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February 2022

Improving Cycle Time

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FEBRUARY 2022 • VOL. 39 • NO. 2

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FIRST PERSON

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DEPARTMENTS

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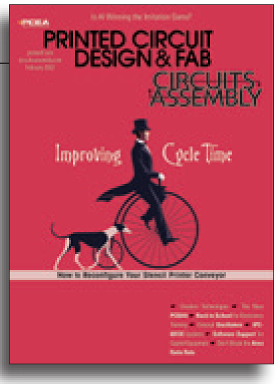

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PRINTED CIRCUIT DESIGN & FAB/CIRCUITS ASSEMBLY is published monthly by Printed Circuit Engineering Association, Inc., PO Box 807 Amesbury, MA 01913. ISSN 1939-5442. GST 124513185/ Agreement #1419617.

Brandi & David D'Aquin

CoralVue HYDROS system

MIKE
BUETOW
PRESIDENT

Diving into DDR: Highlights of PCB East

IT TOOK LONGER than expected, but only by a couple weeks. PCEA is now the owner of a number of publications, websites, educational events and trade shows for printed circuit engineers.

In January, we completed the acquisition of several longtime and popular brands from UP Media Group, including PCD&F, CIRCUITS ASSEMBLY, the PCB2Day webinar series, the Printed Circuit University online education platform, the PCB Chat podcast series, and of course, the leading technical conferences and trade shows for design engineers: PCB West and PCB East. It's the latter one I'll look at today.

Last month's discussion focused on training opportunities. We looked at developments at the college level and new certification programs like the Printed Circuit Engineering Professional course offered by PCE-EDU, the brainchild of a team of veteran design engineers led by Mike Creeden and Rick Hartley.

This month, we dive into the upcoming PCB East technical conference. For the uninitiated, PCB East is the Eastern US version of the popular PCB West trade show. It debuted in the 2000s, then went on hiatus after the industry downturn in 2007-08. At the urging of several companies and individual design engineers, it was set to return last year, until the pandemic got in the way.

Now planned for Apr. 11-13 in Marlborough, MA, a Boston suburb, PCB East (pcbeast.com) features almost 40 hours of classes over its three days. Speakers include a who's who of electronics design, ranging from Rick Hartley and Susy Webb to newer names like Tomas Chester and Zachariah Peterson.

What sets PCB East and PCB West apart from other technical conferences is the depth of its tutorials. These are not to be confused with "paper" conferences, where speakers present 20-minute recaps of research investigations and product pitches. To be sure, those events are important and necessary.

But the genesis of PCB East and PCB West, which takes place in Santa Clara, CA, in October, is the emphasis on longer-form training. Of the 18 classes offered, all but three are at least two hours in length, giving the presenter and attendees ample time to dive into the subject at hand.

That goes for the free sessions, too. We are excited to offer a full day's worth of complimentary classes. Topics range from flex circuits – led by Mark Finstad and Nick Koop, co-chairs of the IPC flex circuit subcommittee – to "The 21 Most Common Design Errors Caught by Fabrication (and How to Prevent Them)," one of the most popular classes we've ever offered, featuring the always entertaining team of Ray Fugitt and Dave Hoover.

Making its debut at PCB East is "Proper PCB Layout – DDR2, 3, 4, etc.," a free new class from Rick Hartley. "The majority of today's digital systems utilize DDR memory," Hartley says. "The advantages are many, mostly that we get twice the amount of information transfer per given 'clock frequency.' More data transfer without increased signal integrity or EMI risk: Fabulous! Over the years, guidelines and rules have been developed, attempting to ensure DDR bus structures function as intended. Unfortunately, many rules are overly conservative and require excessive restrictions in PCB layout, adding time and cost to PCB design. Worse, these restrictions can add layers and cost to the PCB itself."

Hartley's presentation will focus on identifying reasonable rules and guidelines, and proper PCB layout concepts to ensure DDR structures function as intended without adding extra time or cost to the project.

Other new classes this year look at best practices for hardware IP reuse from PCEA chairman Stephen Chavez; high-frequency PCB design by Zachariah Peterson; circuit design and layout from Tomas Chester; and material decision-making from Mike Creeden.

Gene Weiner, fresh off a trip to Europe where he visited several emerging companies, will keynote the conference. His talk, "From Possibility to Reality," will paint a picture of exciting possibilities in additive manufacturing, components, Type 6 and 7 solder pastes, and other developments that may be in full swing in the next few years.

PCB East also offers a trade show featuring leading suppliers of software, printed circuit boards and related products and services. That takes place Apr. 12, and if for nothing else, come for the happy hour and catch up with old and new friends.

Finally, it's last call for abstracts for PCB West, the industry's largest conference for printed circuit design and engineering. Submit your idea here: https://pcbwest.com/abstract-submission-guidelines. □

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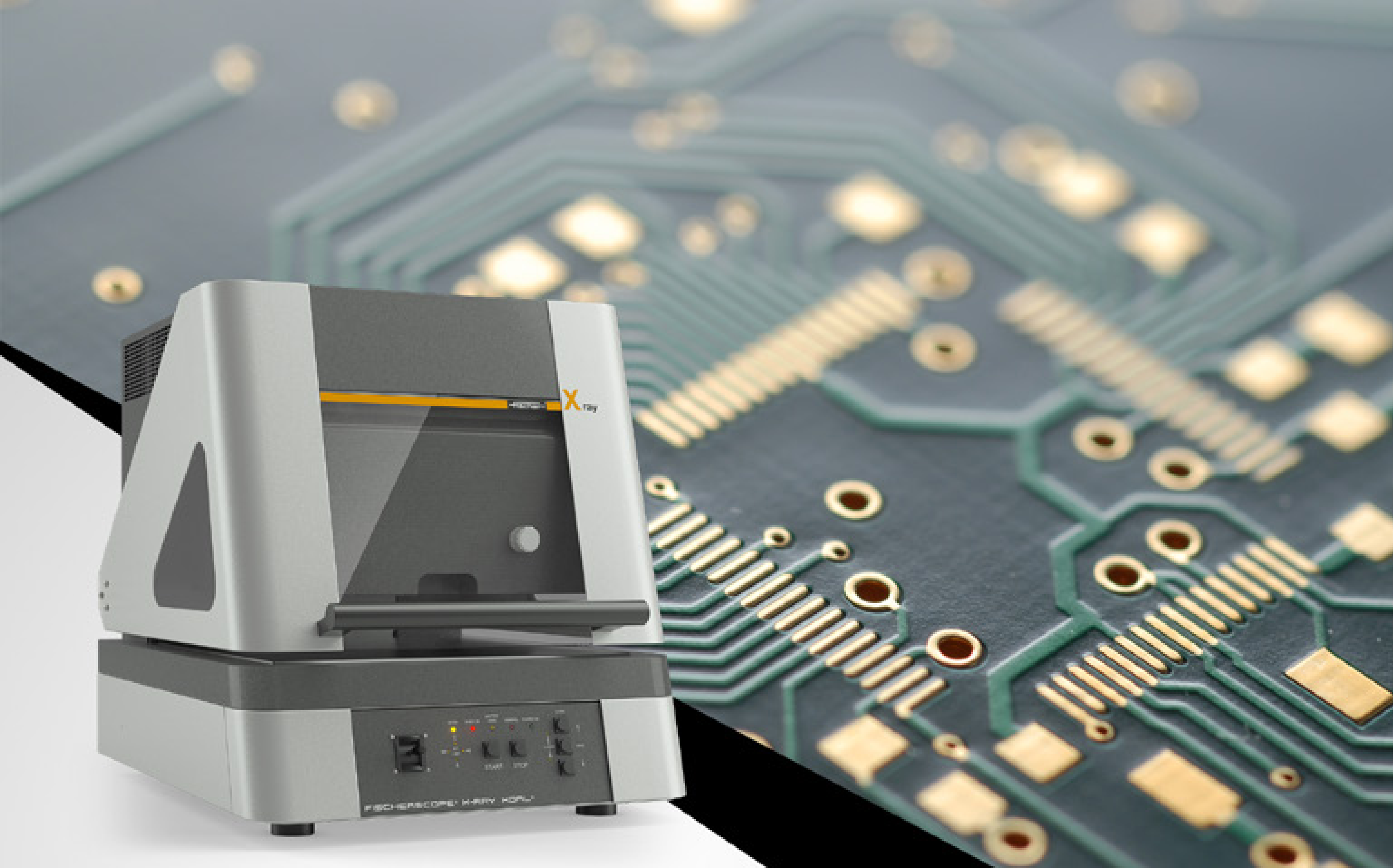


PCDF People

Bowman named **Xin Jiang** principal electrical/firmware engineer. He has a master's in electrical engineering and more than 30 years' experience in digital circuits, embedded software, and product design.

Eltek named **Ron Freund** chief financial officer.

Epec Engineered Technologies promoted **Keith Araujo** to vice president of marketing.

Zuken USA promoted **Mark Geise** to CIO and vice president of operations.

PCDF Briefs

Abstracts for PCB West should be submitted to https://pcbwest.com/abstract-submission-guidelines by Feb. 25.

Altium's Upverter Education electronics engineering courses will now be part of the curriculum for printed circuit board design in the Department of Electronics and Communications at **Chandigarh University** in Mohali, India.

APCT qualified to IPC-1791, Trusted Electronics Fabricator Requirements Qualified Manufacturers Listing (QML) at its PCB manufacturing facilities in Anaheim and Orange County, CA.

Boeing and **Airbus** want the US to delay its 5G rollout because they're worried about interference with aircraft electronics.

CADY raised $3 million to develop an automotive PCB design inspection software that parses the datasheets of chips and electrical components in the electrical schematic and cross-checks them against connections in the design to detect errors at early stages.

Calumet Electronics recertified to IPC-1791 Qualified Manufacturers Listing (QML).

Ericsson has filed another set of patent infringement lawsuits against **Apple** over royalty payments for use of 5G wireless patents in iPhones.

Innoviz is using **Ansys** simulation solutions to drive the technology behind its automotive-grade LiDAR sensor.

IPC named three papers as winners of the Best of Conference for IPC Apex Expo 2022. They are "Analysis of a Dynamic Flexed Flat Cable Harness" by Bhanu Sood, Ph.D., **NASA Goddard Space Flight Center,** coauthored by Mary E. Wusk, Eric Burke, Dave Dawicke, George Slen-

New Webinars from PCEA Focus on DfM, High-Frequency Design

PEACHTREE CITY, GA – The Printed Circuit Engineering Association announced a pair of new webinars for PCB design engineers, RF engineers and digital designers will take place over the next two months.

"Best DfM Practices for Board Engineers," a new three-hour webinar in the PCB2Day training series, will take place Feb. 22.

Taught by Susy Webb, a certified PCB designer with nearly 40 years' experience, the webinar is aimed at PCB designers, design engineers, system designers, and hardware engineers. It is designed for all skill levels: beginner, intermediate, and advanced.

"There is so much more to board design than placing parts and connecting the signals electrically," Webb says. "This half-day webinar will talk about good practices for building footprints, how parts might be placed for manufacturability, routing practices that are helpful, trace widths and spacings that are producible, a stackup structure that can realistically get the impedance and return needed, and documentation for the manufacturer that is complete and understandable.

"This presentation is not about how to build a board, but rather about the practical things the board engineer can do to help make fabrication and assembly easier and therefore increase yields and lower the cost for all," she adds.

On Mar. 22, a new two-hour class called "Designing and Analyzing High Frequency Interconnects" will debut, focusing on an approach to designing high-frequency interconnects, beginning with PCB design and leading into systems-level RF design.

The webinar will cover transmission line design network parameter analysis, including S-parameters, interconnect characterization, parasitics and their effects on signal integrity, and advanced topics like waveguides and emitters.

Design examples involving unique waveguide and cavity structures on high-frequency PCBs will be presented. By the end of the course, attendees will have received conceptual guidance on interconnect design and analysis for any frequency range.

The speaker, Zachariah Peterson, currently provides research, design and marketing services to electronics companies. Prior to working in the PCB industry, he taught at Portland State University.

"High-frequency PCB designs carry a unique set of challenges due to concentration of signal power in a narrow bandwidth. To design high-frequency interconnects, designers must consider an entire interconnect, including its linearity and stability," said Peterson.

To register for these online events, visit pcb2day.com.

Nano Dimension Acquires Global Inkjet Systems for $18M

SUNRISE, FL – Nano Dimension acquired Global Inkjet Systems, paying GIS shareholders $18.1 million in cash. In addition, it will pay between $1.3 million and $10.7 million within the next 27 months if GIS achieves certain financial performance over this period.

UK-based GIS develops and supplies high-performance control electronics, software, and ink delivery systems and is known for 2-D and 3-D printing inkjet hardware and operating software. GIS has more than 130 customers globally and had revenues for the 12 months ended Mar. 31 of approximately $10 million.

"GIS' ink delivery technology and software are essential to any ink deposition methodology within our AME and AM solutions. GIS' research and development roadmap will help us deliver better resolution and higher productivity in our industrial 3-D printing solutions," said Yoav Stern, chairman and CEO, Nano Dimension. "As a result of this acquisition, we will be able to improve our technology's perfor-

ski, **NASA Langley Research Center,** and Stephen Lebair, NASA Goddard Space Flight Center; "Microvia Reliability Testing Utilizing D-Coupons to Understand Best Design Practice" by Kevin Kusiak, Lockheed Martin, and "A Critical Analysis of CAF Testing – Temperature, Humidity, and the Reality of Field Performance" by Kevin Knadle, **TTM Technologies.** The NextGen best paper was awarded to "Bio-based Encapsulation Resins: Good for the Environment, Good for Your Environment" by Beth Turner, **Electrolube.**

Isola opened a new global headquarters in Chandler, Arizona.

Nano Dimension is collaborating with **XTPL** to develop new nanoparticle-based conductive ink for AME applications.

Nano Dimension sold a DragonFly IV 3D-AME printer and FLIGHT applications software package to a leading Western defense force.

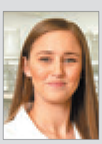
Optomec announced one of its existing production customers recently purchased another six Aerosol Jet 3D electronics printers, bringing its total count to 20 systems.

RS Components expanded its design and manufacturing offerings by partnering with **Eurocircuits.**

CA People

BTU announced **Chris Heesch** as regional sales manager for the Western US, Mexico and Central America.

Indium promoted **Wolfgang Bloching** and **David McKee** to senior regional sales manager in Europe, while **Anders Lunden** is now regional sales manager. Bloching joined Indium in 2009 and has more than 24 years' experience in electronics manufacturing. McKee joined Indium in 2000 and has held roles as process specialist, area sales manager, and key account manager. Lunden has been with the company since 2019 and has more than 20 years' experience in electronics.



Haley Reid, senior research and development chemist at Kyzen, was recognized as one of the Women of Excellence in Metal Forming and Fabricating 2021.

mance and time to market. The combined company will own and have access to innovative and yet-to-be-released printing technologies, providing value and leading-edge solutions tailored to our customers' needs and giving us a clear competitive advantage."

GIS will continue to develop and sell hardware and software globally.

"We are very excited to be joining a company that recognizes the excellence of our technologies, our passion for innovation and matches our customer-focused culture," said Nick Geddes, founder and CEO, GIS. "Working together, we will be pushing the envelope beyond existing printing capabilities in ways our customers will gain advantages that are unmatched yet."

"This is a win-win for both organizations," said Stern. "Combining forces and resources will enable growth for the integrated company at an accelerated pace. This merger will upgrade Nano Dimension's product line with GIS' innovative hardware and software. In parallel, our go-to-market network will expand GIS' commercial horizon and customer base. The combination of both companies will further leverage the customer-focused culture across the entire organization." (CD)

NCAB Acquires German PCB Distributor META

BROMMA, SWEDEN – NCAB Group signed an agreement to acquire 100% of the shares in META Leiterplatten for an undisclosed amount. The transaction is expected to be accretive to earnings in 2022 and close in early January.

Villingen-Schwenningen, Germany-based META was founded in 2000 and serves customers in Germany and expects net sales of about SEK 85 million ($9.4 million) in 2021, with an estimated EBITA of SEK 4.5 million. The company provides customers with PCB solutions in the high-mix, low-volume segment, mainly in the industrial, consumer and medical sectors. Their suppliers are located in China and Taiwan.

The company has 17 employees, all based at its German headquarters.

In a statement, NCAB CFO Anders Forsén said, "META is a well-managed trader of high-quality PCBs and complements our German business very well. It is an important component of NCAB's strategy to actively participate in the consolidation of the market. META will be integrated with NCAB Europe."

Added Annabell Uhl, shareholder and CEO of META, "This is a great opportunity for all of us. META Leiterplatten has been privately owned and dominated by a customer-driven culture with a goal to deliver superior performance and value. Being selected by NCAB Group to be a part of their new Germany team is a great compliment. Joining NCAB will give us even more leverage to support our customers. The major benefits of joining the NCAB Group will come from their extensive factory management organization in Asia and the increase in resources worldwide. I am looking forward to working for NCAB to solidify the transition, continue to grow our business and tackle the most demanding PCB requirements in our industry." (MB)

Harima Buys Henkel's Solder Unit

TOKYO – The board of Harima Chemicals Group has approved a plan to acquire the solder materials business of Henkel for an undisclosed amount.

The deal includes production assets, production technology, trademarks, patents, research equipment, inventory, employees, and commercial rights in Europe, the US and Asia, and factory real estate in Malaysia.

Henkel's solder business has sales of €28 million ($31.6 million). The acquisition is expected to be negligible to Harima's consolidated financial results for its fiscal year ending Mar. 31.

Harima develops solder pastes mainly for the automotive and communication equipment industries. The company noted growing demand for solder materials that

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DownStream's CAM350 and BluePrint-PCB support importation and visualization of PCB designs containing Flex, Rigid Flex or Embedded components. Visualize designs in both 2D and 3D, and easily document complex Flex or Rigid- Flex Stack-Ups for submission to PCB Fabricators.

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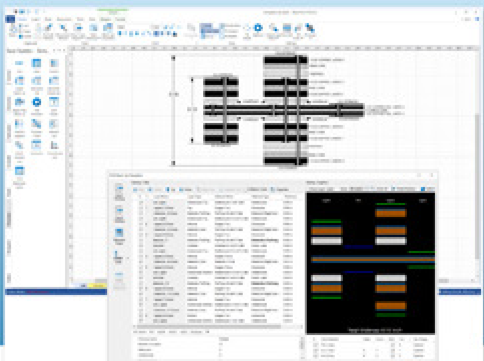
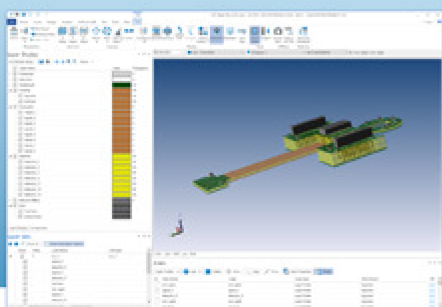
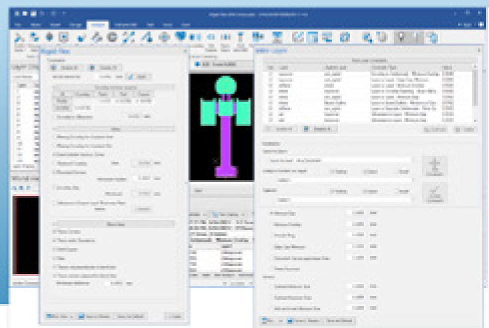


Use Stack Up Visualizer and Blueprint's Rigid-Flex Stackup template to easily manage and document rigid-flex stackups.



A rigid-flex design in 3D. Shown with layers spread to improve visualization of the layer stackup.



Use Rigid-Flex and Inter-layer DFM analysis to analyze flex and rigid-flex designs.

DownStream Technologies

For more information visit downstreamtech.com or call (508) 970-0670

Delphon appointed **Joseph Montano** CEO.

Sionyx named **Denis Boulanger** senior manufacturing engineer.

Southwest Systems Technology named **Victor Migri** outside account manager, covering the North Texas territory.

SVI Public Co. appointed **Verne R. Mundell** acting president effective Jan. 5.

Zestron Americas promoted **Sal Sparacino** to director of sales. He joined Zestron in 2010 and is also a director of the SMTA.

