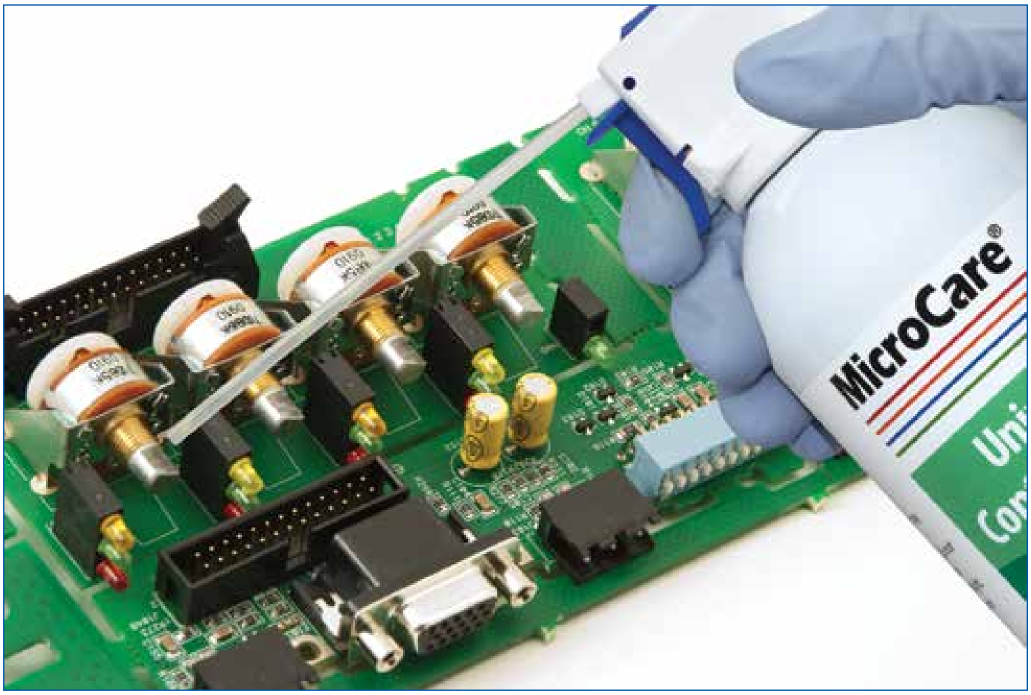

FIGURE 1. Contact cleaners flush away dust and lint from electronics equipment.

First step. Although the capability of the contact cleaner is important, so is its compatibility with the substrate being cleaned. When it comes to choosing the correct contact cleaner, first check for material compatibility. This is a critical area to investigate before any cleaning process is undertaken. Does the device consist of just one type of material, or is it made up of several materials with vulnerable components? Perhaps it has an LCD display made from transparent polycarbonate, contains inks, or includes rubber parts that may be damaged by aggressive solvents.

Think about what the electronics are made from. Many use a range of materials for their structure. One electronic component can be fiberglass, while others can contain materials like copper, elastomers or screen-printed parts. If unsure about the materials of construction, test before widespread deployment of a cleaner.

Contact cleaners. A strong cleaning fluid is often used to ensure cleanliness. It delivers excellent results and cleans quickly. However, a cleaner that is too strong can damage soft plastics, rubber, conformal coatings and even remove inks. It may appear to be a quick and effective solution to cleaning, but the unseen damage caused can be destructive to the component materials.

Modern contact cleaners can be an effective and safe method of cleaning. They remove oxides and other unwanted contaminants from the conductive surfaces of switches, connectors and other electrical components with surface contacts. They are particularly useful if cleaning is required for assemblies with varying material use or those where component parts have not yet been established. Strong cleaners may dissolve, craze or attack softer substrates; therefore, a milder plastic-safe cleaner is often the preferred choice. Ensure the contact cleaner is nonconductive, fast-drying, nonflammable, and safe on all materials of construction.

An array of contact cleaners is on the market. In the past, some technicians used IPA (isopropyl alcohol) with some success for contact cleaning. IPA is slow-drying and highly flammable, causing potential safety risks. In addition, oxides are typically not cleaned by IPA, so alcohol may not be the best choice. On the other hand, most modern contact cleaners, with their high volatility, dry quickly and without residue. They are also nonflammable and can be used on energized equipment.

Keep the Kb value low. The cleaning strength of a contact cleaner is frequently measured by an industry benchmark called the Kauri Butanol (Kb) value. If an electronic device is made from a variety of materials and includes plastic components, use a contact cleaner with a low Kb value. Stronger cleaning fluids with a high Kb value may have compatibility problems with soft plastics, coatings, inks and other components. Ideally, if delicate materials are within the device that requires cleaning, a Kb value of 15 to 40 is usually safest. This Kb range indicates the contact cleaner is mild and suitable for most surfaces.

Kb values can be found on the contact cleaner's technical data sheet. The figure shown will help gauge the cleaner's strength and suitability for the contaminant requiring removal. Cleaners with lower Kb values will remove greases but may not handle ionics and fluxes. Cleaners with higher Kb values may be speedy and effective but may attack plastic components. For this reason, consider the components to be cleaned and the materials of construction. Depending on the contamination, make sure the contact cleaner is strong enough to remove the contamination and clean effectively, while not affecting the components themselves.

A good method of ensuring a contact cleaner is working effectively without affecting the component material is to conduct a "cleaning trial" on a sacrificial or test part. The best practice is to start with a milder cleaner first and progressively try stronger cleaners until the optimal cleaning result is achieved. It is recommended tests be performed in more than one area on the part to ensure it is safe for all the materials the cleaner may contact, directly or indirectly. Leading suppliers of cleaning solutions have field engineers who can provide guidance on testing cleaners and how to select the best one for the component and contamination. Often, the results are unexpected: some mild cleaners may clean as well as or even better than those with much higher Kb values, with the added benefit of maintaining material compatibility.

Many companies will conduct their own in-house cleaning trials, but in some instances, companies may send their sacrificial test parts to the cleaning fluid manufacturer for an in-lab cleaning assessment. Cleaning experiments are conducted on their parts and particular contamination to ensure effective cleaning with the fewest risk to the parts. The lab will typically present the client with a written report, including detailed recommendations on the best cleaner and cleaning methods to ensure cleanliness and safety.

