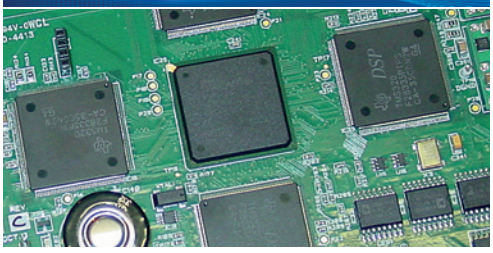
Waukesha Bearings



Leader in Magnetic Bearings Streamlines Innovation with XJTAG® Boundary Scan

"Waukesha Magnetic Bearings, based in Worthing, UK, is using XJTAG to perform boundary scan testing of high-speed real-time digital control boards for its active magnetic bearings. The XJTAG system is in action throughout development and production, speeding up prototyping, saving board re-spins, and helping dramatically reduce production test duration."

Waukesha Magnetic Bearings™ (WMB) leads the industry in custom-engineered magnetic bearing systems for large turbomachinery and high-performing rotating equipment in oil & gas, power generation and defence markets. WMB's hardware designs allow direct immersion in the process fluid often eliminating shaft seals, while the control software provides for automatic tuning, remote monitoring and diagnostics thus reducing operating costs while maintaining near perfect availability. WMB is a Waukesha Bearings Business under the Energy segment of Dover Corporation.

Engineers designing the next generations of digital controllers at WMB's UK technical centre in Worthing, have chosen the XJTAG boundary scan system to help verify new designs, test prototypes quickly, and apply boundary scan tests to production boards.

The XJTAG system quickly gained respect in the development laboratory by helping engineers pinpoint two incorrect connections on the first prototype of a new controller board. These could have taken hours to locate using conventional test techniques, according to Colin Pennifold, Electronics Technician at WMB. "XJTAG saved at least one re-spin of our new printed circuit board (PCB) design," comments Electronics Design Engineer, Steve Dabbs. "The system is easy to use, with time-saving features such as the Advanced Connection Test and ready-to-run scripts for testing many types of memory ICs. We can also test BGA devices, which are almost impossible to test using other means."

XJTAG provides clear reports with clickable links to graphical viewers that guide the user to the detected fault location. These graphical tools include the Layout Viewer and Schematic Viewer, which are featured in both the XJDeveloper application and XJRunner production-test system. The Layout Viewer helps quickly pinpoint faults on the board by highlighting selected components and nets, and allows individual PCB layers to be displayed or hidden for clarity. Schematic Viewer displays the logical arrangement of circuit elements to show how a device is being used in the circuit, and enables faster testing by highlighting areas of interest without requiring the user to continually change applications.

WMB is also using boundary scan as part of the test regime for its production boards, and has integrated the XJRunner system into custom test stations that perform stand-alone testing of the PCBs. XJRunner provided the flexibility for the test engineering department to design and build test fixtures using a CPLD to connect to the PCB under test.

"It was important to have the freedom to create this test fixture, which we are using to test connections and signal paths within the PCB and connections to or from sockets on the PCB," confirms Steve Dabbs. "By adding XJRunner to our production test capability, we have been able to significantly increase test coverage while also achieving substantial time savings over manual testing. In fact, the total test duration has been reduced from around 7.5 hours per board to under two hours.

"Overall, XJTAG has delivered a great return on our investment."

opinion

Steve Dabbs
Electronics Design Engineer
Waukesha Magnetic Bearings

"XJTAG saved at least one re-spin of our new PCB design. The system is easy to use, with time-saving features such as the Advanced Connection Test and ready-to-run scripts for testing many types of memory ICs. We can also test BGA devices."

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"Overall, XJTAG boundary scan has delivered a great return on our investment."

Data Bank

WAUKESHA® MAGNETIC BEARINGS
A Waukesha Bearings Business

Company	Waukesha Bearings Corporation HQ USA
Nature of business	Leading designer / manufacturer of engineered hydrodynamic bearings and magnetic bearing systems
Main product	Custom bearing systems for large turbomachinery and high-performing rotating equipment
Customers	The world's leading OEMs and end-users in oil & gas, power generation, marine/defense and industrial markets
Location	Offices and plants in the USA, UK Russia. Representatives worldwide
Web site	www.waukbearing.com

How NOT to Do an EMS Market Analysis, p. 36

UP

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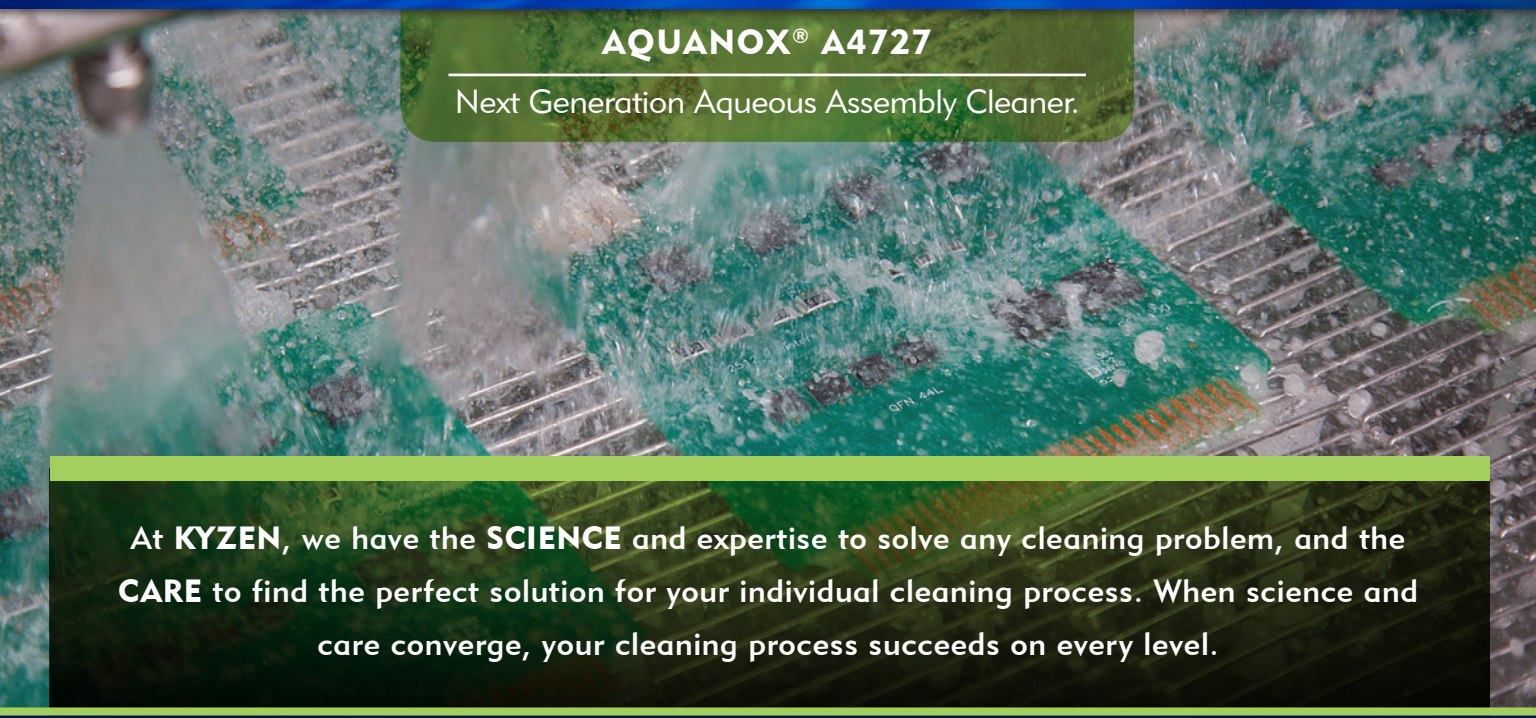

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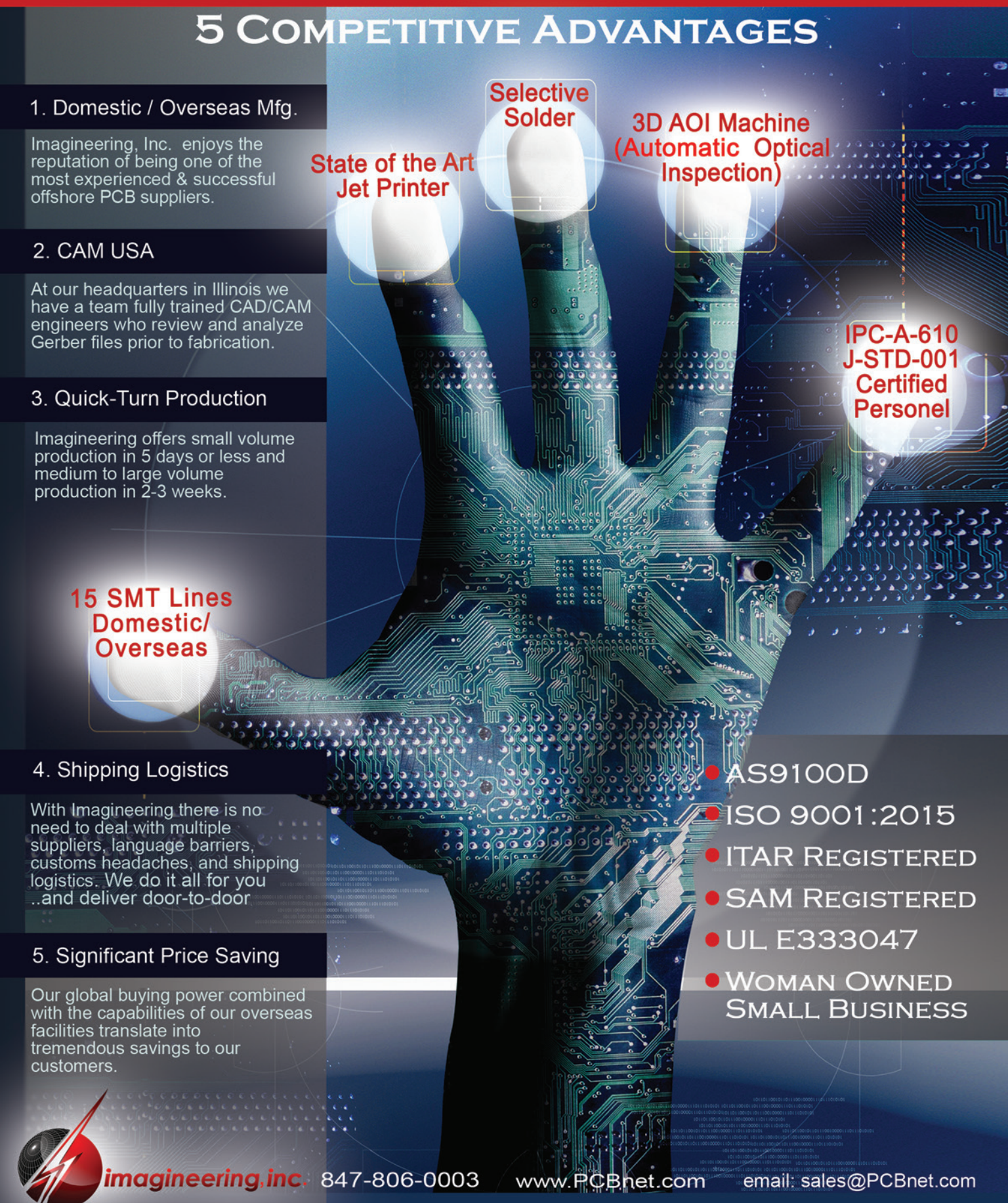

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内容

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FEATURES

IN THE DIGITAL EDITION

The Digital Route
The latest happenings among the IPC Designers Council chapters.
by STEPHEN CHAVEZ

ON PCB CHAT (pcbchat.com)

PCB Chat

Solder Wetting
with TIM O'NEILL

New CAD Platforms
with JEROEN LEINDERS and CHRIS HAMBLETON

Testing Printed Circuit Assemblies
with ROBERT BOGUSKI

Adhesion Testing
with ELIZABETH KIDD

Board Procurement
with GREG PAPANDREW

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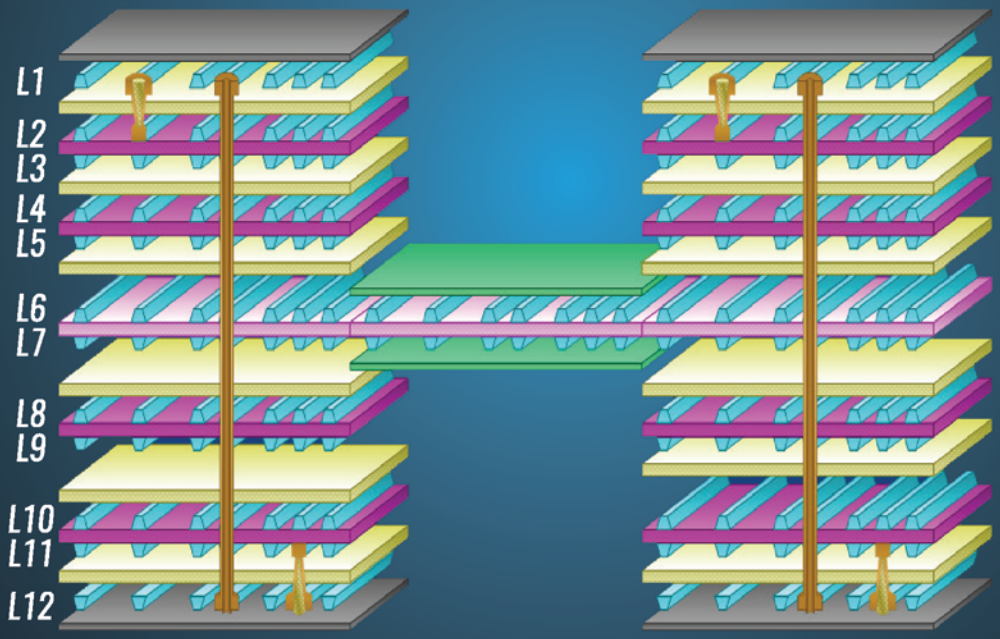

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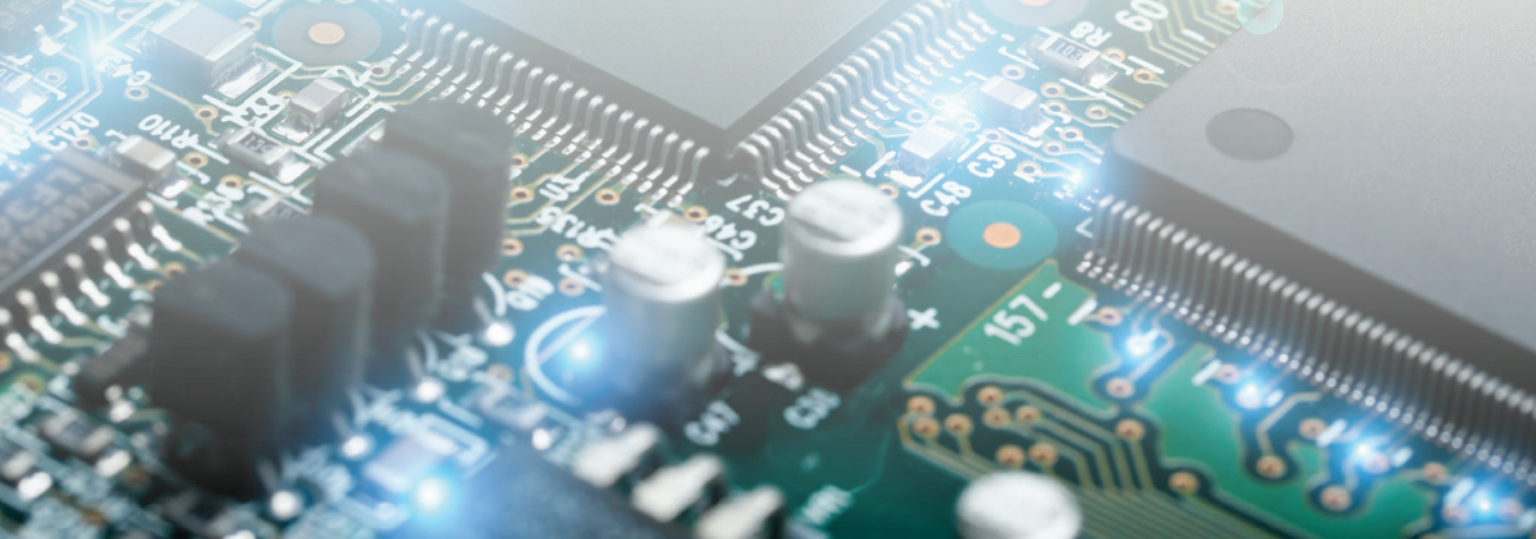

MIKE BUETOW
EDITOR-IN-CHIEF

A Taxing Idea

IT was 16 years ago this month when a group of Chicago-area printed circuit board manufacturers stuck a flag in the ground and declared themselves the new vanguard of the American industry. At an early meeting, leaders called free trade "the seed of our own destruction," and railed against the devastation of the domestic fab industry.

They called on public officials to fight China on currency manipulation and tariffs, and to enact trade policy that better fit the current state of the domestic market. Nothing less than the long-term security of the US was at stake.

The group had a point: Domestic PCB production had fallen by half in three years to $5 billion. Not only was no recovery in sight, but in some cases the deck seemed stacked against them. For instance, raw materials imported to the US from Asia were assessed tariffs, but assembled PCBs were not. Ouch.

(As an aside, just 18 months earlier, a certain editor whose face adorns this page wrote in this space, "How many times have we called the demise of the American PCB industry before, only to be proved wrong?" Double ouch.)

At that time, several regional PCB associations remained intact, if bending under pressure to survive. The USPCA, as the nascent group called itself, grew to roughly 70 members before collapsing, reportedly due to internal friction over direction.

Last summer, a group of Chicago-area printed circuit board manufacturers rallied public officials to take on China. Their platform sounded eerily familiar: They called on public officials to fight China on currency manipulation and tariffs, and to enact trade policy that better fit the current state of the domestic market.

The effort not only sounded much like a repeat of the USPCA, it even included a few of the same players. Shalli Kumar, founder of AVG Group, which was once a large PCB manufacturer, coordinated the session. In an editorial released about the same time, Kumar wrote, "The US manufacturing renaissance we seek and that our national security requires will not take place without a sustained long-term tariff plan that would encourage American businesses, large and small, to invest in new plants and equipment to make these products in the United States once again. What has been stolen from our country cannot be brought back by free trade."

We all know what's happened since.

Another longtime Chicago-area PCB shop owner bent my ear last month over the possibility of reviving or creating an association dedicated to US PCB interests. He suggested setting up a tariff structure that would incentivize onshore procurement. His concept: Orders placed at US plants would be issued credits to offset tariffs paid.