CA Briefs

Advanced Precision Distribution changed its name to **SMT Supplies**, effective Jan. 1.

AIM Solder has acquired its UK distributor **BLT Circuit Services,** which also manufactures consumable products for the printed circuit and chemical milling industries. Financial terms were not disclosed.

Crestview Partners has acquired **Emerald EMS** from **New Water Capital** for an undisclosed amount.

Compal Electronics in January halted production at its factory in Northern Taiwan for a week after several employees tested positive for Covid-19.

Dixon Technologies has formed a joint venture with **Rexxam** to manufacture PCBs for air conditioners for the global market.

EMD Electronics, the North American Electronics business of **Merck,** announced a new factory in the greater Phoenix area for the manufacture of equipment for its Delivery Systems & Services (DS&S) business.

Foxhole Group, a private investment firm focused on the industrial sector, has partnered with J.J. and Sherri Richardson to recapitalize **CCK Automations,** a designer and manufacturer of PCB assemblies, injection molded plastics and specialty machining.

Lockheed Martin's electronics assembly in Lufkin, TX, has adopted the IPC-CFX standard for its surface-mount production lines.

Mack Technologies opened a 164,000 sq. ft. manufacturing facility in Ciudad Juarez, Mexico.

MixComm has selected **Sanmina Advanced Microsystems Technologies** as a lead partner to build its 5G wireless infrastructure solutions.

offer reliability and durability in harsh environments, and for 5G products.

Henkel automotive customers in Europe, as well as in the industrial equipment and consumer electronics industries worldwide, greatly expand Harima's customer base, the company said.

It sees greater market competitiveness through the addition of Henkel's product lines, plus improved profitability and plant productivity through increased volume after consolidation of the two businesses. (MB)

Kitron Completes Acquisition of BB Electronics

ASKER, NORWAY – Kitron in January completed the acquisition of 100% of the shares of BB Electronics for approximately DKK 600 million (US$91 million). The pending deal was announced in late December.

"This transaction fits perfectly with Kitron's growth strategy," said Peter Nilsson, president and CEO, Kitron. "BB Electronics is a profitable company, which adds attractive geographies to the Kitron group and is expected to create significant value for Kitron shareholders. Its well-run operations will continue with little change, but we will immediately identify potential cost savings from coordinating purchases."

The acquisition took place in accordance with the transaction agreement. BB Electronics will be consolidated into Kitron's financial reporting as of January.

BB Electronics has some 750 employees in Denmark, the Czech Republic and China and had revenues of about DKK 1 billion (US$152.2 million) in 2021. (CD)

inTEST Completes Acquisition of Acculogic

MT. LAUREL, NJ – inTEST in January completed its previously announced acquisition of Acculogic and its affiliates. The company on Dec. 9 announced it had entered into a definitive agreement to acquire Acculogic for approximately $9 million.

"We have been making great progress with our five-point growth strategy since its launch at the beginning of the year, and this acquisition further demonstrates our ability to execute on our plan to grow the business at a greater rate than the market by expanding its global reach and enhancing its product portfolio," said Nick Grant, president and CEO, inTEST. "I would like to personally welcome the entire Acculogic organization into the inTEST family as we are excited to add their leading technologies and automation services into our electronic test portfolio."

Acculogic designs and manufactures test systems and provides engineering services for electronic devices, PCBs and EV batteries. Acculogic has engineering and sales support facilities in Maple Grove, MN, Lake Forest, CA, and Hamburg, Germany. The company has approximately 50 employees and generates approximately 75% of its revenue in the defense/aerospace, automotive and life science markets.

inTEST supplies test and process solutions for use in manufacturing and testing across automotive, defense/aerospace, industrial, life science, semiconductor and telecommunications markets. (CD)

East West Manufacturing Acquires Compass' EMS Assets in Mexico, TX

ATLANTA – East West Manufacturing has acquired certain operations of Compass Electronics Solutions, a provider of electronics manufacturing services, including advanced printed circuit board assemblies, box-build assemblies, wire and cable harness assemblies, and new product introduction services. Terms weren't disclosed.

The acquisition enhances the growth of East West by adding established operations in Juarez, Mexico, and El Paso, TX, and advances the company's strategic focus on growing its North American design, manufacturing and distribution capabilities,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HDI; BLIND/BURIED/STACKED VIA

Lam Cycles:	Up to 8x
Micro BGA Pitch:	.2 Millimeters

FLEX / RIGID-FLEX

Standard Flex:	1 – 6 Layers
Rigid Flex:	4 – 22 Layers
Rigid Flex HDI Lam Cycles:	Up to 2x

LEAD TIMES

RIGID

Standard:	15 Days
2 – 10 Layers:	24 Hours
12 - 24 Layers:	48 Hours

HDI; BLIND/BURIED/STACKED VIA

Via in Pad:	48 – 72 Hours
HDI :	3 – 15 Days*

** Depending upon # of Lam Cycles*

FLEX / RIGID-FLEX

Flex 1 – 6 Layers:	5 – 15 Days
Rigid Flex 4 – 22 Layers:	7 – 15 Days
Rigid Flex HDI 2x Lam Cycles	20+ Days

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East-West said in a press release.

The deal does not include Compass' cable and wire harness operations in Dayton, OH.

"We are extremely excited to expand our integrated design, engineering, manufacturing and distribution services into Juarez and El Paso," said Scott Ellyson, cofounder and CEO, East West. "Compass has a strong reputation for putting customers first and has an established presence for innovation in a variety of high-growth sectors such as medical and life sciences, commercial and industrial and aerospace and defense. The joint operations in Mexico and Texas allow us to offer our customers even greater nearshore, higher mix, lower volume, quickturn integrated manufacturing services as the international manufacturing landscape continues to diversify. This initiative fits perfectly with our collective design, manufacturing and supply chain capabilities, allowing us to support customers from product inception to full-scale production on a global basis." (MB)

Rising Material and Labor Costs Continue to Plague Global EMS Supply Chain

BANNOCKBURN, IL – Materials and labor costs continue to be the largest issue facing the electronics supply chain, with nine in 10 electronics manufacturers reporting rising materials costs and more than three-fourths reporting rising labor costs.

That's according to IPC's January 2022 global electronics manufacturing supply chain sentiment report, which also found that although order flows continue to be strong, and capacity utilization and shipments are expanding, survey respondents reported growing backlogs and shrinking profit margins.

Among other conclusions, the survey results found material costs are currently rising at a higher rate in North America than APAC: 96% of North American manufacturers report rising material costs; a significantly lower 74% report material costs are up in APAC.

Inventory available to customers is declining at a higher rate in North America compared to both Europe and APAC: 49% of firms in North America reported declining inventory, while only 21% of firms in Europe and 16% of firms in APAC are experiencing declines.

Manufacturers indicate the current semiconductor shortage is driving longer lead times, delayed deliveries, declining orders, increased inventories, rising costs and lost production. Combined, these impacts are affecting manufacturers' ability to complete orders, ultimately reducing profitability.

"Manufacturers expect to see continued increase in material and labor costs," said IPC chief economist and report author Shawn DuBravac. "Escalating costs are in turn compressing profit margins. Ease of recruiting and finding skilled talent is expected to remain challenging, and inventory levels are expected to remain tight for at least the next six months."

IPC surveyed hundreds of global companies, including a wide range of company sizes, representing the full electronics manufacturing value chain. Survey respondents were from North America (44%), Asia (20%) and Europe (17%). (MB)

Cicor in Talks to Acquire SMT Elektronik's EMS Unit

BRONSCHHOFEN, SWITZERLAND – Cicor Group on Jan. 17 revealed discussions are underway with the owners of SMT Elektronik with the target of acquiring the German company's electronic manufacturing services activities.

SMT Elektronik employs 145 staff in Dresden and had sales of €22.4 million with a net profit of €1.2 million in financial year 2020. The company's EMS activities, which Cicor intends to acquire, are a major contributor to these key figures.

The closing of the transaction is subject to usual conditions and regulatory approval procedures.

In the event the deal goes through, SMT Elektronik will collaborate with Cicor-owned RHe Microsystems in nearby Radeberg. Cicor intends to expand its EMS and microelectronic assembly capabilities and to significantly increase its position in the German high-end electronics market.

Cicor Group is also considering additional investments at the location in Saxony to strengthen its presence in one of the most important microelectronics and IT clusters in Europe. (MB)

Naprotek completed the acquisition of **NexLogic** for an undisclosed sum. The addition expands the EMS company's capabilities in microelectronics packaging and PCB assembly.

Scanfil plans to increase its Atlanta electronics manufacturing factory's production area 50%. The production space is currently approximately 12,000 sq. m.

Quanta Computer's chairman is optimistic about the metaverse platform created by **Meta** and **Microsoft,** which he believes will inspire demand for hardware and software, and that Taiwanese IT makers will satisfy that demand.

SVTronics made **Kyzen** its cleaning chemistry standard for its manufacturing facility in Plano, TX.

Teltonika began construction on a $39 million technology and EMS center in Moletai, Lithuania, expected to be completed in the fourth quarter 2022.

Universal Instruments appointed **B.R. Peterson Associates** channel partner in Illinois, Wisconsin and Michigan.

Vicor is in the final stages of completion of its new $34 million factory expansion located in Andover, MA.

Volex completed the acquisition of wire harness makers **Prodamex** and **Terminal and Cable** for about GBP13 million.

A/V DIALS IN				
Trends in the US electronics equipment market (shipments only)	**% CHANGE SEP.**	**OCT.**	**NOV.**	**YTD%**
Computers and electronics products	0.6	-0.6	0.3	5.7
Computers	-4.3	1.4	0.0	1.4
Storage devices	0.1	-3.5	-0.9	28.9
Other peripheral equipment	2.6	-2.0	-6.6	3.2
Nondefense communications equipment	-0.1	0.7	1.0	7.1
Defense communications equipment	1.7	1.7	-2.5	3.4
A/V equipment	10.0	-0.4	11.6	1.1
Components[1]	3.3	1.4	1.3	6.6
Nondefense search and navigation equipment	-0.1	0.7	-0.8	2.6
Defense search and navigation equipment	-0.8	0.1	0.2	2.2
Medical, measurement and control	-0.2	-1.1	0.8	5.7

[r]Revised. *Preliminary. [1]Includes semiconductors. Seasonally adjusted.
Source: U.S. Department of Commerce Census Bureau, Jan. 6, 2022

US MANUFACTURING INDICES	AUG.	SEP.	OCT.	NOV.	DEC.
PMI	59.9	61.1	60.8	61.1	58.7
New orders	66.7	66.7	59.8	61.5	60.4
Production	60.0	59.4	59.3	61.5	59.2
Inventories	54.2	55.6	57.0	56.8	54.7
Customer inventories	30.2	31.7	31.7	25.1	31.7
Backlogs	68.2	64.8	63.6	61.9	62.8

Source: Institute for Supply Management, Jan. 1, 2022

KEY COMPONENTS	JUL.	AUG.	SEP.	OCT.	NOV.
Semiconductor equipment billings[1]	49.8%	37.8%	35.5%	41.4%[r]	50.6%[p]
Semiconductors[2]	29.6%	30.0%	27.6%	24.4%[r]	23.5%[p]
PCBs[3] (North America)	1.29	1.48	1.25	1.15	1.10
Computers/electronic products[4]	5.27	5.26	5.27	5.30[r]	5.34[p]

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

PCB Design Tool Sales Jump 15% YoY in Q3

MILPITAS, CA — Sales of printed circuit board and multichip module CAD software increased 14.5% year-over-year in the third quarter to $298.3 million, the ESD Alliance announced in mid January.

The four-quarter moving average, which compares the most recent four quarters to the prior four, increased 10.9%.

Overall electronic system design (ESD) industry revenue increased 17.1% year-over-year to $3.46 billion. The four-quarter moving average rose 16.1%.

Overall, the Americas purchased $1.5 billion of electronic system design products and services, up 14.3%. EMEA's sales increased 23% to $452 million; Japan's rose 12% to $260 million; and APAC was up 10% to $1.25 billion. (MB)

Hot Takes

- The overall **electronic component sales** sentiment for December was 114.4, up 19.2 points compared to the outlook projected for December during a November survey. (ECIA)
- **Materials and labor costs** continue to be the largest issue facing the electronics supply chain, with nine in 10 electronics manufacturers reporting rising materials costs and more than three-fourths reporting rising labor costs. Material costs are currently rising at a higher rate in North America than APAC: 96% of North American manufacturers report rising material costs; a significantly lower 74% report material costs are up in APAC. (IPC)
- November shipments among **North American electronics manufacturing services companies** rose 2.5% year-over-year and 4% sequentially. (IPC)
- Twenty percent of large organizations will use **digital currencies for payments,** stored value, or collateral by 2024. (Gartner)
- Seventeen companies are forecast to have **worldwide semiconductor sales** of greater than $10 billion in 2021. Three of them – AMD, NXP, and Analog Devices – are expected to join the “megasuppliers” list. (IC Insights)
- The global **wearable fitness technology market** is estimated to be $9.8 billion in 2021 and is expected to reach $19.1 billion by 2026, growing at a CAGR of 14.3%. (Research and Markets)
- The **global flexible electronics market** is projected to be worth some $61 billion by 2030, a CAGR of 8.5% from 2021 to 2030. (Precedence)
- **The smart wearable healthcare devices market** is poised to grow $15.7 billion during 2021-2025, progressing at a CAGR of 14.38% during the forecast period. (Research and Markets)
- **The average annual tin price** should drop from an expected $31,250 per tonne in 2021 to $31,000 per tonne in 2022. (IndexBox)
- **Third quarter PC shipments** fell 7.2% from a year ago to 34.8 million units. (IDC)

In Support of Capital Equipment, Don't Forget the Software

To best help customers, suppliers must invest in dedicated software experts.

"VALUE ADD" IS a term bandied about, especially when a business is in the process of selling its products or services to another one. Likewise, in manufacturing the term "capital investment" describes the process of a business selling its products to another. All too often, much less "value" is derived by the "investment."

Over the years – decades, in fact – most of the equipment and services I've purchased have been of dubious value and less an investment than a needed cost. A significant portion of any capital budget is spent either replacing legacy equipment or on substantial repairs to keep old equipment functioning. While there are times a new technology is truly a game-breaking investment and provides *real* value for the future, the majority of capital spent is for the same-old, same-old.

Historically, capital equipment used in the fabrication of printed circuit boards has relied heavily on electromechanical/PLC controls to operate. Mechanics in most companies' maintenance departments can troubleshoot and service or fix this technology reasonably well. Many a scrubber, etcher or drill that may be decades old can be found still chugging along in most established fabrication facilities. Technology and events, however, are impacting the same-old and offering an opportunity for some that, to date, have not been embraced.

When capital is spent to replace older equipment, the operating system of choice is no longer electromechanical PLCs but PC-based software instead. On one level this evolution has enabled greater value as functions and controls are significantly improved, enabling tighter tolerances, better yields and higher throughput. These traits in many ways embody what value add is and what a good investment should be.

However, with advancements comes equally daunting challenges. No longer can a mechanically adept maintenance person service or fix this new technology. Instead, an IT-savvy person may be needed to update software, reprogram if needed, and ensure equipment can communicate with other pieces of equipment or servers to operate effectively, if at all. Herein lies the challenge.

Most companies that develop, produce, sell and (allegedly) service capital equipment come from the paradigm of mechanical adeptness. Often capital equipment developers are experts in the mechanical part and outsource the firmware, software and operator interaction experience development to others that are experts in software applications. The staff that installs capital equipment and trains the operator most often is from the mechanical side of the organization and is proficient in the basics of equipment operation, but not in how to maintain, upgrade and troubleshoot software issues.

"MOST COMPANIES WALK AWAY FROM A SALE ONCE THE EQUIPMENT IS INSTALLED."

Worse, most companies walk away from a sale once the equipment is installed and move to selling the next customer or focusing on the next generation of equipment. Time passes and suddenly an event occurs in which the equipment will not operate, not because of a mechanical issue but because of a software issue. Anything can impact software, from a localized electrical spike to Microsoft, or whichever company is "updating" an underlying software system. When these events occur, the mechanically adept maintenance person and the mechanically adept equipment sales rep are left flatfooted, not having necessary software knowledge or skills.

An added kicker to any software-centric capital equipment is the amount of customer unique information (CUI), intellectual property (IP), etc., stored on the operating software. All this makes traditionally off-the-grid, electromechanical, standalone equipment prone to complying with the latest security protocols, such as NIST-800-171, IPC-1791, CMMC, etc., that demand systems and software are up-to-date, and adequate IT and physical security are in place, and hold the company that owns the equipment, the operator, management and potentially the company that produced the equipment and operating software responsible for the integrity and security of data processed on the equipment. In short, the majority of capital historically spent on replacing the same-old is now spent on software-centric equipment that demands a different type of maintenance service.

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Still, most companies that produce or supply current-generation capital equipment fail to understand the critical need and responsibility to be able to service and support the various operating software systems, as much as in the past they serviced the mechanical systems. In many cases, upgrading software replaces spare parts. Being able to provide scripting support to customers when software upgrades disable existing programs is as important as it used to be to have an inventory of spare parts on hand. Having access to tech support for software not loading properly is as important as being able to walk a customer through replacing a mechanical part when it breaks.

There's an opportunity to provide true value add and make replacing the same-old become a true investment. It's called service, not necessarily old-fashioned service, but support of customers who have invested serious money on capital equipment and need a new level of assistance: software support. And, when the world shifts from one level of Windows to the next, for better or worse, the equipment that runs on it must have dedicated effort to transition all customers to the next generation. This is a paradigm shift. This requires investment. This demands commitment.

My prediction is the capital equipment providers that offer dedicated staff to support the operating software – akin to the tech support for applications and mechanical repairs and maintenance – will be those that can charge the most for their products, providing both superior value-add and a true capital investment to their customers. □

Government Incentives Won't Fix Domestic PCB Industry

The source of domestic manufacturing woes is customer service, not offshoring.

I'VE SOLD PCBS for over 30 years, sourcing boards both domestically and internationally, and I find it much harder to source boards from American manufacturers, not so much because of pricing but because of poor customer service.

Of course, many US-based PCB fabricators meet or exceed customer expectations, but unfortunately, even more American shops struggle to deliver printed circuit boards on time and communicate promptly and effectively with customers. That directly affects their sales performance.

Many domestic manufacturing companies point to offshore manufacturing – with its lower pricing – as the cause of their sales woes. They call for government involvement to level the playing field. While I applaud efforts by PCB industry trade groups to bolster business for US-based PCB manufacturers, government intervention is not a guarantee for growth. No matter how hard the government tries to control business – be it with incentives (rewards) or tariffs (punishment) – board buyers aren't motivated to do business with firms that lack good service.

"IT IS OFTEN THE QUOTE THAT COMES IN FIRST THAT GETS THE ORDER, NOT THE ONE WITH THE LOWEST PRICE."

Many PCB buyers would like to buy American, even if it means paying more for their boards, but they will not do it if they can't be certain manufacturers will treat them well. Lobbying the government is expensive and time-consuming. In the meantime, domestic manufacturers should take note of what they can do now to improve their business, while they wait for that government help to arrive.

Here are some suggestions:

Improve customer service. Price isn't the only reason PCB customers choose to buy from offshore manufacturers. It is also the willingness on the part of overseas vendors to jump through hoops to win and retain business. Too many times when dealing with domestic board builders, I've had to call again and again about a quote or order, and *still* haven't gotten a timely response. I can count on one hand the number of US PCB shops that have a human answering incoming calls. The personal touch is invaluable and would help make domestic firms more appealing. I've also noticed a lack of urgency with the basics, like notifying customers about schedule changes or ensuring paperwork is correct. Getting people to respond to an email or promptly return a call is often a struggle.

Quote quickly and accurately. A board house needs to produce quotes in a timely manner, and pricing needs to be consistent. A customer shouldn't have to call to confirm receipt of an RFQ. The customer certainly shouldn't have to follow up days later, looking for an update on the quote. Many US-based sales departments fail to communicate pertinent information to their quoting teams, meaning the quote is often inaccurate, or it sits overlooked on someone's desk or in their email. In my experience, it is often the quote that comes in first that gets the order, not the one with the lowest price. How many orders have been missed because of a delayed RFQ response?