What is out there? Many contact cleaners on the market combine a number of important features. They clean effectively, are worker safe, environmentally friendly and inexpensive. Although mild, they clean thoroughly and can rinse and flush away mineral and silicone oils, as well as remove dust, lint, grit and other particulates, making electronics components clean and ready for the next stage in the manufacturing process.

When choosing a contact cleaner, check its credentials. Not only does it need to clean well, but it must work with the components it is used on. It must be compatible with all materials of the assembly. Look at its Kb value: is it low enough to be suitable for all surfaces? Is it nonflammable, and can it safely clean a variety of electronic mechanisms from connectors and relays to wiring harnesses and mechanical devices, all while the equipment is energized and operating? Does it have strong dielectric properties to prevent electrical shorting while the cleaner is drying? Consider worker safety and environmental and regulatory compliance. Modern contact cleaners on the market today can comply with strict air quality regulations and are formulated to meet stringent safety requirements.

Do not overlook price point. The cleaner must work within the budget. Perhaps consider the use of a controlled dispensing system that attaches to the contact cleaner. This method delivers faster and better cleaning with less waste. □

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Defining Acceptable Voiding Levels Under QFNs

Will IPC accept the >50% voiding recommendation?

WE HAVE LONG had numerical guidelines for voiding levels below which we deem acceptable for BGA joints. Originally from IPC documentation, the limit called for less than 25% voiding of the joint area when the joint is looked at from the top-down in x-ray. More recently, and entirely because of evidential data, this has been increased to 30%.

Many other joint types also given designated qualifications in the IPC guidelines, such as through-hole joint fill levels, can be evaluated using x-ray. However, there has always been an anomaly in the level of voiding in bottom termination components (BTCs). To date, no evidence-backed, indicative values are published detailing acceptable voiding in these joints and, in particular, the large central pad under QFNs.

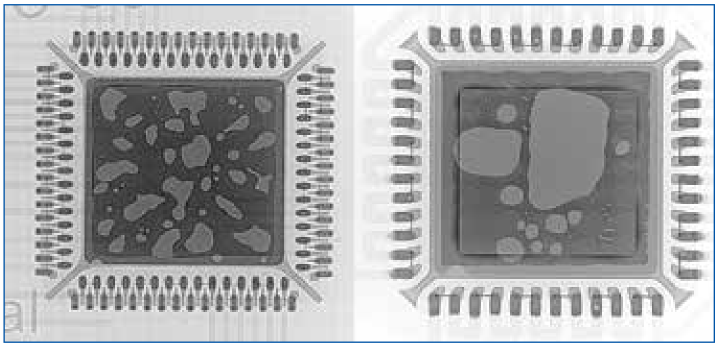

FIGURE 1. Two QFNs with different levels of voiding under the central termination.

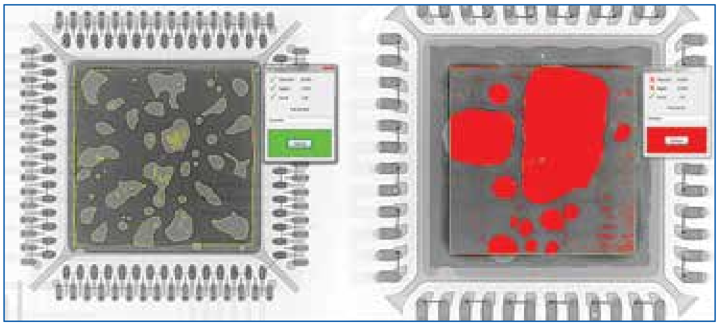

FIGURE 2. Void calculations.

The primary reason for this is the lack of appropriate data upon which to base a criterion. Without evidence, the standards writers cannot propose values that will impact how our industry does business. For QFNs, however, this is now all set to change. For that we thank Dave Hillman, chairman of the IPC Voiding Task Group, and his merry band of volunteers. I had the good fortune to listen to Hillman's presentation at the recent SMTA International Conference for Electronics Enabling Technologies (ICEET) titled "Reliability and Voids in QFN Solder Joints: What's the Issue?" Hillman showed data from device manufacturers that indicate thermal performance of large central MLF pads as a function of solder void. (See IPC-7093, Figure 6-19.) This is a performance criterion, however, and while it may set an upper voiding limit to define a failure level, it does not necessarily indicate what value(s) could, or should, be used as a manufacturing process indicator. To correct for this, Hillman presented initial data on lifetime solder joint integrity as a function of void size in QFN central pads for tin-lead and lead-free solders. Further papers on this topic will be presented this month at the SMTA International Conference.

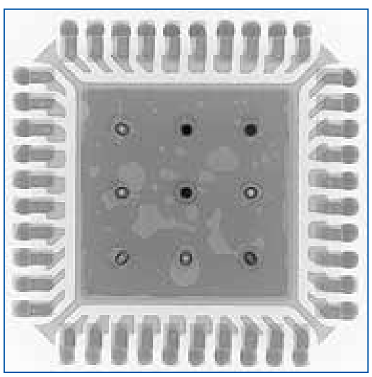

FIGURE 3. X-ray image of a QFN with vias located over the top of the central pad. Vias on the left are much lighter in grayscale due to the presence of solder.

From these data, Hillman and his team are recommending modifying IPC J-STD-001, section 7.5.15, Bottom Termination Components (BTCs), to indicate that, under manufacturing best practices, voiding in the central pad termination be less than 50% of the available wettable area. This recommendation has yet to be voted on by the appropriate IPC committees. Therefore, as Hillman says, those who have any comments or concerns as to why this should not be the case, especially backed with data, should make their representation to the task group, which meets at the next IPC Apex Expo conference in February.

