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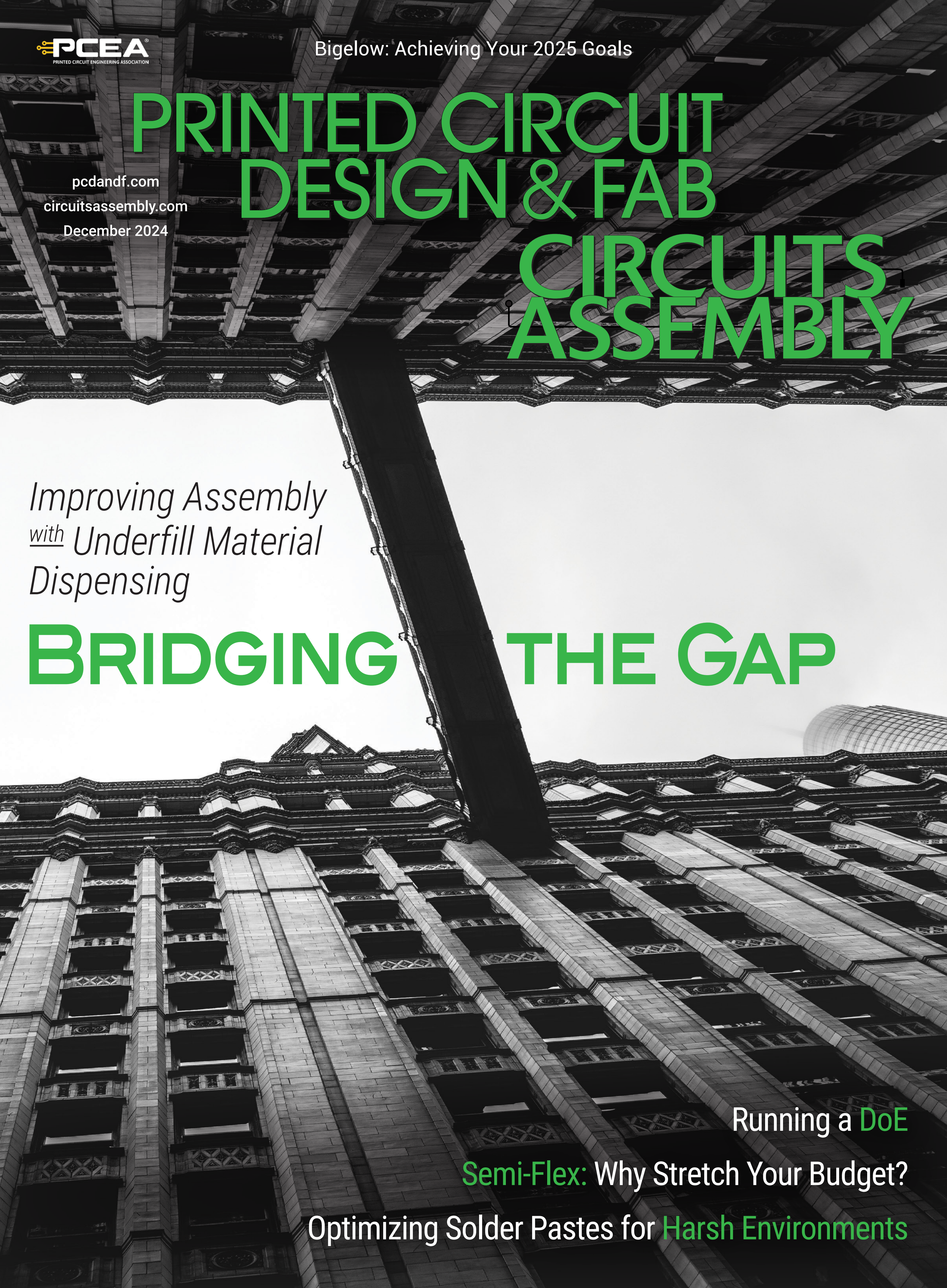
December 2024



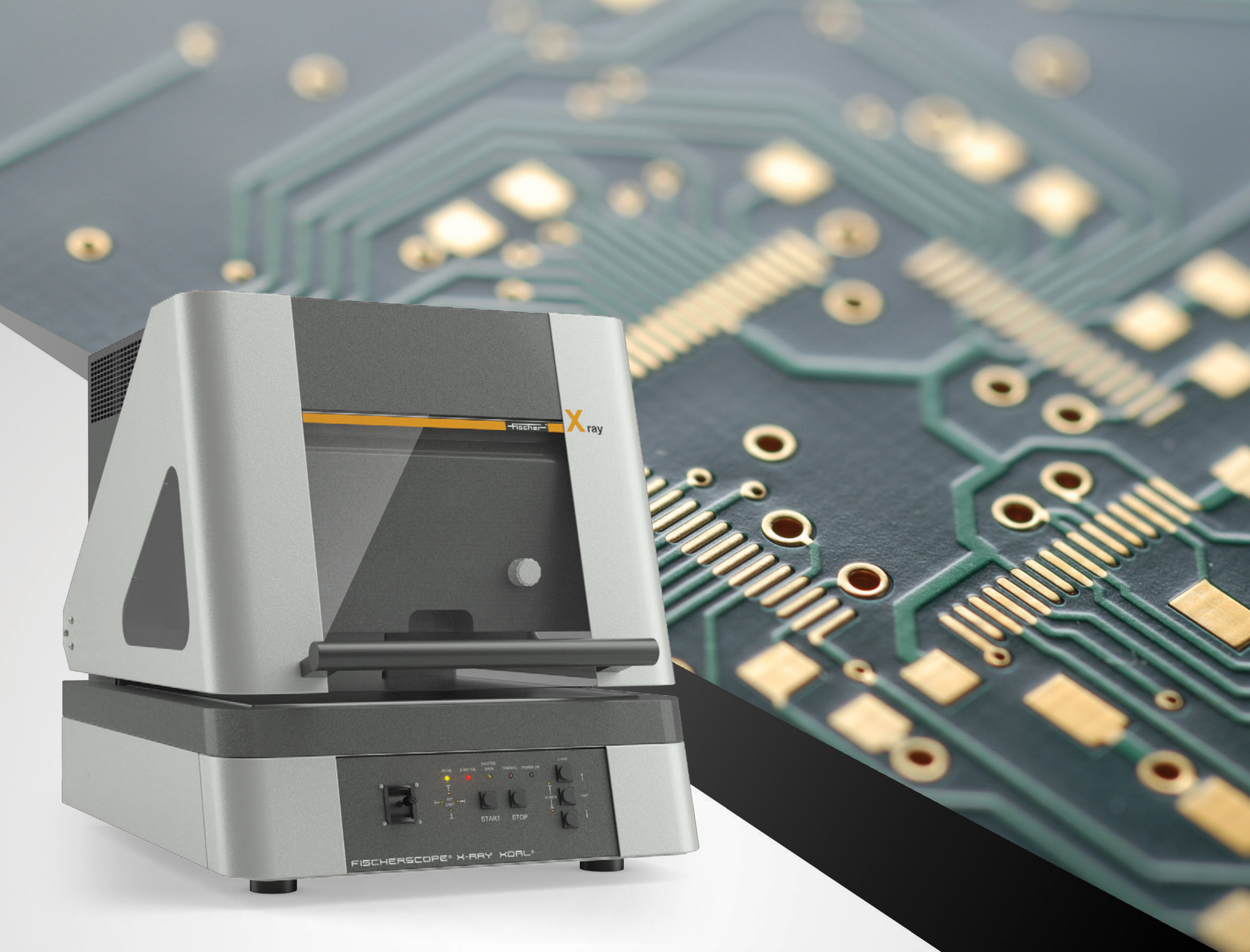
Improving Assembly with Underfill Material Dispensing