Empower your customer service team. The inside sales teams at many domestic PCB manufacturers appear overworked and insufficiently trained. They have no real authority to resolve quality or production issues when they inevitably arise. This causes delay and frustration for customers.

Today's PCB buyers want to feel valued. They need to be able to trust their vendors are continually working to earn their business.

To be clear, I won't deal with certain offshore board houses because of their poor customer service, even with their government subsidies and attractive pricing. It's not only a domestic problem. The truth is, however, no amount of government incentives will guarantee the success of US board shops. Yes, the government can play a valuable role in the success of the domestic PCB industry, but the responsibility for customer service rests squarely with the ownership and management of these companies.

Whether it's printed circuit boards, assemblies, TVs or vacuum cleaners, the basics of stellar customer service are the same. Available training can be easily tailored to fit the PCB industry. When was the last time a professional development course was offered to your key employees? ❑

GREG PAPANDREW has more than 25 years' experience selling PCBs directly for various fabricators and as founder of a leading distributor. He is cofounder of Better Board Buying (boardbuying.com); greg@boardbuying.com.

Alleviating Stress and Avoiding the Cult of Mediocrity

Tips to avoid burnout while applying resources to mitigate the impact of two years of Covid.

BY THE TIME this is published, we will have been working in "Covid new normal mode" for nearly two years, which means EMS program teams have been working under extreme stress for longer than most physical bodies can handle. This is creating two big dangers: physical damage caused by exposure to long-term stress and disappointing customers becoming acceptable because so many variables are outside of the program team's control.

In the '80s, one of the management associations I belonged to had a stress management seminar built around the movie *Twelve O'Clock High*. The movie is set in England in WWII and follows a new squadron commander from his optimistic arrival through his total burnout. The seminar focused on behavior changes related to command stress in situations where the odds were against most crews surviving, including a rise in irritability, an increase in alcohol consumption, insomnia and a breakdown in decision-making. The commander in the movie experienced a physical and mental breakdown.

In the seminar, we looked at coping mechanisms to deal with occasional stress at work. The stress many teams experience today is closer to what was shown in *Twelve O'Clock High*. No matter how well you do your job, the odds are stacked against you. And, sadly, most of us now know at least one friend or family member who has died of Covid-related complications.

That said, the Covid new normal isn't going away anytime soon, so thinking about coping mechanisms is important. Here are a few stress-management tips to consider:

- Sugar, caffeine and nicotine provide an energy spike and then depress your system. If you are hitting the coffee pot or candy machine frequently, you are actually tiring yourself out.
- Junk food is easy and convenient to grab when short on time. However, it may be pushing you closer to serious health issues if it is now the go-to meal.
- Alcohol may seem like a stress reliever, but it is also a depressant.
- Long stretches of sitting at your desk are physically damaging.

You may not be able to control the stress of the new normal, but you can control your coping mechanisms. Good coping behaviors include:

- Limit caffeine and sugar intake.
- Focus on healthy eating. It will end heartburn and help with insomnia.
- Plan time for exercise, including lunchtime walks outdoors or around the facility, using home exercise equipment, and building simple stretches into your daily routine. Exercise releases hormones that combat stress and balances out desk time.
- Develop a disconnect strategy that lets you mentally relax:
  - Headphones at lunch or planned break times
  - Scheduled relaxation time during your off hours
  - Scheduled fun activities with family or friends
- Ask for help if you are overwhelmed. Many department heads I know have told their teams to request resources if the workload becomes overwhelming. HR wellness programs often have resources for stress management or counseling as well. Don't wait until the burnout is overwhelming to explore coping mechanisms.

The second danger relates to the cult of mediocrity. The electronics manufacturing services industry has been built on the idea EMS providers do things faster, better and cheaper than their OEM customers. In the new normal, cost increases are a given, and material and logistics constraints are building frequent customer disappointment into the service equation.

I use the airline gate agent analogy frequently in my articles because it has a similar chaos factor. On a bad weather day, there are two kinds of gate agents: One is customer-avoidant and does the job mechanically with minimum critical thinking or effort; the other communicates frequently and looks for ways to improve the situation in the areas they can still control.

Do something for a few weeks and it becomes a habit. Right now, the new normal habit is accepting customer disappointment as a given. Some things will be out of your control, but in what areas can you improve?

In my consulting business, I see material constraints impacting everyone. Some companies have a little more leverage than others, but none has a magic bullet to change the situation. The one differentiator I see is some companies are actively applying resources to improve areas they can control.

Typical examples include:

- Applying continuous improvement disciplines such as Lean Six Sigma to address higher levels of material-related defects or improve throughput to compensate for material arrival delays
- Developing software tools to increase purchasing's visibility into material availability and automate searches for available stock
- Utilizing engineering resources to identify more complex alternate sourcing strategies when a standard cross isn't available.

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In short, don't let the new cult of mediocrity within your what you can control and then you are improving in the areas to help mitigate the impact of chaos. An added benefit of control improvements is stress larly if you celebrate those small

You can't eradicate the new pletely, but you can control how When things start to improve, ers that have shown they are the extra mile will win accounts of mediocrity. ❑

External Oscillators: Placement and Routing Tradeoffs

Does changing the clock make any difference to the PCB layout?

EVERY SIX MONTHS, it becomes apparent not enough of my household items are part of the "Internet of Things." (Cue ominous violin squeals.) Can we talk about my spouse's wall-clock fetish? At least the one in the bedroom doesn't tick! And, of course, if a battery is near its end, an adjustment will probably put it out of business for good. It's always something getting me back up on that step ladder.

Setting and resetting clocks is also a thing in PCB design.

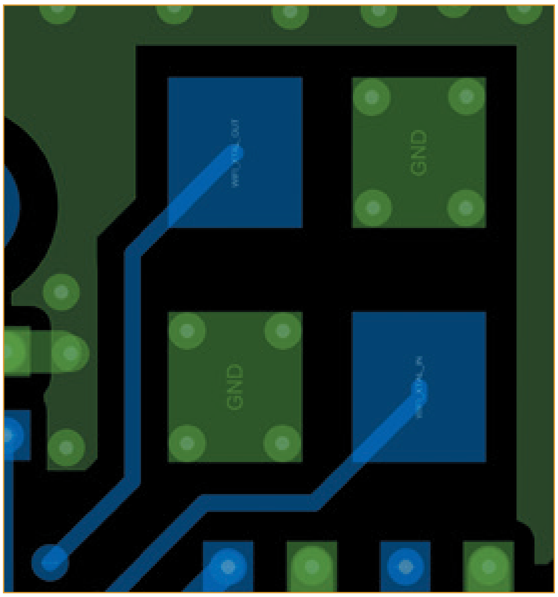

FIGURE 1. The ground pour (green) surrounds the crystal but does not engage with the ground pins. The ground plane on layer 2 is similarly slotted around the crystal to help contain spurious emissions.

FIGURE 2. It would have been cleaner to rotate Y1 and align the passive elements. We compromised to fit inside the EMI shield.

Keep the working circuits intact. The engineers on the analog side of the coin get very attached to a circuit that works. If something is working with sufficient margin, then don't even get near it with "arbitrary and capricious" revisions. Tread lightly in those situations, as there are many ways for things to go haywire. Consider the crystal as a hostile device from the start. That way, if it must grow, the other geometry already leans away from the danger zone.

The main source of frustration during RF chip/board bring-up is out-of-band emissions. Some odd-order harmonic can end up exceeding the mask. There will be an unwanted spike or lump in the graph. Bandpass filters have their limits and cost money while using power. The analog engineers spend nights and weekends passionate to solve these issues. They thrive on tweaking circuits and taking measurements.

A subtle tuning stub or an inductive neck-down on the power feed can be all it takes to solve the issue, but now you've changed the little world around you, and anything can happen. Radio frequencies are everywhere to be picked up and propagated. Making one strong sine wave without disturbing the spectrum in other ways is a tough assignment. We have good reason to venerate a fully compliant link in the chain.

External oscillators: an alarming clock. The cautionary tale is digital circuits above a certain data rate will start to resemble analog circuits. Most MCUs have an option for an external oscillator. What is that? It's usually a way to override the system clock and impose a different cycle time on the system. Why do so? In general, overclocking increases performance, while underclocking saves power. Some are for bootup. Others are only active when certain functions are in use. When it's on, the string on ones and zeros is nonstop clatter to the rest of the circuitry.

The net-names associated with these clocks will typically include the letters "XO." Popular frequencies for these crystals are in the kilohertz range. Each of those available frequencies will have its own harmonics – and its own package size!

So, maybe you start at 16KHz as the external clock. That's in the upper audible range, but, of course, the vibration of the crystal is imperceptible without measuring equipment. Still, byproducts of 16KHz include 32KHz, 48K, 64K,

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80K, 96K, 1.12MHz and so on.

Keep the crystal circuit short and free of vias. It's mostly on every other node, but there are many intersections where 16KHz has common multiples with other frequencies found in nature. A strong resonance will be a detriment to the circuit, particularly when it comes to coexistence. A compact XO circuit is a must, but you can't always get what you want.

One of the worst scenarios is when XO pins are located deep inside the rings of pins of a BGA. Usually this is found in a small enclosure where there isn't sufficient space on the bottom of the PCB for tall components. This means the XO traces will be longer than usual. A typical example is the power management integrated circuit (PMIC) in which all the peri-meter pins seem to be voltage in or out.

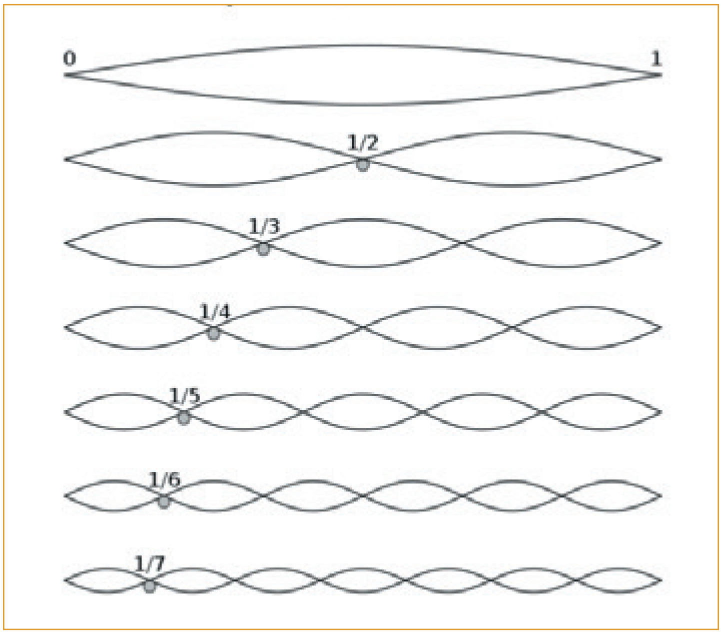

FIGURE 3. A fundamental frequency shows sympathetic wavelengths often generated along with the original. *(Source: SoundGuys).*

The crystal might be on the opposite side of the board but just as likely off in a corner on the side of the board that has the headroom. Make it the corner away from the receive chain. The TX side isn't great either but is usually less of a victim than the RX side, if it's one or the other. Look for a neutral corner with the least amount of signal traffic.

Routing the external oscillator lines out from under a device should be done first. If you have any freedom in the fan-out, a wide path should be carved out for these traces. There's always one row on a BGA where vias can fan in different directions. That row is often around the center line, but it doesn't have to be.

Other signals in the region should go on other layers, allocating as much extra space as possible to the clock nets. If you can create a guard band around the noisiest signals, then you can call it good. We always want an optimal placement that allows no-brainer routing. Because we can't always get what we want, we do what we must to get by. ❑

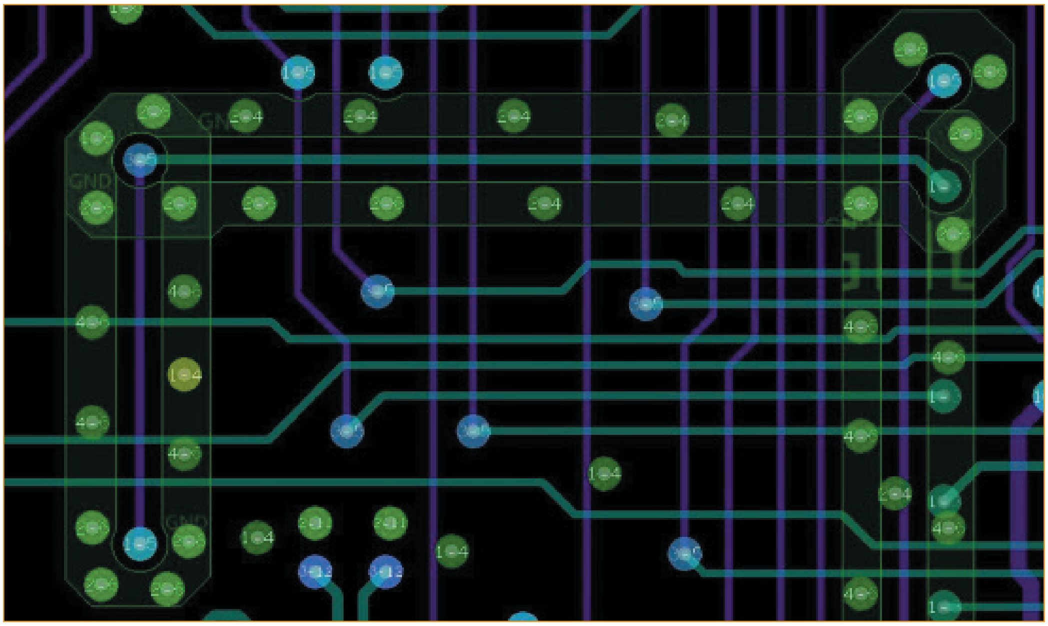

FIGURE 4. The vertical trace on the left (magenta) and the horizontal continuation (cyan) show how to create a guard-band around particularly noisy connections used by externally clocked devices.

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The course references general CAD tool practices and is vendor-agnostic. The instructor, Mike Creeden, CID+, has 44 years of industry experience as an educator, PCB designer, applications engineer and business owner. As Technical Director of Design Education at Insulectro, he helps OEMs and fabricators achieve design success for best material utilization. He has served as a Master Instructor for the CID+ IPC Designer Certification program, was a primary contributor to the CID+ curriculum, and founded San Diego PCB Design, a nationally recognized design service bureau.

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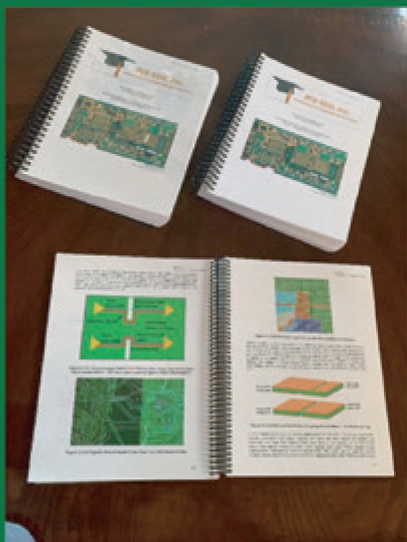

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Printed Circuit Engineering Professional

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Improving SMT Stencil Printer CYCLE TIME

Changing a stencil printing machine's conveyor configuration helps make it more efficient. by MIGUEL ARROYO COLOMER

A well-balanced surface mount line takes into consideration all the equipment comprising it and any indirect factors that affect it. Here we examine stencil printer cycle time (CT).

Internal factors considered for a CT study include conveying time in and out of the machine, stencil and board fiducial recognition, cleaning time, solder paste measurement time, dispensing time, and printing time.

Not all solder pastes have the same rheology, and paste rheology determines a stencil printer's process parameters. These parameters include squeegee speed, force, attack angle, separation speed (detaching), squeegee material, stencil design, solder paste roll diameter, and stencil cleaning profile, which includes frequency, speed, number of passes, dry, vacuum, wet, and other parameters.

Once process engineers have established the optimum stencil/process parameters to obtain maximum process yield, these elements are locked into the process. From that point, we monitor the results for repeatability. For this reason, changing these parameters to improve the line CT is not a viable option. Also, some products are locked into use of a specific solder paste material, so changing it requires an entire process requalification.

Another approach is to evaluate a machine that performs the process steps most efficiently. In this study, we see how changes in the machine's conveyor configuration help make the machine more efficient when conveying a given PCB through the process. (The customer process settings remained the same, and boards were processed to calculate total CT.)

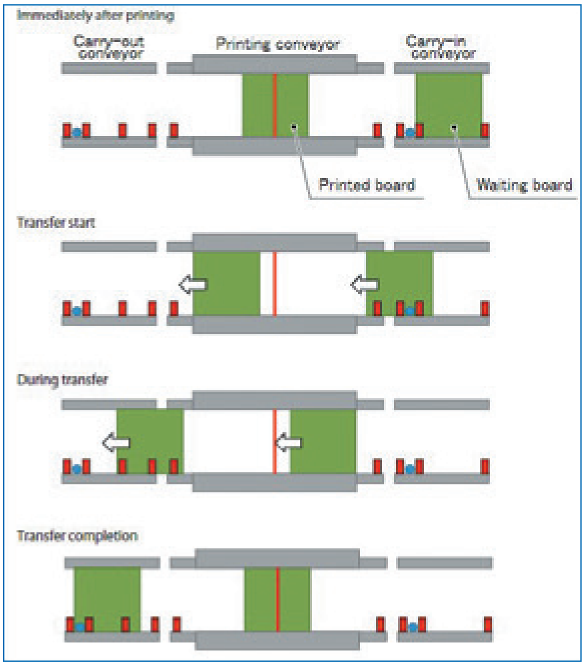

FIGURE 1. How boards are conveyed simultaneously through the stencil printing machine.

Assumptions

1. PCBs will already be staged, and no additional time will be added to the machine cycle time. (The upstream and downstream cycle times were not considered.)
2. The print stability control (PSC) cycle time will depend on the following factors: squeegee length; the amount of solder transfer to the substrate on every squeegee stroke; paste transfer efficiency; solder paste roll size. (For the purpose of this study, the PSC cycle time was not measured.)
3. Stencil fiducials are measured only once. For this reason, no stencil fiducial CT is added to the total cycle time.

Overview

The stencil printer used has staging conveyors in the entrance and exit, with an option to convey the boards in and out of the machine simultaneously. This type of configuration reduces conveying time during processing.

In an overhead view, FIGURE 1 shows how boards are conveyed simultaneously through the stencil printing machine. For this CT optimization, two different PCBs were used, each one with different process settings (**TABLE 1**).

Note: Original print programs were used with our lab machine (Model YSP10) to generate a baseline. Fifty repetitions per board were performed to have sufficient data points from the cleaning cycle time.

TABLE 1. Board Process Settings

	PCB 1	PCB 2
PCB Length (mm)	199	195
PCB Width (mm)	165	144
Number of Fiducials	2	2
Squeegee Speed (mm/sec)	50	45
Board Release Speed	Max Speed	Max Speed
Stencil Cleaning Intervals (PCBs)	10	10
Stencil Cleaning Profile:		
Wet Speed (mm/sec)	32	32
Dry Speed (mm/sec)	32	32

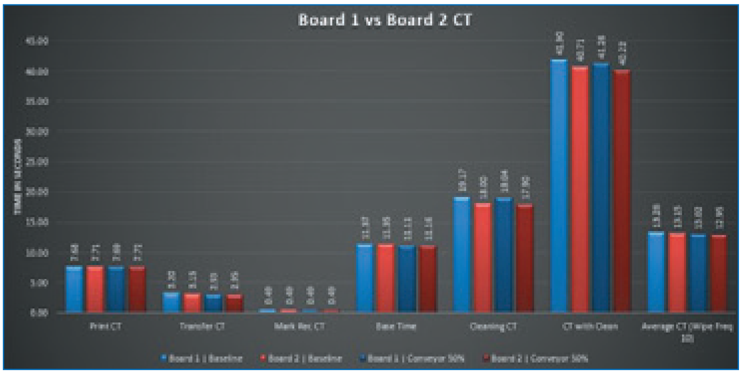

FIGURE 2. CT difference between PCBs at standard speed and at 50% faster conveyor speed.