Note that this guidance is only for the large central termination under QFNs. It does *not* give a suggested value for maximum voiding under the typically smaller QFN edge terminations. The task group does not have data for this. Therefore, for edge terminations, acceptable voiding levels

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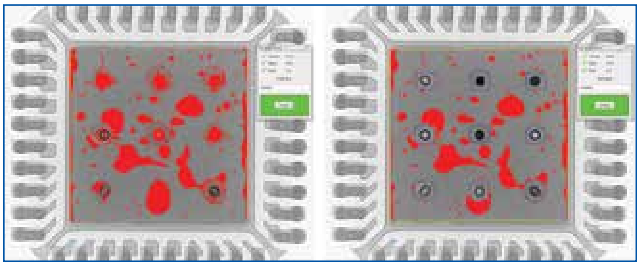


FIGURE 4. Software void calculation without (left) and with (right) adjustment/allowance for the vias of the device in Figure 3.

still need to rely on contracted rules between assembler and customer. (Unless, of course, you have good data that can be shared with the task group to help define this as well!)

The other point to note is the term "available wettable area." This is because QFNs in the dataset used did not have vias in the central pad. When vias are present, they can be seen as low-density areas in the x-ray image and included in the calculation as "apparent void areas" by typical x-ray system void calculation software. These "via voids" should not be included in the total void calculation when determining whether a process is within its parameters. Finally, this recommendation is a limit for the total voiding level. There is *no* clause for the maximum size of a single largest void within the total area, something I have observed has often been discussed in setting void limits under QFNs. Again, this cannot be designated in the committee's recommendation at this time owing to lack of hard evidence.

As examples of the proposed recommendation, consider the following images:

FIGURE 1 shows two QFNs with differing levels of voiding under the central termination. In neither device are vias located over the central pad.

FIGURE 2 shows the void calculation made by the x-ray system on the two QFNs in Figure 1. The calculations indicate the QFN on the left has total voiding under the central pad of ~30%. The QFN on the right has just over 50% voiding under the central pad, thereby exceeding the proposed guidelines.

FIGURE 3 shows an x-ray image of a QFN with vias located over the top of the central pad. Note the vias on the left are much lighter in grayscale compared to their surroundings. In this sample, some vias also include some solder in their depth, making them much darker than their surroundings. Both situations will impact the typical x-ray system void calculation when undertaken on this type of image (see FIGURE 4).

Figure 4 shows the software void calculation both without (left) and with (right) adjustment/allowance for the vias of the device in Figure 3. Without adjustments (left), the void calculation is ~21%. By excluding areas around each via using additional software features (blue boxes, as seen on right) the void calculation becomes ~16%. Both are within the proposed guidelines but also indicate differences will occur and will be especially meaningful if "voids" from the vias push the total voiding above the suggested level.

An alternative approach to editing regions from the x-ray image before making the voiding calculation is to take a schematic of the device and compute the total area percentage covered by all the vias as a function of the total pad area. This value can then be subtracted from the software calculation made from the original x-ray image and without making any additional modifications. However, will you remember the correct value to subtract for each QFN in each board? And what if there is "real" voiding at the pad location under specific vias? In this latter situation, the voiding will not be included in the calculation. Another more interesting approach is to use the PCT technique, if available on the x-ray system, to make a 3-D model of the QFN and select only the pad slice level and make the software calculation only at that depth, thereby removing the vias from view completely (and also from any calculation).

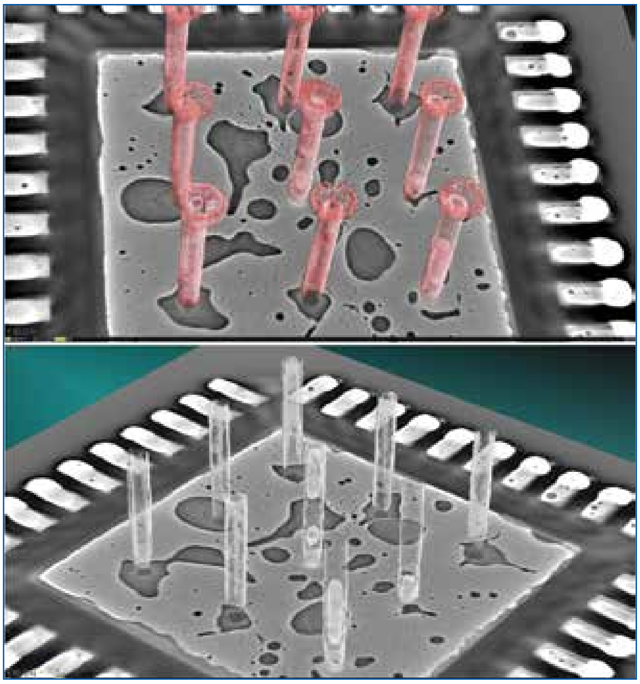


FIGURE 5. 3-D representations of the PCT model created for the device in Figure 3.

FIGURE 5 shows 3-D representations of the PCT model created for the device in Figure 3. The position of the vias above the central pad is clear and indicates the location of the solder down some of the vias.

FIGURE 6 shows 3-D representations from the PCT model only at the pad level in the device. All other information has been removed. Using these data permits the software void calculation to be made on the reconstructed 2-D slice at this level only, as seen in Figure 7.

FIGURE 7 shows the reconstructed 2-D slice at the pad level in the QFN shown in Figure 3 and the software calculation of the total voiding at this level, which is ~24%, again well within the proposed guidelines.

It is worth noting, for most x-ray systems, additional error in the voiding calculations can be caused by how the pad area is defined for the computation. This could be manually, such as by drawing a rectangle around the pad, or by setting a grayscale threshold and letting the software define the pad limits. Whichever approach is used, it is possible to make the value of the pad area smaller or larger than its true number. This will have a meaningful impact on the total void calculation, as the total void area seen in the image may be divided by a smaller or larger value for the pad area than it should be. Therefore, I would suggest all these voiding calculations be considered to include a reasonable error bar of a few percentage points; adjust internal process indicators accordingly. Do not consider voiding of 49.9% = good and 50.1% = bad. Apart from the likely error in the measurements, this misses the point of a process indicator: if voiding is in the ~40-50% range, should this not make you ask questions of your process?

Subject to agreement and approval, for the first time there will be a guideline for the acceptable level of voiding present under central pad terminations of QFNs. It says manufacturing best practices is voiding less than 50% of the available wettable area. Many x-ray systems can make these calculations, but consideration must be given as to the nature and structure of the device so that vias seen as voids, for example, are not included in the calculation. ❑

Au.: Images courtesy Peter Koch, Yxlon International.