Bridging the Gap

Running a DoE

Semi-Flex: Why Stretch Your Budget?

Optimizing Solder Pastes for Harsh Environments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FIRST PERSON

MONEY MATTERS

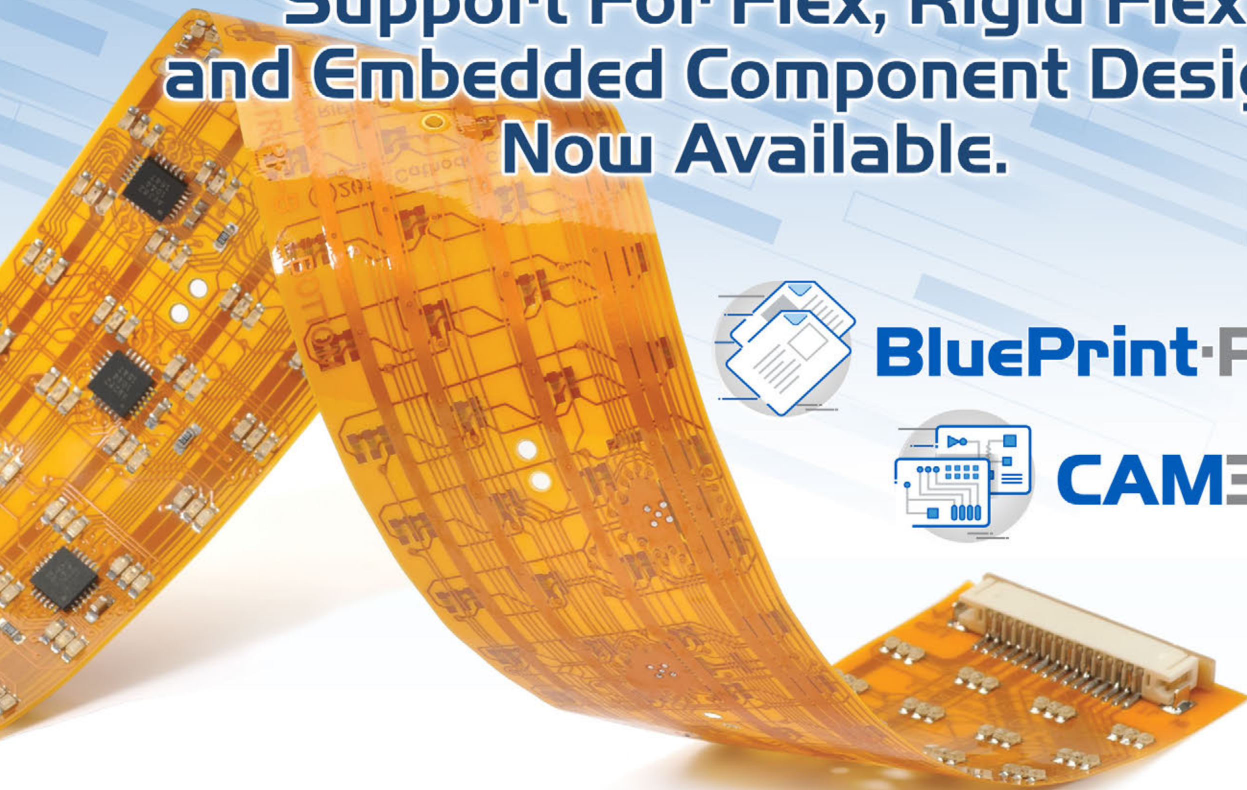
TECH TALK

DEPARTMENTS

FEATURES

ON PCB CHAT (PCBCHAT.COM)

Support For Flex, Rigid Flex and Embedded Component Designs Now Available.