TABLE 2. Baseline (with Standard Conveyor Speed) for Board 1

Board 1 Baseline Printer	Print CT	Stencil Fid	Transfer CT	Mark Rec CT	Base Time	Cleaning CT	CT with Clean	Wipe Frequency	Average CT
Average	7.68	0.00	3.20	0.49	11.37	19.17	41.90	10.0	13.28
Max	7.70	0.00	7.37	0.65	15.72	19.27	50.71	10.0	17.65
Min	7.66	0.00	0.32	0.47	8.45	19.07	35.97	10.0	10.36

TABLE 3. Baseline (with Standard Conveyor Speed) for Board 2

Board 2 Baseline Printer	Print CT	Stencil Fid	Transfer CT	Mark Rec CT	Base Time	CT	Clean	Frequency	Average CT
Average	7.71	0.00	3.15	0.49	11.35	18.00	40.71	10.0	13.15
Max	7.73	0.00	7.66	0.66	16.05	18.03	50.13	10.0	17.85
Min	7.69	0.00	0.32	0.47	8.48	17.96	34.92	10.0	10.28

Test 1. To improve cycle time for these two boards, the conveyor speed was increased 50% (**TABLES 4** and **5**).

FIGURE 2 shows the CT difference between the PCBs at standard speed and at a conveyor speed of 50% faster. For board 1, the average CT with cleaning was reduced approximately 2%, and for board 2, 2.5%.

TABLE 4. Test 1 of Board 1

Board 1 50% Printer	Print CT	Stencil Fid	Transfer CT	Mark Rec CT	Base Time	Cleaning CT	CT with Clean	Wipe Frequency	Average CT
Average	7.69	0.00	2.93	0.49	11.11	19.04	41.26	10.0	13.02
Max	7.96	0.00	6.79	0.65	15.40	19.10	49.90	10.0	17.31
Min	7.67	0.00	0.43	0.47	8.57	19.00	36.14	10.0	10.47

TABLE 5. Test 1 of Board 2

Board 2 50% Printer	Print CT	Stencil Fid	Transfer CT	Mark Rec CT	Base Time	Cleaning CT	CT with Clean	Wipe Frequency	Average CT
Average	7.72	0.00	2.95	0.49	11.16	17.90	40.22	10.0	12.95
Max	7.98	0.00	6.84	0.66	15.48	17.96	48.92	10.0	17.28
Min	7.70	0.00	0.45	0.47	8.62	17.86	35.10	10.0	10.41

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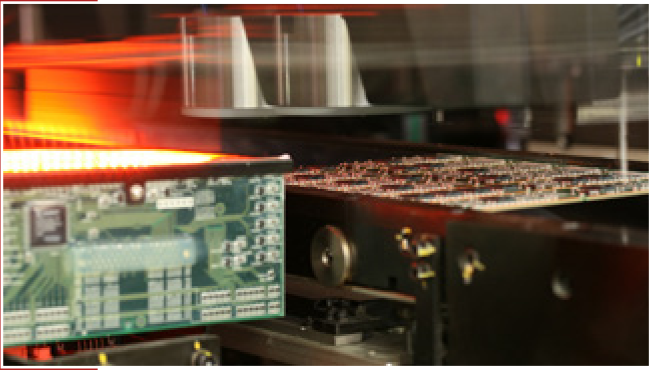

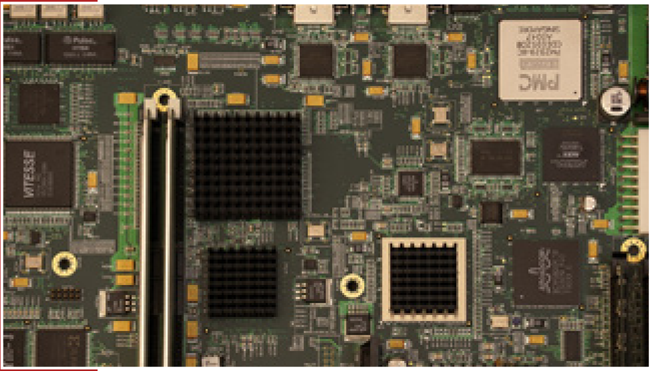

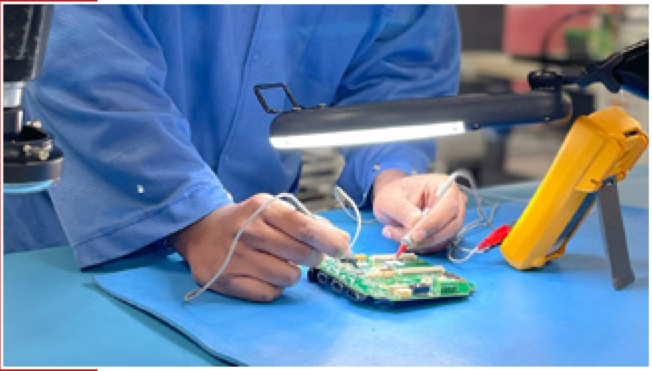

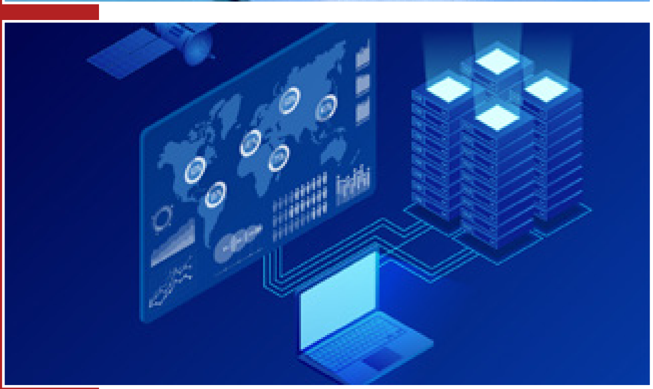

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Test 2. Machine conveyor mode was configured to move the entrance-staged board once the processed board exited the main conveyor, rather than simultaneously. Note the machine's conveyors are still staging the boards (**TABLES 6** and **7**).

TABLE 6. Test 2 for Board 1

Board 1 No Simultaneous Printer	Print CT	Stencil Fid	Transfer CT	Mark Rec CT	Base Time	Cleaning CT	CT with Clean	Wipe Frequency	Average CT
Average	7.68	0.00	5.30	0.49	13.47	18.99	45.93	10.0	15.37
Max	7.70	0.00	7.56	0.65	15.91	19.11	50.93	10.0	17.82
Min	7.41	0.00	2.70	0.47	10.58	18.92	40.08	10.0	12.47

TABLE 7. Test 2 for Board 2

Board 2 No Simultaneous Printer	Print CT	Stencil Fid	Transfer CT	Mark Rec CT	Base Time	Cleaning CT	CT with Clean	Wipe Frequency	Average CT
Average	7.71	0.00	5.25	0.49	13.45	17.85	44.75	10.0	15.24
Max	7.73	0.00	7.23	0.65	15.61	17.92	49.14	10.0	17.40
Min	7.69	0.00	2.71	0.47	10.87	17.78	39.52	10.0	12.65

Test 3. Machine conveyor mode remained with the simultaneous option disabled, and the conveyor speed was increased 50% (**TABLES 8** and **9**).

FIGURE 3 shows the CT difference between boards 1 and 2 at standard speed *without* simultaneous conveying at standard speed and *with* 50% faster conveyor speed.

For board 1, the average CT with cleaning was reduced approximately 5%, and for board 2, 4.5%.

In this case, we increased the conveyor speed 50% and used a machine equipped with staging conveyors, with an option to convey the boards simultaneously.

TABLE 8. Test 3 for Board 1

Board 1 No Simultaneous - 50% Printer	Print CT	Stencil Fid	Transfer CT	Mark Rec CT	Base Time	Cleaning CT	CT with Clean	Wipe Frequency	Average CT
Average	7.69	0.00	4.54	0.48	12.72	18.93	44.36	10.0	14.61
Max	7.95	0.00	6.46	0.65	15.06	18.96	49.08	10.0	16.96
Min	7.67	0.00	2.31	0.47	10.45	18.88	39.78	10.0	12.34

TABLE 9. Test 3 for Board 2

Board 2 No Simultaneous - 50% Printer	Print CT	Stencil Fid	Transfer CT	Mark Rec CT	Base Time	Cleaning CT	CT with Clean	Wipe Frequency	Average CT
Average	7.72	0.00	4.55	0.48	12.76	17.80	43.32	10.0	14.54
Max	7.73	0.00	6.57	0.66	14.96	17.94	47.86	10.0	16.75
Min	7.70	0.00	2.30	0.47	10.47	17.74	38.68	10.0	12.24

FIGURE 4 shows each board's CT difference at standard speed, with simultaneous conveying at standard speed and standard speed *without* simultaneous conveying.

The board's average CT with cleaning increased approximately 16% when the simultaneous conveying was disabled.

FIGURE 5 shows all CT data for all the conditions tested. The size of the board and the print CT did not impact fiducials recognition CT. The board *width* dimension impacted the stencil CT.

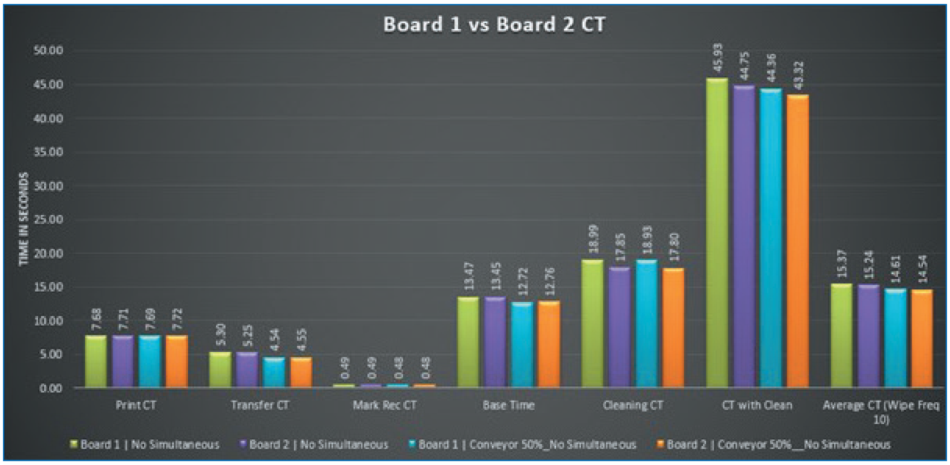

FIGURE 3. CT difference between boards 1 and 2 at standard speed *without* simultaneous conveying at standard speed and *with* 50% faster conveyor speed.

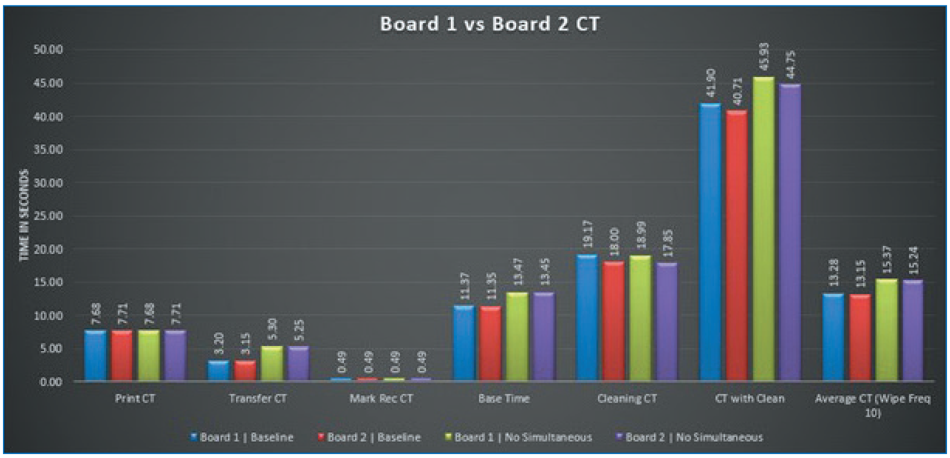

FIGURE 4. Each board's CT difference at standard speed, with simultaneous conveying at standard speed and standard speed *without* simultaneous conveying.

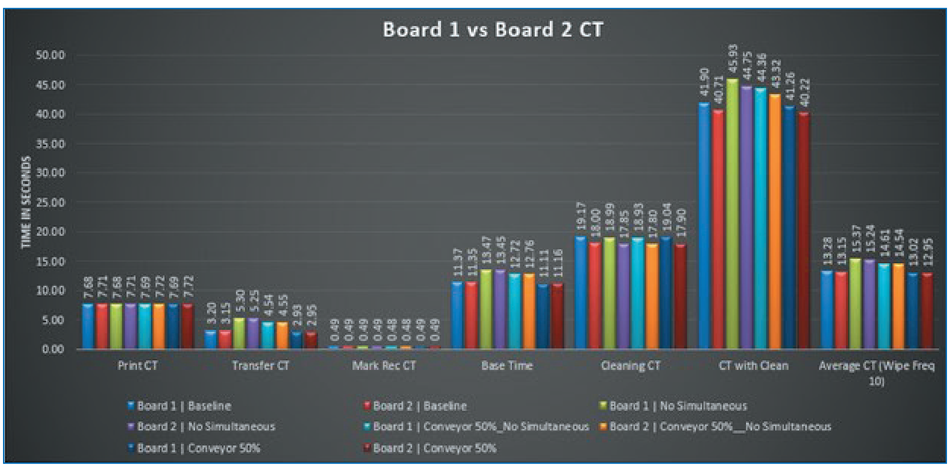

FIGURE 5. All CT data for all conditions tested.

Significant CT change occurred with the simultaneous conveying option. This impacts the average CT with stencil cleaning.

Conclusion

Solder paste rheology dictates stencil or stencil printing process parameters. Therefore, other machine parameters must be taken into consideration for reduction in cycle time if the solder paste remains the same.

Therefore, any operation that can be done in parallel will impact the overall machine cycle time. This is especially true on the stencil printer, where the majority of factors that affect the CT are interrelated with the solder paste and the board size. In this case, the narrower board has a smaller CT during cleaning. ❑

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Man vs. Machine: AI Will Soon Win the Imitation Game

Is it possible to achieve robot ethics when humans providing the framework are inherently flawed?

IT HAS BEEN over 80 years since Jorge Luis Borges published his short story "The Library of Babel," and now the virtual library is open to visit. Borges described a theoretical library of books that, together, contain all possible combinations of letters in the alphabet, with a few provisos and limited punctuation. The idea was this library would contain every book, every article, song, play, etc., that has been – or ever could be – written, among an overwhelming quantity of apparently meaningless material.

It's a mind-boggling concept, used to explore ideas of time, meaning, the human condition – behavior, frailties, the shortness of life – and our place in the universe. It's clear this library was imaginary. Borges never expected it to exist. Now, leveraging the computing power available to us today, the website libraryofbabel.info has brought the literary concept to life as a virtual "universe."

Seven years from now, the era of artificial general intelligence (AGI) will begin, according to Ray Kurzweil. AIs trained for specific tasks such as image, pattern or speech recognition are already in the world and routinely assisting with demanding tasks in industry, medicine, financial analysis, photography and more. Kurzweil said by 2029 a machine will be able to pass the Turing test, the so-called imitation game, in which a human interrogator questioning a machine and a human should be unable to distinguish between the two based on their responses.

According to popular science fiction plots, the inevitable result is super intelligent machines will outpace and outsmart humans, take over, and enslave us. Kurzweil, however, argues the dominant use case will be to augment our own intelligence. We can already see this trend in the ways we use machines like our mobile phones to accomplish tasks impossible or extremely difficult for humans to do otherwise.

Clearly, not all AIs will exist in our pockets or in the cloud. As robots become infused with increasing levels of intelligence, solutions are needed to prevent them from harming humans and vice versa. In his 1942 story "Runaround," Isaac Asimov proposed built-in safety features based on his three laws of robotics to put forward an alternative to the view of robots as human destroyers.

For Asimov, these rules were a comment and a fictional plot device. We are now at a time when intelligent robots will shortly enter society, and a suitable set of rules is needed. As long ago as 2007, work in South Korea was announced to establish a Robot Ethics Charter that covers aspects including the design, manufacture and use of robots. They are expected not only to enshrine human safety and protection of data or knowledge robots acquire, but also to prevent humans from abusing robots.

The European Union is also in the process of developing ethical rules and is keen to ensure robotics and AI develop in accordance with European social values. Those who write the rules for robotics will have a powerful influence on the way we live in the future.

The desire for control is intrinsic to human nature. Ceding control to intelligent machines will be a direct challenge to that aspect of ourselves. There is outrage when a vehicle driving autonomously is involved in a collision, although human error is the cause of far more accidents on the roads and in industry. An embarrassing driverless train crash during the construction of London's Docklands Light Railway was revealed to have occurred during unauthorized testing, with the train in manual mode and before proper buffer stops had been installed. Similarly, Waymo's autonomous vehicles have completed millions of incident-free test miles on public roads and been involved in relatively few accidents, the majority of which have involved human-driven vehicles striking Waymo vehicles.

Once, a manufacturing team I worked with manually overrode a process-monitoring pressure sensor that ultimately resulted in a gas escape and subsequent system failure. Had the automated system been left to operate as intended, this would not have occurred.

However, the question whether machines make better decisions than humans remains valid. We can ensure intelligent machines will make consistent decisions according to the way they have been programmed. Ideally, that programming should be the result of a deeply considered design process that should consider multiple variables and explore all ramifications of each response to specific circumstances. The work on robot ethics seeks to provide a framework for design teams to ensure the machine's responses will be appropriate in every situation. But can this really be achieved?

Asimov's rules, although elegant in their simplicity, are almost certainly inadequate to cover all the situations that will face the intelligent machines of the 21st century. To achieve a broad consensus, any charter of robot ethics is likely to be a complex and weighty document. Human decisions can be emotional, biased, inconsistent, even negligent. It's no small challenge for us as imperfect creatures to create intelligent machines that enshrine human values while eliminating our own faults. ▫

ALUN MORGAN is technology ambassador at Ventec International Group (ventec-group.com); alun.morgan@ventec-europe.com.

What's New in IPC-6013E?

The updated rigid-flex specification overhauls copper thickness requirements.

AS WE START a new year, it's a good time to review what changed in 2021. In the flex world, the IPC Flexible Circuits Performance Subcommittee worked through the pandemic and released a new revision to IPC-6013. Revision E was released in September, replacing an amended Revision D from April 2018. Some updates and changes are subtle, while others are significant. Many changes attempt to increase clarity.

Let's start at the finish – final finish, that is. Tin, silver, and ENIG/ENEPIG will not have minimum thicknesses in IPC-6013. Instead, we are defaulting to the new IPC-4552/4553/4554/4556 specs for thickness and sampling frequency. This avoids unintended differences or conflicts as the finish specs are updated.

Often questions arise related to the rigid-to-flex transition – and what is delamination versus non-lamination? In paragraph 3.3.1.3, we added an explanation about what's happening at the transition and a new Figure 3-1B to provide a more visual explanation of what is acceptable and rejectable.

"THE BIGGEST CHANGE WAS AN OVERHAUL OF THE COPPER THICKNESS REQUIREMENTS AFTER PROCESSING."

Flex circuits have always been more prone to questions about foreign material or entrapped particles. Unlike rigid boards, flex circuits are more transparent, making cosmetic anomalies more evident. Once noticed, disposition is required. We expanded Section 3.3.2.4 to provide more clarity on acceptability, including prepreg resin that may deposit on the external surfaces of flex regions of rigid-flex.

Changes are often made to the spec based on input or questions from users. The team received questions about what holes should be evaluated for hole pattern accuracy. Some questioned the need to inspect all hole locations, especially interconnect vias, which do not have components attached. Most drawings do not have all holes physically dimensioned, relying solely on the CAD data file. Moreover, annular ring requirements control hole locations. We added clarifying verbiage in paragraph 3.4.1 indicating only those holes specifically dimensioned on the drawing itself should be inspected for pattern accuracy.

IPC has always required fillets at the pad/trace junction for Class 1 and 2 designs. If they did not exist or were not allowed, it was implied Class 3 annular ring was required. To be more direct, we added to paragraph 3.4.2 explicitly requiring 0.001" minimum annular ring if no fillets are present.