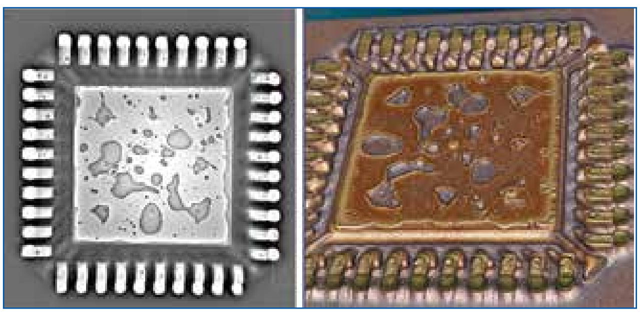


FIGURE 6. 3-D representations from the PCT model at the pad level in the device.

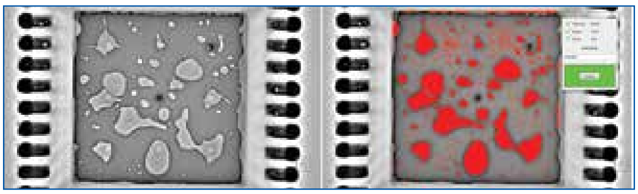


FIGURE 7. The reconstructed 2-D slice at the pad level in the QFN shown in Figure 3.

Further Field Studies

As we venture out among the aerospace industry, it helps to know the lingo.

FOUR YEARS HAVE elapsed since we last provided discerning readers with a helpful field guide to the major species inhabiting trade shows. Four years is a long time. Has anything changed? Have the major species evolved? Regressed? Have some gone extinct or suffered outright obsolescence? What are the replacements?

The quest for knowledge beckons us back to the field.

Curiosity about a changing world and an evolving industry propels us to don pith helmets and binoculars and return to the source. Post-graduate work commences now.

Today's trade show showcases military and aerospace supply chains. Four years ago, we looked at electronics, broadly based, with commercial applications. Wares were hawked, and sales methods were scrutinized at well-known commercial and industrial events. Today we consider items that shoot, explode, report, eavesdrop, interfere (jam), transmit, receive, intercept, and encrypt or decrypt. To exact specifications. Objects sold here ascend, plummet, and follow ballistic trajectories on one-way missions, the warranty expiring on impact (no extension needed). They may settle into low earth or geosynchronous orbit. In many cases, they fulfill an application in which a protagonist initiates action at one end, and their antagonist resides at the receiving end of the transaction. The result is usually transformative for one party. That's a diplomatic way of saying they have a limited lifespan. Some win, some lose.

Because our Way of Life must be preserved. It's also good business.

Serious business.

Button down those collars and trim that hair to regulation length, soldier; we're going in.

Immediately, the difference from four years ago is apparent: shirttails are firmly tucked in at this show. Hawaiian shirts proliferate among engineers at shows for "civilian" applications. Not here. The Big Lebowski does not thrive in Acronymland. This crowd is more circumspect. For a reason. Drawing attention to oneself is not in your best interest. Stick with the acronyms, follow the statement of work, and complete the mission. You will be audited.

Speaking of which: NASA, JPL, NRO, SBIR, NRO, NIST, ANSI, DTSC, AS9100, NADCAP, NSA, ITAR. Know the lingo or you won't pass muster, mister.

This world knows a different business cycle. Defending our cherished values means eternal vigilance.

From which follows eternal cashflow.

If what you build is built correctly. In a world where there often is one customer, mistakes have existential effect, with no statute of limitations.

With that sobering background, which new or evolved species do our field surveys reveal?

Consider:

The New Hire (*Millenianus Niavae*). Easily identified by youth and propensity to address others, irrespective of name, title, rank, social position, or educational pedigree with the salutation "hey." Often dispatched by unseen superiors to shows like these for information-gathering purposes, without attribution. Frequently does not possess business card, the better to avoid intrusive salespersons. Rarely makes eye contact with anything or anybody, aside from smartphone screen. Unsubstantiated reports say this species subsists on a daily diet of avocado toast. Studies speculate only a small minority of this cohort will work for the same company their entire career. Good with apps. Does not carry cash. Often does not know what cash is. Known also to harbor delusions of entitlement (to what is not always clear).

Our future. Prudence and good business sense demand we subsume judgment (easily dispensed) for the greater good. Lord knows it's a target-rich environment, inviting critical commentary as gravity to a black hole. The temptation to speak one's mind (speaking truth to lack of power?) never ends. Easy. Recognize the talent. Those countless Little League participation awards were earned for a reason.

If we want to go to the moon again, or Mars and beyond, these young people will be writing the equations steering the trajectory of the vehicles to get us there.

Just check their math.

Next:

The 3D Printing Engineer (*Tridimensionalis Additivae*). Creates all manner of objects quickly, frequently one-off, to validate product designs quickly. Like circuit boards. Or hip joints. Or solid and liquid fuel rocket engines. Ideally suited for aerospace applications because of the unique, limited nature of each production run. The species existed in 2015, but it rose to prominence concurrently with the rise of commercial spaceflight engineering. Thinks in days and weeks, rather than months and years. Often observed in the wild as a hybrid, blended species, combining the attributes of the New Hire (described above) with the software knowledge necessary to create three-dimensional objects from materials as varied as plastic composites and metals such as titanium. Persistent rumors abound that representatives of this species are actively researching means of creating 3-D printed avocado toast.

ROBERT BOGUSKI is president of Datest Corp. (datest.com); rboguski@datest.com. His column runs bimonthly.

Once championed as the universal prototype manufacturing solution, 3-D printing techniques, additive as well as subtractive, have hit their stride recently by focusing on mechanical engineering, medical, and aerospace products. Regarding the latter, 3-D-printed rocket nozzles, struts, engine nacelles and fairings, to name but a few among hundreds of applications, are now the norm. With NASA withdrawing to the background and apparently transforming itself from a spaceship builder to a new primary role as a certifying and regulatory agency, technologies like 3-D printing have become integral to the proving process.