It would work like this: Say you purchase $10 million worth of PCBs offshore and the tariff is 25%. If you give a portion of that spend to domestic plants instead – for instance, $1 million goes to TTM in California – you would get $1 million worth of credit toward tariffs on offshore purchases.

His hypothesis: If companies were to move 10% of what they were buying offshore to domestic plants, their costs wouldn't rise much. But from that swing in revenues, an entire ecosystem would be created. Suppliers would come back. The industry would be healthier.

"We don't need to get back to $10 billion. But $5 billion (would be a big improvement)," he said.

Many, many details would obviously have to be worked out for such a plan to be enacted. How is the value of credits on purchases moved onshore from offshore accounted for in the wake of normal demand swings, for instance?

Most parties we've spoken with agree that tariffs, over time, are more hinderance than help. The feeling here is the tariffs will eventually go away. But even after that fire has been put out, we must still confront the absence of a unified, consensus strategy for the US industry.

What's more certain is that US OEMs and EMS companies will need incentives to buy local. Their offshore supply chains are intact. Adding heavy taxes to core durables will just raise costs for consumers and eventually slow demand. That's counterproductive. I think it's a lesson that's been learned more than once.

Could a new US trade group fill the gap? I think that lesson's been learned too.

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P.S. For more on how suppliers are handling the tariff situation, see our interview with Jack Pattie of Ventec USA on pg. 30.

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PCD&F People

TTM Technologies named **Cathie Gridley** senior vice president and president of the Aerospace and Defense/Specialty business unit.

Z Axis named **Taylor Fowler** electronics design engineer and promoted **Cathy Snow** and **Elizabeth Bennett** to the engineering documentation team.

PCD&F Briefs

Brigitflex installed an **Excellon** 154L vision drilling/routing system.

Cicor installed an **MK Instruments** ESI CapStone laser drill.

Dynamic Electronics told the Taoyuan government it will cut 85% of its PCB workforce in October.

ESI is on the hunt for a new headquarters in Beaverton, OR.

MKS Instruments announced a multi-system order from a leading Chinese flex PCB manufacturer for the ESI CapStone laser drill.

Molex opened a state-of-the-art optical R&D facility in New Jersey.

Subaru is creating control systems for hybrid electric vehicles using Ansys embedded software.

Taiwanese firms are slashing investments in China and upping their spend at home. Government data revealed 123 Taiwanese entities have been approved to make a total of more than $18 billion in new investments in Taiwan this year, while only one Taiwanese electronics company has indicated plans to expand on the mainland.

Zuken has set a three-year growth target of 6.1% annually, reaching 32 billion yen ($302.6 million) by fiscal 2022. Zuken also completed its **Vitech** acquisition, which had approval of the US Department of Defense and the Committee on Foreign Investment in the US.

CA People

ABchimie appointed **Marie Kaing** conformal coating specialist.

AIM Solder appointed **David Kammerer** sales manager for the DACH region in Europe. He will be responsible for new business development and support to existing AIM customers throughout Germany, Austria and Switzerland.

IPC to US Labor Dept.: Qualifications for SREs 'Not Sufficiently Defined'

BANNOCKBURN, IL – IPC submitted comments in late August to the US Department of Labor concerning its proposal to establish a process for recognizing standards recognition entities, which in turn would recognize industry-recognized apprenticeship programs.

In the statement, the trade group said it welcomes the administration's focus on workforce development. IPC's investments in education and training programs are centered on a goal of creating one million new skilled workforce opportunities over the next five years. As part of its efforts, the association plans to introduce new earn-and-learn programs.

IPC said the private sector is best-suited to identify occupational skills workers need to succeed. However, it added, the qualifications for SREs are not sufficiently defined to ensure the most appropriate entities will be given that role. IPC recommends the standards-setting entities be limited to well-established, industry-recognized associations or non-profits.

IPC also calls for apprenticeship programs that require learners to acquire portable, competency-based, industry-recognized credentials, not just certificates of completion.

The DOL proposes to recognize standards-setting entities only in sectors that lack significant registered apprenticeship opportunities today. IPC is concerned about the exclusion of any industries from the program, which could result in uneven incentives and results. – *CD*

Loomia, Eastprint Team on Soft Circuit Systems

SAN FRANCISCO – A maker of patented soft circuit systems and a veteran OEM of printed electronics systems have signed an agreement to manufacture soft circuit systems at scale. The collaboration will enable sensor, lighting and heating integrations, according to the companies.

Loomia has raised more than $1.7 million and is ready to scale its technology. The firm has two patents and has completed three years of research.

PE OEM Eastprint's facilities in Massachusetts and Mexico will be set up to produce Loomia technology.

The firms have conducted trial runs of a non-ink-based soft circuit production system this past year and produced a heating system certified by the Federal Communications Commission.

"From automotive to apparel, our soft circuit systems can be used when standard PCBs aren't up to the task, bringing heating, lighting and sensing to car seats, medical apparel and outdoor gear," Loomia says.

"E-textiles (soft circuits) are predicted to be a $2 billion market in the next decade but lack the supply chain and manufacturability to reach that potential. We believe our Loomia Electronic Layer technology is a solution to this problem." – *CD*

Compeq to Spend Millions on More Capacity in Taiwan

TAIPEI – Compeq Manufacturing plans to invest NT$2.5 billion ($8 million) to expand capacity for PCBs for 5G equipment, Taiwan's Ministry of Economic Affairs said. The printed circuit board fabricator will add about 250 jobs, the agency added.

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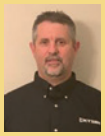

Kyzen named **Jody Saultz** sales support manager. He spent more than 30 years at ITW prior to joining Kyzen.

Libra Industries promoted **Tom Dykeman** to executive vice president of business development. He has more than 35 years in diversified direct sales, contract negotiation, sales force development and management, the past six with Libra.

National Circuit Assembly promoted **Nick Nguyen** to director of quality. He has been with NCA as a quality engineer since 2014 and has an MBA.

PCBASupplies.com named **Scott Fillebrown** president. He has more than 25 years' experience in EMS, including 25 as president and CEO of ACD.

Scienscope named **Adrian Radu** European sales manager. He has experience as in processing engineering and sales with Leoni Wiring Systems, Honeywell and Danutek.

SMTA announced **Ben Stewart**, a graduate student at the Georgia Institute of Technology, has been selected this year's Charles Hutchins Educational Grant winner.

SMTA elected **Julie Silk** of Keysight Technologies, **Ivan Roman** of Continental Powertrain, and **Robert Boguski** of Datest to its board of directors.

CA Briefs

Apple's supply chain is suggesting PCB order momentum ahead of the new iPhone launch has been weaker than that seen in previous years.

Barco is investing $5 million to expand its operations and adding 50 new jobs to its existing facility in Gwinnett County, GA.

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.

BPM Microsystems named **Murray Percival Co.** representative in Michigan, Ohio, Pennsylvania, Indiana and Kentucky.

Cal-Comp Technology (Philippines) expects to raise $169 million from its planned IPO this year, the bulk of which will be used for expansion.

Compeq is the world's seventh largest PCB fabricator, according to the latest NTI-100. – *MB*

Isola to Open New HQ in Arizona

CHANDLER, AZ – Isola Group has completed a 118,000 sq. ft. lease to relocate its headquarters, R&D and manufacturing operations here.

The company will be moving into a newly constructed industrial building. The facility will be optimized for the quickturn PCB market.

"The finalization of the lease agreement and the build-out of our new facility will allow us to optimize our ability to serve the evolving electronics market in North America as it continues to shift from volume manufacturing to low volume, high customization," said Travis Kelly, executive vice chairman and CEO, Isola.

The facility is expected to open in multiple phases starting this month. – *CD*

iNEMI's Value Recovery Project Successfully Reuses Hard Disk Drives

MORRISVILLE, NC – iNEMI's Value Recovery from Used Electronics project participants published a report describing how the project successfully used end-of-life hard disk drives to demonstrate a viable process toward the development of a multi-stakeholder circular economy.

Project activities focused on construction of a set of decision trees to identify the options at each step in the value recovery chain in the context of a circular economy and what information each of the stakeholders needs to pursue higher value recovery along a given pathway; development of economic models, lifecycle assessments and logistics models to determine which value recovery options generate the highest value by type and size of drive. These models provide the basis for business decision-making by the stakeholders, both individually and collectively, as part of supply chains; demonstration projects to prove the efficacy of major critical-to-market circular economy pathways.

The demonstration teams were able to successfully reuse magnet assemblies, recover intact magnets for non-HDD use, make magnets from magnets and shred, make rare earth element oxides from HDD magnets and develop business models that would allow functioning HDDs to be reused/resold after secure, verifiable, economically viable data wiping.

"This report represents a significant body of work," said Marc Benowitz, CEO, iNEMI. "It details the well-coordinated efforts of organizations from across the electronics supply chain that worked together on a practical application of circular economy concepts for electronics. These electronics manufacturing companies, national labs, universities and research institutes were able to successfully demonstrate a circular economy can be a reality for used electronic products."

The Value Recovery project was organized using the Ostrom Framework as a self-managing, sustainable system. The project team went beyond the theoretical in demonstrating value recovery pathways for used HDDs in a circular economy.

"A major emphasis of this work was going beyond theory to identify existing economic and technology challenges to achieving sustained circularity," said Bill Olson, coleader of the Value Recovery project. "In areas where we identified gaps, we worked to bridge those gaps via demonstrations. Our multi-stakeholder teams' demonstrations overcame gaps by applying existing technology in new ways, developing new technologies, or capturing existing but as-yet unrecovered value to achieve sustainable supply via the Ostrom Framework."

The demonstrations proved the effectiveness of multiple recovery pathways for reusing HDDs, including business models needed to securely destroy data so functioning hard disk drives can be sold to new users.

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Cemtrex sold its EMS business, ROB Cemtrex, to a German private equity group for €6.37 million ($7.06 million).

Count on Tools has signed an agreement with **PCBASupplies.com** to distribute COTs' products throughout North America and Mexico.

Danfoss signed **Scanfil** to a global supplier agreement.

Eguana Technologies signed **Jabil** to a multi-year master supply agreement to manufacture residential and commercial energy storage systems.

European Circuits installed a **Seamark** ZM R7220A BGA rework station.

Europlacer will offer **Aegis'** FactoryLogix NPI (New Product Introduction) software module with its automated placement line equipment.

Flex, the largest foreign company in Zhuhai, has seen one of its two campuses go quiet in the wake of the loss of Huawei.

Hanza Holding acquired **Ritter Elektronik** for approximately €12 million ($13.4 million).

Incap is investing more than €4 million ($4.4 million) to expand and upgrade its production facilities in India and Estonia.

Karnataka, India, is working on an incentive package to attract investments for manufacturing of electronic components and assembly of mobile phones and other devices in the state.

Manz has been awarded a contract for several Light Assembly assembly lines from a leading international provider of power electronics.

Mycronic sold two full-line solutions of jet printers, pick-and-place machines and material handling towers to **Eurocircuits**, and a Mycronic MY300 Trilogy placement line to **Wavetronix**.

Northrop Grumman awarded a multi-year contract to **Sypris Electronics** to manufacture a variety of mission-critical electronic assemblies.

ParPro has completed an expansion of its factory in Mexico, adding SMT equipment and staff to the 135,000 sq. ft. plant.

PDR named **Pacific X-ray Imaging** (PXI) exclusive distributor of industrial x-ray products under the PDR brand name.

Pro-Active Engineering acquired design engineering firm **Apex Embedded Systems** for an undisclosed sum.

Quanta Computer is considering building a new factory in Southeast Asia, most likely Chonburi, Thailand.

"The most ambitious goal of the project team was true circularity at the highest possible value: making hard drives from hard drives," said Carol Handwerker, professor of materials engineering and environmental and ecological engineering at Purdue University, and coleader of the Value Recovery project. "The team was able to accomplish this goal, as well as create all the other value recovery pathways needed to make a circular HDD lifecycle a reality.

"Today, almost all of the value of HDDs is lost by shredding them into mixed aluminum scrap sold at $0.25/lb. This contrasts with the significantly higher value recovery this iNEMI project demonstrated is possible, from HDD and component reuse, to recovery of REEs as magnet powders, oxides or metals to turn them back into RE magnets. Establishing that all of these pathways can be realized economically, logistically and with lower environmental impact is a significant accomplishment."

To download a copy of the report, visit inemi.org/value-recovery-2-final-report. – *CD*

Jabil to Invest $42M in Albuquerque 3-D Printing Site

ALBUQUERQUE, NM – Jabil announced plans to invest nearly $42 million here to expand its 3-D printing operations. The company plans to add technology and equipment, as well as about 120 jobs in the next five years.

"Think of more personalized healthcare, where you put devices that match maybe your profile as an individual," said Steven Borges, executive vice president and CEO, Jabil Healthcare. "That's everything from orthopedics, surgical instruments for the surgeon, and things of that nature."

Jabil will work with New Mexico colleges and universities to develop a workforce.

The expansion is supported by New Mexico's Local Economic Development Act. The state and city are expected to provide $1 million to help with the project.

"They are bringing in money from out of state for work that they do here," said Mayor Tim Keller. "There are other ways to define it, but that has the highest return of investment for us."

"It's really important we have the skill sets," Borges said. "Learning what is important technically in order to do these particular positions and use that and leverage that – build that workforce that we can essentially hire from at some point in time." – *CD*

Schleifring Medical Systems purchased a **Kurtz Ersa** IR 650 rework system.

Sigma Connectivity and **Scanfil** won a development and manufacturing contract from a global leader in logistics and material handling.

Southwest Systems Technology has signed a representative agreement with **InnoScopes**.

SVI Public Co. has approved the establishment of a subsidiary in India.

A **US Chamber of Commerce** survey found that since June 1, 43% of Fortune 500 executives raised or addressed concerns over the impact of tariffs and trade policy tensions in earnings calls, mounting evidence that tariffs pose a growing concern for American businesses and present a major threat to growth and the longest economic expansion in US history.

The Vietnamese government has begun taking steps to clamp down on shipments of products from China and elsewhere that pass through Vietnam and are relabeled as Vietnamese to avoid US tariffs.

Yamaha's acquisitions of **Shinkawa** and **APIC Yamada** have been integrated and renamed **Yamaha Motor Robotics Holdings**.

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PC CYCLES

Trends in the U.S. electronics equipment market (shipments only).

	% CHANGE			
	MAY	JUNE	JULY	YTD%
Computers and electronics products	0.4	-1.2	0.2	4.9
Computers	-4.5	-6.7	-0.5	-19.0
Storage devices	-5.6	-4.2	1.5	21.3
Other peripheral equipment	1.8	0.5	-4.8	6.0
Nondefense communications equipment	-0.3	1.0	0.6	11.7
Defense communications equipment	8.0	12.1	-3.2	6.4
A/V equipment	7.7	0.0	2.4	39.1
Components[1]	0.7	1.6	-1.3	3.1
Nondefense search and navigation equipment	-0.9	-1.6	0.5	3.8
Defense search and navigation equipment	-3.0	-1.3	1.3	3.2
Medical, measurement and control	-0.1	-3.2	1.3	1.6

ʳRevised. *Preliminary. [1]Includes semiconductors. Seasonally adjusted.
Source: U.S. Department of Commerce Census Bureau, Sept. 5, 2019

Report: Companies Shipping 5G Phones to Spur Sales

AUSTIN, TX – Many smartphone manufacturers are offering 5G handsets in a bid to increase mobile phone sales, says TechSearch International. Several 5G-compatible smartphones are in mass production, and more are scheduled for release this year.

Smartphone sales have stagnated, so OEMs and carriers are pushing 5G development and deployment, with the hope customers will be enticed to upgrade their phones, according to the firm. These early 5G phones are primarily designed to enhance 4G LTE by adding sub-6GHz frequency spectrum. Support for the millimeter-wave version of 5G, which many consider to be the "true" 5G, is limited, as rollout of the technology is still in its infancy.

Hot Takes

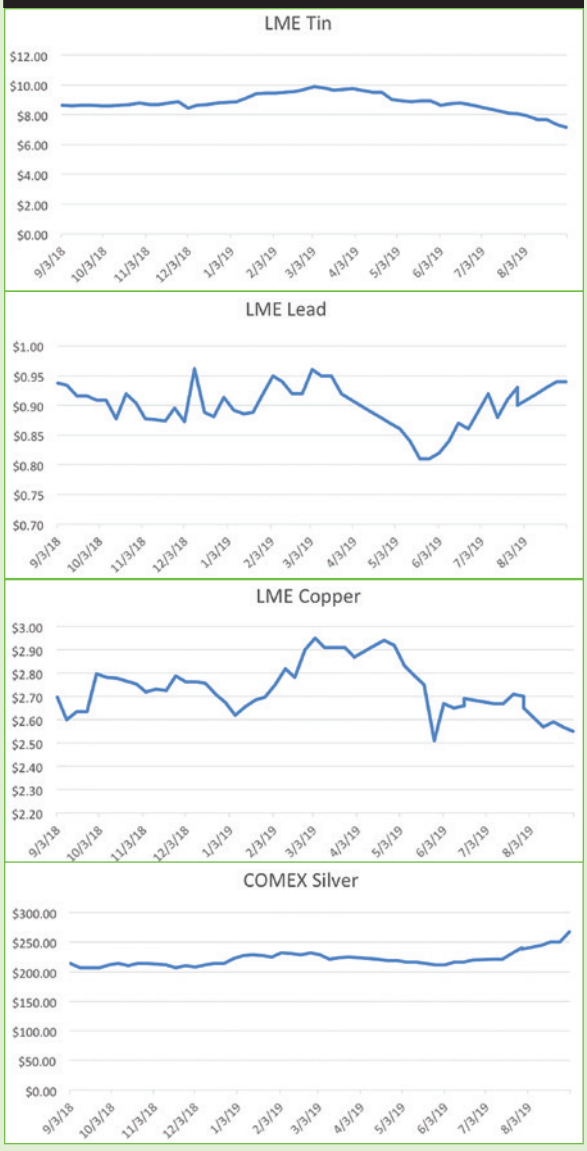
- Japanese PCB fabricators' sales fell 6.9% year-over-year in the first half to 219.79 billion yen ($2.06 billion). Sales of flex circuits fell 28.7% from a year ago. (JPCA)
- Worldwide semiconductor manufacturing equipment billings in the second quarter fell 20% from a year ago to $13.3 billion. (SEMI)
- Server shipments declined 9.3% year-over-year globally to fewer than 2.7 million units during the second quarter. (IDC)
- PCB manufacturers in Austria, Germany, and Switzerland posted a 12.8% drop in second quarter sales year-over-year and 10.6% sequentially. Overall first-half sales were down 10%. (ZVEI)
- Worldwide smartphone assembly shipment volumes in the second quarter were up 11.9% sequentially, with total shipments of 332.6 million. (IDC)
- DRAM sales are forecast to drop 38% this year to $62 billion. (IC Insights)

KEY COMPONENTS

	MAR.	APR.	MAY	JUNE	JULY
Semiconductor equipment billings[1]	-24.9%	-28.5%	-23.6%	-18.4%ʳ	14.5%ᵖ
Semiconductors[2]	-13%	-13.7%	-14.8%	-16.5%ʳ	-15.5%ᵖ
PCBs[3] (North America)	1.00	1.02	0.99	1.00	1.00
Computers/electronic products[4]	5.35	5.35	5.39	5.46ʳ	5.43ᵖ

Sources: [1]SEMI, [2]SIA (3-month moving average growth), [3]IPC, [4]Census Bureau, ᵖpreliminary, ʳrevised

METALS INDEX



US MANUFACTURING INDICES

	APR.	MAY	JUNE	JULY	AUG.
PMI	52.8	52.1	51.7	51.2	49.1
New orders	51.7	52.7	50.0	50.8	47.2
Production	52.3	51.3	54.1	50.8	49.5
Inventories	52.9	50.9	49.1	49.5	49.9
Customer inventories	42.6	43.7	44.6	45.7	44.9
Backlogs	53.9	47.2	47.2	43.1	46.3

Sources: Institute for Supply Management, Sept. 3, 2019

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In Praise of 'Thank Yous'

The simplest motivational measures can go a long way with tomorrow's workers.