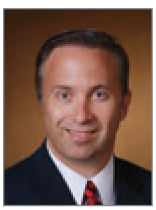
HDI features within rigid-flex products have been rapidly adopted and include employing blind vias and microvias. Often these vias are "via-in-pad plated over," meaning the via is in the middle of an SMT pad. Questions related to the inevitable dimple or bump created by this via included, "Was it rejectable like any surface anomaly in the pristine area of an SMT pad?" We modified the overall requirement for anomalies in the pristine area to limit the dimple or protrusion vertical dimension to match the dimple protrusion requirement for filled vias.

In the same vein of HDI features, if microvias or blind vias are on both top and bottom layers of a board, thermal stress coupons must reflect these via structures; we included this language in the specification. In addition, both the top *and* bottom via structures must be *directly* exposed to the solder. This may result in testing extra coupons to accommodate this requirement.

Another IPC activity across multiple specifications attempts to discern between dewetting and the natural high/low variations in the hot air solder and solder reflow processes. In hot air solder leveling (HASL), it is common to see solder pooled up toward the trailing edge of the pads. This is a mechanical issue caused by the air knife blowing the solder to one end of a pad. In addition, surface tension of solder tends to cause mounding of the solder. The following note has been added to IPC-6013 (and will be added to IPC-6012 and J-STD-003): This thickness variation is a natural occurrence and is not rejectable.

An attempt was made to clarify maximum copper plating wicking condition in a plated through-hole.

NICK KOOP is director of flex technology at TTM Technologies (ttm.com), vice chairman of the IPC Flexible Circuits Committee and co-chair of the IPC-6013 Qualification and Performance Specification for Flexible Printed Boards Subcommittee; nick.koop@ttmtech.com. He and co-"Flexpert" **MARK FINSTAD** Mark Finstad (mark.finstad@flexiblecircuit.com) will speak at PCB East in April.



Wicking occurs when the copper plating "wicks" down the glass weave bundles in areas where the resin is removed or is not intimately joined to the glass. There has been confusion between etchback, wicking and a combination of the two attributes. While the new wording is improved, it is still not clear enough. The IPC team stepped back and created a tiger team to revise this topic in its entirety. Stay tuned for a complete rework of the etchback and wicking requirements in IPC-6012 and -6013, either in the next revision or an amendment in the near future.

Probably the biggest change was an overhaul of the copper thickness requirements after processing. After much discussion, debate, and finally consensus, the entire section was rebuilt:

- It differentiates between unplated and plated internal layers, as well as external plated layers.
- The new requirement permits more reduction of the initial base foil, provided the total copper thickness requirement is met after plating.
- For button-plated designs, it clarifies copper thickness outside the button area to meet the internal layer foil requirements, not the external (plated) requirement.
- Absence of copper at the knee of the hole may be acceptable if other requirements are met.
- The thickness table was simplified by eliminating columns.

Much of the discussion related to this section revolved around assumptions and expectations. Given the wide spectrum of via structures and plating and planarizing processes, it is not prudent for designers to assume a certain minimum thickness of copper on any given layer. If a designer has a true need for a specific minimum thickness of copper on certain layers, it is recommended to explicitly state it on the drawing to ensure it is accounted for.

IPC-6013E includes other changes too. Any section that has been changed is highlighted in gray to alert the user.

Changes to the specifications are truly user- and supplier-initiated. Input from members is how we refine and update the specifications. Participation in the process is encouraged. The industry wins when you volunteer, as it helps bring needed changes to specifications. You win as a volunteer, as you get a better understanding of the specifications and build a healthy network of industry experts you can leverage throughout your career. □

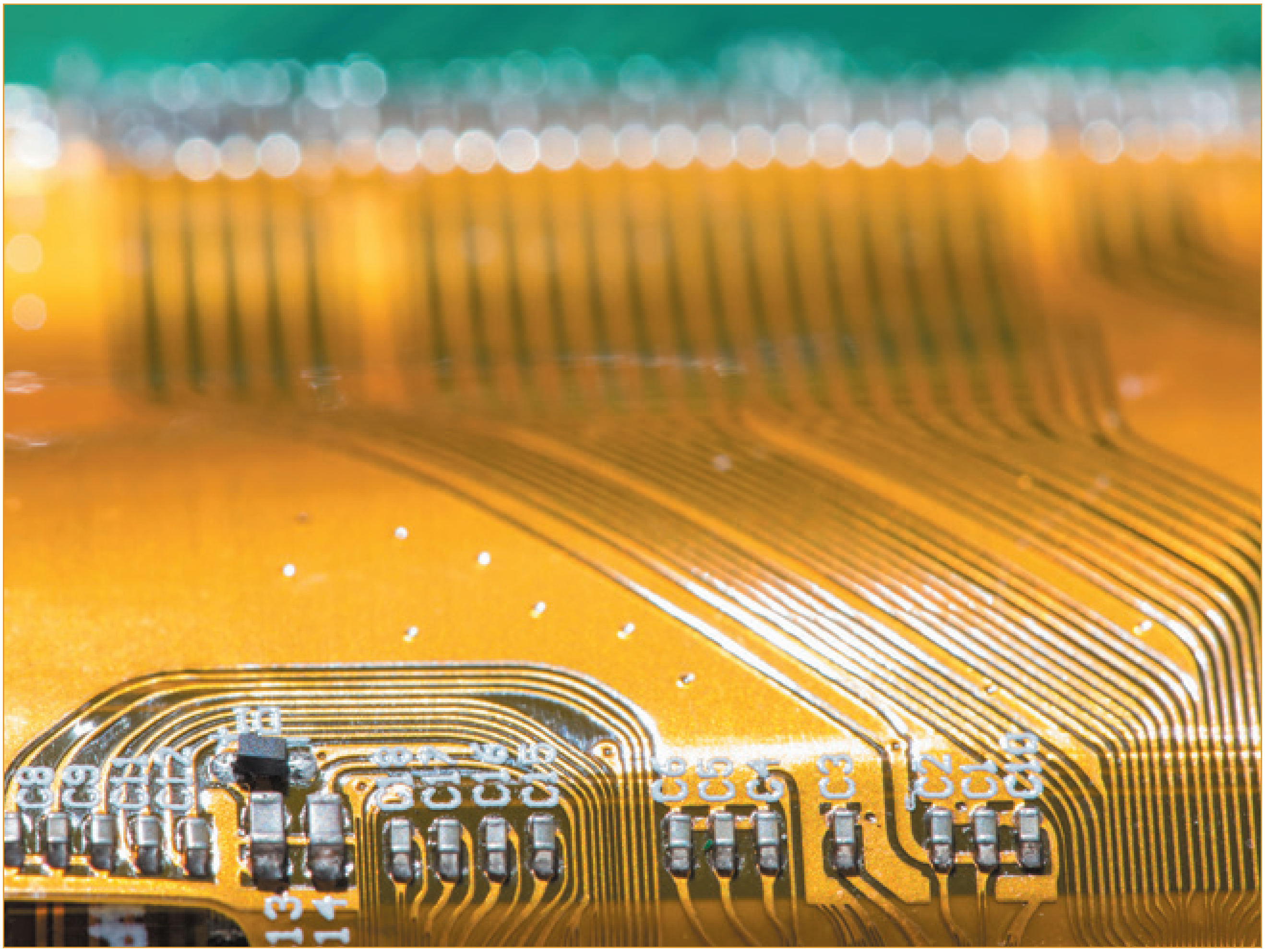


FIGURE 1. If there is a specific minimum thickness of copper on certain layers, explicitly state it on the drawing to ensure it is accounted for.

Building a Resilient US SUPPLY CHAIN

"Chips don't float," the saying goes, but it's up to the PCB industry to push its message to Washington. **by MIKE BUETOW**

It's hard to believe now, but veterans of the printed circuit board industry will remember when the US was neck and neck with Japan as the largest PCB manufacturing market. It peaked in 2000-2001 with sales north of $10 billion each year and close to a 30% share of the overall market.

How things change.

Today, US domestic PCB manufacturing output is around $3 billion, and its share of the global market is in the mid-single digits. Meanwhile, China has surged ahead of the pack, as more than half the bare boards produced each year are built on the mainland. Moreover, nations like Vietnam that didn't even register a decade ago are now larger than the US market.

Last July, in response to two decades of a falling tide, a group of printed circuit board fabricators and suppliers established the Printed Circuit Board Association of America (PCBAA). This new consortium of US-based companies supports initiatives to advance US domestic production of PCBs and base materials.

The organization seeks market fairness and a level playing field on which US PCB manufacturers can compete against competitors subsidized by foreign governments.

Travis Kelly, president and chief executive of Isola, the materials developer, and chairman of the PCBAA, spoke with Mike Buetow for the PCB Chat (pcbchat.com) podcast in late December. The following transcript is lightly edited from that interview.

Mike Buetow: On its website, PCBAA asserts three main mission objectives. Let's talk about them and how you settled on those three as focal points.

Travis Kelly: Just taking a quick step back, the PCBAA was formed by five prominent companies in the PCB industry that identified a need to educate, advocate, and legislate to support the competitiveness of the domestic PCB industry. That's [how] we really got to the three pillars of what we stand for. First and foremost, it's making people conversant – not only the general public but also the government – relative to microelectronics as it relates to the PCB industry. How do we educate and make people conversant on the topic? How do we advocate for the domestic industry, looking not only at semiconductors, which is an obviously big topic, but as we all know, chips don't float. Chips have to be embedded in something. That's why printed circuit boards are so important. So, advocating for printed circuit boards as part of the overall microelectronic ecosystem. And then, how do we advocate for legislation to get more recognition around the importance of PCBs and PCBAs?

Travis Kelly, PCBAA Chairman

MB: I spent quite a few years going to Washington as part of the IPC Capitol Hill Days, where we lobbied Congress to support the PCB industry. This effort began in the 1990s, well before the crash. But even as the domestic market migrated offshore, Congress's response was effectively none at all. Fast forward to today. The past couple administrations seem much more intent on shoring up the domestic electronics manufacturing market. Much of the attention, however, is going toward semiconductors. I don't intend to diminish these obviously critical components, but how do you propose to ensure PCBs are in the conversation?

TK: That's a great point, Mike, and ultimately they have to be. There's a systemic issue. Covid-19 was the catalyst for some of the global supply chain issues that we're facing as a nation. It's getting more recognition in terms of getting a resilient supply chain. Semiconductors are extremely important, but so are PCBs. We have to look at the overall ecosystem and not just one or two specific examples. What we're trying to do now is bring the education around printed circuit boards as it relates to microelectronics. You brought up a strong point: The US once produced over 26% of the world's PCBs. That number is down to 4%. Our goal right now is sustained government investment in the domestic PCB industry. I think with a lot of the tailwinds we are having, because there is a lot of focus on the global supply chain as it relates not only to semiconductors but microelectronics, consumables and a lot of other areas and a lot of other industries that are being impacted, it's been helping us spread our message to help people be conversant on the importance of the ecosystem as it relates to microelectronics.

MB: Four or five years ago, the Department of Commerce undertook a study to assess the state of the domestic PCB industry. My understanding is one reason they did so was to help present data to the Defense Department to convince them to pay more attention to the interconnect industry. I'm not sure what really came out of that study, except for a lot of data and paper. Is the sense you get that the interest by Washington is focused mostly on defense suppliers, or do you think this effort will lead to a more widespread, robust PCB market if done correctly?

TK: The PCBAA has been at the table for the full legislative cycle this year to be sure our industry's concerns are being communicated and addressed. We've advocated successfully for language in the Department of Defense legislation, the National Defense Authorization Act, requiring more domestic sources of materials and manufacturing. That addresses your first point: Is it really focused on defense? The answer in terms of the NDAA is absolutely. But as you start peeling back the onion and people start focusing on what we consider critical applications, it's a broader reach. If you think about medical, infrastructure, 5G, critical applications as they relate to aerospace and defense opportunities, it's going to be a broader scope. That's something we all need to focus on because, just living through the last nine months of the global supply chain issues, it's bigger than just defense products that are impacted. It's a lot of different products, even if you go back to when Covid first happened, and there was a significant need in the US for ventilators, and automotive OEMs started producing ventilators as opposed to vehicles. A lot of us took part in terms of printed circuit board manufacturing for those ventilators, and the laminate and the materials that go in printed circuit boards. It's a broader reach than just defense.

MB: The number of PCB factories in the US has dropped from 780 in 2000 to fewer than 200 today. Moreover, the size of the factories – the amount of capacity – is considerably less as well. By comparison, China has almost 1,500 factories. Has PCBAA set any goals as to what a healthy US industry looks like, size-wise?

TK: I think you have to bifurcate the discussion. A lot of people focus on brick and mortar and how many companies is the right number of companies. I really think you have to get more into the specifics of what technology is needed to ensure we have a resilient supply chain within the United States. It's less about the number of brick-and-mortar companies and more around are we fast enough as an ecosystem where we can produce the material, the technology that is needed to sustain the nation? That's where the focus has to be. When you get into a discussion relative to 26% going down to 4%, or in Europe, for example, 800 [fabricators] going down to 200, that is significant, and that's a lot of manufacturing that has been lost in this country. But furthermore, when you pursue offshoring, especially to the extent we have as a country, you also offshore knowledge. What we're advocating for is how do we work with universities, with institutions, to bring that knowhow back? We see significant weakness there, and we need the government support to really focus on STEM, to partner with universities and bring back some of that technical know-how that we've lost over the past several decades.

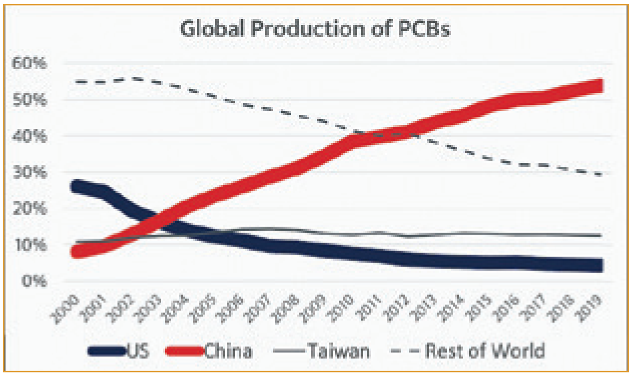


FIGURE 1. The US's share of global PCB production has plummeted in the past 20 years.

MB: Do you think we need a JFK moment right now? By that I mean, in 1960, John F. Kennedy announced the mission for the moon. There was the goal to put a human on the moon, but the bigger goal was to excite people about technology. Do we need something like that again to get people excited about what a career in electronics manufacturing could look like?

TK: I think we do. I think if you were to poll a lot of young professionals just entering their last year of post-secondary education or coming out into the workforce, most of those professionals or young students would not perceive this industry as something they would envision going into. You hear a lot about the larger software companies or data companies. You don't really hear a lot of passion around the electronics manufacturing sector. I think we do need to really understand how we get in front of a lot of these talented students and talented young professionals to create that momentum. I think the onus is not only on the government, but also once again private industry to really build up on that momentum. What we do as a microelectronics industry, and primarily around PCBs and the material that goes into it, is exciting. We're con-

stantly innovating. There's more to it than just what people say is a "green board." There are a lot of complexities, a lot of challenges. It's actually a very rewarding industry. We have to do a good job communicating and educating the public on what it takes to be successful in this industry, and I think that will create the momentum we need.

MB: Think back about 20 years ago. We used to think 5GB per second was the max we could get on a copper line through FR-4. Fast forward one generation and we are at 10 times that. These things are only known to the folks in the trenches, just how much development and progress there's been over the past 20 years. All these devices we walk around with are unbelievably capable relative to a generation ago.

TK: Absolutely. It is fascinating. A lot of organizations within this industry are promoting that concept, that paradigm. We view IPC and USPAE as complementary organizations to what our goals are. As long as we continue to push this message to make people conversant and the government conversant on the fact that it's a much larger ecosystem than just semiconductors, I think we can all be very successful. Success is having people understand the importance of the overall ecosystem of microelectronics, and how in fixing one problem – although it's significant with semiconductors – you still have other significant issues that are going to hamper the success of the US if we don't focus on a broader set of microelectronics including PCBs.

FIGURE 2. Some of the first members of the PCBAA.

MB: In 2004, a group of primarily Chicago-area PCB fabricators formed the US Printed Circuit Association. That group, which was primarily formed to perform state and federal lobbying, garnered about 70 corporate members, but survived only a couple years. What's different this time?

TK: I can't speak too much to what happened with that organization, but ultimately there's a lot of heavy lifting that has to be done for the domestic microelectronics industry. When we think about the recent successes, we've had such a short period of time. We have 10-plus members now with PCBAA, [which] doesn't sound like a large group when you actually count them as wholly owned facilities or companies. However, when you think about the number of employees we represent, it is significant. I think with the quick wins we've had, and significant wins we've had in such a short period of time since this organization came to fruition, we'll continue to have more momentum [and] broaden our membership base. It's not as simple as, "Let's get some language into a legislative bill that can help the overall industry." We've talked about what has to happen in the educational system, what has to happen at the government level, what has to happen at the private level, even what has to happen with the infrastructure of this overall industry as it relates to PCBs. This is a heavy lift for many years to come. As we continue to develop our organization and grow our membership base, there's always going to be activity. Activity can be defined as advocating for legislation; it can be defined as educating; it can be defined as creating different educational workstreams that help the overall industry. I don't see this as a short-term organization. This is going to go well into the future because there's always topics that have to be addressed, and not just from a high level. It's looking at the systemic issues and trying to correct those, so we actually do have a resilient supply chain, as opposed to focusing on one or two items. Semiconductors [are] the main topic, but until we start addressing the real root cause of some of these issues, it's never going to correct itself because, once again, chips don't float. They have to be embedded on something. People have to take a broader look and understand the macros before they can start identifying root cause identification and solutions.

MB: You've enlisted some of the biggest names in the US PCB industry as members: Isola, TTM Technologies, and Summit Interconnect are among the founding members. What is the cost relative to membership in, say, IPC?

TK: So, not to leave anyone out, we [also] have Calumet Electronics, Insulectro, DuPont, Rogers, MacDermid, and the list goes on and on. We're going to continue to grow that momentum. In terms of the structure of the membership, we do not want to exclude companies that want to take an advocate role in this organization. We've set up different tiers. Depending on the size of the company – Is it an individual? Is it a company? Is it an educational institution? – we have different tranches of membership levels. If you're [with] a large company and potentially want to have a board seat, that will be the gold level, and it will be based on a certain quantitative measurement. You'll be able to sit on the board and have a voice at the table. If you want to fly the flag and show you're a member of the PCBAA but want to do so at a lower level, we have different tiers set up. We're trying to cover the gambit as it relates to membership, and it's more just having momentum and good companies that want to be part of something bigger than just their sole company.

MB: What does it take to convince smaller fabricators, particularly ones who have felt left behind by Congress, that the investment now will make a difference for them?

TK: I think what we've been able to prove with our early successes as a young organization is creating a level of comfort for potential members, and because we continue to get our message out of what has been accomplished and what we see that needs to be accomplished in the future, regardless of size, a lot of different fabricators and assemblers will want take part in it. They had the opportunity to look at the different membership levels and say, "This may make sense for me. I'm part of something bigger than just my organization." Then you may have some other fabricators that want to have a real voice at the table and help set the direction of the PCBAA, and a different tier may be right for them. Hopefully, the way we've thought about it is going to help generate more members as we continue to get this message out.

MB: We've talked a lot about fabricators. Where does the assembly industry fit into all of this?

TK: It's not just PCB, not PCBA. It's a large ecosystem, so we are being inclusive of everyone. That's why, if you look at our membership base, it's very interesting. We have suppliers of yarn that goes into materials. Isola is a material supplier. We have copper suppliers. We have chemical suppliers. So, we're covering the gambit as it relates to different constituents within the PCB and PCBA industry, which is very helpful. It's very inclusive, and it's not just strictly PCB or PCBA. It's people and companies that have direct input into the overall microelectronics industry.

MB: Finally, what does a unified, consensus strategy for the US industry look like, or is it too early to really describe that?