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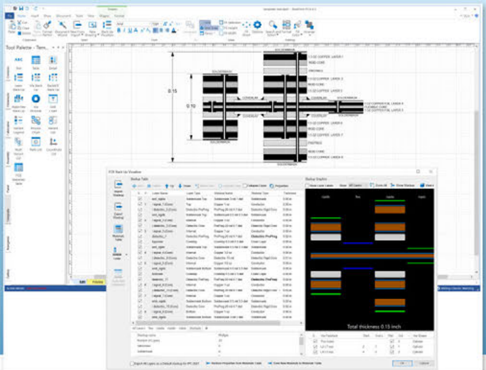
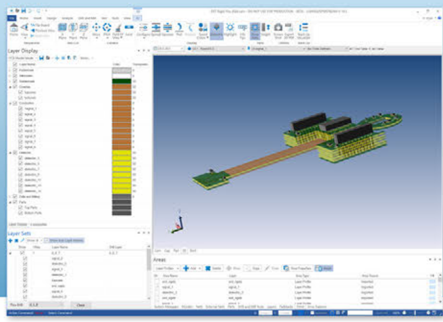
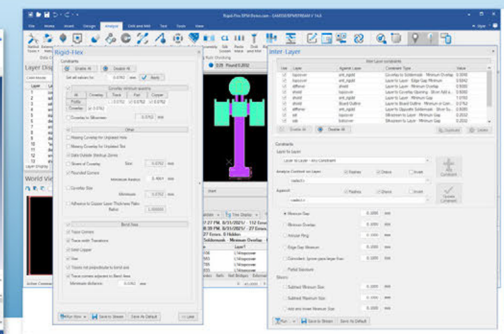
- **3D Visualization to Validate PCB Construction and Component Assembly**
- **Manage Variable Stackup Zones for Rigid-Flex Designs**
- **Easily Create Custom Flex or Rigid-Flex Fabrication and Assembly Documentation**
- **Use DFM analysis to analyze a flex or rigid-flex design for potential fabrication or bend related defects**



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.

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PCEA
Printed Circuit Engineering Association

PCEA
PO BOX 807
AMESBURY, MA 01913

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CIRCUITS ASSEMBLY
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MANAGEMENT
PRESIDENT
Mike Buetow 617-327-4702 | mike@pcea.net
VICE PRESIDENT, SALES & MARKETING
Frances Stewart 770-361-7826 | frances@pcea.net

PCD&F/CIRCUITS ASSEMBLY EDITORIAL
MANAGING EDITOR
Tyler Hanes 205-258-0067 | tyler@pcea.net

COLUMNISTS AND ADVISORS
Jeffrey Beauchamp, Peter Bigelow, Robert Boguski, John D. Borneman, John Burkhert, Jr., Stephen Chavez, Geoffrey Hazelett, Mark Finstad, Nick Koop, Jake Kulp, Alun Morgan, Susan Mucha, Greg Papandrew, Chrys Shea, Jan Vardaman, Gene Weiner

PRODUCTION
ART DIRECTOR & PRODUCTION
blueprint4MARKETING, Inc. | production@pcea.net
Nathan Hoeller | nathan@pcea.net

SALES
VICE PRESIDENT, SALES & MARKETING
Frances Stewart 770-361-7826 | frances@pcea.net
SENIOR SALES EXECUTIVE
Will Bruwer 404-313-1539 | will@pcea.net

REPRINTS
sales@pcea.net

EVENTS/TRADE SHOWS
EXHIBIT SALES
Frances Stewart 770-361-7826 | frances@pcea.net
TECHNICAL CONFERENCE
Mike Buetow 617-327-4702 | mike@pcea.net
EVENTS MANAGEMENT
Jacqueline Bress 404-955-7675 | jacqueline@pcea.net

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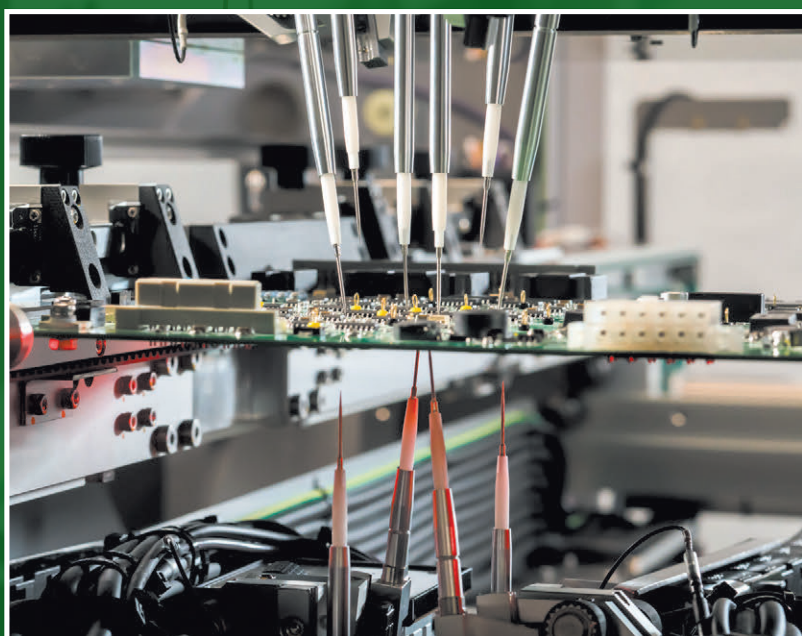

On AI, Shipwrecks and the Search for 3 Layers

I'M NOT ONE to harp on the supposed deficiencies of higher education. The reasons why not to are numerous, but foremost is the disconnect between what industry often wants from higher ed (I'm including colleges and universities in this mix, although there are certain fundamental differences that distinguish them) and what those institutions are designed to (and not to) do.

Universities and colleges are places to seek knowledge and conduct research. They are (generally) not out to make a buck, although I would point out that "nonprofit" does not equal "for loss." And they aren't designed to churn out employees ready-made for the working world. Hands-on training is left to those who know exactly what the job entails. Schools are too far from the center to keep up with changing industry needs.

And it's to their credit, I think, that they have remained somewhat immune to the wider forces that constantly try to shape their approaches and output. Facts matter, and the aim for dispositive critical inquiry means following the scientific method as envisioned by Aristotle no matter where it leads.

But there are limits. And sometimes the guardrails mean that those inside them are not just protected from outside influence, but to certain degrees ignorant of what's actually happening on the ground.