As test engineers, we participate in this evolution by imaging 3-D-printed parts, whether in an inspection role (looking for flaws, voids, or other defects), or performing what is called nominal/actual comparisons, in which the finished object is scanned and rigorously compared to the original design data for dimensional faithfulness. We could tell you a lot more, but we'd have to ….

There's more:

The Artificial Intelligence Engineer (*Gnosis Pseudonomae*). Big data person. Likes drones (the flying vehicle kind, not the earthbound, rulebound, eyeshade-wearing accountant kind). Responsible for pipelining massive amounts of data from aircraft and spacecraft systems, especially navigation systems and engines. Developer of machine vision systems and algorithms for identifying air traffic hazards, runway and taxiway incursions, and automating flight maneuvers previously controlled exclusively by human input. Risk assessment in action, data derived from artificial intelligence determines whether certain air missions are best conducted by humans or robots. Embodiment of evil in the minds of some futurists for allegedly spreading the belief that robots will take over the world.

Beep!

The spawn of drones and data. Not that data delivery is new. It's just bigger. As recent Apollo 11 retrospectives have shown, telemetry data monitoring spacecraft performance goes back to the 1960s. We just have more of it now, and in volumes inconceivable 50 years ago. Every aspect of vehicle performance is now recorded as a routine matter, and sometimes not so routine (plane crash forensics, for example). Drones seem now to proliferate in the same manner of development as 3-D printing was thought indiscriminately applicable 10 to 15 years ago. The winnowing of applications for drones has yet to begin (pizza delivery?). So, the field for engineers is wide open. As is the need for digital imaging activities to support hardware development and validation.

Yet another species:

The Biofuels Engineer (*Alternativus Propulsionensis*). Developer of chemistries and engine systems not exclusively dependent on fossil fuels. Invents fuels from agricultural feedstocks and synthetic sources. Also intimate with electric and hybrid-electric propulsion systems.

Fertile ground (pardon the expression) for chemical engineering and materials science graduates. Alternative aviation fuels represent less than 1% of total consumption today, per *Aviation Week & Space Technology*, but the field, and the demand, is growing. Could the day arise when America's farmers depend on aerospace rather than China for their livelihood? One wonders.

Fuel and propulsion technology involve materials. CT scanning evaluates materials. Hence our involvement.

The last new sighting:

The Cubesat Engineer (*Economicus Vehiculae*). Designer of micro-miniature satellites for (mostly) scientific applications. Can be launched into Earth's orbit in large groups, thereby distributing cost over many applications. Works with colleges, universities and aerospace startups to develop projects of particular academic or commercial interest, or whose inherent risk does not justify the expense of larger, more costly launch vehicles. The cubesat engineer often works for a college or university. Some of these schools actively exhibit at aerospace trade shows, touting their minisatellite expertise.

The Poor Man's Sputnik, Cubesat clusters frequently occupy otherwise unused space on research rockets. The standard 1U Cubesat is 10 x 10 x 11.35cm (4 x 4 x 4.5") and weighs about 3lb. To date, nearly 1,000 cubesats have been sent into Earth's orbit, exciting aeronautical engineering graduate students across the globe. The standard volume enables quick payload interchangeability. Cubesats are easily grouped together into 2U and 3U clusters for launch.

Most cubesats and their payloads eventually outlive their usefulness and burn up in Earth's atmosphere upon reentry. The very few that manage to make it back to terra firma eventually find themselves in laboratories such as ours, where payloads are examined under x-ray and CT scanning for mechanical stress and suitability for relaunch. Thin college space budgets can be stretched even thinner, if lifecycle analysis is favorable.

Enough with the new. Lest you think the wild has changed completely, fear not, because one species is immortal:

The Sales Rep (*Granularius Preposterii*). Preternaturally optimistic. If not optimistic enough, switches careers to become more so. ("Weren't you selling circuit boards the last time I saw you?") Makes abundant use of buzzwords (granularity, reaching out, circling back, touching base, synching up) to divert attention from lack of technical know-how. Says business is always good, even when it isn't. Has disturbing propensity to bend the truth to suit his or her interests. Has very short attention span.

This species is also abundant. It has yet to be replaced by a robot or sustained by biofuel. As to the artificiality of this species' intelligence, reader, you must judge.

Let us also salute the Old Guys. The Old Guys never go away. We just get new ones, with new stories of analog computers and vacuum tubes. And now Saturn V rockets and short-sleeve white shirts and thin black ties. Trade shows for them are social events.

In parting, they also harvest our swag pens in bushels.

As if we didn't notice.

Like always. ◻

An In-House Solution to Odd-Form Part Inspection

When commercial AOIs were not up to the task, a little internal ingenuity saved the day.

WHILE THERE IS great debate in the quality community as to who first made the observation that visual inspection by humans is not 100% effective (both W. Edwards Deming and Dr. Joseph M. Juran have been given credit) and even some debate about the true effectiveness rate (is it 75%? 80%? 85%?), all agree it is inefficient and error-prone. Yet, automated optical inspection is often deemed not cost-effective for relatively simple processes in many factories.

One area that is often problematic for electronics manufacturing services providers is odd-form part through-hole insertion. Through-hole odd-form parts continue to be used when a part's weight or need for a more robust solder joint makes that level of interconnection more reliable. Transformers, large capacitors, diodes, relays, connectors and pressure sensors are few examples of parts that are often still packaged as through-hole. Manual assembly, like manual inspection, is prone to variation and associated defects, particularly issues such as misaligned parts, missing parts or wrong parts. Odd-form parts are typically of a size or shape that makes automated insertion methods impractical.

SigmaTron's facility in Chihuahua, Mexico, performs high-volume assembly of products, which includes printed circuit board assemblies (PCBAs) with paced, manual assembly requirements driven by odd-form parts. The engineering team wanted to automate the visual inspection process of that segment of production. Commercially available vision systems were cost-prohibitive, and in most cases could not be customized to inspect the full range of parts that needed inspection. So, the team decided to create its own inline inspection system, utilizing in-house process engineering, machine shop resources, technicians and test engineering development personnel. The engineering team developed a system using an off-the-shelf camera system and mechanical components combined with internally developed software and fixturing for each board type.