THE PAST COUPLE years have been good ones. Despite increased and costly quality protocols, foreign competition, escalating raw material costs and fewer material suppliers – and even the advent of punitive tariffs – business has been good. With fewer negative issues to contend with, the one that continues to be most talked about is the difficulty to locate, recruit, develop, and retain quality employees. Indeed, this may be the challenge of our times. As older employees approach retirement, ones who are just beginning their careers seem less interested in manufacturing as a career path than at any time we can remember.

This talent gap threatens to upturn our industry – nay, most industries – more dramatically than any new disruptive technology. Much has been said about the difficulties attracting millennials to our industry. Many initiatives have been started to educate, entice and attract younger people to companies that build technology, products and the "things" we need and use in our day-to-day lives. Some have been more successful than others, but none has been a silver bullet that works all the time in every circumstance, across all industries. While creating work environments that more resemble a summer camp than a place to produce high-quality, complex products may be the way to emulate the software-centric businesses so many millennials yearn to be part of, maybe there is a simpler approach.

Despite all the hype over employee-centric, motivational work environments at companies such as Google, before we invest in the likes of basketball courts in the plating area or coffee bars in the QC department, it might be more effective to revisit time-tested, yet often forgotten, basics of managing and supervision. For instance, saying "thank you!"

In a busy, highly competitive industry, it is easy to focus on what is not going right, especially when hiring and training a new employee. We all want the inexperienced new hire to hit the floor running, to be a plug-and-play for someone calling it quits to a long career, or to fit seamlessly and effortlessly in a swamped department in need of added capacity. The problem is it has never worked that way.

It is rare to hire someone with the precise experience from an identical environment who hits the ground running on day one. Every new employee, regardless of experience or lack of same, requires training, mentoring, direction and patience. When historically a company has added one to a few new employees every quarter – or year – the time, patience and expectations are manageable. However, when a relatively large number of experienced employees need to be replaced, and business conditions are such that everyone is overloaded, finding the individual and collective time, plus the patience to train and mentor an inexperienced person, can be trying. On top of that, much of the available talent is from a generation with a very different view on responsibility and skillsets more suited to handling quick "Wikipedia" bursts of information, rather than longer, process-driven, rote training. It's no surprise everyone's patience goes out the window!

Which is why it is so important to celebrate the successes, no matter how often they occur. Everyone, regardless of age or generation, appreciates a simple "thank you." That universal message succinctly says the task, big or small, has been done well and is appreciated. Most important, it provides the much-needed encouragement that motivates workers, especially those new to a job, to repeat it, and provides confidence to try another new and daunting task.

"Thank you" it also therapeutic for the person who says it. It focuses the speaker on the good a new employee is doing, rather than, perhaps, on how long it may be taking that worker to get up to speed. In short, it extends the patience needed for a supervisor or coworker to successfully mentor a new hire.

Saying "thank you" can be contagious. We too often forget the basics of giving thanks for a job done well, on or ahead of schedule, and performed with a positive attitude. When companies are busy, it is easy to focus on what needs to be done, rather than on what has been accomplished. A simple "thank you" can be the difference, transforming exhausting pressure into uplifting feelings of appreciation.

Will saying "thank you" make it easier to locate and hire needed talent? Maybe not. It won't hurt, however, and may make the difference for prospective employees seeking a positive, supportive environment.

Best of all, it requires no consultants, investments in special or new training or workplace gadgetry, or changes to the day-to-day schedule. All it takes is paying attention to what every employee, new or tenured, does and celebrating their success by uttering two heartfelt words.

Giving thanks may not solve the world's problems, or even those of our industry. It will, however, help transform an inexperienced hire into a valued team member, while reminding all employees they are central to each other's success, as well as the success of the business, and most of all appreciated. This simple gesture has worked for generations. Even in our rapidly changing, technological world, the basics of motivation are as relevant and effective today as ever. ❑

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Is It Time for Manufacturers to Move?

Would you stake your reputation on a new supply chain in a new region?

THE ONE PREDICABLE OUTCOME of trade wars is they tend to make sourcing teams evaluate their outsourcing strategies. Given that project requirements and cost drivers change over time, even without fluctuating tariffs, periodic evaluations can help better align electronics manufacturing services (EMS) partners with current needs. That said, moving to mitigate tariff concerns alone can create a cascade of unplanned costs that far outweigh the cost of tariffs.

Areas to evaluate when considering a move include:

- Supply chain implications
- Transfer of work costs
- Market factors

Supply chain implications. Moving a project into a different region can trigger supply chain woes on two levels. First, while the materials market is less constrained than a year ago, materials allocation can vary by region. Consequently, material that was available in one region may not be available in a different one. There can also be surprises in the precision engineering realm. Molding and metal fabrication equipment can vary by region. In some cases, that impacts preferred tooling sizes, which could result in a need to fabricate new tooling. If the original supplier licensed the design being used or amortized tooling as part of the unit, a decision to move could create a requirement for an entire custom part redesign and tooling development effort. If new tooling is required, one important question to consider is whether a product is too far along in its lifecycle for new tooling to be cost-feasible.

Additionally, the business "culture" of a region's custom part suppliers is usually heavily influenced by the industries it serves. If the bulk of work done in the new region is high volume, there may be limited availability of suppliers willing to do smaller lot sizes. This can be a concern for low-volume, high-cost products that utilize large numbers of fabricated parts. The speed of quoting those projects may also vary by regions, and that can add unanticipated lead-time to the transfer process.

Transfer of work costs. Any transfer of outsourced work typically generates some level of nonrecurring engineering (NRE) costs and may generate tooling costs as well. It also creates an unmeasured cost internally at the OEM. Auditing, coordination of work with the new EMS provider and reacting to learning curve issues typically add a lot of hours to work schedule plus travel cost. And, in a labor market with less than 3% unemployment, that may also translate to key staff attrition as work demands or time away from home increases.

The transfer of work learning curve factor should not be discounted. Projects that have been at an EMS provider for a long time often benefit from institutional knowledge built up at that EMS provider. If the project transfers to a new EMS provider, that internal, unwritten product expertise may not. As a result, inefficiencies and unaddressed challenges may pop up at the new EMS provider, even if that company has a fairly robust NPI process. That often carries both a time and monetary cost. In the worse-case scenario, it can create disappointment for end-customers if learning curve-related defects make it to the field.

Another factor to consider in evaluating new location options is whether the rest of the world is making the same choice. If that is the case, unanticipated logistics delays, competition for key suppliers and labor market challenges may impact project startup dates.

Market factors. Perhaps the biggest factor to consider is the impact on the end-market. Will customers pay a higher price or switch to a competitor? Will the costs associated with transferring the project elsewhere ultimately raise the price higher than a tariff would? Could learning curve mistakes impact the brand? Are there any negative brand issues associated with building in the new region?

I'm reminded of a story an older colleague shared when I was first getting started in sales. He had worked for a test equipment manufacturer that dominated its market. When he felt he was in danger of losing a sale to a lower-priced bidder, he would always ask, "Do you really feel confident enough in your decision to bet your reputation on it?" At that point, the buyer started contemplating whether they had enough confidence in the lesser-known test platform to bet their reputation on the choice. That often swung the decision in that salesperson's favor.

Trade wars are political and, therefore, transitory. If a reevaluation of an outsourcing strategy determines a need for change because of multiple factors, it is likely worth the cost. If it is simply a move to mitigate tariffs, however, a good "gut check" question to ask before making that decision is, "Do you feel confident enough in your decision and assumed cost model to bet your reputation on it?" ❑

SUSAN MUCHA is president of Powell-Mucha Consulting Inc. (powell-muchaconsulting.com), a consulting firm providing strategic planning, training and market positioning support to EMS companies, and author of *Find It. Book It. Grow It. A Robust Process for Account Acquisition in Electronics Manufacturing Services*; smucha@powell-muchaconsulting.com.

The Future of PCB and Designers' Roles

The convergence of ECAD and MCAD into mechatronics means more changes ahead for the profession.

IN OUR PREVIOUS COLUMNS we covered all aspects of design fundamentals. As this series comes to a close, it's important to understand why being knowledgeable on all facets of the design process is integral to design success and how this affects the future of PCB design.

Printed circuit board technology is evolving rapidly. Likewise, engineers need to evolve just as quickly. PCB designers' roles will soon become even more important. Empowering engineers with the knowledge needed to understand design fundamentals, effectively leverage today's technology, and learn from others' mistakes is crucial.

Automation plus the latest software capabilities have made it much easier for even the most inexperienced users to "complete" full designs. But the lack of design fundamentals and collaboration can lead to major issues later and make it almost impossible to leverage the technology available to its fullest potential.

The constant evolution of technology drives the future. No matter where you are in your career, this will always be true. To remain successful, designers must adapt quickly and take on new roles. Ultimately, it is about adequately preparing for the next electronic generation.

With emerging technologies such as 3-D printing, artificial intelligence and machine learning becoming synonymous with daily life, the impact on the design process is all but inevitable. The emergence of 3-D printers from companies such as Nano Dimension, Voxel8 and Siemens, among others, has made the idea of 3-D printed circuits a reality.

"From a micro perspective, I firmly believe an engineer of the future will be sitting at their desk and will click 'file > print,' and over in the corner there will be a 3-D printed circuit board printer just knocking out a prototype board," said Manny Marcano, CEO of EMA Design Automation.

"Due to the nature of how 3-D printers work, the EDA industry will need to develop tools to keep pace with the additive manufacturing process of printed electronics, just as their mechanical predecessors did when they embraced the technology," said Mike Brown, principle PCB design consultant.

The process of PCB design is evolving and, with that, the role of the electrical engineer. A once highly segmented process – libraries, schematics, PCB layout, DfM, etc. each managed by a separate person – has converged into a single role. This new role, the PCB design engineer (or whatever title it might be called in the future), requires one to understand not only every aspect of the PCB design process, but the tools that will ultimately help accomplish these myriad tasks on-time and on-budget. Having a complete understanding of design processes will ensure utilization of these evolving technologies to their fullest potential.

As we look toward the future, ECAD and MCAD are slowly becoming synonymous with one another. This convergence is causing the emergence of a new discipline called mechatronics, and its adaptation will change how engineers of the future work.

The desktop workflow of the future will be a mechatronics solution, where many of the individual disciplines we know today will be absorbed into one consolidated engineering profession. Knowing how to properly design a printed circuit board will provide engineers the foundation they need to be successful. Merging both electrical and mechanical knowledge is slowly becoming essential to creating a proper design at the mechatronics level. Engineers must adapt and become the reference point for the other specializations.

"Mechatronics is the most compelling issue in front of us. Innovation and technology will always be compelling, but it must be converted to the real world. That is where the PCB comes in. The PCB converts concept to reality. Whether it's a tiny system on a chip to a large telecom design, it all has to be turned into the physical realm of a PCB," Marcano stated.

The future of printed circuit board design is very bright if engineers can stay flexible and keep up with the pace of rapid changes in the world of technology.

Few people will be doing the job of many, basing their design workflow on automation and resources available on an industry-wide basis. Mechatronics is a field that opens the doors to many breakthrough ideas that can turn into reality. Since the electronics industry is already known for its competitive landscape, designers will have to constantly review trends and evolve with them. Those armed with a fundamental understanding of design and manufacturing process will set themselves apart from their peers. □

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

The First Open IPC DC Executive Board Meeting

A confab at PCB West connected chapter members from around the world.

THE IPC DESIGNERS COUNCIL (DC) Executive Board held its semiannual meeting on Sept. 10 at PCB West. This year, the Executive Board decided to open the meeting to the public. This decision bore good fruit, as we had roughly 30-plus attendees at the meeting. Gary Ferrari, who is an IPC Hall of Famer, DC Executive Board Chairman Mike Creeden and I facilitated the meeting, with Gary taking the lead.

This was the second time we implemented a Webex for those who could not attend the conference in person. As a result, domestic and international executive board members were able to attend remotely. We also had individual chapter leaders connecting online and an IPC staff member in attendance. Further, there were a few representatives from several industry ECAD tool suppliers, including Mentor, Altium, Cadence and DownStream. We also had representatives from industry media and EPTAC.

The meeting was very positive. Each attendee added to the buzz in the room. Everyone was given the opportunity to introduce themselves and speak regarding the agenda. The main topic of discussion involved individual chapter activities. During the open floor dialogue, I provided a status update that covered the ongoing success of the eight local chapters and their respective activities, as spotlighted in this column series. Gary also presented updates from overseas chapters covering Southeast Asia and Paris.

The feedback from all attendees of this open meeting was very constructive, and I doubt it will be the last. A lot of excitement and collaboration took place that will help take the local chapters to the next level and hopefully start new ones. Stay tuned for announcements and activities that may be coming to your area.

Also, after hours, the Porch Dawgs were let out of their kennels and made a rare appearance at this year's PCB West. Pete Waddell, Andy Shaughnessy and Kelly Dack – the original Porch Dawgs – played music in the hotel lounge for conference attendees accompanied by backup singers Frances Stewart, Judy Warner and Tara Dunn. Songs included "Mustang Sally" with Kelly Dack on lead vocals (and occasionally on harmonica).

IPC CID/CID+ Certification Success

We continue to have successful IPC CID and CID+ certification classes. This year, 23+ participants took part in CID/CID+ certification at PCB West. The four-day IPC certification sessions kicked off the weekend before the conference start date. The certification sessions were followed by four days of jam-packed professional development sessions that included a show floor filled with enthusiastic professionals and ever-evolving industry content.

The excitement in the air at the PCB West conference did not disappoint! If you didn't, or couldn't, attend this year, I highly recommend you attend next year's event. The conference presents a great opportunity for networking and professional development in PCB design in our advancing industry.

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

2019 Training and Certification Schedule

IPC Certified Interconnect Designer (CID)

- 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+

- October 21–24: Anaheim, CA
- November 2–5: Raleigh, NC
- December 3–6: Manchester, NH

Note: Dates and locations are subject to change. Contact EPTAC to check current dates and availability. A minimum enrollment of seven students is required for a class to be held.

PCB Design Events

AltiumLive 2019

- October 9–11: San Diego, CA

PCB Carolina 2019

- November 13: Raleigh, NC

PCB West 2020

- September 7–10: Santa Clara, CA □

FIGURE 1. At their semiannual meeting at PCB West in September, Designers Council members reviewed plans for the coming year.

STEPHEN CHAVEZ is a member of the IPC Designers Council Executive Board and chairman of the communications subcommittee. To read past columns or contact Chavez, click here.


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How to Avoid Getting Totally Skewed, Part Four

When sourcing materials, consider dual-ply glass.

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

IN MY JULY ARTICLE, Part One of a series on glass-weave skew, I introduced its causes and when or why a hardware designer might care. In Part Two I discussed various mitigation techniques and cost. Part Three presented 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.

Obviously, PTFE-based materials often used for RF/microwave designs don't have glass-weave skew concerns to begin with, though at a cost premium. This column is focused on what the industry refers to as "anisotropic" materials, however. Isotropic laminates will be discussed in more detail in a future installment.

Review: When and why to care about glass-weave skew. At what frequency should you care? Each differential serial-channel standard and speed has its own tolerance for skew. Most standards or chip manufacturers offer guidance on skew tolerance, but we can generically characterize that a channel's tolerance for skew is described as roughly 25% of the bit stream's unit interval (UI). For example, a 1Gbps (500MHz) signal would have a UI of 1000ps. Using 25% as a guideline, that represents a 250ps skew tolerance. That's a wide window, and that's why most engineers didn't need to worry about GWS 20 or more years ago.

Fast forward to designing at 10Gbps (5GHz). The unit interval is 100ps, and the skew tolerance decreases proportionally to around 25ps. PCI Express 4.0's signaling speed, at twice the speed of PCIe-3.0, is even faster: at 16Gbps (8GHz). This maps to roughly a 60ps UI and 15ps of skew tolerance – half of the 30ps skew tolerance in PCIe-3.0.

TABLE 1[1] shows data rates (Gbps), unit intervals (ps), and approximate tolerances for skew (quarter UIs). If you aren't dealing with GWS on your current designs, it's likely you will in the not-too-distant future as speeds escalate.

Basic theory behind these alternatives. The underlying mechanisms by which the two GWS mitigation approaches in this column operate are actually very different.

Dual-ply glass seeks to reduce the probability that one signal in a high-speed differential pair will see systematic resin gaps because the two plies of glass have little likelihood of aligning identically under one another. This is illustrated in **FIGURE 1**. The blue top ply would, as a single ply, have resin-only "windows" (my term for it) similar to the larger yellow square shown in the figure. The red second ply of glass in the figure, including random manufacturing variation from panel to panel of glass, will typically serve to shrink the resin-only window, mitigating glass-weave-induced skew.

Low-Dk glass seeks to reduce the Dk variation a signal would see as it traverses the yellow resin windows shown in Figure 1. As discussed in Part One, standard E-glass has a Dk of around 6.8, while resin

TABLE 1. Bit Rate + Unit Intervals + Skew Tolerance

Data Rates (Gb/s)	Unit Interval (pSec)	Quarter UI (pSec)
1	1000	250
2.4	417	104
3.125	320	80
5	200	50
6.125	163	40.8
10	100	25
13.5	74	18.5
27	37	9.3
40	25	6.25
100	10	2.5

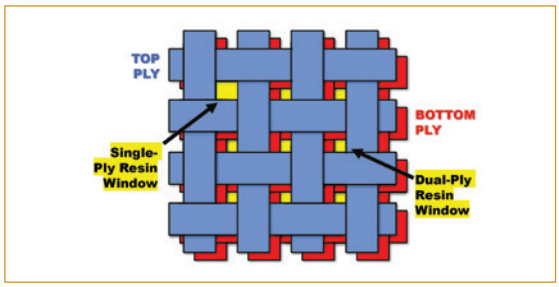

FIGURE 1. Dual-ply glass reduces the probability a trace will be routed over a portion of the glass that has resin-only windows (in yellow) in the glass structure. The second ply, shown in red, serves to reduce the single-ply resin window size and hence glass-weave skew.