TK: I think that's pretty abstract. It's a global economy, so it's not going to be 100% onshoring in the United States; we all recognize that doesn't make sense. What we're trying to do is ensure we have a resilient supply chain within the domestic industry, and [define] those critical applications that need to be addressed, and how can we ensure we're shoring up the supply chain to make sure if there is another pandemic down the road, or even this current one with different variants, we don't find ourselves scrambling to make ventilators for the population? That's what we need to do, and that's what success looks like. We live in a global economy, and that's not going to change, but at the same time it's not a mutually exclusive conversation. You can still work and participate in a global economy, as well as create a very robust supply chain domestically. ❑

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IPC Report Outlines Steps US Gov., Industry Must Take for PCBs to Survive in US

BANNOCKBURN, IL – The US has lost its historic dominance in a foundational area of electronics technology – printed circuit boards – and the lack of any significant US government support for the sector is leaving the nation's economy and national security dangerously reliant on foreign suppliers, according to a new report by IPC.

Joe O'Neil's report outlines steps the US government and industry must take if it is to survive in the US.

O'Neil writes that for any such measures to achieve stated goals, Congress must ensure printed circuit boards and related technologies are covered by it. Otherwise, the US will become increasingly unable to manufacture the cutting-edge electronics systems it designs.

"The PCB fabrication sector in the United States is in worse trouble than the semiconductor sector, and it's time for both industry and government to make some significant changes to address that," writes O'Neil, principal, OAA Ventures, in San Jose. "Otherwise, the PCB sector may soon face extinction in the United States, putting America's future at risk."

Since 2000, the US share of global PCB production has fallen from over 30% to 4%, with China now dominating the sector at around 50%, says IPC. Four of the top 20 electronics manufacturing services companies are based in the US.

Any loss of access to China's PCB production would be "catastrophic," with computers, telecommunications networks, medical equipment, aerospace, cars and trucks, and other industries already dependent on non-US electronics suppliers.

To fix this problem, "the industry needs to intensify its focus on research and development, standards, and automation, and the US government needs to provide supportive policy, including greater investment in PCB-related R&D," O'Neil says. "With that interconnected two-track approach, the domestic industry could regain the ability to meet the needs of critical industries in the coming decades."

Adds Chris Mitchell, vice president of global government relations, IPC, "The US government and all stakeholders need to recognize every piece of the electronics ecosystem is vitally important to all the others, and they must all be nurtured if the government's goal is to reestablish US independence and leadership in advanced electronics for critical applications."

Why Don't Colleges Graduate SKILLED WORKERS? (They Do.)

An Ohio community college breaks the mold with an applied bachelor's degree in electronics manufacturing. by **MIKE BUETOW**

In my three decades in electronics engineering, perhaps the only thing that never changes is the need for more skilled workers. No matter the state of the economy or the geography, having knowledgeable and competent engineers and operators is always critical, and there are never enough of either.

But while the tension is notable between industry and academia over who is responsible for preparing the next generation of workers for specific tasks, some schools are quietly taking the lead by putting in place programs that include true hands-on training in printed circuit board manufacturing.

I'm talking specifically about Lorain County Community College. Lorain is in Northeast Ohio, about 30 miles west of Cleveland.

In 2012, LCCC launched an associate's degree program to train students in electronics manufacturing. In 2018, LCCC became the first community college to offer an applied bachelor's in microelectronics manufacturing, and two years ago, it formed the Manufacturing Electronics & Rework Institute for Training, or MERIT, the hands-on training lab. Last spring, the program graduated its first students.

Johnny Vanderford, the director of MERIT and an assistant professor of MEMS at LCCC, and Courtney Tenhover, program developer in engineering, business and information technologies, explained how the program came about and detailed its successes.

Mike Buetow: There's so much I want to ask about the LCCC and MERIT programs. Whose idea was this in the first place?

Johnny Vanderford: It was the industry's idea. About eight companies in 2012 got together and said, "We're short on workforce, and colleges aren't graduating people who can work for us starting from the beginning. They all require potentially a year's worth of training, on-the-job equipment handling, and everything like that, and nine times out of 10 they are either not skilled or just not a good enough worker to keep with the team." They said, "What we want is a college that is going to actually step up and help us with our workforce shortages." Several of these supporting companies were being hit by what's called the Silver Tsunami, which means their workforce is growing gray hair, and their generation is retiring to places where drinks are served with little umbrellas in them. They're taking all the knowledge they gained from their companies and leaving, and there's nobody fresh coming in or graduating from college with the hands-on skills. Nobody coming out of universities knows how to solder, or knows very little, as in, "Yeah, I've seen it on YouTube," or "I've done it once." It just wasn't good enough for these companies. They were short on workers, so in 2012 they said, "Can somebody help with this?" That's when I heard about it, and I said, "Yes, I want to join the team here at Lorain County Community College to teach this associate's degree" called microelectromechanical systems, or MEMS, and it took off from there. It's all about helping companies find skilled workers, while also having a training and education system that's meant to train people in an affordable college [program].

FIGURE 1. Lorain County Community College saw the first students in its applied bachelor's degree program graduate in 2021.

MB: I would agree folks coming out of engineering school today may know very well how gas moves in a chamber, for example, but if you put them in front of a convection reflow oven, they have no idea how to set up a profile or

make the machine run. What goes into launching a program like this? Did you have to do much market research to convince LCCC of the need?

JV: When we launched, what we first looked at, ironically, were the job markets that were asking for people. We went to Indeed; we went to LinkedIn; we went to the Surface Mount Technology Association's website. We asked, "What do companies want right now? What do they want for their technicians? What do they want for their operators?" And we were literally hit with waves of job requests that just weren't being met. It seems like a pretty easy step to say, "Let's ask the state for a little bit of funding to buy some capital equipment. Let's get buy-in from our college to be able to say, 'Let's launch a class with this,' and let's get a professor to teach some classes."

They hired me initially as an adjunct instructor, while I was working for a packaging company called Smart Microsystems, which makes chips, and initially it was [conceived] as part-time work. We started with three students in 2013. We started training them in ESD, what it means to ground yourself, and why it is important. We started them with soldering training, doing through-hole and surface-mount components. We showed them pieces of equipment: "This is how you use a microscope." A microscope is a legitimately difficult tool to use, but if you're going to be working with 0402 and 0201 components with lead-free solder, you better know what you're looking at and how to use the tools available to you. That first year, we had three students and eight supporting companies that were asking for people. All three of those students were hired before they finished their associate's degrees.

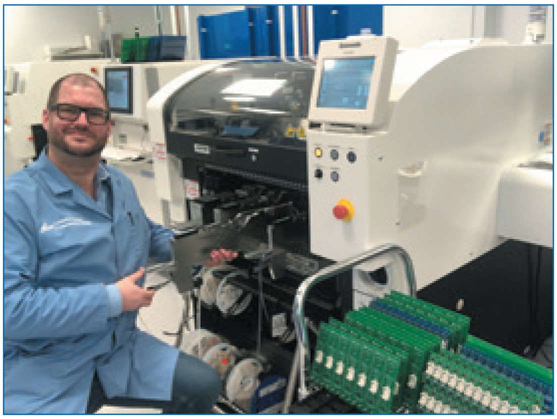

FIGURE 2. Johnny Vanderford was tapped from industry to lead LCCC's microelectronics manufacturing program.

The next year, we had five students, and all five were hired before they finished their degree. Once we had a student who said, "I'm an artist. I'm really good at painting." This student in particular could do calligraphy on rice. It's a hobby I thought was dead a long time ago. Wouldn't you know it, she's really good at soldering. Now she's soldering ribbons in ZIF connectors for the biomedical industry for cardiovascular systems. It started with employers who told us, "This is what our needs are," a small handful of students, and some funding from the state to get us laboratory equipment and training equipment so we could train and educate these students to get careers in the industry.

MB: Let's talk a little more about the program curriculum, and then we can get into the facilities and the equipment. What are the prerequisites for matriculating students?

JV: If you could balance a checkbook, that's pretty much all the requirements you really need. [laughs] I'm serious, though. You need high school sophomore-level English, high school math equivalency, and then you're in. We aren't teaching rocket science. It's not advanced calculus or anything like it. It is hands-on skills that involve using tweezers in one hand and a soldering iron in another, while looking through a microscope. It involves practice of near-surgical skills with the knowledge of material handling, as well as working in a quality manufacturing system. That's what it ultimately involves.

The whole program curriculum, in order to get in and start taking classes, you could start as long as you could pass high school math, high school English. We have students in the degree program right now who are coming from art backgrounds, nursing, business, construction, welding, administration. We have folks who are working in one industry and going through JobsOhio for funding to get education to get into a new career field. We have a retired letter carrier from the US Postal Service and a retired corrections facility officer from the Lorain County prison. One of our students is a radio broadcaster, and he knows how to solder circuit boards and manufacture them in high volume.

The entire curriculum was made by our industry supporters. Everything in our current curriculum is meant to get folks trained in what I would call a blue-collar degree. There's no calculus, no quantum physics, no crazy science stuff. It's all skills. On day one, [we teach] "this is ESD; this is how you ground." Day two: "This is a soldering iron. Let's start with 1206 resistors." That's where we started. The associate's degree was built entirely based on our employer needs, so we could train folks who may come from all over the place. These are non-standard students who come in not just out of high school, although we do get a good amount of them out of high school. There are military veterans using the GI bill. There are newly divorced parents trying to work for the first time because they haven't had a job for a while. There are folks coming from all different backgrounds, and with a little bit of practice and some hands-on training, they're able to work for and expand at these companies. After years of doing this, we have over 80 industry supporters within this program, and to this day everyone who has ever been through the associate's degree program and graduated from the associate's degree program has been hired into work at our 80 industry supporters. That's a 100% hiring rate. There aren't a lot of universities or colleges that can say that. I'm proud to be able to say every student who graduated from here with [either] the associate's or bachelor's degree has been hired.

MB: For clarification, the MEMS degree – the applied bachelor's degree – is a two-year program that's on top of an associate's degree?

JV: Yes, the associate's degree is very heavy in the areas of what I would call hand solder training. We certify all our students to IPC J-STD-001, in addition to them taking three other classes to where they're soldering with an iron, with a hot air rework station using a microscope, doing through-hole and surface-mount lead and lead-free, teaching them the difference between the two.

We start every student with lead because that's the easy stuff. Then we show them lead-free and they'll [say], "This is kind of hard!" "Yeah, and you have to learn this because you might work for a company that only does lead-free soldering." The bachelor's degree feeds off the associate's degree and basically trains them in high-volume PCB production. By the time they finish their associate's degree, they've got a truckload of hand solder training, a little bit of PCB design, as well as some PCB prototyping experience. Most important of all is we require every student in our associate's degree program to be employed for at least 300 hours in order for the students to get their degree and in order for LCCC to continue receiving funding from the state. All state colleges get funding based on graduates of their programs.

Every time a student graduates from our program, the state gives us funding. They give funding like that to all the other bigger universities, but [those schools] have tuitions astronomically higher than where we are. Our tuition is $3,900 a year for a full-time student. It's the lowest tuition for any associate's or bachelor's degree in the state of Ohio. We're dependent on the state share of instruction, that funding coming in from the state. The logic is, if a student hasn't been hired by the time they get their associate's degree, not only are they not going to get their degree, the college won't get funding to continue the program, and maybe the college, if they do this enough, should start to look at offering degrees that do get career experience and get people hired.

In fact, every student who goes into our bachelor's degree is required to have work experience in order to gain entrance into the program. That's unique criteria for us. We have companies that are hungry and interested for more students from our program, but the bachelor's degree has classes in addition in high-volume PCB manufacturing, how to operate a stencil printer, pick-and-place, reflow, an AOI … not just how to operate it but how to program it, how to design in CAD and very specifically to design for manufacturing, put in fiducials, put in mounting holes, make sure you have test points on your surface board, put on rails so it can sit on a conveyor without problems. Then we go into additional sidetracks like electronics and testing, how to use the multimeter, how to use the power supply. We've got classes in mechanical design, how to do AutoCAD, SolidWorks GD&T, and blueprint reading, and classes in quality, which include ISO 9001 Yellow Belt Six Sigma Lean manufacturing principles, statistical process control, gage R&R. I didn't put all this in … the companies wanted it, so we put in all this information so these companies could get training to their potential workforce and get a whole pile of potential workforce. The companies let Courtney know about job descriptions, and Courtney is the funnel between students getting résumés out to the company, and companies that have job requests go straight to Courtney.

MB: So quite literally, you don't get paid until the students get paid.

JV: Yes, we don't get paid until the students are hired in, which makes us uniquely like training and education and somewhat recruiting as well.

MB: Courtney, within the MEMS program is something you call "earn and learn." What does that mean?

Courtney Tenhover: Earn and learn was the program we developed so students can essentially earn while they learn. We worked with employers to begin this program, and students can work with an employer three days a week and have their classes scheduled on two days a week, so all their classes can fall on those two days, leaving them available for the employer for those three days a week, so they're not just offering four hours here and there. It's more of a consistent schedule for both the student and the employer. It helps employers minimize the time they spend to recruit someone, and hopefully the student has a fulltime job at the end of completion, so all the time employers spent working with the student and training them was money well spent because now they have a fulltime worker with the skills they requested to Johnny.

Courtney Tenhover,
Program Developer,
Workforce Development

MB: So, someone could start as a student and start working at a company outside of LCCC, or they could actually be already employed and start taking classes at LCCC in the MEMS program?

CT: That's correct. We've worked both ways, where it's students whom we are helping find employment or incumbent workers who want to upskill their skills within this area.

MB: You offer courses in assembly, plus the opportunity to learn fabrication and design to the students. Do students do all this in MERIT, or is there actually any classroom instruction?

JV: There are some lecture-based classes and discussion, but the model is the only way to learn how to ride a bike is to get on the damn bike and ride it. You can watch a YouTube video of someone riding a bike, but that doesn't mean you know how to do it. If you want to watch a YouTube video of someone soldering 0402 components or operating a pick-and-place system or x-ray, that's grand. Let's sit you down on the equipment to do it. As of right now, we have three training laboratories in the core classes of our program. One of them is a solder laboratory that has soldering irons, hot air rework stations, microscopes, ESD testing equipment, electronic testing equipment, and that's where we train folks in the earliest stages of the program. Typically speaking, before they are employed with one of our employers, a student usually has to work with us for six months to a year's worth of training and education. The demand is so high for people, however, that we've had some students hired literally within seven to eight weeks of our program. The companies are like, "Wait, they held a soldering iron before?" And we say, "Yeah, actually we're doing 0603 resistors and polarity-specific devices." "Yes, that's exactly what we need. Everyone else we've ever hired can't spell solder, let alone do it."

Our second laboratory is very similar, except it's in a Class 10,000 cleanroom. Several of our sponsor companies make biomedical devices and have a need for people who know how to do electronics manufacturing within a cleanroom environment. Some also do things beyond typical PCB soldering. Several companies do PCB fabrication, so we train students on photolithographic processing, ferric chloride chemical etching, development and chemical handling, and expose them to some of the material processes it takes to actually fabricate a board.

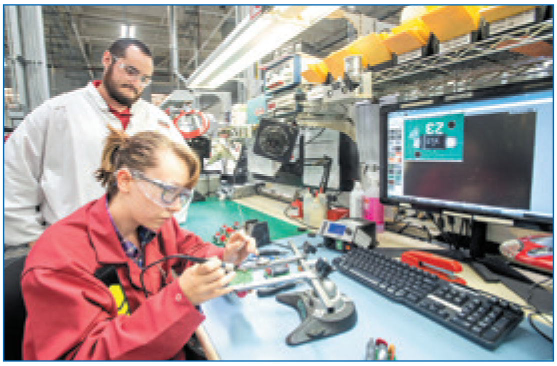

FIGURE 3. At LCCC, students learn the intricacies of rework and hand soldering.

We also have equipment in our cleanroom for wire bonding and die attach for chip-scale packaging, and in the case of our class, we do a lot of chip onboard processing, so we wirebond them to a board to create a functional circuit board. On top of that, we have soldering, microscopes and what I would call semiautomatic introductory equipment for doing SMT prototyping and low-volume production. We have stencil printers that are more or less mechanical. We are printing on 5" x 5" stencils. It's not big, but we are using our funding appropriately to be able to give people training, education and skills to get hired.

We have four semiautomatic pick-and-place systems where the operator has to operate it with their hand on a gantry, but they also have to load the feeder. The feeders have a button where if you push the pickup tool nozzle down onto the button, it feeds fresh parts forward. There's a vacuum nozzle the operator has to control with a button in their other hand. We've got a three-zone reflow oven that's sitting on a bench that teaches them. This is a belt-driven oven just like what you see in the industry, just 10 times its size.

In our bachelor's degree, where we also do a lot of our training at MERIT, we have a high-volume Panasonic stencil printer and fully automated Panasonic pick-and-place system with 48 feeders both front and rear and a 20-tray loading system. It has two heads: one with 16 nozzles, one with three nozzles. The throughput is something like five or six parts every second. We have an Omron screen print inspection system and an AOI that we're doing all the programming on. We have an eight-zone reflow oven that we teach M.O.L.E., what it is they will put forward through the temperature profile. We have a Creative Electron x-ray microscope [with which] we train students on how to look for solder points. BGA rework tools by Manncorp that we teach how to line up a BGA. Every student who takes that class hates BGAs at the end of it. "Why are we using these? They are such a pain to be able to put on!" We tell them this is what's in modern design. People want more functionality in their electronic devices, so you have to know what to do in case it doesn't go right.

MB: Wait until they see QFNs.

JV: Yeah! We make them put down QFNs, and they all hate them afterwards. And wait until you see a truckload of these boards with it!

In MERIT, we have a lot more of the high-volume-based equipment for training the students in their nighttime classes. Usually when they're taking classes there, they're all working during daytime shifts or on the Train Ohio schedule in different places. Then they swing by us and take classes at night, which allows us the luxury of being able to offer workforce training through MERIT during the daytime. If a company wants to hire our students or put a job description on us, we will do it. We have had about 12 or 15 companies from outside in the last year or so. They'll say, "Could you train our folks if they fly out there?" We say, "Yeah! We will train them. We will teach the same thing we're teaching in our associate's and bachelor's degrees. We will teach in short-term private seminars where it is still hands-on; they still can see the equipment. We had a company recently that hired three people who have never done electronics manufacturing. They've never seen a soldering iron. They have no idea what a pick-and-place system is. They were surprised to see solder paste is made of small particles. "I thought it was just some gray mush." We take a microscope and say, "Look: There's the solid pieces. Let's actually reflow it so you can see what this looks like afterward." We're able to train them so they get the same hands-on training as the day student but in a shorter timeframe, albeit at a higher cost since it's a private class.

MB: Was all that equipment donated, or was that part of

your startup costs?

JV: We bought it. The college asked for funding originally from the state of Ohio to get some of the equipment for our associate's degree. The state had kind of a strict requirement. They said we need employer support to do this. We said, "Sure, we'll get employer support. We'll make it so students have to be hired as part of our program."

Then the state gave us funding for our first laboratory, and eventually we expanded into an additional solder laboratory. Once we became the first community college in the state to have its own bachelor's degree in microelectronics manufacturing, the college put money toward buying this equipment and since, for the funding to be able to get this third laboratory of high-volume production equipment. But it's so awkward because we get companies that say, "Well, what kind of research are you doing? What kind of prototyping are you doing? What kind of product are you building?" We tell them the same thing every time: "The product is the people we are pumping out. We have students coming out of the program who are trained how to do this. If you want to send your workforce, we will train them." We will train a new workforce coming in, so they have a clue as to what's going on, and using our college education appropriately. We're not heavily involved in any kind of research or prototyping. In fact, we're not involved in prototyping at all. We have companies that say, "Can I use your equipment to build something?" We have a fully automated line. We could, but we say, "Here's our company supporters who are already hiring our students. We will train your folks, but if you're looking for other companies, there's a whole bunch in our area who can do this type of work."

FIGURE 4. Tearing down and restocking the placement feeders is all in a day's work for LCCC students.

MB: All that hands-on learning means you have to have good teachers. Tell us a bit about the instructors. Does the faculty draw on its own industry experience? How did you recruit staff?

JV: Courtney and I were just talking about the mechanism we have, or maybe the lack thereof right now. We're young. We're only eight years old, and we feel we are unique in the United States. I'm not aware of a lot of other places that are doing what we do, and I'd love to know if there are. I'd love to be able to get some feedback from folks in other places who are doing something similar because what we're doing is working. So, if it does exist, can we talk to you, and if it doesn't exist and you're interested, can we share what we're doing so we can spread this out?