A pilot system was developed and tested in the fourth quarter 2018. The team made improvements after finding that larger PCBAs required more cameras, and the illumination system required adjustment to compensate for reflections off the PCB substrate. A barcode scanner is being added to facilitate automated test data capture. Fine-tuning was required to achieve consistent identification of wrong polarity capacitors, since polarity markings on some were difficult for cameras to see. Once the improvements were added, the only type of defect the system couldn't identify was lifted parts. Four systems have been built and deployed in production. An additional four are scheduled to be installed later in 2019.

The systems have been installed pre-wave solder, so insertion defects can be identified and corrected prior to the components being soldered to the board. Each line's conveyor system runs through the machine, and the inspection timing is paced to line output goals, so inspection adds minimal time to the process. An operator next to the system provides real-time feedback to operators further up the line if defects are found so immediate corrective action can be initiated.

From a Lean perspective, the system helps eliminate variation because it identifies issues prior to soldering and eliminates unnecessary processing time and added thermal cycles associated with rework.

The results provided by automating visual inspection were so positive, the team built a modified version of the system for SigmaTron's facility in Elk Grove Village, IL. That production area's volumes are much lower, and, in this case, the system is table-based and used post-wave.

Use of the system in Chihuahua has reduced rework by 90%. It takes less than half the time of a human inspector to inspect each PCBA. In EGV, gauge R&R validation tests indicated it is inspecting with 100% accuracy. It is also about 5% of the cost of third-party systems, which makes it cost-effective to use at multiple points in production processes with minimal adjustments.

The result is an automated vision solution that provides the required customization capability at a cost point that makes deploying systems at multiple areas in production cost-effective. Throughput has been improved, since inspection time has been significantly reduced. Most important, the inefficiencies and thermally driven defect opportunities created by rework have been significantly minimized in operations using the systems pre-wave. ❑

GERARDO RUELAS is engineering superintendent at SigmaTron International Chihuahua, Mexico (sigmatronintl.com); gerardo.ruelas@sigmatronintl.com.

CESAR DE LA TORRE is test software development engineer at SigmaTron.

01005 Termination Lift

Inappropriately sized pads can result in excessive solder and, eventually, defects.

THIS MONTH WE show soldering of 01005 chip resistors from an early project with lead-free assembly. The microsection image in FIGURE 1 shows a few issues, but it's the circles in both joints that caught my eye. Yes, they are voids before they are unmasked. During sectioning we stopped just before entering the void. Most would have continued a few more micros to remove the thin sliver of solder, which was the wall of the void, to show the void. But everyone has seen voids before!

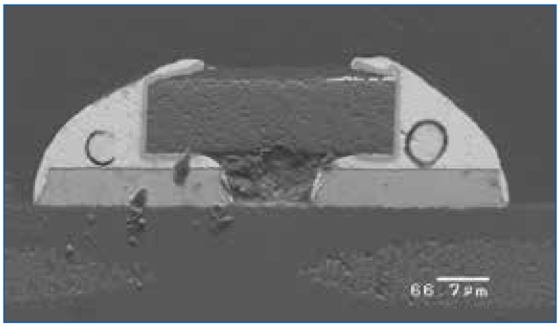


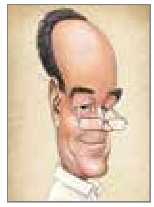
FIGURE 1. SEM images show round circles on the joints, excessive pad length and termination lift on top of the resistor.

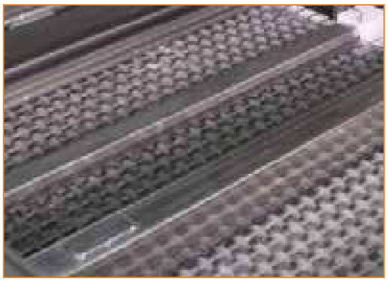
Now to the important part. The pad size is too large for this small passive device and contributed to the addition of too much paste during printing. The length of the pad was reduced in further trials. During soldering, solder reflowed and wet over the top of the resistor termination. This resulted in lifting of the wraparound termination on both sides.

We have only experienced this on resistors in package sizes of 0201, 01005 and the next level of micro parts. Close examination of parts before assembly from the same batches of resistors did not show termination lift or damage on new parts. Lifting of the termination will most likely be due to contraction of the solder during solidification.

We have presented live process defect clinics at exhibitions all over the world. Many of our Defect of the Month videos are available online at youtube.com/user/mrbobwillis. ❑

BOB WILLIS is a process engineering consultant; bob@bobwillis.co.uk. His column appears monthly.



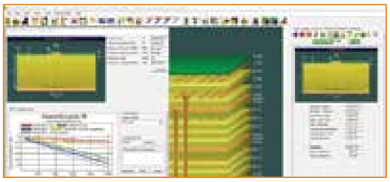


HORIZONTAL WET PROCESSING

Polygon PLB horizontal production equipment line is for multilayer, rigid-flex and HDI panel processing. Wet-in-wet, inline, desmear and electroless copper production line has advanced fluid delivery system, reduces consumption rates for chemistry and water, and an operator-friendly design. Comes with Securiganth and Printoganth product series.

Atotech

atotech.com

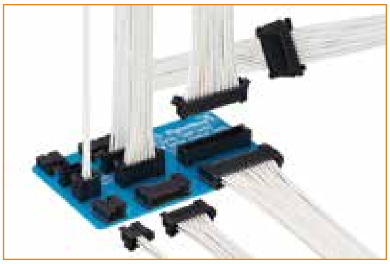


S-PARAMETER LOSS ANALYSIS

Si9000e now comes with LA9000 S-parameter loss analysis options and new Monte Carlo analysis option. Updates bidirectional copy/paste interface between Speedstack and Si9000e. Has improved support for loss tangent (RefTanD). Causal modeling now extended to copper losses.

Polar Instruments

polarinstruments.com



WIRE-TO-BOARD CONNECTOR

DF51 series 2.0mm pitch connector has a lock that provides a clear tactile click and secures a reliable connection. Dual side-lock design prevents socket lift due to vibration or cable wrenching. Crimp connector comes in straight, right-angle, inline connection, and single- or dual-row. Single-row versions are offered in two to six positions, while the double row comes in four to 30 positions. Operating temp. -40° to +105°C.