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systems typically have Dks approaching 3.0. (This varies from laminate to laminate.) Low-Dk glass – typically manufactured by AGY in the US (L glass) or Nittobo (NE glass) in Japan – seeks to bring the glass Dk closer to the resin Dk, with typical values of 4.8, cutting the difference by roughly 50%. Since signal-propagation delay is proportional to the square root of the cross-sectional Dk, cutting the difference in half provides a significant benefit relative to mitigating glass-weave skew.

Electrical parameters for E-glass and low-Dk glass. I've done some research on Dk and Df (dissipation factor/loss tangent) comparisons between E-glass, L-glass (AGY, US), and NE glass (Nittobo, Japan), and concluded Dk and Df values for all but E-glass depend on whom you ask, when you ask, and of course frequency.

Park Electrochemical, now AGC-Nelco, was a pioneer in this space, launching N4000-13 with E-glass, and N4000-13SI with low-Dk glass, in 1996. In the words of Doug Leys, vice president of engineering at AGC-Nelco, "In 1996, achieving lower Dk was the primary concern, so the addition of low-Dk glass was a natural fit. Today, the driving force is reduced loss. Anything that can squeeze a little more attenuation out of the design is desirable." Lower Dk values enable thinner dielectrics and thinner high-layer-count PCB stackups. Today, many laminates with low-Dk glass are on the market. **FIGURE 2** shows a handful of materials from the Z-planner dielectric library that include both an E-glass version of the laminate, as well as a low-Dk glass version, using glass from either AGY, Asahi (a weaver rather than a supplier of yarn), or Nittobo. The vertical axis is Dk, and the horizontal is Df, both at 10GHz and 50% resin content. Arrows connect the E-glass laminates to the low-Dk laminates. Although we refer to this class of glass as "low Dk," it's clear from the figure that each of these products – and the underlying glass constructions – also offer much lower loss. Many more laminates are offered with low-Dk glass. Each laminate vendor uses its own convention for low-Dk glass. AGC-Nelco uses "SI" as a suffix. EMC, Nanya and Panasonic use "K." Shengyi uses "N," TUC uses "SP," etc. Check with your fabricator for availability.

Availability and Cost Considerations

Availability. It should come as no surprise a fabricator may or may not have dual-ply core configurations in stock in the thicknesses you need. It's even less likely it will stock low-Dk glass configurations unless it's coordinated proactively. This is an important consideration, in fact. By comparison, other GWS strategies, like angled routing, artwork rotation, or routing differential pairs with the glass pitch, are all immediately available.

Cost. From a cost standpoint, it's helpful to first realize the approximate cost breakdown for laminates. Roughly speaking, 50% of the cost of a core comes from the copper. Another 25% comes from the glass, and the final 25% comes from the resin (more or less, depending on the copper weight, roughness, glass type, and resin system). Obviously, for prepregs, it's a 50:50 split between the resin and glass, depending on the resin system, resin content (%), and relative weight of the glass style. Using the above as a baseline, dual-ply glass does add additional cost, but for the same overall laminate thickness, the cost difference should be less than 10%.

Low-Dk glass, on the other hand, carries an addi-

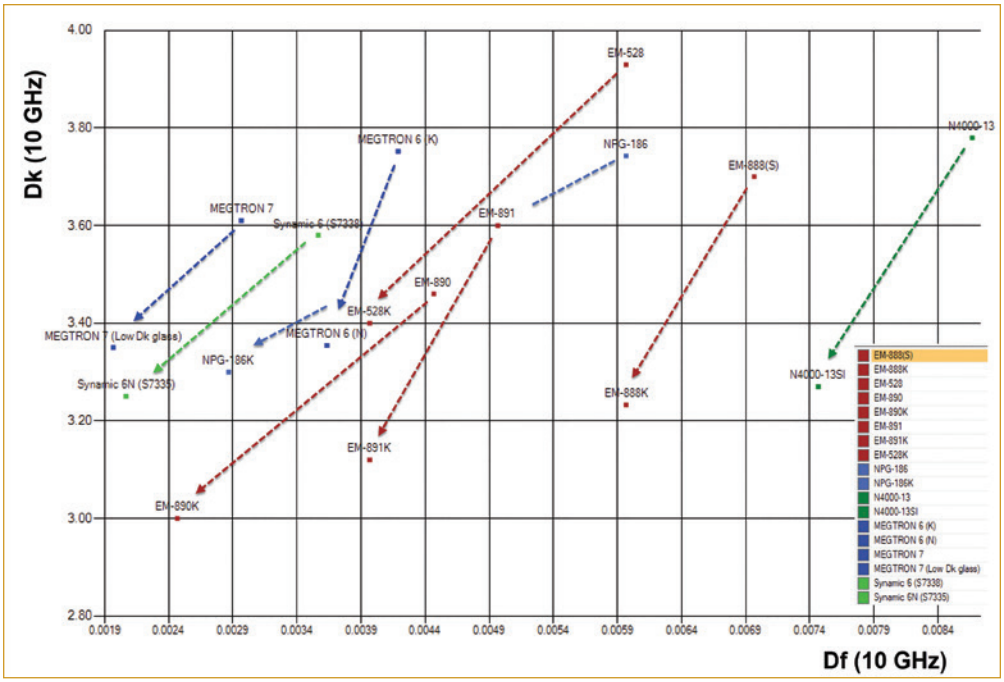

FIGURE 2. A handful of materials from the Z-planner dielectric library that include both an E-glass version of the laminate, as well as a low-Dk glass version. Values are shown at 10GHz and 50% resin content.

tional cost of 50% for cores and roughly a 5x cost increase for prepregs (more or less, depending on the laminate vendor, PCB fabricator, and the day). Depending on the stackup, my history says this doubles the cost as a rule-of-thumb.

TABLE 2 shows a simple stackup comparing E-glass to L-glass cost factors. Note cores cost a good bit more than prepregs because of the copper. Designers should check with fabricators for specific pricing and lead times if they've reached the tipping point on speed and feel the need to incorporate low-Dk glass.

TABLE 2. Simple Stackup Comparing E-glass to L-glass Cost Factors

Layer Description	Cu Weight	Material Cost Factors E-glass (Dk=6.8)	Material Cost Factors L-Glass (Dk=4.6)	Multiplier
L1 - Top/Signal	H oz			
Prepreg 2116		1	5.25	5.3
L2 - Plane	1 oz			
Core 6mil 1/2(2112 x 2)-RTF*		11.6	18.44	1.6
L3 - Signal/Plane	2 oz			
Prepreg 1080HR x 2 + 24 0/0**		1.8	7.625	4.2
L4 - Signal/Plane	2 oz			
Core 6mil 2/1(2112 x 2)-RTF*		11.6	18.44	1.6
L5 - Plane	1 oz			
Prepreg 2116		1	5.25	5.3
L6 - Bottom/Signal	H oz			
TOTAL PCB MATERIAL COST FACTOR:		**26.9**	**55**	**2**

*Smoother copper would be a cost adder. **This is a dummy core - for thickness and rigidity.

Glass-weave skew research. There isn't a huge body of research to point to relative to glass-weave skew. The reason, in part, is the stochastic nature of the phenomenon. That's not a word we use much in PCB design, but it definitely applies here. In other words, glass-weave skew has a random probability distribution that may be analyzed statistically but may not be predicted precisely. Anyone who's taken an applied statistics class (for research purposes) knows getting good answers for something with a probability distribution requires a lot of data. In this case, a lot of comparative data require a lot of test structures with different glass configurations, trace orientations relative to the weave, and a lot of time in the lab. These are some of the issues we ran into when we embarked on an ambitious research project a few years ago.

With the support of laminate materials provided by Nanya Plastics, 66 different test vehicle configurations were fabricated, each with 160 nets: 40 parallel to the warp, 40 parallel to the fill, and 80 traces angulated to the warp or fill. As we expected, the 80 angulated traces showed the lowest line-to-line delay differences in the study. As mentioned in Part Two of this series, angled routing is a commonly-recommended design strategy for GWS control, and an approach that our research confirmed to be a reliable means toward preventing the problem. We sought to compare 13 different glass configurations outlined in **FIGURE 3**, including spread glass, non-spread glass, single-ply and dual-ply glass, along with standard E-glass (electrical-grade fiberglass) and low-Dk glass.

Test vehicles included eight different single-ply E-glass configurations, one single-ply L-glass configuration, and four different dual-ply glass configurations, including one using AGY L-glass. It was an ambitious experiment, and we learned with time that the scope of analyzing all the configurations was beyond our budget and time window. Nevertheless, we learned some interesting things I'll share here.

First, we wrestled with the fact that tracking all the glass and "grain" (warp) direction details through the supply chain to finished boards was quite difficult. (You're only as good as the weakest link in the supply chain as far as managing the details.) It's important to consider this when negotiating changes in your design approach. Aligning GWS strategies with your fabricators is critical for any approach to be effective.

Second, we found about 75% of the time the weave wandered under our transmission lines enough to make it impossible to make firm statements about the skew results from the underlying constructions. The remaining 25% of the transmission lines provided a sample from which we could make some high-level determinations, although without being able to claim statistical significance based on the

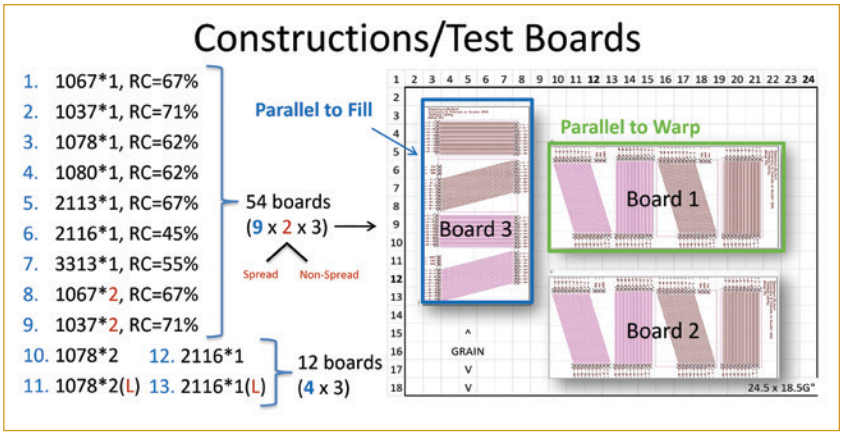

FIGURE 3. Overview of 66 test vehicles in 2015-2016 study of glass-weave skew.

sample size. The variation, in terms of the weave orientation, was +/-5°, centered around 0° (perfect alignment).

Third, we learned an angle of only 0.5° was necessary between the glass and trace alignment to reduce glass-weave skew significantly – an unintentional, but interesting artifact.

Fourth, we confirmed that test traces routed at 15° relative to the glass weave predictably reduced skew to essentially zero. (In fact, our study showed that 7.5° would have done the job.)

Finally, we learned a few things that could be used as guidelines for further research. We learned that dual-ply glass, where we had the ability to make apples-to-apples skew comparisons, reduced skew significantly. Low-Dk glass did the same thing, and using these two factors in concert had the lowest skew in the study, excluding 15° angled routing.

Conclusion

Some mitigation techniques outlined in this four-part series are what I call "deterministic" solutions. These solutions, including artwork rotation and angled routing, are almost guaranteed to mitigate skew. In the case of angled routing, another benefit is the routing process is entirely within the OEM hardware team's control, and – at the cost of board space – the practice only directly affects the high-speed differential interconnects about which you're concerned.

Other mitigation techniques are "probabilistic," meaning they reduce the probability of a skew problem, while not necessarily guaranteeing skew problems will never occur on a unit in high-volume production. See Part Two in this series for some of the skew-control techniques, roughly ranked in ascending order of cost in manufacturing. I'd be interested in your comments if this series rang true. Feel free to download the evaluation software that includes a tutorial for mitigating glass-weave skew from z-zero.com. ▫

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Medical Micro-Technologies Could Mean Better Healthcare for All

Why PCB substrates are well-suited to lab-on-a-chip applications.

THE SEMICONDUCTOR INDUSTRY has pursued Moore's Law for more than 50 years. Some now say it is dead: Progress has certainly become increasingly difficult in recent generations. On the other hand, chip design is only at the beginning of some very exciting avenues, two of which could revolutionize digital healthcare.

We know the world must deal with aging populations. Diabetes rates are increasing, particularly in North America, Europe and parts of Asia. As our transport networks shrink the globe, travelers can pick up viruses or diseases almost anywhere and present to their local practitioner, who likely has little or no experience of the exotic strain they are carrying. Our doctors are only human; we cannot expect them to know all the symptoms of all the ailments in the world and diagnose the right treatment in time, every time.

All the while, the global population continues to grow and further squeeze healthcare resources. Seeing a doctor is increasingly difficult, and practitioners' time is increasingly precious and expensive.

The world is looking toward technology to help overcome these challenges. New Lab on a Chip (LOAC) and Organ on a Chip (OOAC) devices offer promising solutions. An LOAC can perform several laboratory procedures, such as testing blood or other samples on the spot, extremely quickly. These devices, known as BioMEMS (biomedical microelectromechanical systems) leverage advancements in technologies such as microfluidics to handle tiny quantities of blood samples or other biological fluids, as well as miniaturized electronic actuators and components for sensing and measuring.

The market for biochip products is expected to more than triple from $4.7 billion in 2015 to $18.4 billion in 2020, according to BCC Research. Many of us have already experienced LOAC devices in desktop machines such as blood-cholesterol testers, which enable general practitioners to carry out basic tests using minimally invasive methods and provide results within a few minutes while we wait. We can all appreciate the speed and relative lack of pain these devices now enable.

To help diagnose more complex or serious conditions, OOAC devices make it possible to simulate an organ such as a heart or kidney that is DNA-matched to an individual patient and applied to the tissue quickly and harmlessly. Multiple different tests can be done in parallel if needed, to avoid time-consuming test-wait-retest sequences and thus ensure much faster time to diagnosis, capturing results tailored to the individual patient. In this way, OOAC devices can help identify the treatment required and get the dosage right more quickly than traditional approaches.

As these technologies mature, we can expect basic diagnostic tests to move from healthcare professionals' desktops into the homes of individual patients. Many will involve single-use electronic devices. Multiple millions of units will be needed, creating a tremendous opportunity and a great responsibility for electronics designers and manufacturers. There will be large demand for bio-compatible substrates, both flexible and rigid types, to carry OOAC or LOAC devices, or for use as patches such as the flexible, disposable glucose-quantification patches being developed as part of the CHIRP program at the UK's Bath University. CHIRP's goal is to enable cost-effective and child-friendly early diabetes screening and is aiming to create – among other innovations – a flexible printed circuit platform for the microfluidic/glucose sensor. Bio-compatibility must be addressed. Copper, which is generally used in PCB conductors, is a broad-spectrum biocide, and it is necessary to apply a gold or silver plating to make it suitable to be used in Bio-MEMS. The low reactivity of PCB substrates renders them generally bio-neutral and thus well-suited to LOAC and OOAC applications. Ventec's product specialists work with customers on an individual basis to provide robust assurances on bio-compatibility.

More evidence of our use of technology to overcome healthcare challenges comes with the arrival of powerful medically trained AIs. These can answer the need for a fast and accurate first call to diagnose illnesses based on their observed symptoms. In the same way AIs are beating human champions at games like chess and Go, they have now begun to outscore human experts at diagnosing illnesses based on user-described symptoms. Babylon and Isabel are examples of services available now. These could increase the quality of healthcare, dramatically reduce wait times, and provide access for large numbers of people in areas of the world where healthcare has historically been prohibitively expensive or logistically difficult to reach. These emerging AI doctors can access all the world's databases of diseases and quickly analyze biomarkers that may be unfamiliar to human doctors and therefore demand time-consuming research to categorize.

All these innovations will be aided and abetted by other technologies, such as our smartphones, the default gateway for many personal medical devices, and, of course, 5G networks with their support for massive machine-type communications to aggregate

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the vast quantities of medical data – both personal and anonymized – into the cloud. With these tools, we will also be able to map the progression of diseases and epidemics to improve our understanding and develop more effective responses.

Clearly there will be resistance to some of the coming changes, possibly from medical professionals who may be unhappy about the career implications for doctors or the prospects for treating patients based on third-party diagnoses. On the other hand, the AIs driving Babylon and Isabel have been built by engineers that expect them to work with human medical experts as part of the service-delivery team, instead of replacing them.

There will also be questions as to what type of information – such as genetic predispositions – should be made available to organizations such as insurers. Answering them could involve more people and more time than the technical challenges researchers and designers now grapple with. If we can find solutions to the ethical issues, these technologies have the potential to provide better healthcare for more people, at an affordable price. And that has to be good for all of us. ▫

Flex in the Stackup

Does it make a difference where the flex on a rigid-flex board resides?

I AM WORKING on a rigid-flex design. Does it matter where the flex layers are in the stackup?

Where flex layers are in a stackup does matter. Rigid-flex circuits come in all configurations. Fabricators can make rigid-flex boards with the flex at all different locations in the stackup; each has their reasons and constraints.

As a general rule, we recommend putting the flex in the center of the stackup. This permits the design to have an asymmetric stack. (Symmetry is very important when it comes to managing bow and twist.)

That said, there are a number of reasons why the flex may not reside in the middle of the stackup.

First, the board may not have an even number of total layers, or the flex itself may have an odd number of layers. This can throw the flex off the centerline. This is common and is usually not a concern.

Sometimes the flex may be shifted toward the top or bottom for the purpose of managing high-speed signals. This can permit a short z-axis transition before the signal is transported across a flex region. This may also be coupled with back-drilling to manage stub lengths.

In other cases, the flex may be biased to create separation between certain noisy signals and other sensitive layers.

Occasionally, designers will move the flex toward the top or bottom of the stackup to increase the bend radius. This can be done but may only add a few mils to the total bend radius.

Sometimes there are multiple flexes, and the designer will create extra separation between them to try to make bending easier. Some say this helps; others say it makes no difference.

In each of these situations, rigid laminate remains on both sides of the flex. Having rigid material on both sides of the flex means the flex will not get copper-plated, maintaining the original foil thickness. However, there is some risk that bow and twist may be impacted. The amount of bias of dielectric and copper on each side of the centerline of the stackup drives bow and twist.

If the desire is the flex as an external layer (top or bottom), keep in mind these considerations.

First, do you want that external flex layer to be copper-plated? This means adding electrodeposited copper onto rolled annealed copper. This impacts the flex endurance of the copper due to the grain structure of the plated copper. This can be minimized by performing selective or button plating where the plating buildup exists only at the through-holes.