So we experienced at a trade show this fall. (I'm not going to name which one, except it wasn't one of PCEA's, because the sentiments expressed had nothing to do with the show producers, and frankly, I admire that they encourage academics to share their space.)

A professor at a nationally recognized institute of higher learning made a pitch for industry help to get federal grant funding for a mobile training center intended to bring electronics training to underdeveloped (read: rural) areas. This would involve, he explained, developing and promoting a curriculum covering all facets of circuit board development.

With excitement, I approached him, hoping to offer use of PCEA Training's Printed Circuit Engineering Professional (CPCD) curriculum. The CPCD content, I felt, could be packaged inside the broader program. Why reinvent the wheel?

I was surprised, then, to find the good professor resistant to my offering. Between his deviations into three-layer boards (seriously) and leaving teaching to the educators (by which he meant high school, not higher ed), I quickly realized making headway was a lost cause. He went so far as to assert that his engineering students were leaving college with sufficient knowledge of circuit theory to teach themselves PCB design and layout. (I'll let that sink in for a moment.)

Reading between the lines, my guess is he wanted full control (read: ownership) over any content. And he asserted – strongly, I will add – that printed circuit design will be overtaken by AI within “five to seven years.”

On that last point, he’s just wrong. The adoption curves for new technology vary, but in electronics they have always been best described as “cautiously paced.” The downsides of product failure are simply too great to rush headlong into anything. We simulate, validate, inspect, test and simulate again. Our industry has yet to invent a way to short-cut the scientific method.

Or as the French philosopher Paul Virilio said: “When you invent the ship, you also invent the shipwreck; when you invent the plane, you also invent the plane crash; and when you invent electricity, you invent electrocution. Every technology carries its own negativity, which is invented at the same time as technical progress.”

So while AI is very good at scanning data sheets and consolidating reams of manufacturing data points, as of today, AI in electronics design is not even close to being ready for prime time. It simply cannot do what an experienced designer or design engineer can do. And no one I speak with – the users, the developers, other seers – thinks this will change anytime soon. Indeed, it’s hard to see the demand signal, other than the obligatory “What is your AI strategy?” question that kicks off every sales meeting. We need to know where the ship will wreck, and how much damage and cost we will sustain when it does.

Our good professor did offer a few salient points, however. Like any organization, the educational system has its constraints. He noted, for instance, that any program that attempts to worm its way into an educational setting must make a convincing case for replacing something else, because otherwise the bandwidth – in terms of classroom time, educator time and production costs – will not support such changes. He’s right about that, of course.

And he’s also correct in pointing out that while industry asks for engineers and other graduates who can hit the ground running, already knowledgeable and competent in their chosen field, businesses don’t support higher ed with anything close to the amount of funding needed to mold those young minds. Successful ventures work because the financial incentives between supplier and user are aligned. If industry doesn’t underwrite the costs in academia, then industry isn’t seen as academia’s customer.

Getting back to the professor’s dream project, I fully realize any application for grant funding is an uphill climb. I wish him well in his efforts, although given some of his misconceptions, I admit to having a hard time taking him too seriously. Perhaps instead of pontificating about how AI will take over, he might want to check out the real world. Even without the three-layer boards, it’s pretty darn exciting.

mike@pcea.net
@mikebuetow

P.S. On behalf of PCEA, we wish a safe and happy holiday to all our members, customers, suppliers and colleagues around the world.

MIKE BUETOW is president of PCEA (pcea.net); mike@pcea.net.

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FCT Expands EMS Ops to China

MINNEAPOLIS, MN – Flexible Circuit Technologies has expanded its electronics manufacturing and contract manufacturing services with the opening of FCT-Huizhou.

FCT-Huizhou, operating as inTFlex in Huizhou, China, merged FCT's manufacturing services into a new facility featuring more than 900,000 sq. ft. of production space. The new facility features high-speed, fully automated SMT smart lines, plastics molding, membrane switches, CNC capabilities and fixtures, and permits FCT to continue providing EMS services to customers across the medical, automotive/EV, consumer and industrial markets, the company said.

"FCT is committed to expanding our resources to meet the needs of our customers," said Ray Cottrell, executive vice president, FCT. "Our new manufacturing space coupled with bringing on a wealth of knowledge to our team, speaks to our commitment. Our continuous growth is a testament to the hard work and dedication of our team, and the loyalty of our customers. This growth enables us to serve our customers better and opens new opportunities for expanded innovation and research. We are excited about the future of FCT and look forward to continuing our growth!"

PE Group Carlyle Acquires Kyoden

TOKYO – Global investment firm Carlyle in November announced the acquisition of Kyoden, a leading Japanese manufacturer of printed circuit boards. Terms were not immediately disclosed.

Founded in 1983 and headquartered in Nagano Prefecture, Kyoden is a leader in the design and manufacture of PCBs and board assembly for electronics devices, with a focus on small-lot and high-variety products delivered in short turnaround times. The business employs about 2,100 employees, with manufacturing plants in Japan and Thailand and a regional sales presence across APAC. It has deep experience in electronics manufacturing services, providing end-to-end solutions for component design and manufacturing, procurement of materials and assembly of units and large-scale devices.

The company's product suite spans a diversified set of industrial applications, including automated guided vehicles, semiconductor manufacturing equipment, amusement machines, wired and wireless equipment, and automotive devices.

In partnership with Kyoden's management team, Carlyle said it will support the company in further accelerating its growth plans through the continued development of its manufacturing capabilities focused on high-layer-count and build-up PCBs and commercial operations. Leveraging its global platform and resources, Carlyle will also support the business' international expansion.

In a statement, Kazuhiro Yamada, co-head of Carlyle Japan, said: "Kyoden has a high market share in the PCB industry thanks to its differentiated business model and advanced technological capabilities. Customer needs are becoming more diverse every day, and there is a growing need to incorporate more functions into more compact and lightweight devices. In acquiring Kyoden, we will support the business in responding to those evolving customer demands, continue its focus on technology and innovation, and accelerate its international expansion. We look forward to partnering with Kyoden's management team in its journey to becoming a leading international PCB manufacturer."