Hirose

hirose.com

OTHERS OF NOTE

POWER MICROWAVE LAMINATE

TC350 Plus ceramic-filled PTFE-based woven glass reinforced composite materials have thermal conductivity of 1.24W/mK. Advanced filler system enables improved mechanical drilling performance. Offered with smooth (Rq= 1.0µm) ED copper foil cladding to reduce insertion loss and RF heating of conductors. Thicknesses of 0.010" to 0.060". Z-axis CTE of 38ppm/°C, loss tangent of 0.0017 at 10GHz, moisture absorption of 0.05%, dielectric strength of 650V/mil. UL 94 V-0.

Rogers Corp.

rogerscorp.com

CIRCUIT SIMULATION SUITE

PathWave Design 2020 accelerates design workflows for RF and microwave, 5G, and automotive design engineers. Includes new releases of PathWave ADS 2020, GoldenGate 2020, SystemVue 2020, and Genesys 2020. Includes libraries, customized simulators, and automation improvements. Integrates circuit design, EM simulation, layout capabilities, and system-level modeling. Integrated EM simulators for RF and power electronics.

Keysight

keysight.com

SEMIAQUEOUS PHOTORESIST STRIPPER

LDI Strip 77 is for stripping very fine-line and high-density boards. Produces particles 2 mils in diameter and smaller. Provides resist removal with standard dry film and LDI dry film. Additive package protects metal surfaces against corrosion, including copper and tin. Enables ease of inspection at outerlayer AOI.

RBP Chemical Technology

rbpchemical.com

AUTOMATED DESIGN REVIEW

Valor NPI 11.0 DfM software automates design reviews where PCB technology and manufacturing processes are employed. Adds assembly DfM checks to new process flow. Results simplify execution of DfM application and integrate DfM into Xpedition software layout application. Scales process to access DfM results on demand. Works with all major PCB layout tools.

Mentor

mentor.com

'EASY-ASSEMBLY' CONNECTORS

1.25mm pitch SlimStack floating board-to-board connectors are designed to prevent fretting corrosion. High vibration resistance. Spring design increases contact reliability. Wide floating range in three different directions reduces PWB gap and facilitates assembly, even in misalignment and blind joining situations. Include improved contact design and soft floating force. Have 10 circuits, a 125V voltage rating, a 1.0A current rating and 10-cycle durability.

Molex

molex.com

STRETCHABLE FPC

Stretchable flexible printed circuits offer elasticity; replace polyimide used in existing FPCs with elastic substrate. Can be stretched repeatedly and are heat-resistant, permitting components to be solder-mounted. Circuit conductor incorporates same copper wiring as existing FPCs, but wiring method is designed to allow it to work with stretchable substrate. Copper wiring minimizes variations in conductor resistance due to FPC expansion or contraction, permitting use of FPC as a sensor.

OKI Electric Cable

oki.com/en

'TOOLLESS CHANGE' TIPS

Active RT soldering tips for WX soldering stations comply with IPC standards. MS versions are Mil-Spec-compliant. Boomerang handle permits precise handling and has ergonomic and secure grip. Patented tip/handle unit enables toolless tip change.

Weller Tools
apextoolgroup.com

DIGITAL MEGOHMMETER

#880 static control instrument is for use in electrostatic protected areas (EPA) for testing static dissipative surfaces. Is said to be accurate and dependable for point-to-point (RTT) and resistance-to-ground (RTG) compliance verification and qualification assessments. Results are shown in numeric value within 10^{e3} to $10^{e12}\Omega$. Applies 10V and 100V manually or automatically.

ACL Staticide
aclstaticide.com

ORBITAL SCARA ROBOTS

YK-XG and YK-TW robots contain advanced features for efficient movement and long-term accuracy. By placing the tip-rotation axis directly in line with the speed-reducing gear, leveraging a specially designed hollow motor, the YK-XG beltless drive permits fast R-axis rotation with large offset loads that require traditional belt-driven robots to decelerate. Latest models feature x-y axis speeds of 7.6m/s.

Yamaha Factory Automation
yamaha-motor-im.de/en/fa/

OTHERS OF NOTE

IOT DEVICE HANDLER

SentriX enables the secure provision and personalization of IoT devices using NXP EdgeLock SE050 secure element. EdgeLock SE050, along with SentriX-enabled provisioning as-a-service, offers combination of hardware-based security robustness, design flexibility and manufacturing production ease of use. Is for prototypes through high-volume production. Plug-and-Trust features permit implementation of high-performance security for sensing and control, secure connections to multiple cloud services, and offer integrity protection for IoT platforms.

Data I/O
dataio.com

AUTOMATED ASSEMBLY PLATFORM

Microfactories combine software, machine learning, computer vision, and adaptive robotics into an automation platform for assembly and inspection. Leverage AI and cloud-based architecture. Comprised of cloud-based software for design, simulation, and deployment of configuration and instructions used to set up and run physical production assembly lines, including factory applications that intelligently monitor, track and manage the line, robotic cells, and more.

Bright Machines
brightmachines.com

CONFORMAL COATING CLEANER

Atron DC removes conformal coating from pallets, fixtures and tools. Removes acrylics, urethanes and epoxies. Water-based, pH-neutral formula improves worker safety. Is suitable for use in most maintenance cleaning equipment, including dip tank and ultrasonic machines.

Zestron
zestron.com

2-PART POTTING COMPOUND

EP21TP-2NV is a two-part epoxy polysulfide formulated for use as an adhesive, sealant and potting system. Withstands prolonged exposure to harsh chemicals. RoHS compliant. Elongation between 40-80% at room temp. Tensile strength of 3,000-4,000psi.

Master Bond
masterbond.com

LED PLACEMENT MACHINE

MC-LEDV6 LED pick-and-place machine is capable of speeds up to 30,000cph. Handles 4-ft. long boards in single pass. Has fly-over vision, six placement heads and newly designed x-axis linear drive mechanism. Also places connectors and other parts up to 20mm x 18mm.