Next, will you use coverlay or flexible solder mask on the external flex layer? Coverlay is more robust for tight bends and dynamic flexing. However, if you have dense SMT patterns on the part, then solder mask may be the better choice. We can't create square or rectangular openings in coverlay. In some cases, a designer may take a hybrid approach. This involves placing coverlay on the external flex layer in the flex region and applying solder mask in rigid zones. This provides the best of both worlds: robustness in the flex zone and standard SMT openings at the components. This adds cost but can be worth it.

In some cases, flex may be used as the top two layers to aid with HDI. Layer 1 copper may exist only in the rigid sections of the circuit, while layer 2 spans the rigid and flex zones. Microvias can drop signals from layer 1 to 2 with very shallow vias and no stubs. As a big extra benefit, the flex core is completely resistant to CAF (conductive anodic filament) because there is no fiber in the flex laminate.

One challenge when the flex is on the outside is that at the rigid-to-flex transition, the flex substrate will not be perfectly smooth. This can impact etch quality at the transition. There can be a tendency to have irregular edges on the traces here, which may limit the density of the pattern that spans the transition. We recommend lines and spaces be at least 0.008" (0.2mm) wide to minimize these risks.

Flex as an external layer creates another constraint. If designing with flex as an external layer, nonconductive epoxy via fill is not an option. Reason: the very high risk of damage to the substrate when the fill is planarized. Any filled vias need to terminate on a rigid layer to avoid risk of material damage to the flex.

To conclude, for best uniformity and processing, keep the flex in the middle of the stackup. When needed, however, flex can be anywhere in the stackup, provided the designer takes into consideration the via structures, bow and twist needs, and features on the external layers. □

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Emerging Challenges in MODELING, SIMULATION AND DESIGN Tools

IoT and high-end systems are driving the need for increased sophistication in analysis tools. **by LESLEY POLKA, PH.D.**

Ed.: This is the second 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).

Previous iNEMI roadmaps indicated that increasing cost and time pressures were driving the electronics industry to rely more heavily on modeling, simulation and design tools (MS&DT) over experimental prototyping during product and technology development. That theme continues to be relevant and central.

The emerging challenges in the MS&DT area are bound on the one end by the emergence of the Internet of Things (IoT) and growth of many connected and smart devices, and on the other end by the complex, high-speed, high-bandwidth devices that represent the growing high-end (HE) systems market. This latter market supports and comprises the connected infrastructure for communicating and processing large amounts of data – the "big data" of the connected world comprised of smart and connected devices.

Thus, challenges for MS&DT now include analyzing at very high speeds/frequencies and being able to incorporate and holistically design and analyze complex integrated devices and systems. The revolutionary pace of innovation in the HE space now provides a compute environment and platform that can revolutionize the level of detail and the size of problem that can be analyzed. Having tools that can take advantage of this computing power in an effective manner is another critical area for development for the MS&DT area.

Being able to model and analyze accurately in the face of increasing complexity across many applications and markets is a key challenge. The complexity and diversity of devices and systems under the umbrella of these two growing areas drives a need for increased sophistication in the area of MS&DT, which also drives the need for improved modeling inputs – most critically, material parameters. This, in turn, drives a dependency on improved characterization techniques. In addition, the emergence of improved computing infrastructure to host MS&DT, along with the rise of algorithms that take advantage of these systems (e.g., artificial intelligence and machine learning), provides a rich environment and opportunity for improvements in thearea of MS&DT that take advantage of these capabilities.

In terms of design tools, the MS&DT chapter of the roadmap identified five broad technical areas in need of research and development or further implementation over the next two to five years (listed below in bold).

There is a lack of standardized **EDA tools (electrical and thermal) for 2.5-D and 3-D systems.** 2.5-D and 3-D-specific EDA toolsets must be developed and validated.

No full-blown **EMI (electromagnetic interaction) models** address all PCB-level components. Instead, they are limited to single components. Modeling and simulation of the full PCB, including components, must advance up to wireless frequencies (GHz range).

Current **silicon-package and package-board co-design tools** are not optimized to give correct design/performance tradeoffs and have long iteration times. Tools that can perform co-design optimization, along with electrical modeling capabilities, are needed. Predictability of solution cost vs. performance will also be beneficial. Integration of optical components needs to be addressed in the toolset.

Actual prototype build results are different from simulation results. **Modeling and simulation tools** with built-in correlation capability with collected data are needed.

Often, designs work well during prototype build and test, but suffer systematic volume production yield loss. Next-generation tools should be able to **predict yield and** process capability index **for volume production**. Such simulation should integrate materials, process and line setup variations into an early production margin analysis.

Longer term development and implementation are expected of algorithmic modeling interface (AMI)-based SerDes modeling and simulation tools, and chip-to-chip system channel optimization tools for cost/performance. (The channel includes chip, package, PCB, connector and/or backplane.). Tools will evolve to incorporate machine learning and AI to make optimization faster and more efficient. □

This excerpt from the *2019 iNEMI Roadmap* is based on the Modeling, Simulation and Design Tools chapter, chaired by LESLEY POLKA, PH.D., principal engineer at Intel; lesley.a.polka@intel.com.

A Closer Look at DDR5 SOCKETS and How They Help Next-Generation Technology

The new memory technologies provide double the bandwidth and density of DDR4. BY WAI KIONG POON

As the Internet of Things evolves and millions of internet-connected devices get deployed, data center operators are working hard to keep up with the movement of data. They must find ways to meet ever-increasing data and storage needs, while ensuring the quality of service and keeping costs down. For many data center operators, minimizing power consumption is one of their top priorities to reduce operating expenses. Double Data Rate 5 memory, officially abbreviated as DDR5, looks to provide the performance enhancements and power management required in the data center to support 400GE networking speeds.

The new Jedec DDR5 will offer improved performance with greater power efficiency compared to previous-generation DRAM technologies. As planned, DDR5 will provide double the bandwidth and density over DDR4, along with delivering improved channel efficiency. These enhancements, combined with a more user-friendly interface for server and client platforms, will enable high performance and improved power management in a wide variety of applications.

Major manufacturers will soon release their first DDR5 memory modules, bringing increased bandwidth and lower power draw to the table. The new modules will bring in a new generation of high-speed memory that will replace existing standards.

Key Design Considerations

With the improved performance and greater power efficiency of DDR5 versus DDR4 technology, the need for compact, robust DIMM sockets to support this new technology becomes more important. More compact than their DDR4 predecessors, DDR5 DIMM sockets have reduced overall dimensions and heights, along with anti-buckling features for smooth module insertion and crowned contacts that prevent contact-stubbing.

DDR5 provides double the bandwidth and density over DDR4. This means DDR5 DIMM sockets deliver 6.4Gbps speed with lower seating plane for greater PCB and vertical space savings. The pin counts for both DDR4 and DDR5 are the same. Both DIMMS have 288 pins. Also, the pitch is the same for both DDR4 and DDR5. Besides the speed increase, there are some differences in the overall dimensions and the module card thickness. The dimensions of the DDR5 socket connectors are shorter than those for DDR4. For modular card thickness, DDR4 is 1.40+/-0.1mm, while DDR5 is 1.27+/-

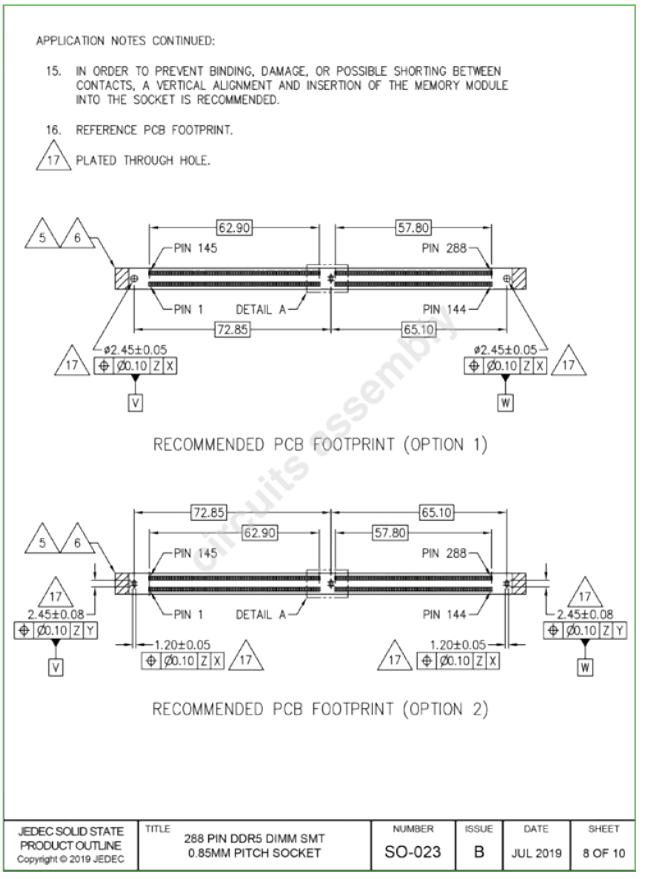

FIGURE 1. Jedec-recommended PCB footprint options for a DDR5 DIMM 0.85mm pitch 288-pin SMT socket.[1]

0.1mm. For the seating plane, it will be reduced from 2.4mm max. on DDR4 to 2.0mm max. on DDR5.

When it comes time to move to DDR5, designers should keep several key considerations in mind specific to socket connectors. DDR5 sockets are keyed to prevent insertion of DDR4 modules, and DDR4 modules cannot work in DDR5 and vice versa.

DDR5 does have higher speed requirements. For SMT terminations, there may be process challenges, and SMT packages perhaps will be more difficult to process compared to through-hole or press-fit terminations. CTE mismatch with the PCB could cause dynamic warpage of the connector.

When using automatic module insertion, it becomes more critical to have a robust DDR5 connector. Some sockets have metal at the latch tower to improve mechanical strength.

DDR5 will have heavier module cards, and the module weight may potentially increase to 65g from 50g. Hence, good and mechanical retention of the connector to the PCB needs to be considered.

Moving to DDR5 Sockets

When moving ahead with DDR5, consider a connector with anti-stubbing contacts that enable robust mating contact and electrical reliability. A halogen-free, high-temperature nylon housing can support high reflow temperatures, while providing environmental sustainability. A vibration and shock-resistant solder tab offers performance and robust PCB retention during rugged operations. Additionally, a metal insert on the socket can support rigorous latch operations, while strengthening the latch tower. A robust, ergonomically designed latch can improve rip-out force and vibration resistance during latching and release of module card. To solve for crushed pins, seek a well-designed terminal and housing.

For other DDR5 considerations, dynamic warpage is a possible concern. In terms of processing, SMT terminations will be more challenging and difficult compared to TH terminations. The assembly process must be properly controlled, and the design and housing material selection are very important. An optimized molding process can reduce internal stress built up inside the housing.

As speeds in the data center increase, DDR5 will be ideal in supporting those speed increases. DDR5 socket production is growing and will continue to grow in the next year. ▫

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Leveraging SUPPLY CHAIN COMMAND for Lower Material Prices

As trade battles between the US and China heated up, Ventec USA has had a front seat. **BY MIKE BUETOW**

Ventec USA president Jack Pattie talked with PCD&F editor-in-chief Mike Buetow in August on how the laminate manufacturer is coping with US tariffs, capacity constraints, and his advice for designers of short-supply materials. Excerpts. (See pcdandf.com for the complete interview.)

Mike Buetow: How are the tariffs affecting Ventec at present?

Jack Pattie: We followed the US trade representative website [ustr.gov] very closely, so we knew that there was a good chance that it was coming, but in order to fulfill our commitment to serving our customers, we still had to import material from our main factory in China. In the interim we were working on a transition of our US orders to our Taiwan factory. Fortunately, since April 2019 we are a publicly traded company in Taiwan, and we have a fully capable factory in Taiwan, but it took some time for that transition.

So initially we imported many containers and paid the tariffs and the main reason we did that was our commitment to the North American market, in particular the US obviously, because the tariffs are just in the US. It did cost Ventec a lot of money to absorb the tariff costs and ensure continued material supply for our US customer base while we transitioned production to our Taiwan facility, but that's all part of our long-term commitment to our customers.

MB: What's the capacity situation look like for Ventec in Taiwan right now?

JP: It's good. We have plenty of capacity to support the US market from our Taiwan facility. We've been running that facility since 2011, and in line with all our facilities, our customers are assured by the strict quality-controlled processes there that are certified to IATF 16949:2016 and ISO 9001:2015.

MB: With 5G and related technologies eating up much of the high-speed laminates market, what advice are you giving designers and buyers working on new products today?

JP: We are telling designers and OEMs not to be "locked into one type of material." Many of the designs are hybrid buildups, meaning they are mixing one type of bond-ply with another type of core. Getting locked into a design will put them at a disadvantage if a material shortage or lead times become an issue because they have no alternative. We recommend they spec out a slash sheet number and material properties that would allow alternatives to be used.

MB: In terms of capacity, my understanding is finding the higher-speed laminates right now can be a challenge. Alun Morgan has written on this in our magazine that one of your advantages is that you have the whole chain inside of Ventec.

JP: It's true. We are really the only laminate manufacturer that basically owns its own distribution channel in North America, the UK and Europe. That certainly is an advantage for us, especially where you'll see prototyping in the West and production volume in the East. We are able to manage that full supply chain for the customer.

MB: Let me go back to the tariffs for a moment. Have you noticed any changes in customer buying patterns since they went into effect, or is it more of a matter of having to communicate and reassure customers that there will be material available and there will be some kind of cost containment if possible?

JP: We haven't seen changes in buying patterns, but you must remember that the US is mostly prototypes, so a lot of our customers have had a very difficult task in forecasting. We try to look at their usage history and we can clearly see patterns, but a lot of customers don't have the bandwidth and capability to forecast what they're going to need in the future. □

THE PCB FABRICATOR, as Seen Through a First-Timer's Eyes

An experienced engineer takes their first trip to a board shop.

BY MIKE BUETOW

Time was, PCB fabrication was a standard in-house function of OEMs. IBM, Digital Equipment, AT&T, Texas Instruments, Rockwell and hosts of other large and not-so-large OEMs had captive operations. Board "design" meant place and route, and was a specialty, as was library management and engineering.

Today, of course, that's all changed. As specialization on one end has ended, it's become the norm on the other. Fabrication is largely a merchant exercise. And a designer does a little bit – or a lot – of everything.

What's been lost on the way is the knowledge of how a board is made. No longer can designers take the long walk from one end of the campus to the other to witness the process and talk to the operators and process engineers in person. Communication now ends at the CAM station, if it even makes it there. A surprisingly large contingent of designers today have never seen the inside of a board shop, let alone had the opportunity to get their questions answered.

What, PCD&F wondered, would a board shop look like through a first-timer's eyes? We had the opportunity to find out in late July, when we accompanied one such person on his first trip through a plant.

Joe Labonte is by all metrics an industry veteran. He's been involved with OEMs in the industrial instrumentation sector nearly four decades. Some of these large- and mid-sized companies had fabs, but none were local to his site. He's visited many EMS companies and is the engineering interface for the one used by his current employer, an international OEM of industrial water treatment control systems. He has done some designs and still handles parts of the PCB design process, although most of his career has been spent as the interface among electrical engineers, experienced PCB designers, PCB fabricators, and contract assemblers. But before July, he'd never stepped foot inside a fab plant.

The first thing Labonte noticed – as is typical with most who walk a board shop – was the odor. It was familiar to him, but he couldn't quite place it. That scent was the ammonia that is part of the etching chemistry. To the uninitiated, it can be strong. Over time, while it remains noticeable, it becomes part of the background, like gasoline at a filling station.

Circuit Connect operates a 27,000 sq. ft. site in Nashua, NH. Years ago, the area was hopping with major fabricators. Hadco (and later Sanmina) operated multiple plants in and around Salem. Fifteen miles away, Teradyne operated perhaps the most technologically proficient board shop in North America. Even closer was Parlex's primary flex circuit plant and international headquarters.

Today, like most of the US, volume production has disappeared. In the heydays of the domestic PCB market, Circuit Connect would give away prototypes in order to attract future volume orders. But the volume stopped materializing. It went through a fundamental transition in the mid-2000s, shifting from a volume plant to one that makes its living in the high-mix/low-volume space. The company now employs 35 to 50 staff, depending on the season, including four engineers. It holds 10 certifications and registrations, including ISO 9001 and 14001, ITAR and UL.

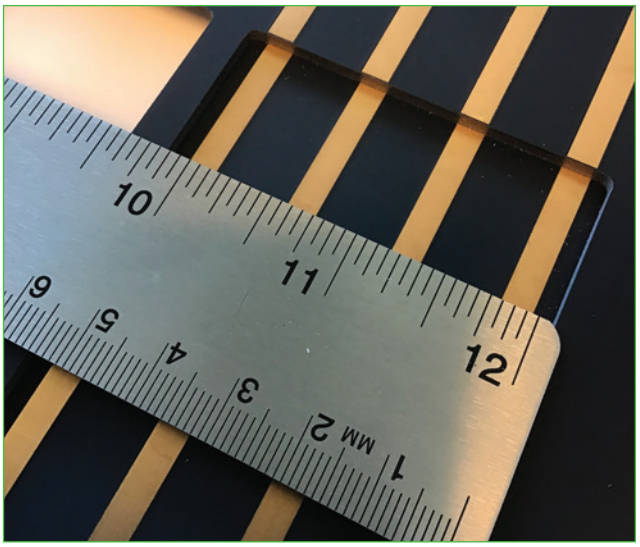

FIGURE 1. A "sculpted" PCB made for Teradyne.

Our hosts included CEO and owner Rick Clutz Jr. and president Bob Lazzara. Clutz is an industry lifer, having previously run CuTronics in Baltimore. He purchased CuTronics' Nashua plant in 1990, forming what became Circuit Connect. He then acquired Time Sensitive Circuits in 2010, which was rolled up into the Nashua plant.

Common Background

Perhaps more than anyone, Lazzara could relate to Labonte. Lazzara started his career in electronics not in fabrication but as a designer with Bell Labs/Western Electric, at which he worked nearly 20 years. He joined Circuit Connect in 1995 and became president in 2014.

US shops have become adept and creative, and Circuit Connect is no exception. Its typical product is two to 12-layer boards with lines/spaces down to 3/3. Boards will have standard copper plating, or up to 10 oz. with 5/5 lines/spaces. Circuit Connect can build up to 42 layers in production. On a given day, it will produce about 150 panels.

Circuit Connect also makes non-PCB products. Examples we saw included a 0.320" heavy copper product with solder mark and gold edge plating used for motors (**FIGURE 2**), and a 10-layer (with 3 oz. copper per layer) submersible pump. A third product was a 38-layer solid state rectifier (**FIGURE 3**), which is built for Boulder Wind and is used in wind farm generators in the North Sea.