Hiroshi Naganuma, president of Kyoden, added: "We are excited to start the new partnership with Carlyle to sharpen our unique business model and accelerate Kyoden's further growth in high-multilayer and build-up PCBs, the global PCB market, and EMS business. We believe Carlyle, with its deep knowledge and track record of growing Japanese companies like Kyoden, is the perfect partner to support the business' accelerated growth trajectory."

ISU Petasys Says Looking at Possible Non-PCB Company Acquisitions

DAEGU, SOUTH KOREA – The parent company of printed circuit board fabricator ISU Petasys acknowledged reports in Korean business media that it is considering possible mergers and acquisitions to diversify its business portfolio.

Chosun Biz reported that ISU Group is considering acquiring JEIO, a carbon material developer for products like batteries.

The move, Chosun Biz said, is part of a broader strategy by ISU Group to diversify beyond PCBs.

According to the report, ISU Group is looking to acquire approximately 40% of JEIO's shares for around 300 billion won.

The report quoted an unnamed ISU Petasys representative as saying, "We are reviewing various measures including mergers and acquisitions (M&A) to diversify our business structure, which is currently focused on existing PCBs, but no specific details have been confirmed yet."

New Vern Solberg Book Highlights PCB Design Techniques

SAN JOSE – Industry veteran Vern Solberg has released a new book on designing for SMT and ultra-high-density interconnect boards.

Design Guidelines for Surface Mount and Microelectronic Technology is a guide developed for printed circuit board design engineers focusing on SMT assembly processing; land pattern development; DfM for HDI and UHDI circuit boards; flexible and rigid-flex circuits; advanced semiconductor package technologies; and 2-D, 2.5-D, 3-D and hybrid bond interconnects.

The author, Vern Solberg, is an SMT design and assembly expert with over four decades of experience in surface mount, microelectronics and manufacturing technology. He has led multiple industry standards committees for land pattern development, BGAs and other areas.

The book offers proven methods and techniques for developing a reliable and assembly process-compatible product. The text and illustrations emphasize the relationship between printed circuit board design, manufacturing, and assembly processing, and are applicable to product design specialists, material procurement professionals and those responsible for manufacturing, assembly and product testing.

Key issues include developing process-compliant land pattern geometry, selecting suitable circuit board base materials and specifying surface finishes that are most compatible with the termination process selected for assembly.

The book is available at solbergtech.com.

XLR8, IMI Sign Alliance, Employee Transfer Deal

SAN CLEMENTE, CA – XLR8 EMS and Integrated Micro-Electronics Inc. have signed a deal to form a strategic alliance that includes the transfer of certain employees to XLR8. Financial and other terms were not disclosed.

The transaction, announced in November, noted an undisclosed number of IMI employees in Tustin, CA, will transfer to XLR8.

The alliance between IMI and XLR8 EMS brings together two complementary companies with strong, specialized expertise within EMS. By leveraging their capabilities and technology, the partnership aims to offer their respective customers a broader range of services.

IMI is one of the largest EMS companies in the world, according to the latest CIRCUITS ASSEMBLY Top 50. XLR8 is an EMS provider specializing in quickturn, prototype and high-mix, low-volume manufacturing.

XLR8 is a multi-time winner of the CIRCUITS ASSEMBLY Service Excellence Award for small-tier EMS companies.

Jabil Looks to Expand India Investments

ST. PETERSBURG, FL – Jabil in November signed a memorandum of understanding with India's Gujarat state government to permit the company to explore long-term goals, opportunities and support in the state.

The signing comes after another MoU signing with the Tamil Nadu state in September.

"Jabil is committed to expanding in India to meet and grow with the future needs of our customers in the Intelligent Infrastructure segment, which covers our capabilities across cloud, compute, storage, networking, telecommunications, semiconductor capital equipment, and data center infrastructure, among other end-markets," said Fred McCoy, executive vice president, operations. "The planned expansion also opens up opportunities for Jabil's customers in the automotive and transportation industry to consider manufacturing in India."

Jabil has invested in its Intelligent Infrastructure segment to drive innovation and support the increasing demands of next-wave cloud and AI data center growth. The company said those investments include silicon photonics-based products and capabilities, liquid cooling solutions for thermal management, and an expanded server portfolio purpose-built for scalability.

"Beyond attracting foreign direct investments and job creation, this MoU reflects our shared ambitions to pursue sustainable growth and create long-term value," said Bhupendra Patel, chief minister of Gujarat. "We are excited at this opportunity to work with Jabil to explore new avenues for long-term growth together."

Asteelflash Opens Polish Production Facility

SAINT-CLOUD, FRANCE – Asteelflash opened a $19 million production facility near Wrocław, Poland, enhancing its box-build and high-level assembly capabilities in the automotive and industrial sectors.

Asteelflash, a member of USI, celebrated the grand opening of the 14,000 sq. m. facility in late October. The factory features 6,655 sq. m. of state-of-the-art clean room production space, which will enable the company to better meet the demands of its European clients, it said.

"Our expanded facility here in Wroclaw ensures we can meet the needs of our clients as the market grows, providing them with the advanced manufacturing capabilities and capacity they need to succeed," Asteelflash CEO Nicolas Denis said at the opening ceremony. "Our commitment also extends to responsible growth. This facility was designed with sustainability in mind, incorporating energy-efficient systems and environmentally friendly practices to reduce our footprint. We are growing in a way that respects the environment and the future of the communities we serve. With this expansion, we aim to set new standards for our industry and hope to inspire others to invest not only in technology but also in the environment and society."

"This factory isn't just a finished project," said Brian Shih, chairman of USI Poland and SVP of USI. "It shows how much USI is dedicated to Poland and how we're committed to growing in a way that's good for everyone. We're proud to have been here for a long time and will keep investing in this community. This new place will help our customers and partners, not just in Poland, but all over Europe."

Cicor Expanding into Sweden, Talks to Add German EMS

BRONSCHHOFEN, SWITZERLAND – Cicor Group has acquired Swedish development company Nordic Engineering Partner AB and established a significant presence in the Nordics.