The faculty and staff who work with us typically are coming from two places. The first place is from our industry supporters and places where they've already had working experience. If they're going to be a part of our educational system, they also have some degree. If they want to teach bachelor's degree classes, they have to have a master's degree. If they want to teach associate's classes, they have a bachelor's. We have to find a nice mix of people who have a degree and someone who has experience. I want someone with more experience. Occasionally we get some Ph.D. who calls. I ask, "What kind of work experience do you have?" and they say, "Well, I've got 30 publications and this and that," and when I ask what companies they worked for, the answer is zilch. So, they typically don't make their way over here.

The second area is kind of a homegrown mechanism. We have several student workers and technicians who are graduates of this program who see an interest in helping other people find work and employment. They've had some work experience, but they are ultimately interested in being able to help other students, help run our equipment, help clean the laboratories, help train other people.

We had a couple of student workers, and they didn't have anything to do at the time. I said, "Go downstairs and load every feeder up," and they sure did. They went down, got a tape and reel and a bill of materials and loaded every single feeder. "Now what?" they asked. I said, "Tear it down and do it again," because they have to know how to do it, and they have to look good while they're doing it, to show other students how you do it. A lot of times it's just practice to be able to do it. As the program goes, we are somewhat of a smaller program. Including [me] and Courtney, we have four instructors and three student workers and a couple of laboratory assistants or techs. It's not the mightiest of programs, but we're growing with the natural way other companies will want to hire people and just kind of watching how it goes to see how we can provide them a better workforce.

MB: How many degree students can you take each year?

JV: That's a good question. Prior to Covid we were ready to expand to either 36 or 48 students every single year. Covid took a nasty toll because two things happened simultaneously. First, the college asked a lot of folks to teach anything they could online from home. The problem was I tried to get soldering irons into some of the students' homes, and we just couldn't do it. We require a lot of hands-on training, so the students have to be on campus. That alone led to some difficulties in training. The other problem was the companies that were manufacturing biomedical electronics – specifically the hospitals – all of a sudden had second and third shifts that popped out of nowhere. Courtney and I have never seen so many job requests from companies. These students literally have a huge amount of job opportunities available to them, should they be interested in taking a position.

Now we're taking I think … 24 or 36 students. Due to Covid restrictions, we have to keep the class sizes limited. We have to keep everything kind of limited, but once it starts to change a little bit more and we're allowed to increase the capacities, we expect to go back to a full set of classrooms the way we were in 2019 where we had all our classes maxed out for years.

A lot of students see this program leads to careers. It's affordable, and in some of the cases these students are really interested in what they're doing. They're really interested in working with their hands, working with local companies, working with the materials and equipment. We're expecting after maybe a year or so, this goes back up to maybe 36 to 48 students every single year, but we do expect it to climb beyond that. The job requests are just huge right now, and we don't have enough students to provide all the job requests that are there, but are we going to work toward getting them those students and getting the most workers? You bet.

MB: You mentioned that when the program began you had eight corporate partners and now something like 80.

JV: Yes, that's over the life of the program.

MB: What's the nature of that partnership? Are they advisors? Companies that are helping place your graduates? All of the above?

JV: In many ways all of the above. These companies that support our program, our industry partners, are first and foremost our advisors. We don't want to teach students or train people in things that won't lead them to careers. In the early parts of our program, that was part of it, so we had a couple of companies that did fabrication processes and wanted more chemistry, more chemical handling within the program. So, we took physics out as a science class and introduced chemistry to create a fabrication class with students doing chemical processing on bare printed circuit boards. We originally had calculus in our program and, to quote Greg Vance of Rockwell Automation, "I don't need someone to do a derivative. I need someone to work with my team, work with my equipment, and make my company money. We make circuit boards, and that's what I want the program content to be." So, we kicked out calculus. The highest level math class in our program is a statistics class, which is appropriate for the discipline of what we're training people to do: to be designers, manufacturers, technicians, operators, and manufacturing engineers. In some of the cases, doing integrals and differential equations is not going to give them skills necessary for that particular career. Are those classes worthless? Maybe not. They're just better for other degrees.

Ultimately where a lot of these industry partners come into play is in hiring our students. It's partner or perish. We either get our students hired to work with the company, or we cease to exist. We're very interested in the feedback from our industry partners and to hear what it is a student should know in order to get hired, what we can give them in terms of that experience.

CT: We also understand that not every employer can hire someone all the time, so we invited players to even just provide feedback and hope in two years from then they could hire someone. Their feedback has been part of the process, and employers can review résumés, provide mock interviews, provide degree feedback. We want employers at the table whether they can hire someone today or in two years.

MB: The program itself hypothetically could be, or the model at least could be, packaged and offered at other community colleges around the country. Is that a fair assessment?

JV: To add onto that, in addition to 100% of all students who graduated being hired 85% of our current students are working as part-time workers or interns, or in some cases they are full-time workers while they take part-time classes. It all depends on the companies and the student schedule. That ability to have what we're doing duplicated elsewhere is a big factor of what we want to talk about.

In fact, we're currently working as part of a grant the Air Force provided to the state of Ohio called ADMETE [Assured Digital Microelectronics Education & Training Ecosystem]. ADMETE is basically there to train students to work in trusted and assured microelectronics solutions. It is based on six colleges working as an ecosystem together to create degrees and create training opportunities. One of the ones that's working with us is Wright State University. Vance Saunders there is working on a computer science and engineering program where students are learning how to solder circuit boards as a skill that would be beneficial for them working at a company. So, Vance is asking, "Can you share some of the content with us?" and our response is, "Here you go." Then we say, "What kind of equipment are you using? Here is the exact equipment we have." Now Vance has the third problem of who's going to do it, and we say, "Send us your folks. That's what MERIT was built for. MERIT is built to train not just workforce but other institutions in the areas of electronic manufacturing. Send us your workforce or your faculty, your staff, your grad students, your adjuncts, or whomever you want." They get hands-on training and short-term classes. They go back to Wright State, which now has a laboratory with the equipment that's going to train people to work, educational material that's based on what industry wants them to be trained in, and a training mechanism where they could send others to MERIT in case somebody graduates or goes somewhere else. That together makes for a well-rounded hands-on training ecosystem that any university in the entire United States could do.

If readers are interested in more about what this is, the website is lorainccc.edu or lorainccc.edu/merit. There's more information on the curriculum and videos, some success stories, and information about the degree program and workforce training. ❑

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CREATION TECHNOLOGIES: Born to Soar

Under the radar, the newest addition to the $1B EMS club is flying high on A&D. **by MIKE BUETOW**

In 2021, with pandemics and parts shortages still grabbing all the headlines, Creation Technologies quietly joined an exclusive club: the $1 billion electronics manufacturing services companies. Fewer than 30 companies in the world are members of such rank, and of those, only two others are privately held.

That Creation attained such lofty revenue heights on the downlow is keeping with its unsung nature, however. Despite accumulating several CIRCUITS ASSEMBLY Service Excellence Awards over the years, the EMS company has historically remained in the background, ceding the limelight to the latest Wall Street darling of the week.

It will be tough to keep the proverbial lid on, now that its private equity owners have acquired not only Creation, which is nearing, if not now in, the top five EMS companies based on North American revenues, but also Summit Interconnect, which is a top three board fabricator in the same geography.

For a company that has grown by acquisition – at least a dozen across its 30 years in business – Creation itself has been the object of others' affections. Early on, cofounder Geoff Reed and chief executive Arthur Tymos spearheaded an ESOP, giving employees a stake in their surroundings. In 2007, Birch Hill Equity Partners invested $65 million for a stake in the firm. In 2019, Lindsay Goldberg consolidated the ownership, acquiring Creation Technologies outright.

To manage its new investment, Lindsay Goldberg brought in DeFalco. DeFalco brought a long track record with blue chip firms and in key markets. Previously he was CEO of MDS, a publicly traded life sciences company; president and CEO of Crane Currency, which is the producer of banknotes for the US; Senseonics, which makes glucose monitoring systems, and president of PerkinElmer Instruments. He launched his career in engineering and product development at IBM.

The past two years have been a whirlwind for the firm, snatching up Applied Technical Services in 2020 and Computrol and IEC Electronics this year, while also inaugurating a new plant in Mexico. The moves cemented the company's North American footprint, while expanding its penetration in its core aerospace and defense and medical markets. While ATS was perhaps a surprise because of its proximity to Creation's plants just north of the Canada border, the IEC acquisition, in particular, caught the industry's attention. The $174 million paid was an eye-popping 14 times earnings. (Given IEC's backlogs and book-to-bill ratio – 1.76 at the time of closing – and the lack of overlap with Creation's existing customers, Lindsay Goldberg may have bought low.)

All the while, DeFalco and his team are focused on increasing its share of the burgeoning lower-volume, high-reliability market, where margins remain much more attractive than the consumer and computing sectors.

In an exclusive interview, Creation Technologies chairman and chief executive Stephen DeFalco laid out the company's market focus, its acquisition and growth strategy, and its approaches to the biggest issues facing the industry today: supply chain shortages and talent recruitment and retention.

Mike Buetow: Creation Technologies had a series of acquisitions in the mid-2000s. Then activity slowed. In the past two years it has acquired ATS, Computrol and IEC. What's changed?

Stephen DeFalco: The acquisitions of ATS, Computrol and IEC deepen our focus on our core markets: aerospace and defense, medical, and tech industrials. Post-acquisitions, we have 14 manufacturing locations, over 30 SMT lines and 4,400 employees. Our annual revenues now exceed $1 billion.

My passion is growing and building a business, and it's been great to have the opportunity to do that here at Creation Technologies. We are investing to make Creation Technologies a "category killer" in the high-reliability, low- to medium-volume market segment that includes customers in aerospace and defense, medical, and tech industrials. I might be the only CEO in the industry who would no-bid a $100 million customer opportunity and instead ask my sales team to bring me ten $10 million opportunities.

Our private equity sponsor, Lindsay Goldberg, has struc-

tured its fund with a long-time horizon. The idea is a "buy and build" strategy that is driven by serving our current customers well to grow our business with them and opportunistically executing on strategic acquisitions. EMS is a great industry to invest in because nearly all products are becoming more technology focused, requiring complex electronic assemblies. We believe our focus on specialty EMS will allow us to build a superior offering for our customers.

MB: At one time Creation was partly an ESOP. Is that still the case?

SD: No, there were various minority holders at one time, but we now have a very simplified capital structure.

MB: The multiple paid for IEC got the industry's attention.

SD: IEC has a great track record of strong, organic growth and a wonderful reputation with customers in the aerospace and defense market. We like the aerospace and defense market because it generally leads to long-term customer partnerships. Once a company sets up a supply chain, they tend to be partners for life. They want a reliable, long-term partner that minimizes risk while manufacturing sophisticated technologies. This fits well with our partnership model. We are very deliberate about which customers we onboard because we view it as a marriage.

CEO Stephen DeFalco has continued to focus on high-reliability, lower-volume markets.

MB: I first toured a Creation Technologies plant in 2012. At the time, the company's sweet spot for customers was around $3 million. The plants were capped at roughly $100 million in revenue and 300 employees, after which another plant might be built just blocks away. Notably, in an industry where companies often conceal their customers, Creation had signs with customer logos hanging above the SMT cells. Does that still hold true?

SD: Our sweet spot really has more to do with the type of customer than a particular dollar amount. We look for customers looking to partner with a company that offers a global scale combined with the agility to serve the medium-volume, high-reliability markets. Creation Technologies doesn't have a single customer that accounts for more than 10% of our revenue. We do still put the customer logos above the production cells. It is a great motivator for our teams who work in each of those cells.

MB: The NPI Centers in Denver and Milwaukee are a new approach. What's behind that strategy?

SD: The founders of Creation did a really good job of building a service-oriented culture. We've expanded on that as we built it into a global company. We have developed an enhanced NPI process which we call LEAP, for Launch to Excellence to Advanced Production. It encompasses design, value analysis, value engineering and test development. LEAP covers all aspects of the product lifecycle from new designs to product transfers. We have invested in this process to improve execution of product launch activities. Speed to NPI is very important to our customers, but we also focus just as much on the quality of execution to help them get to volume production in a qualified process.

MB: Most of your plants are less than 60,000 sq. ft. At 205,000 sq. ft., the new site in Hermosillo is an exception.

SD: Hermosillo is a purpose-built greenfield facility designed for lean factory flow with the most modern manufacturing equipment. We had the opportunity to design a site that could accommodate our growth and can support up to 12 SMT lines. In addition to offering efficient product flow, the new facility will provide fully integrated EMS solutions, including dedicated areas for PCB assembly, system integration and test, as well as forward and reverse logistics.

Mexico offers customers a low-cost option and has a significant logistics advantage. Customers with medium-volume, high-reliability products are looking for Mexico.

MB: Are the factories aligned to work together? For example, is product moved from site to site?

SD: Our approach is to give customers access to everything we offer globally. Customers can determine which sites make best sense for them based on their various needs and products. Our SMT practices are harmonized across our sites. Customers want us to do what we do excellently and are attracted to our global offering.

MB: Even more recently, Lindsay Goldberg acquired Summit Interconnect, the second-largest printed circuit board fabricator in the US. Is there a strategy to leverage that company with Creation?

SD: This investment is separate from Creation, although Lindsay Goldberg felt comfortable buying Summit because of its experience with Creation Technologies. Summit is very selective and has a portfolio of high-quality customers.

Creation has relationships with a number of great PCB suppliers, and Summit works with and ships quality product to a number of our competitors. With that said, if a customer wants a joint Creation-Summit team, we can make it happen, but it has to be driven by the customer. If the customer drives

it and wants it, we will have a great offering with our "sister" company.

MB: IEC CEO Jeff Schlarbaum is widely credited with turning around that company. What is the plan with regard to retaining IEC management?

SD: Retaining management is extremely important in our acquisitions. Jeff and his team have done a great job of building a successful company that has an excellent reputation with those customers. In fact, Jeff was recently appointed to the Creation board of directors. We are thrilled to have Jeff, with his knowledge and expertise in the EMS business, continue as part of our team.

MB: Let's talk about the big issue facing the entire industry: parts supplies. What is your take on that? And what steps did Creation take to keep customers informed?

SD: When the component shortage situation hit, phase one was "scramble like hell." Now the focus is how the semiconductor factory is producing and how we can manage procuring allocated components. The situation will ease slowly, probably through mid to late 2022.

In dealing with the supply and logistics issues, we live our values. We have proactive, high-integrity conversations with customers. For any product, typically there are three to five critical components on the bill of material. We keep customers informed. We tell them exactly what the situation is and how it will affect them every day. It really affects team morale when you are used to delivering what your customers want and you just can't because of supply disruptions. There is tightness in labor, tightness in freight. It will return to normal, but probably not as soon as we'd hope. I think our industry will be in an inflationary environment for a significant period of time.

MB: That's a good segue into the labor situation. I've been in the electronics industry since 1991, and the industry has always pointed to a lack of available skilled operators and engineers. That was true in 2000, and also true when unemployment spiked during the 2008 recession. What's the picture for Creation?

SD: More aggressive hiring. The labor situation has shifted the way we hire and we have increased our starting wages. But adding pay isn't going to do it alone. We've put more emphasis on 401(k) matching and improved benefits that appeal to our target market of employees. Once they join, it's all about training and providing opportunities for career progression.

MB: Has the pandemic affected acquisition velocity? I'm wondering whether activity slowed for a while, and the number of recent deals is due to a lot of pent-up M&A demand.

SD: It's bizarre that two acquisitions hit within two weeks of each other. It was more coincidence than plan. We do have the financial capacity to do more, but only if they are on strategy. We have our investor's backing and confidence to build and grow the business as appropriate.

MB: My research indicates there are about 130 or so publicly traded EMS companies worldwide. Being public adds pressure, of course, to what is already a low-margin industry. Do you think there's an appropriate size for a public EMS company?

SD: I think there are a lot of EMS companies that are public that shouldn't be. And there are significant financial and overhead costs to being a publicly traded company in terms of board fees, filings, etc. With Lindsay Goldberg, we don't have to incur these costs and can focus on investing in our factories

The new Hermosillo site is Creation's largest to date.

to better serve our customers.

MB: How do you spend your time?

SD: At first, it was upgrading talent and sharing best operational practices across the sites. For instance, when I came in, SMT changeovers took up to 140 minutes. Now they average 25 minutes. And circuit card assembly throughput time is down 50%.

Now I'm spending more time with customers. About 50% is with customers. Talent development is about 25%, and operations is 25%. I am very privileged to work with such an outstanding leadership team.

MB: What should customers think of when they hear "Creation Technologies?"

SD: We provide a long-term, intimate partnership. We are passionately in the fight with them to make them successful and will deliver resources across our global team to make that happen. ▫

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Creation acquired Computrol in September ...

... Followed by IEC the next month.

Reaffirming the Relevance of the Area Ratio Rule

How using a thinner stencil corrected transfer efficiency.

SMT SPECIALISTS ARE intimately familiar with the guiding rule of stencil printing: the area ratio. The correlation between stencil aperture dimensions and the predictability of solder paste transfer efficiency is well understood, and IPC has standardized design guidelines outlining ideal conditions. The accepted area ratio for maximum transfer efficiency is approximately 0.60, which is a function of the aperture open area and aperture wall area (stencil thickness). When the area ratio falls below the recommendation, challenges arise.

Reaffirmation of the relevance of the area ratio rule occurred recently when our company was asked to analyze a customer assembly where bridging was observed. The printing dimensions of the PCB's bridging area were tight. The 01005 apertures measured 200µm x 200µm, the stencil thickness 80µm and the interspace about 150µm. So, while not at the bleeding edge like some newer-generation designs, the board was nevertheless challenging. With these aperture dimensions, the area ratio was an acceptable 0.63. The volume of paste on pad was 2.08 nanoliters (NL), and the standard deviation was less than 10%, but SPI analysis revealed bridging.

For its part, the customer had logically attempted to lessen the bridging propensity by narrowing the aperture width to reduce the amount of solder paste being transferred onto the pad. Unfortunately, doing so resulted in conflict with the area ratio rule, and taking this route ultimately impacted repeatable transfer efficiency.

IPC has illustrated this with its aperture guideline (FIGURE 1). In any situation where the ratio is 1 or greater, the transfer efficiency expectation is 80% or more. In other words, one would anticipate the theoretical volume of material deposited onto the pad at 80% minimum. When the area ratio is tightened, the transfer efficiency begins to drop off, and the standard deviations from the aperture increase dramatically. No longer is it guaranteed the same volume of material will be released from the aperture print after print, and this is what the customer experienced.

In this application, when the aperture perimeter was reduced to 200µm x 180µm, the area ratio dropped below the acceptable 0.6 slightly to 0.58; the standard deviation increased to greater than 10%; and the transfer efficiency landed at 60%, with paste-on-pad volume at an average of 1.7NL. For high-volume manufacturing, this is not acceptable. The goal in this case was to

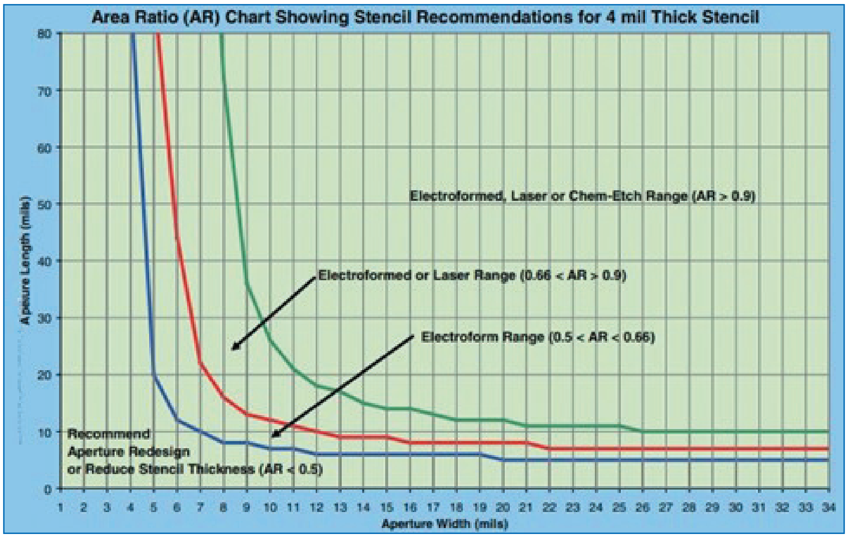

FIGURE 1. IPC area ratio curve.