Circuit Connect's engineers resolved a problem for a power semiconductor manufacturer in which the glue for the heat sink was failing, and the chip would fail. Some material vendors had epoxies that could handle the conductive or adhesion functions but not both. Circuit Connect helped devise a design that shored up the device.

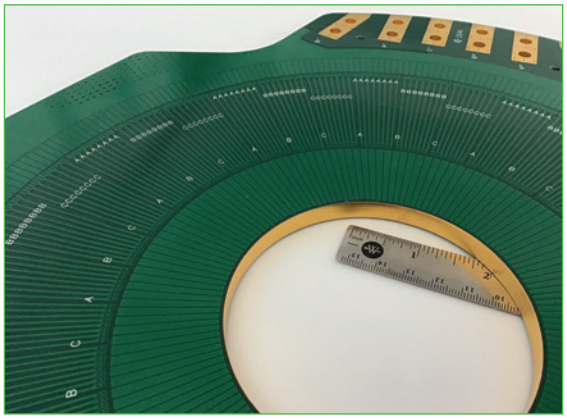

FIGURE 2. Circuit Connect applies its PCB knowledge to non-PCB products, such as this 0.320" heavy copper product with solder mark and gold edge plating ...

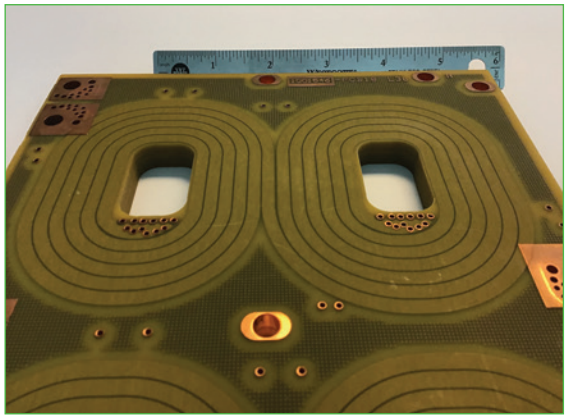

FIGURE 3. ... And this 38-layer solid state rectifier (solder mask removed).

A more assertive example of its engineering prowess was a military weapon in its conference room, in which Circuit Connect machines wells (pockets) in the FR-4 to add a connectorless flex. (Taiyo makes a non-glossy solder mask just for this product.)

"Our core business will always be the fabrication of bare, ready-to-assemble PCBs," explains Lazzara. "We can build one PCB and give you a plan for how we can build 10,000. However, Circuit Connect is surviving offshoring by augmenting our core PCB business with the manufacture of non-traditional PCB products. These are designs that combine PCB materials and methods of manufacturing for end-products that are not PCBs.

"This is a growing market in want of a name. With these quasi-PCBs, the novelty starts with the materials and methods of manufacturing before leading to very novel – some would say revolutionary – end-products. IP is of equal or greater importance today" for the US domestic market, he adds.

Processing materials is, of course, what fabricators do. Yet, as Lazzara notes, "Decisions aren't always based on experience. Designers often lack materials knowledge. They sometimes rubber-stamp things on prints."

Targeted Automation

Circuit Connect uses FR-4 and polyimide, including a range of thin high-frequency materials. It competes with other fabricators through targeted automation and avoiding material waste.

"PCB fabricators in North America used to be able to sell technology or time," he notes. "They still can, but look at the cellphone PCBs. It's almost impossible to compete on that."

To that end, Circuit Connect explained its transition to digital imaging. Labonte asked about the multiple operations the digital imager performed, seemingly new to that technology. Lazzara showed an RF panel built for a prime defense contractor (**FIGURE 4**). The panel was seven-up, a switch from a previous design in which each board was purchased individually. That meant seven unique board processes and seven solder paste stencils. Now, Lazzara noted, the panel requires a single setup and just one solder paste stencil. Although the re-spin means the entire board is done in gold and with Rogers material, the final panel is less expensive, even at the PCB level, because it consolidated the board processes. As a bonus, Circuit Connect found the new design tuned better, which improved first-pass yield at test. It also simplified paperwork because it reduced the RoHS declarations, certificates of conformance (C of Cs) and first article reports again from seven to one.

Circuit Connect uses a standard panel size of 18 x 24", and squeezes as many boards as possible into each one. It offers a fixed price for two, four or six layers. And while it mixes different layers on the same pallet, it does not build multiple customers' part numbers on the same panel.

"So, you take several different design outputs and quote it?" asked Labonte.

Lazzara: "We do. We try to bring all those elements together. It may not work on everything, but where it does, it saves money" (FIGURE 5).

Labonte appeared impressed. His company's typical board design is two to eight layers, with 4/4 lines/spaces. (Its supplier, although US-based, is not Circuit Connect.)

A tour of the factory proved equally informative. We walked the plant in somewhat the same way the design travels from the OEM to finished goods. Most CAD files Circuit Connect receives are in Gerber 274X format, as they prefer. They use Frontline Genesis and Numerical Innovations for CAM.

One interesting development, unexpected for a shop this size, was Circuit Connect's investment in its own DI water system. The company is working with New Hampshire state regulators toward a zero-discharge system, which is driven by personal goals, not regulation, Clutz explained.

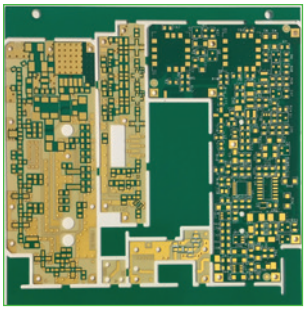

FIGURE 4. A five-up RF panel built on Rogers material.

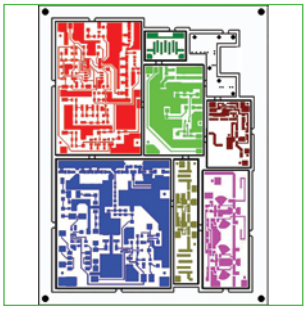

FIGURE 5. An actual eight-unit layout proposed to a client during quote.

Labonte wanted to know Circuit Connect controls surface cleanliness. His company is "drifting back" toward cleaning, he added. "At the customer's request, we use a DI water rinse and check with a contamination checker," Clutz said.

Two Maskless Lithography LED direct imagers were present for solder mark and outerlayer imaging, the second having been installed in late 2018 (FIGURE 6). With the additional machines, Circuit Connect was able to reduce its head count while increasing its output. Now, one operator runs both machines. The direct image solder mask can yield 3-mil dams.

FIGURE 6. Recent investments include Maskless Lithography LED direct imagers for solder mark and outerlayer imaging.

The two developers have a capacity of 600 panels/day. The batch copper electroplater includes acid and alkaline systems. We spent a moment discussing the differences between vertical and horizontal plating. Less elaboration was on the graphite line, which works by chemically bonding a layer of graphite to the hole wall and is used in place of electroless copper.

The plating lines were typical: copper, tin, nickel, gold. Circuit Connect also has a Teledyne Halco 175 horizontal Pb-free hot air leveling line, and offers ENIG, immersion silver and hard gold finishes.

Clutz indicated that Circuit Connect sees silver as the most-economical lead-free finish today. Labonte allowed that his current company underwent a thorough assessment of finishes during its RoHS conversion, settling on ENIG as the best and most cost-effective method.

At lamination, Burkle hot and cold presses are used. Labonte wanted to know how much time product spends in lamination each day. (Answer: two to three hours.)

Circuit Connect has three mechanical drills: an Excellon Century 2001 six-head drill, a Mark VI five-head drill and an Excellon five-head drill, plus Excellon routers. The question was raised about laser drilling and why it would be used. Circuit Connect cannot justify the cost of a laser, given the speed and hole sizes it currently needs. However, an x-ray drill is under consideration for tight stackups, as it can readily locate targets within the copper of innerlayers. Labonte also wanted to know how many layers are stacked on a drill. The answer is it varies, based on the thickness of the materials.

Testing is a big part of Circuit Connect's protocols. As Clutz said, "I believe in testing everything." It features a CIMS (formerly Camtek) AOI with 2-D metrology, plus four testers, including a CL Tech Precise FP8 four-head flying probe, and ATG A5NEO eight-head flying probe, the latter of which was installed this year. There are multiple automated cross-sectional analysis machines. Other services include advanced analytical tools, for instance scanning electron microscope (SEM), which is uncommon for the region's board shops.

Circuit Connect goes beyond traditional PCB fabrication. What it does is fundamental – lamination, plating, etching, testing – but the broad range of its end-products, processing strategies, and investment priorities makes it atypical. Indeed, there might not be a "typical" US board shop anymore.

Still, Labonte was enthusiastic about the day, and PCD&F was thrilled to join him. "I really got a lot out of it," he told me. Designers, take note and don't be shy about reaching out to your local fabricators.

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Evolving Production from Job Shop to ONE-PIECE FLOW

How a PICK analysis helped cut EMS staff by 19% and raise production output 24%. **by ANTONIO FRANCO**

One challenge for smaller EMS providers is evolving from a job shop model focused on expeditiously completing small runs to optimizing processes in higher-volume production projects. In many cases, the facility's ability to be flexible and do both types of projects is a business advantage. However, the focus on speed often reduces the focus on process optimization. For Spectrum Assembly Inc., flexibility combined with the ability to assemble cables, PCBAs and systems under one roof has been its biggest advantage. For the majority of projects, distributing workload among functional areas such as cable assembly, SMT and final assembly has represented the best division of labor since it put production near the automation required for each process. As the business has grown and skilled labor has become less available within its Carlsbad, CA, community, however, SAI's engineering team decided to evaluate some processes to identify potential improvement opportunities.

The production engineering team tackled its first process improvement target on Jun. 10, doing a value stream map of the current state production flow, which identified the steps in the process, travel time and the number of people and workstations involved. As part of this analysis, the team shot video and conducted a time study of each assembly process; created a process flow spaghetti diagram; calculated capacity, Takt times and workload balance; and identified wastes, bottlenecks and improvement targets. The product chosen was a bezel unit with wires that is scheduled to ramp to 3,300 per day later this year.

FIGURE 1. Product in original workcell traveled 30,000 ft. to assembly.

The initial analysis found the product took 5.5 min. to build and traveled through 30,000 sq. ft. of production floor during its assembly process. From a Lean manufacturing perspective, this represented the wastes of excess transportation and excess movement. The assembly process involved 32 people building 1,800 units per day. This extended batch process flow also created a large amount of work-in-process (WIP), which drove long wait states at each machine and consumed unnecessary production floor space. Other identified areas for improvement included the opportunity to introduce fixtures and jigs to reduce assembly process variation, better balance assembly time vs. takt time, and implement a more visual system in terms of process flow.

The next step was to design a future state value stream map that reduced travel time and headcount. The approach focused on analyzing gaps vs. proposed solutions utilizing a Lean Six Sigma tool known as a PICK (Possible, Implement, Challenge and Kill) chart. A PICK chart is a four-quadrant grid that helps visually segregate brainstormed solutions into four categories based on a horizontal scale of payoff/benefits and a vertical scale of ease of implementation. The four quadrants represent:

- Low payoff, easy to do – possible
- High payoff, easy to do – implement
- High payoff, hard to do – challenge
- Low payoff, hard to do – kill.

During the analysis phase, the team realized the bulk of the assembly time was associated with travel time. The solution was to design a one-piece flow "W"-shaped workcell feeding two assembly lines that reduced the distance the products traveled for various assembly operations. In the redesigned workcell, the product traveled through less than 5000 sq. ft. from wire cut and strip through packing. Headcount was reduced to 26 operators.

The new workcell was launched on Jun. 17. Assembly time per unit was reduced to less than 30 sec., and the workcell is now producing over 2,000 units per day, with fewer operators. Operators have been cross-trained on operations to ensure they have variety in repetitive operations to avoid repetitive stress injuries. But SAI's team is not finished with planned improvements.

The team is now working with the manufacturer of its cable stripping equipment to develop a custom accessory blade that can cut through braided cable shielding. Automating that process should further increase the run rate and reduce headcount. Additional fixturing is being developed to minimize process variation and improve speed per operation. As customer volumes increase beyond the capacity of the first cell, additional cells will be added.

Cumulatively, the expected benefits of the process redesign are:

- A 19% reduction in headcount by shift
- A 24% increase in production output
- A 52.6% increase in productivity per operator
- A 98% reduction in WIP
- A 41.7% reduction in workstation tables utilized
- A 50% reduction in production areas utilized
- An 85.7% reduction in the number of subassembly operations.

The team is now looking at other subassemblies that may also benefit from a one-piece flow workcell approach.

The benefits of this process improvement effort include better resource utilization both in terms of facility space and personnel, plus faster throughput. Production efficiency can now easily be monitored visually. Additionally, SAI is growing and finding skilled production operators in a labor market with low unemployment challenging. Reducing headcount in one project frees skilled operators for deployment to new projects. The ability to support growth with redeployed skilled operators also contributes to increased quality, since skilled operators don't have the learning curve issues found with entry-level personnel new to manufacturing. ▫

FIGURE 2. The redesigned workcell has a "W" shape that cuts the distance traveled to 5,000 ft.

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Pitfalls of EMS MARKET ANALYSES in Europe

With so many studies available, which one(s) can you believe? (Not many.) by DIETER G. WEISS

When meeting with potential customers, never talk about the disadvantages of your competitors; only talk about the advantages of your product. I am not here to sell something. I am here to bring light to the dark, to separate the chaff from the wheat. My talk is straightforward. Some people do not like this. For those people I have advice: stop reading.

I have been conducting market analyses for different parts of the electronics market for the past 19 years, starting with the PCB industry in my function as managing director of the German Association of Printed Circuit Industry, and for member companies of the OEM, EMS and ceramic hybrid industry. Fruitful discussions with industry colleagues were helpful, and my understanding of the principles of market behavior and interpretation of numbers grew every year.

Having experienced how fast markets can move, whether to China or other countries in the Far East, in 2015 I decided to bring my experience to all EMS companies in Europe. My objective was to help the European industry make better decisions in strategic planning, benchmarking and understanding of the European EMS market. This marked the launch of the in4ma (information for manufacturers) EMS statistical program for Europe.

Many others called themselves market researchers, I knew, but over a period of more than 12 years their reports had been discussed inside the association, and the majority were ripped apart as they were not worth the price at which they were sold.

The Global Pitfalls with Currency Conversion

Global market reports typically suffer in that they do not understand the basics of currencies. Last week, for instance, I received a report that showed numbers for multiple regions, including Europe. To compare different global regions, all numbers were given in US dollars. TABLE 1 shows this report's timeline for EMS in Europe. On a first view, the numbers show no unusual growth rates, and most readers would probably just accept those numbers as accurate.

Now, we need to realize Europe does not use the US dollar as legal tender. Of the 38 European countries that have EMS production, 24 use the euro as legal tender, and the others use their own currency, some strongly connected to the euro. When calculating the total European production value, one first must convert the different currencies to a common currency, which is the euro. This means each year one must calculate the average exchange rate for the 14 different currencies to get to a common value in euros.

The next step is to convert this euro value into US dollars to make the numbers comparable to the other global regions. Again, first you need the average exchange rates from euro to US dollars. Here they come (TABLE 2).

Now we take the numbers in US dollars and convert them into euros. Please realize the numbers in US dollars were converted to make the numbers comparable to other global regions. The reality for Europe is the euro. If you want to judge how Europe developed, you must have the euro numbers. Judging an individual market within Europe requires the appropriate conversion rate into the legal tender of the country in question.

TABLE 1. European EMS Revenues from a Global Market Report

2013	2014	2015	2016	2017
$39,500M	$41,000M	$42,800M	$44,500M	$46500M
	3.8%	4.4%	4.0%	4.5%

In $US millions

TABLE 2. Average Annual Exchange Rates, USD to Euro

	2013	2014	2015	2016	2017
1 Euro =	$1.3281	$1.3285	$1.1095	$1.1069	$1.298

TABLE 3. European EMS Revenues from Table 1, Converted with Exchange Rates of Table 2 to USD

2013	2014	2015	2016	2017
€29,740M	€30,860M	€38,580M	€40,200M	€41,160M
	3.8%	25%	4.2%	2.4%

In euros millions

Look closely at TABLE 3. In euros there is a 25% jump in Europe. The market does not jump! In this report, the numbers for Europe never had been collected in the appropriate legal tender and then converted. They were estimated in US dollars, probably in 2013, and then some smart estimation was made to make the numbers look reasonable for the next four years. That the exchange rate to the euro changed dramatically from 2014 to 2015 was ignored. To judge the development of a market, one must look at it in the appropriate legal tender. For comparison, one can then convert the numbers into US dollars.

Looking at the real numbers for Europe, which can be found on my website (in4ma.de), the picture looks like TABLE 4. The numbers have a last digit because they are the sum of the revenue numbers of the individual countries, and the different countries are the sum of the revenues of the individual companies.

In 2015, the growth rate in euros was 5.8%. When converting the numbers to US dollars using the aforementioned conversion rates, 2015 shows an 11.7% drop (TABLE 5).

Realize this has nothing to do with the actual market. It is simply the byproduct of changes in the conversion rates. One needs brains to do market analysis. Europe is not the United States of Europe. We have many different cultures, many different languages, many different currencies, many different business habits, and every European country is unique.

In summary, in the event I wasn't clear, the numbers in Tables 1 and 3 were generated by someone who does not understand the financial world of currencies.

TABLE 4. The in4ma European EMS Revenues, Real Numbers from Primary Analyses

2013	2014	2015	2016	2017
€31,047M	€32,218M	€34,076M	€35,098M	€36,097M
	3.8%	5.8%	3.1%	2.8%

In euros millions

TABLE 5. The in4ma European EMS Revenues of Table 4, Converted with Exchange Rates of Table 2 to US Dollars

2013	2014	2015	2016	2017
$41,234M	$42,802M	$37,807M	$38,850M	$40,782M
	3.8%	-11.7%	2.8%	5%

In $US millions

Secondary Analysis Pitfalls

Be careful when you read "extensive secondary research was conducted for collection of data required for estimations, as well as forecasting." This was one of the sentences in the report which did not reflect the currency changes mentioned before. It means it is guesswork, nothing more. Unfortunately, this sums up the majority of market analysis reports.

Papers about the European EMS industry on the market – I refrain from calling them studies on purpose – are obviously so

wrong, it is unbelievable how many large European EMS companies use them, even in communications with shareholders.

Just recently, I was confronted again with such a paper. The paper gave detailed information for European countries. I picked the first one: Austria. It gave an EMS value of €486 million in 2017 and forecast an average growth of 3.46% until 2022. Yes, you read correctly: not 3.45% or 3.47%, but exactly 3.46%. For the record, 0.01% equals €48,600. That must be a very precise market analysis.