Additionally, Cicor is in advanced negotiations to acquire another German EMS provider.

The acquisition of NEP gives Cicor a presence in Sweden, one of Europe's leading markets for advanced electronics in the healthcare technology, industrial, and aerospace and defense sectors. Its four engineering offices in the Stockholm area offer custom development services and prototype production for complex electronic systems. NEP, whose customers are in Cicor's target markets, has 45 employees and generated sales of SEK52 million ($4.7 million) in the financial year ended June 30. Post-closing, NEP will continue to its sites in Sweden with existing staff.

The integration of NEP is another important step in Cicor's transformation toward becoming the leading pan-European electronics design and manufacturing partner in its chosen markets by 2028, Cicor said in a statement. The acquisition doubles Cicor's product development capacity and significantly broadens its portfolio of capabilities.

The target company in Germany is a service provider for developing and manufacturing electronic assemblies and systems. Its longstanding customers include medium-sized companies and leading corporations, mainly in the industrial electronics and medical technology sectors. With its state-of-the-art machinery, excellent infrastructure, and further expansion reserves, this acquisition is an ideal next step in Cicor's growth strategy in Germany, Europe's largest electronics market. In the last financial year, the company generated sales between EUR20 million and 30 million ($21 million to $31 million) with an operating margin at the level of the Cicor Group.

The transaction is expected to be signed in the coming weeks, subject to usual regulatory and other closing conditions, and completed in early 2025. With this acquisition, Cicor said it intends to further expand its market position in Germany while maintaining its focus on the three target markets of medical technology, aerospace and defense, and industry.

SP Manufacturing Expands Asian Operations

SINGAPORE – SP Manufacturing in November announced the acquisition of the Asia operations of Ideal Jacobs, a Hong Kong-based EMS provider.

"IJA is thrilled to join the SP Manufacturing group," said Ben Meng, chairman of IJA. "The leadership of IJA remains committed to growing our customers and our business, and we're excited about building the next chapter of growth together with SP Manufacturing. Partnering with SPM gives us important access to a broader range of capabilities, geographies and scale to serve our customers more deeply over time."

IJA specializes in high-performance printed electronics and human-machine interface (HMI) solutions for the medical, industrial, semiconductor and communication industries. Its customers are primarily in the US and Europe.

"We welcome IJA to the SP Manufacturing group," said Philip Ong, CEO, SPM. "We've taken time to build a positive and productive partnership with IJA's leadership, and both companies share deeply-held beliefs in building meaningful, long-term relationships with great customers around the world."

SPM said the acquisition expands its capabilities with HMI and die-cut solutions, adds additional engineering capabilities, provides access to a new set of customers and enlarges its capacity in Asia, including a facility in Penang, Malaysia.

"SP Manufacturing continues to grow impressively," added Pei-Shan Wong, director of SPM. "And the addition with IJA is well-aligned with SPM's strategy of building meaningful, industry-specific capabilities to serve the most valuable mission-critical industries and customers in the world. SP Manufacturing now serves its customers with onshore services in the US and Europe, and offshore in key strategic geographies in Singapore, Malaysia, Indonesia, and China, reflecting the onshore/offshore future of the global supply chain for our customers."

Zollner to Acquire Thai EMS Bluechips Microhouse

ZANDT, GERMANY – Zollner Elektronik is expanding its Asian business capabilities by acquiring Bluechips Microhouse, a contract manufacturer based in Thailand.

The German-owned Bluechips has around 650 employees, mainly at its Chiang Mai, Thailand, headquarters. It provides electronics services ranging from PCBAs to full box-build products in industries that include automation, transportation and medical. It has customers in the European, American and Asia-Pacific markets.

"It was important to us to offer our employees a secure future," Bluechips founder and managing director Thomas Zimpfer said about the alliance. "Through the partnership with Zollner, we are confident that our team and our company will have the best environment to grow into the opportunities that lie ahead. Our shared goals and values form the basis for an exciting partnership."

In the second half of 2025, Zollner will acquire the majority shares of Bluechips, with the company's management remaining with the company. The company said the acquisition will strengthen its presence in Southeast Asia by adding additional capacities and technologies while expanding its customer base in the region.

"Bluechips and Zollner are both family-run companies that share a similar history," said Zollner board member Markus Aschenbrenner. "Through organic growth based on customer performance, Bluechips was able to position itself in a foreign market environment, which is really very impressive. We are convinced that this partnership will contribute to a successful expansion in the Asian region."

Electronic Source Co. Acquired by PE Firm

LOS ANGELES – EMS provider Electronic Source Company has been acquired by private equity firm Sverica Capital Management, which aims to lead the company through its next stage of growth.

ESC is a provider of high-reliability electronics components for demanding environments, primarily in the aerospace and defense and space industries. The company offers services from circuit card assembly through complex box build, as well as engineering services, prototype assembly, new product introduction, test services and supply chain solutions.

Jabil, Cyferd Launch AI-Driven Supply Chain Platform

ST. PETERSBURG, FL – Jabil has announced a joint venture with AI company Cyferd to introduce ID8 Global, a GenAI-driven autonomous supply chain and procurement platform.

By combining Jabil's experience across the global supply chain with Cyferd's advanced platform capabilities and self-learning AI engine, ID8 Global's customizable software will allow teams to autonomously manage their supply chains while addressing disruptions, optimizing procurement processes and responding to market changes in real time, the companies said in a release.

"By merging Jabil's industry expertise with Cyferd's cutting-edge AI capabilities, we're not just improving the supply chain; we're reimagining it," said Frank McKay, chief procurement and supply chain officer at Jabil. "This platform will help organizations scale faster and adapt to global demands. We're at the forefront of something truly transformative that will strengthen Jabil's relationships with its customers and suppliers."