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TABLE 1. Transfer Efficiency of Different Approaches

Solution	Aperture Width (µm)	Aperture Length (µm)	Stencil Thickness (µm)	Area Ratio	Transfer Efficiency (%)
Original design	200	200	80	0.63	65
Aperture width narrowing	180	200	80	0.59	60
Area ratio compliance	180	200	70	0.68	80

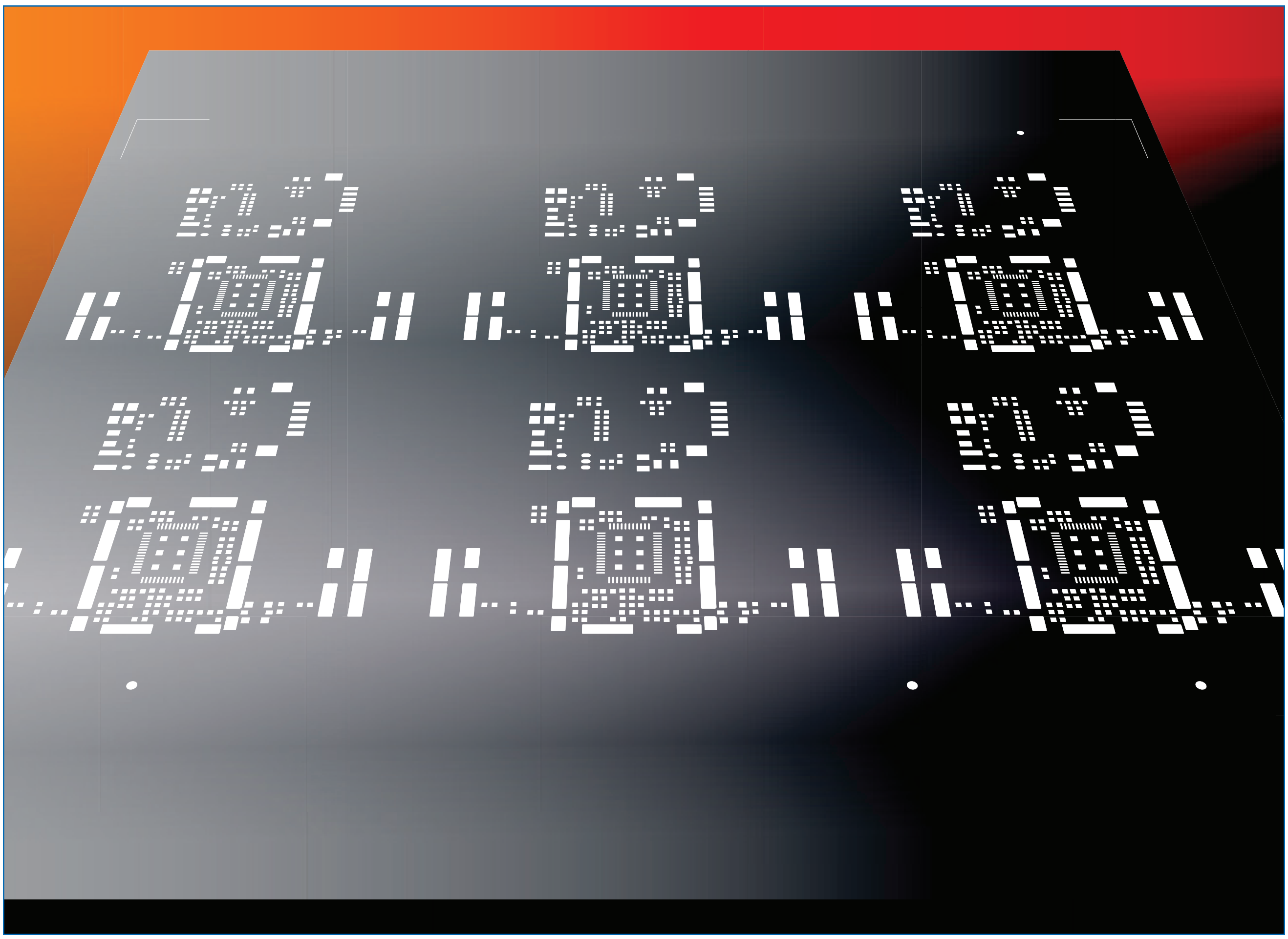
reduce volume from 2.08NL, but within a 4 Sigma process and a less than 10% deviation with ideal 80% transfer efficiency. To comply with the area ratio rule and this aperture dimension, the only solution was to use a thinner stencil.

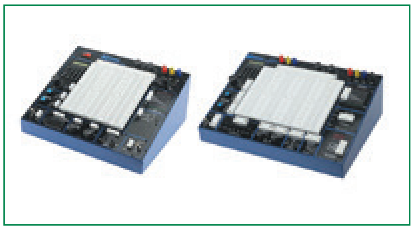
"But how?" you may ask. Historically, stencils came in standard thicknesses: 150µm, 125µm, 100µm, 75µm, and so on. If that were still the case, the math wouldn't work from an area ratio perspective for this application. Times have changed, however, and today's stencil manufacturers can produce just about any thickness desired with no preset limits. For our customer's situation, reducing the thickness of the stencil to 70µm would permit the print to stay within the area ratios.

One also might assume if the material volume is reduced, interconnect issues may result. However, in looking at IPC's area ratio curve, thinning the stencil with the reduced aperture size increases the area ratio, delivering more efficiency out of the aperture. And that's exactly what happened. When the stencil thickness was set at 70µm, and aperture dimensions were maintained at 180µm x 200µm, the standard deviation was again less than 10%, as in the original design, but transfer efficiency increased dramatically to 80%, and material volume was 2.0NL **(TABLE 1)**. Once again, the area ratio rule prevailed, and the bridging issues were resolved. Stencil printing is not a sport for rule-breakers.

"THINNING THE STENCIL WITH THE REDUCED APERTURE SIZE INCREASES THE AREA RATIO, DELIVERING MORE EFFICIENCY OUT OF THE APERTURE."

(Caveat: This was a miniaturized assembly for a mobile device. For a heterogeneous PCB that requires large material volumes in some areas, the use of a step stencil would allow compliance with the area ratio rule to allow for increased paste volumes for specific components.) ❑





GLOBAL SPECIALTIES PB-503A, PB-505A CIRCUIT DESIGN TRAINERS

PB-503A and PB-505A feature function generator with digital display for accurate settings. Can dial in frequency to nearest 0.1Hz. Generator provides 100kHz signal in two ranges. Outputs 10Vp-p into 600Ω load (20Vp-p into open circuit). Choose from sine, square, triangle, and TTL waveforms. Reportedly ideal for classroom use. Combine elements of benchtop lab, including power supply, function generator, and breadboard. Both are equipped with triple output DC power supplies; removable breadboard for multiple users; two digital pulsers; high- and low-buffered logic indicators; 8 channel logic switches; 2 SPDT switches; 16 LEDs for logic indicators; 2 BNC connectors; 2 potentiometers (1kΩ and 10Ω); speaker. Have switchable input to work in 120 VAC and 240 VAC environments. Additional features on PB-505A: AC power supply (12.6 VAC center-tapped); logic probe; BCD to 7-segment displays.

Global Specialties
globalspecialties.com

POLAR SPEEDSTACK 2022 DESIGN STACKUP TOOL

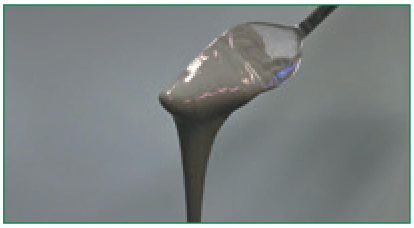
Speedstack 2022 incorporates "snap-to" dimensioning for impedance trace dimensions. This feature in Si8000m and Si9000e is now implemented in Speedstack PCB and Speedstack Si. When installing new version, previous version auto-uninstalls. Testing impedance on fine lines will be simplified with release of 2022 CITS880s impedance test software.

Polar Instruments
polarinstruments.com

VENTEC AEROLAM LAMINATE

Aerolam laminate and prepreg material is curated for requirements of aerospace and defense applications. For equipment intended to operate in command-and-control center to high-performance fielded systems that must withstand tough conditions, including extreme temp., high vibration and G-forces, salt spray, and humidity.

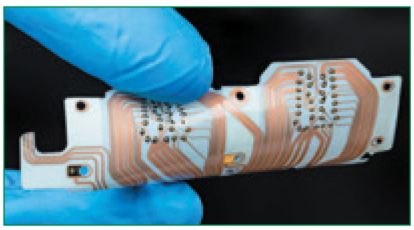
Ventec
venteclaminates.com



TANAKA SINTERING NANO-SILVER PASTE

Low-temp. sintering nano-silver paste enables miniaturization and improved bending resistance of wiring for use in screen printing. Is for smartphones and wearable devices that need bending resistance, improving transparency in window defoggers, and transparent antennas for 5G applications. Suited to printing fine wires directly onto glass of 30μm or less. When sintered at heating temp. of around 90°C, wires have resistance value below 10μΩcm. Consists of nano and submicron silver particles.

Tanaka Precious Metals
tanaka-preciousmetals.com



DUPONT PYRALUX HP LAMINATE ADHESIVE

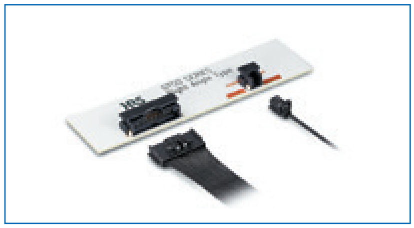
Pyralux HP laminate adhesive system is epoxy-based and combines insertion loss performance with increased functionality and processing. Designed for OEMs and PCB manufacturers to address needs in high-performance and high-reliability applications in telecommunications, networking, medical, industrial, military and aerospace markets. Reportedly possesses robust processability, while maintaining electrical performance to optimize signal integrity in extreme environment PCB applications. Is IPC-certified and available as sheet adhesive or coverlay. Suited for multilayer flex and rigid-flex applications. Enables processing at lower temp.

DuPont Electronics & Industrial
dupont.com

EVS 11KLFHS SOLDER RECOVERY SYSTEM

11KLFHS solder recovery system reportedly recovers up to 80% of pure solder. Automatic, with touchscreen display. Includes 11kg (24lb.) pot. Provides clean ingot bar as it filters solder through gauze. Features sealed cabinet, enclosing dross bucket and fume extraction, and tilting pot mechanism. Inverting and rotating dross/solder pot and hot air activated auto drain tap create solder ingots. ISO14001 compatible.

EVS International
solderrecovery.com



HIROSE GT50 SERIES CONNECTOR

GT50 series wire-to-board connector has pitch of 1mm. Features heat and vibration resistance in ultra-small housing. Suited for automotive applications. Two-point contact system is enclosed between two springs; minimizes effect of heat shrinkage on contacts and improves contact reliability. Supports high heat applications up to 125°C. Stabilizer reduces wear in contact area between header and crimp contacts commonly caused by vibration. Retention force is 25N. Lock design has tactile click to prevent incomplete mating. Cable routing design prevents disconnecting.

Hirose
hirose.com

NORDSON EFD ULTIMUSPLUS-NX FLUID DISPENSER

UltimusPlus-NX fluid dispenser provides

Ethernet connection with TCP/IP for smart factory and Industry 4.0 manufacturing integration. Can be 100% remotely managed. Captures dispense process data. Can control all dispensing parameters from programmable logic controller or other manufacturing plant controller. Can program multiple fluid dispensers from centralized location. Can download dispense log data directly to FTP site. Dispensing parameters can be accessed from tablet, PC or mobile device using remote interface. Remote interface matches local interface.

Nordson EFD
nordsonefd.com

KURTZ ERSA I-CON TRACE SOLDERING STATION

i-Con Trace soldering station enables traceability during manual soldering. Has integrated WLAN, Bluetooth and network card. MES connection permits integration and storage of soldering parameters used in networked manufacturing processes that already run via MES. Power is 150W. Heats and reheats quickly.

Kurtz Ersa
ersa.com

XURON ESD-SAFE CUTTERS, PLIERS

Ergonomic ESD-safe cutters and pliers are suited for precise electronic applications such as reaching into densely populated PCBs. Made of alloyed steel and feature static dissipative hand grips that exhibit 106-109Ω surface resistivity and Light-Touch return springs. Come in range of head styles. Conform to ANSI/ESD.S20.20 and DOD-HDBK-263 specs. Cutters produce square cut without spikes. Head styles employ Micro-Shear bypass shear cutting. Pliers come in 10 head styles designed for crimping, forming, and bending wires and leads.

Xuron Corp.
xuron.com

INDIUM INDALLOY 291 SUPPLEMENTAL BAR ALLOYS

Supplemental bar alloys for Indalloy 291 wave solder pots are designed to maintain recommended solder pot specifications. Supplemental bar and bar chips are added to Indalloy 291-containing solder pots that have fallen below or have elevated above the recommended specifications. Dross reduction bar aids in reduction of solder dross buildup within Indalloy 291 solder pots. Replenisher bar is used to bring copper levels within recommended solder pot specs.

Indium Corp.
indium.com

MASTER BOND EP4S-80 EPOXY

EP4S-80 one-component silver-filled epoxy meets NASA low outgassing requirements. Has unlimited working life at room temp. and heat cure requirement of 80°C. Has viscosity of 10,000-15,000cps. Is for EMI/RFI shielding and static dissipation. Can be used in bonding, sealing, coating, gap filling and encapsulating. Tensile modulus of 500,000-600,000psi and compressive strength of 22,000-24,000psi at 25°C. Electrically conductive system offers volume resistivity of 0.02-0.06 Ω-cm and thermal conductivity of 1.30-1.44W/(m•K).

Master Bond
masterbond.com

VJ ELECTRONIX APOGEE 90 X-RAY INSPECTION

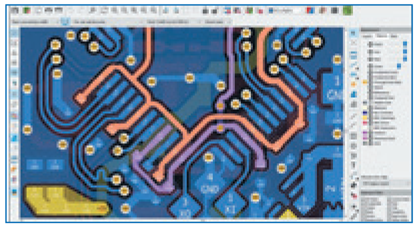
Apogee 90 x-ray inspection system performs manual or semiautomated inspection of PCBs, components and assemblies. At-line NDT comes equipped with 90kV, sealed, microfocus x-ray source that can achieve spot size as small as 4μm; HD digital flat panel detector with 85μm resolution and 6-axis motorized motion control with oblique angle inspection of up to 65°. Is for basic inspection and enhanced analysis of BGAs, QFNs and more. Captures 2-D and 2.5-D x-ray images for defect detection and failure analysis in production environments.

VJ Electronix
vjelectronix.com

VITROX V810I S3 AXI

V810i S3 AXI system's inspection speed reportedly has been improved up to 30%. Is equipped with machine Internet of Things and AI integration; can troubleshoot systems and perform preventive maintenance actions. Is now equipped with phase shift profilometry and optical assist system capable of supporting barcode reading, optical alignment and bad mark detection.

ViTrox Technologies
vitrox.com



KICAD 6.0 EDA SOFTWARE

KiCad 6.0 open-source EDA software is for schematic capture and PCB layout. Refreshed user interface makes visual design language, hotkeys, dialog layouts, and editing workflows consistent; reportedly does not look like two different tools when switching between schematic and PCB editors. Schematic editor now uses same object selection and manipulation paradigm as PCB editor. Includes new schematic and symbol library file format based on format used for KiCad board and footprint files. Symbols can be embedded directly into schematic file; cache libraries are no longer needed. PCB editor offers options to navigate complicated designs. Save and restore custom view presets. Hide certain nets from ratsnest. Control opacity of zones, pads, vias, and tracks independently. Set colors for specific nets and net classes and apply those colors to ratsnest or to all copper attached to net. To improve board visualization, 3-D viewer features raytracing lighting controls, highlighting objects selected in PCB editor, and access to frequently used controls. Offers new custom design rule system that allows design rules to be defined, including area-specific rules, layer-specific rules, and other required constraints. Runs under Windows, Linux, and macOS and is licensed under GNU GPL v3.

KiCad
kicad.org

In Case You Missed It

Additive Manufacturing

"Charge Transport Mechanisms in Inkjet-Printed Thin-Film Transistors Based on Two-Dimensional Materials"

Authors: Erik Piatti, *et al.*

Abstract: Printed electronics using inks based on graphene and other 2-D materials can be used to create large-scale, flexible, wearable devices. However, the complexity of ink formulations and the polycrystalline nature of the resulting thin films have made it difficult to examine charge transport in such devices. Here the authors report the charge transport mechanisms of surfactant- and solvent-free inkjet-printed thin-film devices based on few-layer graphene (semimetal), molybdenum disulfide (MoS_2, semiconductor) and titanium carbide MXene (Ti_3C_2, metal) by investigating the temperature, gate and magnetic-field dependencies of their electrical conductivity. (*Nature Electronics,* December 2021, https://www.nature.com/articles/s41928-021-00684-9)

Conformal Coatings

"Prediction of Solder Joint Reliability with Applied Acrylic Conformal Coating"

Authors: Duarte Nuno Vieira, *et al.*

Abstract: The exposure of miniaturized components to the environment leads to new failure analysis as a result of environmental conditions and constant innovation of the component materials and dimensions. Generally, these failures occur on the solder joints. Conformal coating encapsulates the components and their solder joints to protect against harsh environments. However, this application is not recommended in some component packages such as BGAs and QFNs, since it can reduce the reliability of the solder joints when exposed to temperature fluctuations. Therefore, by using a finite element analysis, a thermal cycle test was simulated with and without conformal coating. The simulation output was extrapolated to lifetime theoretical methods with the aim of predicting the number of cycles until the failure of the solder joints. This study demonstrates, for both components without conformal coating, solder joint lifetime was a precise approximation. Coated solder joints reveal a drastic reduction in reliability due to the influence of the conformal coating behavior and its thermomechanical properties. (*Journal of Electronic Materials,* January 2022, https://link.springer.com/article/10.1007/s11664-021-09232-9)

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.

Flexible Electronics

"Stencil Printing of Liquid Metal upon Electrospun Nanofibers Enables High-Performance Flexible Electronics"

Authors: Dr. Zhao Gang, *et al.*

Abstract: Materials and fabrication technologies are key factors restricting the development and commercialization of flexible electronics. The authors report on a simple, fast, and green flexible electronics preparation technology. The stencil printing method is adopted to pattern liquid metal on the thermoplastic polyurethane membrane prepared by electrospinning. Besides, with layer-by-layer assembly, flexible circuits, resistors, capacitors, inductors, and their composite devices can be prepared parametrically. Furthermore, these devices have good stretchability, air permeability and stability, while they are multilayered and reconfigurable. This strategy is used to fabricate flexible displays, flexible sensors and flexible filters. Finally, flexible electronic devices are also recycled and reconfigured. (*ACS Nano,* November 2021, https://pubs.acs.org/doi/10.1021/acsnano.1c05762)

Optical Computing

"All-Optical Computing Based on Convolutional Neural Networks"

Authors: Dr. Xiaoyong Hu and Dr. Qihuang Gong

Abstract: The scaling of computing speed is limited not only by data transfer between memory and processing units, but also by RC delay associated with ICs. Moreover, excessive heating due to Ohmic losses is becoming a bottleneck for both speed and power-consumption scaling. Using photons as information carriers is a promising alternative. Here, the authors reveal a new all-optical computing framework to realize ultrafast and ultralow-energy-consumption all-optical computing based on convolutional neural networks. The device is constructed from cascaded silicon Y-shaped waveguides with side-coupled silicon waveguide segments (weight modulators) to enable complete phase and amplitude control in each waveguide branch. The generic device concept can be used for equation solving, multifunctional logic operations, as well as other mathematical operations. Multiple computing functions, including transcendental equation solvers, multifarious logic gate operators, and half-adders, were demonstrated to validate the all-optical computing performances. The time of flight of light through the network structure corresponds to an ultrafast computing time of the order of several picoseconds with an ultralow energy consumption of dozens of femtojoules per bit. The approach can be further expanded to fulfill other complex computing tasks based on non-von Neumann architectures, thus paving a new way for on-chip all-optical computing. (*Opto-Electronic Advances,* November 2021, https://www.oejournal.org/article/doi/10.29026/oea.2021.200060)