Manncorp
manncorp.com

FAST-PROCESSING EPOXY

Delo-Duopox DB8989 light fixation two-component epoxy resin provides fast process speed. In a couple of seconds, light fixation secures components. After an irradiation time of 5 sec. at an intensity of 1000mW/cm², fixing strength of 1N/mm² is achieved. Final curing, including shadowed areas, is done at room temp. or via heat curing at 80°C for 60 min. Storage life 12 mo.

Delo Industrial Adhesives
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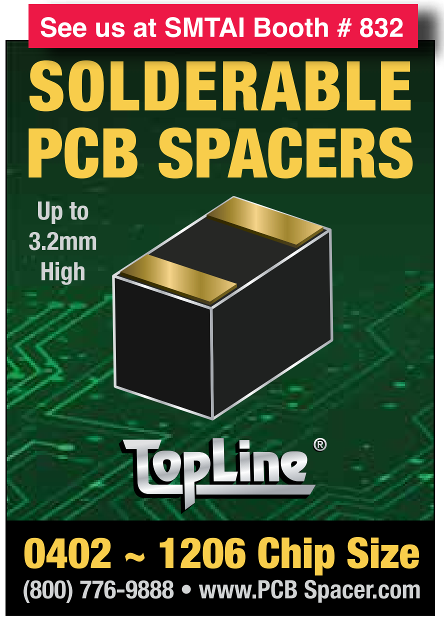
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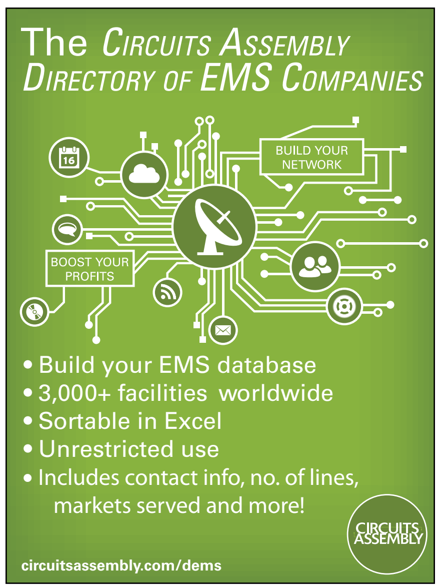
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In Case You Missed It

Advanced Materials

"Metal Oxide Semiconductor Nanomembrane-Based Soft Unnoticeable Multifunctional Electronics for Wearable Human-Machine Interfaces"

Authors: Kyoseung Sim, Zhoulyu Rao, *et al*; cyu13@central.uh.edu.

Abstract: Wearable human-machine interfaces (HMIs) are an important class of devices that enable human and machine interaction and teaming. Recent advances in electronics, materials, and mechanical designs have offered avenues toward wearable HMI devices. However, existing wearable HMI devices are uncomfortable to use and restrict the human body's motion, show slow response times, or are challenging to realize with multiple functions. Here, the authors report sol-gel-on-polymer-processed indium zinc oxide semiconductor nanomembrane-based ultrathin stretchable electronics with advantages of multifunctionality, simple manufacturing, imperceptible wearing, and robust interfacing. Multifunctional wearable HMI devices range from resistive random-access memory for data storage to field-effect transistors for interfacing and switching circuits, to various sensors for health and body motion sensing, and to microheaters for temperature delivery. HMI devices can be not only seamlessly worn by humans but also implemented as prosthetic skin for robotics, which offer intelligent feedback, resulting in a closed-loop HMI system. *(Science Advances,* Aug. 2, 2019; https://advances.sciencemag.org/content/5/8/eaav9653).

Flexible Electronics

"Heat-Free Fabrication of Metallic Interconnects for Flexible/Wearable Devices"

Authors: Andrew Martin, Martin Thuo, *et al*; mthuo@iastate.edu.

Abstract: Exploiting interfacial excess (Γ), Laplace pressure jump (ΔP), surface work, and coupling them to surface reactivity have led to the synthesis of undercooled metal particles. Metastability is maintained by a core-shell particle architecture. Fracture of the thin shell leads to solidification with concomitant sintering. Applying Scherer's constitutive model for load-driven, viscous sintering on the undercooled particles implies they can form conductive traces. Combining metastability to eliminate heat and robustness of viscous sintering, an array of conductive metallic traces can be prepared, leading to a plethora of devices on various flexible and/or heat-sensitive substrates. Besides mechanical sintering, chemical sintering can be performed, which negates the need for either heat or load. In the latter, connectivity is hypothesized to occur via a Frenkel's theory of a sintering-type mechanism. This work reports heat-free, ambient fabrication of metallic conductive interconnects and traces on all types of substrates. (*Advanced Functional Materials,* July 15, 2019; https://doi.org/10.1002/adfm.201903687)

Solder Materials

"Effects of In and Zn Double Addition on Eutectic Sn-58Bi Alloy"

Authors: Shiqi Zhou, Yu-An Shen, Hiroshi Nishikawa, Tiffani Uresti, Vasanth C. Shunmugasamy, and Bilal Mansoor; charleszhou1992@gmail.com.

Abstract: The effects of 0.5 wt. % In as well as 0.5 wt. % In and 1 wt. % Zn double (In & Zn) additions to eutectic Sn58Bi alloy on the microstructure and mechanical properties were studied before and after thermal aging. Newly designed In & Zn-added Sn58Bi alloy showed much finer microstructure than eutectic Sn58Bi and In-added Sn58Bi alloys. The elongation improvements of 36% and 41% before and after 1,008 hr. aging were obtained in In & Zn-added Sn58Bi alloy compared to eutectic Sn58Bi alloy. In-induced solid solution softening (SSS) effect on Sn phase was revealed by nanoindentation tests. A hardness decrease and a large creep displacement were obtained in both In- and In & Zn-added Sn58Bi. The effects of Zn and In combined were responsible for the elongation improvement of In & Zn-added Sn58Bi. (IEEE Electronic Components and Technology Conference, May 2019)

This column provides abstracts from recent industry conferences and company white papers. Our goal is to provide an added opportunity for readers to keep abreast of technology and business trends.