"ID8 Global will embed AI-driven automation and efficiency gains directly into the core of customers' procurement and supply chain operations," said Jeff Austin, vice president of procurement and supply chain services at Jabil. "Through this joint venture, we're driving smarter, more sustainable decision-making workflows across the supply chain ecosystem and building the foundation for autonomous, resilient supply chain management."

"Our alliance with Jabil through this joint venture redefines what's possible in supply chain and procurement management," said Ranjit Bahia, CEO, Cyferd. "With Cyferd's self-learning engine, which can create AI agents and applications in minutes, we're creating dramatic efficiencies in digital transformation and seamless data integration within organizations. Paired with Jabil's unparalleled knowledge and decades of expertise, we're creating one of the most advanced self-learning platforms on the planet. This is a leap forward for flexible, proactive supply chain operations."

PCD&F

DuPont and **Zhen Ding Technology** announced a strategic cooperation agreement to further their cooperation in advanced PCB technology.

OVES Enterprise, a Romanian software development company, launched its first PCB, which is designed for critical defense and autonomous systems applications.

Schmid Group opened a new Asia-Pacific division.

Wus Printed Circuit is planning a CNY4.3 billion ($600 million) PCB factory to hike its production capacity and meet a surging demand.

Ventec will be the primary supplier of PCB base materials for **Teltonika's** PCB plant in Vilnius, Lithuania.

Taiwanese PCB equipment factories, including **Zhisheng, Mass, Qunyi** and **Yutian**, are finding new growth momentum by entering semiconductor-related fields.

CA

Aequs, an Indian electronics manufacturer, has reportedly moved to the "trial stage" to be onboarded as an Apple supplier.

Apple is reportedly conducting initial production testing of its new iPhones in India, moving away from China for the first time.

Austin American Technology installed a HydroJet cleaning system at its Guadalajara, Mexico, facility and secured a new project in Juarez.

BAE Systems will develop advanced electronic warfare countermeasures to protect US Army combat vehicles.

CE3S was appointed East Coast distributor for **The Millice Group**.

Cicor Group announced a plan to become the leading pan-European electronics designer and manufacturer in its key markets by 2028 as part of its latest investment strategy.

CMC Electronics, a Canadian aerospace firm, will establish an R&D facility in Reston, VA, which is expected to create about 90 new jobs.

Cope Technology, a UK electronics manufacturer that recently became employee-owned, successfully won back a contract that had left the UK for production in China.

Cyient DLM, an integrated partner for design-led manufacturing, announced a partnership with **Honeywell Aerospace Technologies** for its breaking micro vapor cycle system (Micro VCS).

Dixon Technologies announced the creation of a wholly owned subsidiary, **Dixon Teletech,** which will focus on producing IT hardware components.

ECD has increased production capacity by 100% to accommodate significant order growth for its SmartDRY Intelligent Dry Storage portfolio.

Escatec Switzerland installed a customized UV-curing system to enhance its micro-assembly capabilities.

Etek Europe will represent **ITW EAE's** Despatch products in the United Kingdom and Ireland.

Flex acquired **JetCool Technologies,** a leading liquid cooling company for data centers.

Foxconn procured $32 million of equipment for its Tamil Nadu, India, factory as it gears up to start manufacturing the iPhone 16 Pro Series, and will also build new physical robotics factories in the US, Mexico, and Taiwan to meet the demand for **Nvidia's** new Blackwell chips.

Gen3 will distribute **RAS'** HATS^2 (Highly Accelerated Thermal Shock) test system globally.

GOCL Corp. is venturing into high-growth sectors like electronics manufacturing services and metal cladding.

Indium named **InnoJoin** exclusive global sales partner for NanoFoil nanotechnology material in component mounting applications.

Kimball Electronics will close its Tampa, FL, EMS site after sales dropped nearly 15% in its fiscal first quarter.

Legrand UK & Ireland will open a new electronics manufacturing hub in Northumberland, UK, next year.

MKS Instruments broke ground on a super center factory in Penang, Malaysia, that will support wafer fabrication equipment production.

NetVia Group invested in **KLA's** Frontline InCAM Pro software to boost its precision PCB manufacturing capabilities.

Pegatron is poised to expand its server operations significantly, with initial results from its automotive and server businesses expected to materialize in 2025.

Physik Instrumente, a developer of high-precision positioning technology and piezo applications, has expanded its electronics manufacturing site in Rosenheim, Germany.

RBB entered a strategic partnership with **LogiSync** to enhance its in-house design capabilities.

Scanfil and **Etteplan** began a redesign program of 21 printed circuit board assemblies for a global industrial customer in construction and living.

Shunsin Vietnam Technology, a **Foxconn** subsidiary, is seeking an environmental permit for a $80 million chip manufacturing project in the northern Bac Giang Province.

Solid State, a UK-based specialist in electronic components and design manufacturing, has acquired **Q-Par Antennas USA** for up to $2 million.

Texas Instruments is expanding its in-house manufacturing capacity and AI capabilities for embedded and edge designs.

TT Electronics' board of directors has rejected a second "unsolicited" proposal from **Volex.**

TVS Electronics is boosting its manufacturing capabilities with a new SMT line, 400KV solar plant and other improvements to its plant in Tumakuru, India.

ViTrox appointed **MaRCTex** representative for Texas, Louisiana, Oklahoma and Arkansas.

PCDF


Lance Riley


Michael Jackson


Elena Chapa-Gunderson


Lars Ullrich


Dana Korf

American Standard Circuits named **Lance Riley** director of strategic programs.

Cadence Design Systems promoted **Michael Jackson** to corporate vice president and GM, System Design and Analysis.

Flexible Circuit Technologies named **Elena Chapa-Gunderson** business development manager.

Methode Electronics appointed **Lars Ullrich** senior vice president, Global Automotive Business.

The Occam Group added **Dana Korf** to its leadership team.

CA


Greg Beck


Craig Hamilton


Steven Waterston


Vlad David


Jim Dickerson


Eric Wendt


Jeff Hassannia


Juan Arango


Chris Marion

Absolute EMS appointed **Greg Beck** director of sales.