Now I looked at the in4ma EMS database of 1,835 EMS companies in Europe. I took the eight largest Austrian EMS manufacturers, as shown in **TABLE 6**. These eight companies have one thing in common. They are called big capital companies (>20 million euros in total assets, >50 million euros in revenues, >250 employees) in accordance with §221 of the UHG (the Austrian trade law) and have to open their books in full in the company registers. The company registers are public (firmenbuchgrundbuch.at); one need pay only a fee to access the annual reports. This is the typical way I do market analyses. I read all reports, and the numbers go into my database. Numbers for the different countries are simple addition.

Looking at the revenues of the above eight companies, their revenues totaled €869 million in 2017, which is 78.8% higher than the number of this "analyst."

Austria has 38 EMS firms, so revenues of 30 more companies need to be added. Now there are ways to get to the revenues of these companies as well, the small ones with a minor inaccuracy, as explained later. Total revenues of these 38 EMS were €1.05 billion in 2017 and €1.11 billion in 2018. The growth rate was 8.5% in 2017 and 5.8% in 2018. The real revenues of Austria's EMS companies were 116% higher than the "analyst" numbers for 2017.

This comparison can be done for every individual country. The biggest deviations are in Western Europe, but, even in Eastern Europe, on average there is a deviation of 9.9%. How so? Eastern Europe has much fewer EMS companies, but many have large revenues, as they are subsidiaries of global EMS players (Foxconn, Flex, Jabil, PCE Paragon, Wistron, Kimball, and Celestica). In Eastern Europe, 409 companies generated €17.57 billion in revenues, while the 1,426 EMS companies in Western Europe generated €18.55 billion in revenues in 2017. By contrast, this "analyst" reported Western European EMS had revenues of €12.61 billion, and, interestingly, Hungary showed higher EMS revenues than Germany. In reality, revenues at EMS companies in Germany were more than 36% higher than in Hungary in 2017.

TABLE 6. Top 8 EMS Companies in Austria

1	Melecs EWS GmbH & Co.
2	Flextronics Althofen
3	CMS Electronics
4	A.B. Mikroelektronik
5	Becom Electronics
6	SVI Austria
7	Digital Elektronik
8	Jabil Circuit Austria

TABLE 7. Deviation of Fake Numbers to in4ma Primary Analysis

"Electronic Research" revenues Austria 2017	€486M	
Top 8 EMS companies Austria 2017 (Table 6)	€869M	78.8%
38 EMS companies Austria 2017	€1.05B	116%

Geographical Pitfalls

Although UK-based, the same "analyst" seemingly has a geographical problem. In his charts, Western Europe is separated from "CEE, MENA & other," and then he adds the two different numbers to calculate "Total Europe." Whereas in sales organizations it is common practice to combine Europe and MENA (Middle East and North Africa), as the latter is too small to be handled separately, market analyses call for precision. MENA is not part of Europe and therefore should not be added to "Total Europe."

The same "analyst" combines the numbers for Russia and Ukraine and states the total as €205 million for 2017. Russia invaded Crimea in 2014 and annexed it, but not all Ukraine. The Ukrainian people find it an affront to be aggregated with Russia. Russia has 60 EMS companies, with 2017 revenues of €354 million. This number comes from the Electronics Developers and Manufacturers Association in Moscow. The biggest EMS company in Ukraine alone has higher revenues than stated in the report for Russia and Ukraine together.

NACE Code Pitfalls

Several market research reports base their analyses on NACE (Nomenclature of Economic Activities) codes. NACE is the European statistical classification of economic activities. NACE groups organizations according to their business activities. Statistics produced based on NACE are comparable at the European level and, in general, at the global level are in line with the United Nations' International Standard Industrial Classification (ISIC). At least this is the theory.

In practical terms, it is not usable for certain analyses such as the EMS market. EMS companies manufacture many different products. They are subcontractors to OEMs. This means OEMs and EMS companies use the same NACE codes. An EMS company primarily manufacturing telecommunication products uses a different NACE code (C26.2.0 manufacture of computers and peripheral equipment) than an EMS company for whose majority of manufacturing is computer equipment (C26.3.0).

In case an EMS company only manufactures PCBAs, the regular NACE code is C26.1.2 (manufacture of loaded electronic boards). In reality, more than 50% of all EMSes doing only PCBA work use the NACE code C26.1.1 (manufacture of electronic components), which is also used, for instance, by PCB manufacturers (**FIGURE 1**).

One might wonder about some of the NACE codes, but the explanation is easy. A company generating revenues with different products and services classifies its revenues by the majority percentage. If a company manufactures loaded electronic boards (C26.1.2) as an EMS service, and this is 50% of

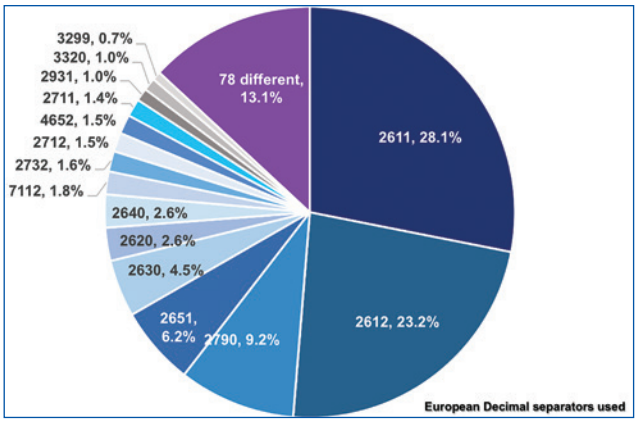

FIGURE 1. NACE codes used by the EMS industry in Europe, 1,250 of 1,835 EMS companies analyzed.

revenues, manufactures its own computers (C26.3.0), generating 28% of revenues there, and makes 22% of revenues with installations of machinery (C33.2.0), it will report C26.1.2. If numbers change and installations become the main revenue share, C33.2.0 will be reported. In talking with some EMS companies in Europe that report C26.1.1, they did not know C26.1.2 exists.

The Content Trap

A customer charged more than $5,000 for a market report wants a return. This is why report samples come with long, detailed tables of content and a lengthy list of companies covered. What can you expect? Do you really think you will get confidential information about the listed companies, or is it a summary of what you can read on the corporate websites and in annual reports? In my opinion, it is better to read the original annual report, rather than a summary. But the main objective is to show that for $5,000 you get many pages.

Knowing the pitfalls for good market statistics, I started a primary analysis of the European EMS industry in 2015. The objective was to get to reliable numbers for the European EMS industry, without the EMS companies having to pay thousands of dollars or euros for highly flawed reports. The basis was a list of 1,300 EMS companies I had from my previous work. Over a period of three years, a total of more than 1,800 EMS companies in Europe were identified. For all companies, the country company registers were consulted. Some were free of charge. Others required a fee for every paper filed. In addition, there are databank systems with direct access to the company registers, which make the research a little easier but are very expensive.

In Europe, all large companies must file annual returns with the company registers. Revenues, number of employees

and total assets are the criteria establishing whether an entity must file a full profit and loss account, a P&L account that starts with gross profit, or the balance sheet only.

Some 70% of all revenues are taken from the P&L of the company registers. Another 5% are retrieved from the in4ma annual EMS statistics, where more than 125 EMS companies from the Germany/Austria/Switzerland (DACH) region report revenues and many more data two weeks after the end of the calendar year. A total of 13% have the P&L published with the gross profit only. For 11% of revenues, you see only the balance sheet, and about 1% of revenues come from private companies, where one must judge the revenues from information of suppliers mainly by getting the number of employees.

There is no general rule how to calculate the revenues of a company. It depends on the country. In the UK, for example, one looks for the trade debtors and can assume an average payment time of debts and thus calculate the annual revenues. In the European Union a new law implemented five years ago requires all companies to report the number of employees. (In Germany it is called Bilanzrichtlinie-Umsetzungsgesetz, or BilRUG.) As such, 97% of all employee data come from a primary source. This in part explains how in4ma is generating the European EMS statistics.

The general rule for the in4ma statistics is every individual number can be explained in detail. Analyses for growth rates

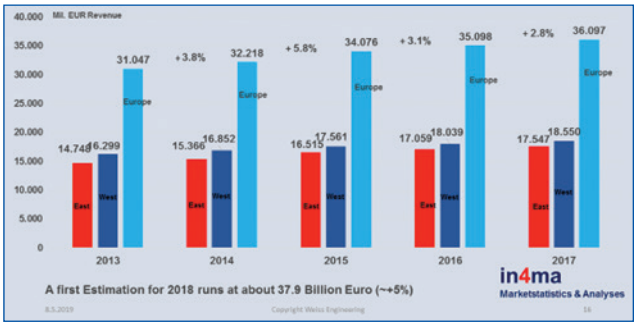

FIGURE 2. Revenues of 1,832 EMS/ODM companies in Europe, 2013-17.

by country are just simple additions of all the EMS companies of the country analyzed.

Logic says the market would be looking for precise numbers and use them. Wrong. There is no logic in the EMS market. Many EMS companies are managed by people who either overestimate themselves and think they know the market, or never learned what to do with market data and how to use them. Others use reports with lower numbers, as they suggest a higher market share and suggest they grew above average.

In fact, in 2017 the EMS industry in Europe had €36.097 billion in revenues, and the growth rates until 2022 will be more than 5% (**FIGURE 2**). (Sorry, I do not calculate to the hundredths decimal). This projection is the outcome of questions from the in4ma annual EMS statistics. For 2018, so far everything indicates the EMS industry in Europe had €37.9 billion in revenues. For Germany, growth in 2018 was 6%.

The reason for the late numbers is simple. A primary analysis uses only numbers from primary sources, the majority of which in this case are the company registers. Companies are required to file annual reports six to 12 months after the end of their fiscal year, depending on the country. The biggest European EMS company is Foxconn, and it typically uses the full 12 months granted to file their reports. This causes a 12-month lag for the final numbers. Everything before that is just an estimate.

So, when buying a market report, make sure you ask beforehand how the analyst arrived at their numbers, where they got them, what calculations they made, and make sure market and production revenues are not mixed. The European market is European production value minus exports plus imports. This was more than €40 billion in 2017. There was an additional €70 billion in market potential, the approximate value of PCBA production of European OEMs. True numbers can be easily explained. Lies take a bit longer. ▫

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Taking off the Mask

How proper investigative work can alleviate misguided print process adjustments.

PRINTING is arguably one of the most sensitive processes within the entire PCB assembly operation. Not surprisingly, stencil printing's multi-input interdependency and sensitivity have become more pronounced as miniaturization has taken hold. Even slight variations can cause process shifts, a reality our team was reminded of while conducting recent internal testing.

Our engineers set up a test with a really long board run to evaluate time to bridge, a fairly standard analysis used to understand how many PCBs can be printed for a particular product until solder paste bridging begins to appear. The evaluation, which was performed using a relatively complex ASM test board, was proceeding beautifully until we noticed a sudden shift in the output. The measurable Sigma shift went from a process running at 4 Sigma (1.33 Cpk) to 3 Sigma (1.0 Cpk). The engineer running the evaluation was looking at the process window and robustness, beginning at a 10,000 ft. view with a box plot, which gives reasonable stability insight across the entire run. When a more granular examination of the data was conducted, the data spike appeared on three boards in the batch, with one PCB being more extreme.

To be clear, the data did not show bridging at the point at which the shift was observed, and in fact, the board at 1.0 Cpk was still within the specification range. But, seeing this unusual spike indicated that if the trend continued, the process would most certainly become out of control. The printed boards were put back through solder paste inspection (SPI) to verify repeatability, and, indeed, it was confirmed. The chance of SPI having a wobble exactly on the same board was remote, and we ran it three different times. So, the culprit wasn't SPI but rather some characteristic with the board or other input.

The solder deposit on the board before the errant PCB and the board after looked fairly similar; these were the three with Sigma shifts. The list of potential candidates for the cause of the problem included the normal things one would consider: mesh fatigue on the stencil, debris on the squeegee, something in the paste roll, etc. All were reviewed, and none was determined problematic. Eventually, our team got down to close inspection of the board and discovered the solder mask on the three outlier PCBs had a different characteristic, a different shape than the other boards. The figures compare standard solder mask and non-standard solder mask. With the good, 4 Sigma boards, the mask came down in one consistent slope to the pad (**FIGURE 1**). The triad of 3 Sigma boards had solder mask that was slightly thicker than the others and it stepped down to the pad, almost like a stair step (**FIGURE 2**). On the compromised boards, the solder mask was also closer to the pad, and the combination of the odd shape and the proximity to the pad interfered with the board-to-stencil gasket.

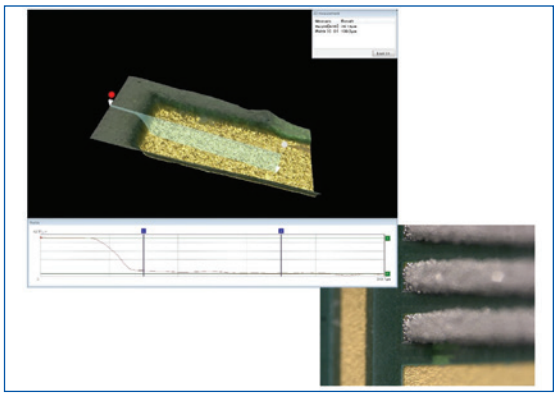


FIGURE 1. Standard solder mask rolls down to the pad in a consistently sloped plane, permitting robust gasketing.

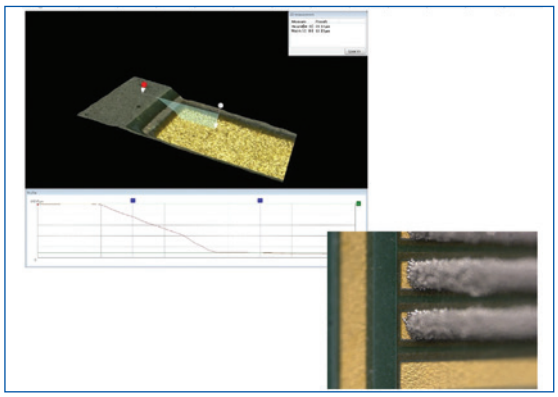


FIGURE 2. Nonstandard solder mask steps down to the pad, resulting in poor gasketing and an opportunity for process variation.

For assemblers, there are lessons to be learned here. This experience underscores how incredibly sensitive the printing process is. For us – and we source our boards from a respected supplier – with board runs that were evaluation volumes and certainly not ultra high volume, it was fairly easy to isolate, even though all the boards (good and bad) were part of the same batch number. For a manufacturer, however, this could be a red herring, and one might adjust the

continued on pg. 43

CLIVE ASHMORE
is global applied process engineering manager at ASM Assembly Systems, Printing Solutions Division (asmpt.com); clive.ashmore@asmpt.com. His column appears bimonthly.

Cleaning Before High-Temperature Aging

Flux becomes increasingly tenacious the longer it sits on the board.

THIS MONTH OUR topic is not so much a defect as something to consider when running environmental tests before any destructive analysis on solder joints. The through-hole joints shown in **FIGURES 1** and **2** were soldered with a high-temperature alloy as part of our trials on robotic laser and single point soldering. The amount of flux in high-temperature cored wire tends to be higher, hence more residues after soldering. If sample boards will be exposed to high-temperature storage, in this case 200°C for 1,000 hr., or temperature cycling, clean the residues first. It is much more difficult to clean after this level of aging, and mounting samples in epoxy for microsections is much more difficult.

Cleaning the samples before aging is also good practice if samples will be coated before scanning electron microscope (SEM) assessment.

FIGURES 1 and **2** are examples of through-hole connectors rated at 260°C. All pins were soldered with SnAg using robotic laser and soldering iron. In each case, results were satisfactory and exceeded IPC Class 3.

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. ▫

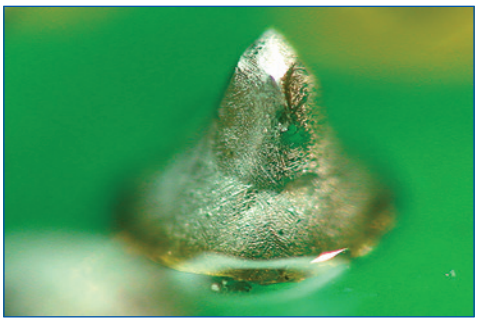


FIGURE 1. Connector pin soldered with SnAg using robotic laser.

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

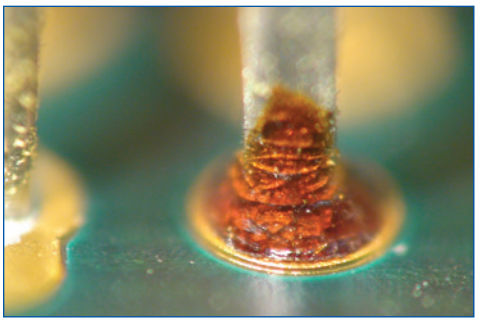


FIGURE 2. Connector pin soldered with SnAg using soldering iron.

Screen Printing, continued from pg. 42

printer to attempt to correct the issue. However, when a shift in the process is observed, it is highly advisable to look a bit deeper than the print platform. It's easy to assume it's the equipment. More times than not when it comes to printing, however, it is an input other than the sophisticated machinery. Take it slow. Don't immediately start twisting knobs and pushing buttons. Do the investigative work, and good results will follow. ▫

When and How to Clean/Flush Selective Coating Equipment

Build-in cleaning time during chemistry changeovers and after extended line shutdowns.

Much time and planning are invested in the choice of the ideal conformal coating material and process to adequately protect printed circuit boards. This often includes multiple qualification trials. There is also sometimes long and detailed testing in areas such as electrical performance, flame resistance, and thermal or mechanical cycling. Unfortunately, the qualification and testing process for conformal coatings is simply a snapshot of the process at the start. To maintain consistency, an often-overlooked activity remains: regular cleaning and flushing of the selective conformal coating equipment.

In general, the following comments and guidelines are designed for a discussion involving typical modern selective coating equipment (**FIGURE 1**). However, nearly all the principles are applicable to manual spraying operations as well.

Why clean and flush? Before discussing the specific considerations involved in the clean and flush process, let's explain the reasoning behind it. Beyond the obvious answer that it is simply good practice, there are a few reasons to regularly clean and flush the selective coating system:

- The process improves the working life of key components such as valve(s), nozzles and spray heads, and feed and return lines.
- The process minimizes inconsistency due to clogs or buildups.
- Cleaning and flushing improve reliability and consistency of flow rates and material usage, application thickness, and coating pattern width and edge definition.
- Regular maintenance prevents cross-contamination from incompatible chemistries.

(Note: When a silicone coating chemistry is used, never use the same fluid lines, valves or pressure pot when converting to other chemistries, such as acrylics, urethanes, synthetic rubbers, and so forth.)

When to clean and flush? There are a number of fairly obvious circumstances and times when it is advisable to thoroughly clean and flush your selective conformal coating equipment. They include the following:

- Startups or changeovers to different coating chemistries, such as acrylic to urethane and synthetic rubber to acrylic.
- At startups after shutdowns of 48 hr. or more for acrylic, synthetic rubbers, and non-moisture-sensitive materials.
- At the end-of-production day for moisture-sensitive materials, including most silicones and many urethanes.
- Any time inconsistent spray patterns or flow rates are observed.

How to clean and flush? Here are the basic steps to cleaning and flushing manual or selective coating equipment. (Note: Please consult the respective equipment manufacturer to discuss details before attempting.)

1. Remove excess coating from the reservoir or pressure pot.
2. Remove the air cap (if applicable) of the valve and back off the micrometer (if applicable) to permit more needle travel.
3. Flush the coating from the coating reservoir, fluid lines and valve until there's no coating coming out.
4. Add a compatible solvent/thinner (MEK, xylene, commercial thinner) to the fluid reservoir. (Important: Use thinners provided by your coating manufacturer, not stripping agents, which are used for removing cured coatings from PCBs.)
5. Turn on the machine blacklight.
6. Flush until the solvent/thinner stops fluorescing blue. Do this if the coating contains fluorescing agents; otherwise, flush until the coating appears to be eliminated.
7. Add a small amount of additional thinner.
8. Flush just until the moment when the fluid becomes spray. The fluid will go from a stream to a spray when the flushing fluid runs out. Then stop. If done correctly, the process will leave a very small amount of solvent/thinner in the fluid lines/valve.

To restart the process, flush the remaining solvent from the fluid reservoir/fluid lines/valves. Now the machine and valve are ready to be filled with fresh coating. □

MATT EVELINE is senior technical specialist at Chase Corp. (Humiseal).

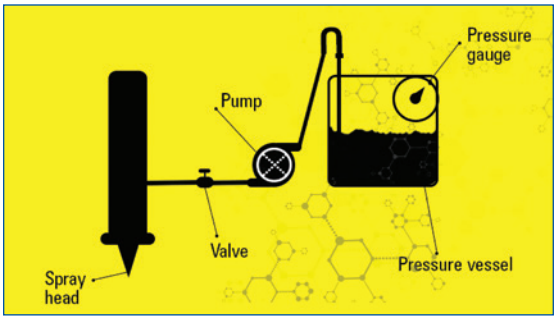


FIGURE 1. Typical pressurized application system.

WHITE GLOSS SOLDER MASK

TechniMask ISR1000F/900G liquid photo-definable mask is for LED applications. Offers high-rated reflectance value; exhibits little to no discoloration after multiple reflow applications. Reportedly eliminates pink/violet discoloration after reflow. Operates with standard exposure and UV/LED direct imagers.

Technic
technic.com

ADDITIVE MANUFACTURING SYSTEM

DragonFly Lights-Out Digital Manufacturing prints multilayer PCBs, antennas, capacitors and sensors. Is capable of 24/7, uninterrupted production of prototypes and low-volume manufacturing. Has new printer head software management algorithms. Automatic self-cleaning of print heads every few hours. Real-time automatic material monitoring.

Nano Dimension
nano-di.com

AUTOMOTIVE FLEX CONNECTOR

CFI features a unique metal terminal connection structure for direct connection between an automotive flexible circuit and the board. Eliminates wire harnesses; permits use of fewer components. Double-clip contact structure resists vibration and is compatible with LED lights and BMSs. Inertial lock structure prevents incomplete engagement for reliability. Rated 2.0 A/pin max. Voltage: 50V DC. Ambient temperature: -40° to +125°C. Contact resistance: 20mΩ max. (initial). Insulation resistance: 100MΩ min.

Panasonic
panasonic.com

OTHERS OF NOTE

POWER CIRCUIT CAPS

SVPT surface mount-type OS-CON conductive polymer-aluminum-solid capacitors come with a rated voltage of 2.5VDC, 6.3VDC and 16VDC. Capacitance values of 100µF up to 560µF and ESR characteristics of 15-24mΩ max. Withstand +105°C for up to 20 hr. For use in power circuits in servers, base stations, as well as smart meters or other power management systems. Excellent noise-reduction capability and frequency characteristics. RoHS-compliant and halogen-free.

Panasonic Industry Europe
industry.panasonic.eu

HIGH-SPEED (400GBPS) CONNECTORS

Quad Small Form Factor Pluggable Double Density (QSFP-DD) connectors, cages and cable assemblies reach speeds up to 400Gbps. Have eight lanes. Are designed for 28G NRZ and 56G PAM-4 protocols. Backward-compatible. Include 1 x 1 through 1 x 6 cages and SMT connectors on 0.8mm pitch.

TE Connectivity
te.com/usa-en/home.html

PROCESSING EQUIPMENT CLEANER

Equipment Cleaner IV removes water hardness residues, photoresist scum and metal salt deposits. Reportedly causes no damage to metal or plastic parts. Is odorless. Is useful for spray equipment. Can be used in stainless steel, titanium and polypropylene equipment.

RBP Chemical Technology
rbpchemical.com

SLIVER STRADDLE-MOUNT CONNECTORS

Sliver straddle-mount connectors for SFF-TA-1002 support faceplate-pluggable open compute project NIC 3.0. Designed to be useful for OCP NIC 3.0 cards in a low profile for ease of system maintenance and improved thermal management. Support high speeds through PCIe Gen 5, with a roadmap to 112G. High-density, 0.6mm pitch connectors support next-gen silicon PCIe lane counts.

TE Connectivity
te.com

THERMOPLASTIC PART SEALING

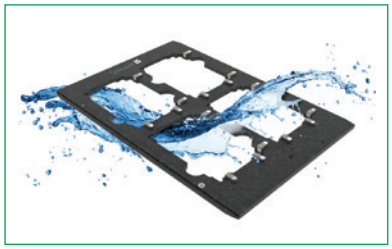
PostPro3DColor and PostPro3DMini machines are designed to smooth thermoplastic 3-D printed parts. Blast is a physio-chemical performance- and aesthetic-enhancing process that smooths thermoplastic 3-D printed parts with complex internal cavities; seals surface of parts being processed, removing porosity and sealing them against liquid or gas ingress. PostPro3DColor adds color to 3-D printed parts in a single step without water.

Additive Manufacturing Technologies
amtechnologies.co.uk

EMI FILTER INDUCTORS

HM66M shielded, miniature low-profile SMD inductors are for high-frequency power conversion systems and EMI filter applications. Power inductance optimized within frequency range from 700kHz to 4MHz. Designed for switching frequencies up to 4MHz and operating temperatures at 125°C.

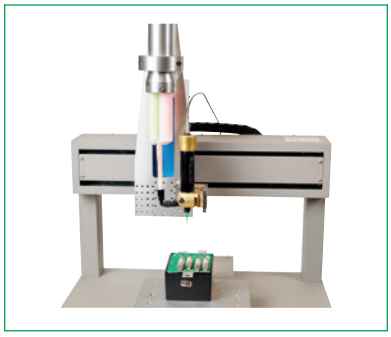
TT Electronics
ttelectronics.com



CONFORMAL COATING CLEANER

Elpespec R 5888 cleaning agent dissolves and removes conformal coatings from product carriers, tools and fixations. Suitable for dipping processes in ultrasonic bath. Selective application with mechanical support or spray processes is also possible. Contaminated carriers can be left in cleaning agent overnight. Is water-soluble and biodegradable. Comes as concentrate.

Lackwerke Peters
peters.de



2-SYRINGE DISPENSING

Dual syringe dispenser is designed for dispensing 50ml dual syringes. Can accommodate 50ml side-by-side syringes in ratios 1:1, 2:1, 4:1 and 10:1. Includes secure attachment adaptor. Pulsed air pressure operation. Multi-configurable robot integration bracket allows semiautomated use.

Techcon
techcon.com

X-RAY COMPONENT COUNTER

AXC-800 III manages parts inventory by starting counts automatically after reels are placed in system and door is closed. Counts four 7" reels in 23 sec. or one 13"-15" reel in 16 sec. Features internal barcode scanner and reel removal sensor for automatic label printing.

Scienscope
scienscope.com

OTHERS OF NOTE

FIELD DEPTH IMAGING

Focus stacking with UHD (4K) imaging combines multiple images taken at different focus depths for greater depth of field. Can stack from 6 to 22 images at different focus planes to create one image with a large depth of field. For boards with large discrete components, connectors and other mechanical assemblies. Two focus stacking modes: auto and manual.

Inspectis
inspect-is.com

N_2 PISTON SOLDERING

SWF-KL piston soldering module carries out piston soldering process under nitrogen, including fully automated changing of soldering tip. Is speed-controlled with 100% traceability. Integrated nitrogen gas supply. Intelligent sensors inform operator when wire is tending toward the end in feeder.

Eutect
eutect.de

COMPACT LASER FUME EXTRACTOR

LAS 200.1 is a compact mobile system with a new filtration concept that reportedly increases pollutant separation efficiency. Pre-filter package includes filter mat and panel filter; enables longer filter life. Coarse and fine dust filter increases H14 main filter's durability. HEPA filter is offered in combination with an adsorption filter to increase main filter's separation rate up to >99,995%. Can be equipped with additional filter modules.

ULT
ult.de/en

LOW-SPATTER SOLDER WIRE

TipSave N flux-cored solder wire reportedly extends soldering iron tip life 3x. Paired with (032) no-clean, halogen-free cored-flux, it provides fast wetting and low spattering. Is a good match for hand soldering, as well as continuous robotic soldering; reduces required soldering tip changeovers.

Nihon Superior Co.
nihonsuperior.co.jp/english

THERMAL IMAGING CAMERA

LC-IRP01, a diagnostic tool for PCBs, displays heat images to identify damaged or malfunctioning components or short circuits. Microscope contains two imagers: one for visible wavelengths and one for infrared heat images. Images can be combined on PC display to identify problem areas. Searches for missing, incorrect or charred components, bad solder joints, and solder bridges.

QianLi
Union Repair / unionrepair.com

DESKTOP REFLOW OVEN

IN6 desktop-type reflow oven provides constant temperature, thanks to dynamic warming-up control system. Built-in solder smoke filtering system. Has six top and bottom heating zones. Stabilizes temperature within +0.2°C. TUV CE certified.

Neoden USA
neodenusa.com

In Case You Missed It

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.

Heat Shielding Materials

"Ultra-High Thermal Isolation across Heterogeneously Layered Two-Dimensional Materials"

Authors: Sam Vaziri, *et al*.

Abstract: Heterogeneous integration of nanomaterials has enabled advanced electronics and photonics applications. However, similar progress has been challenging for thermal applications, in part due to shorter wavelengths of heat carriers (phonons) compared to electrons and photons. Here, the authors demonstrate unusually high thermal isolation across ultrathin heterostructures, achieved by layering atomically thin two-dimensional (2-D) materials. The authors realize artificial stacks of monolayer graphene, MoS_2, and WSe_2 with thermal resistance greater than 100 times thicker than SiO_2 and effective thermal conductivity lower than air at room temperature. Using Raman thermometry, we simultaneously identify the thermal resistance between any 2-D monolayers in the stack. Ultra-high thermal isolation is achieved through the mismatch in mass density and phonon density of states between the 2-D layers. These thermal metamaterials are an example in the emerging field of phononics and could find applications where ultrathin thermal insulation is desired in thermal energy harvesting or for routing heat in ultracompact geometries. (*Science Advances*, Aug. 16, 2019, advances.sciencemag.org/content/5/8/eaax1325)

PCB Design

"EMC & EMI on High-Speed PCB Design"

Authors: Zhiwei Tang and Xiaoqing Chen; 99chaoyang@163.com.

Abstract: In higher complexity electronics systems, PCB clock frequencies and densities increase as well. Signal integrity is a top priority in high-speed PCB design. Many factors such as electromagnetic compatibility (EMC), PCB electrical parameters, component layout and high-speed signal line cabling affect the performance of the final system. How to reasonably avoid the impact of these factors and issues of note are the key to successful design of high-speed PCBs. (International Conference on Applications and Techniques in Cyber Security and Intelligence, Jul. 31, 2019)

PCB Processing

"Advanced Manufacturing Technology of Microwave Multilayer Printed Circuit Board"

Authors: Zhaohang Zhang, *et al*; zzh_william@126china.com.

Abstract: The requirements for new-type antenna electronics equipment are high performance, high reliability and large capacity, but small size and lightweight. This paper discusses the processing of rigid antenna microwave multilayer PCBs, which presents some key developing fields and solutions, specifically in registration control and any-layer interconnect. With performance requirements increasing for rigid antennas, a PTFE-based composite lays a foundation for the development of microwave multilayer PCBs. From the advanced mechanical manufacturing point of view, the future technology development of microwave multilayer PCBs includes control of the deformation and expansion/contraction of the PCB substrate, large data software systems, any-layer interconnect design requirements, and performance indicators. (Proceedings of the Seventh Asia International Symposium on Mechatronics, Aug. 31, 2019)

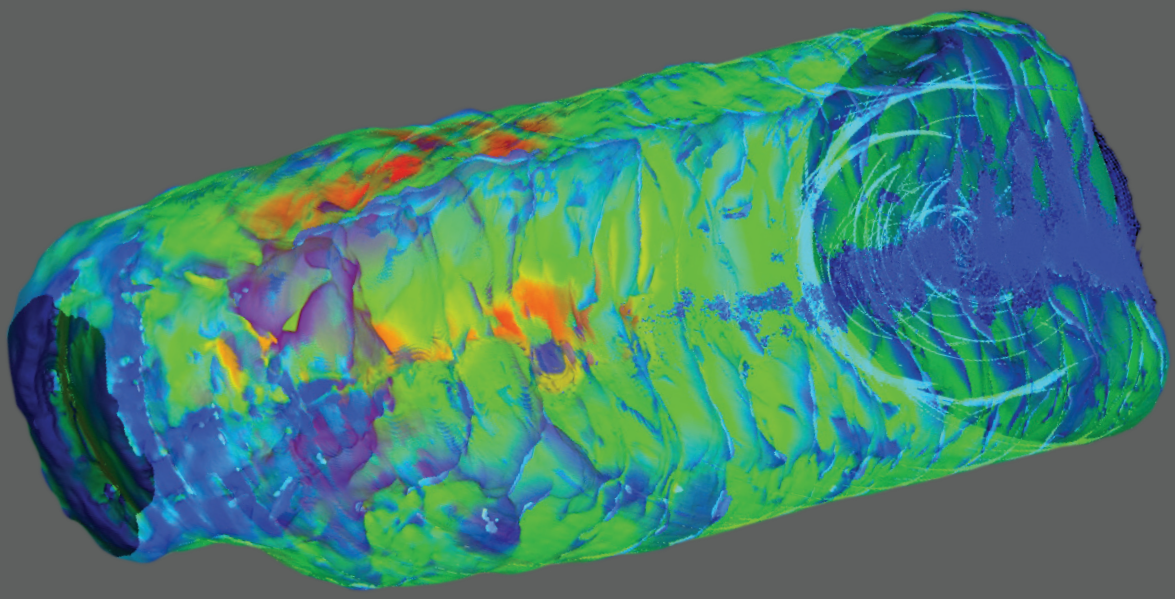
Reliability

"Solder Joint Reliability of a 0.65mm Pitch Molded Array Package for Automotive Applications"

Authors: Burton Carpenter, Mollie Benson and Andrew Mawer; andrew.mawer@nxp.com.

Abstract: BGA components used in high-reliability automotive microprocessor applications have historically been 0.8mm pitch or larger. Recently, emerging market requirements have pushed BGA pitches down to 0.65mm. However, industry expectations of solder-joint reliability remain constant; customers expect cyclical thermal fatigue lifetimes to be the same as or, in some cases, more robust than prior generations of packages. In addition, automotive Tier 1 electronics manufacturers often include drop test and other board-mounted testing criteria to mitigate the risk of module-level failure during SMT, module or final vehicle assembly. The paper reports the board-level reliability of a 0.65mm pitch, 10 x 10mm MAPBGA (molded array plastic BGA) package used as an automotive radar microprocessor. Thermal fatigue life was assessed per IPC-9701A using AATS (air-to-air thermal shock) between -40°C and +125°C, while drop testing followed Jedec JESD22-B111A at 1500G. (SMTA International, October 2018) ▫

Datest's Imaging Technology Illuminates Fossils.



This is a fossil.

The colors correspond to thickness.

After 2 million years, technology tells a colorful tale.

Why does that matter?

Because CT scanning provides meaningful interpretive data for lots of objects.

To help scientists understand the work of millennia, and help engineers solve problems.

Test Engineering. Failure Analysis. Answers.

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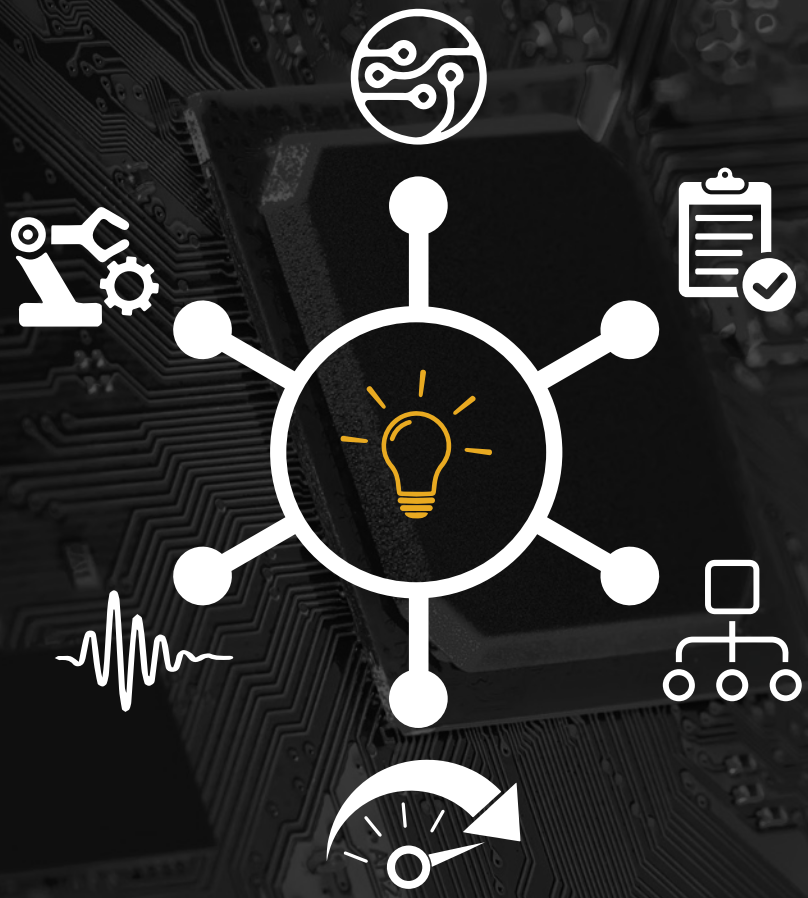
RISE ABOVE THE AVERAGE



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