Celestica promoted **Craig Hamilton** to senior director, business operations, Advanced Technology Solutions division.

Flex promoted **Tippy Wicker** to director of operations.

Escatec appointed **Steven Waterston** director of business development.

Humiseal promoted **Vlad David** to Eastern Europe sales manager.

Inovaxe appointed **Jim Dickerson** western regional sales manager.

Mouser Electronics appointed **Eric Wendt** vice president of supplier management.

Naprotek appointed **Jeff Hassannia** to its board of directors.

Parmi USA appointed **Juan Arango** head of sales and business development.

Synthomatic AI Solutions announced **Chris Marion** as co-founder and chief operating officer.

Upcoming PCEA PCB Design Training Classes Announced

PEACHTREE CITY, GA – PCEA Training announced the winter/spring schedule for the Certified Professional Circuit Designer training and certification program.

Classes will be held in successive weeks starting Jan. 20, Feb. 28 and May 9, respectively. Each class is 40 hours long and includes a copy of *Printed Circuit Engineering Professional,* a 400-page handbook on circuit board design, and the optional certification exam.

The deadline to register for the class beginning Jan. 20 is Jan. 3. The deadline for the February class is Feb. 3.

The instructor-led classes cover the gamut of printed circuit design engineering, from layout, place and route to specifications and materials to manufacturing methods. Schematic capture, signal integrity and EMI/EMC are also part of the comprehensive program.

There are no prerequisite requirements to enroll. Upcoming classes will be held online. All courses are led by experienced instructors.

Printed Circuit Engineering Professional was authored by Michael Creeden, Stephen Chavez, Rick Hartley, Susy Webb and Gary Ferrari, industry veterans who combined have more than 200 years' experience designing and building PCBs for all types of applications.

The course includes an optional certification exam recognized by the Printed Circuit Engineering Association (PCEA).

For information about the course overview, class format, and materials to prepare in advance for the class, visit pceatraining.net/course-overview. For information about the instructors of the course and authors of the course material, visit pceatraining.net/instructors-authors.

To enroll, visit pceatraining.net/registration for the next available class or email pceatraining@pcea.net for additional information.

PCEA to Hold Conference and Exhibition in Detroit in June

PEACHTREE CITY, GA – Printed Circuit Engineering Association (PCEA) will host a new technical conference and exhibition in June in Detroit for printed circuit designers, design engineers, fabricators and assemblers.

PCB Detroit will take place Jun. 2-3 on the campus of Wayne State University. It will include two days of technical sessions, plus a tabletop exhibition on Jun. 2.

Wayne State University is Michigan's third-largest university, and a licensee of the PCEA Training Certified Printed Circuit Designer curriculum.

The conference will feature presentations on controlling noise, low layer count board design, using AI in hardware and PCB design, flex and rigid-flex materials and DfM, and HDI via design, among others.

For information on attending, please contact pcbdetroit@pcea.net. For information on exhibiting, please contact Frances Stewart.

PCEA Issues Call for Abstracts for PCB West 2025

PEACHTREE CITY, GA – Abstracts are sought for the PCB West 2025 technical conference taking place next fall in Santa Clara, CA. The conference, the largest of its kind in Silicon Valley, focuses on training and best practices for printed circuit board designers and design engineers, electronics hardware engineers, fabricators and assemblers.

The four-day technical conference will take place Sept. 30 – Oct. 3 at the Santa Clara (CA) Convention Center. The event includes a one-day exhibition on Oct. 1.

Papers and presentations of the following durations are sought for the technical conference: one-hour lectures and presentations; two-hour workshops; and half-day (3.5-hour) and full-day seminars.

Preference is given to presentations of two hours in length or more, and no presentations of less than one hour will be considered.

Abstracts of 150-500 words and speaker biographies should be submitted to PCEA. Papers and presentations must be noncommercial in nature and should focus on technology, techniques or methodologies related to printed circuit board design, fabrication, assembly, test, components or packaging, and additive manufacturing.

Submit abstracts at pcbwest.com by Jan. 24, 2025. No emailed abstracts will be accepted. Submitters will be notified by early April if their abstract has been accepted. Presentations are due Sept. 5, 2025.

Speaker benefits: Presenters of accepted abstract(s) for the 2025 program receive the following event benefits.

- Complimentary access to the online proceedings
- Complimentary pass to the technical conference
- Invitation to the Speaker Reception

For more information about PCB West, visit pcbwest.com or contact conference director Mike Buetow.

2025 CIRCUITS ASSEMBLY NPI Award Registration Now Open

PEACHTREE CITY, GA – Printed Circuit Engineering Association (PCEA) has opened registration for the 2025 New Product Introduction (NPI) Awards for electronics assembly equipment, materials and software suppliers. The deadline for submissions for the annual awards is Jan. 3, 2025.

To be eligible, entries must have been introduced to the market (any region) no earlier than Jan. 1, 2024. Register now at https://na.eventscloud.com/npi2025.

Colloquially referred to as the Engineer's Choice Awards – a nod to the background and independence of the judges – the 18th annual NPI Awards recognize the leading new products for electronics assembly during the past 12 months. Recipients are selected by an independent panel of practicing industry engineers and are presented by CIRCUITS ASSEMBLY.

The 2024 winners included AIM Solder, Anda Technologies, Arch, ASYS Group, Brooks Automation, BTU International, CalcuQuote, Cetec ERP, Hanwha Techwin Automation Americas, Henkel, Indium, ITW EAE, Juki Automation Systems, Kurtz Ersa, Kyzen, Pemtron, PVA, StenTech, Tagarno, Vayo, ViTrox, and Weller Tools.

How it works. Entrants must submit a single registration form for each product and category entered. All entries must include a 250- to 1,000-word statement describing the product in the following terms:

- Creativity and innovation
- Compatibility with existing technology
- Cost-effectiveness
- Design
- Expected reliability
- Flexibility
- Expected maintainability/reparability

- Performance
- User-friendliness
- Speed/throughput.

Evaluations will be based on the above list.

PCEA CURRENT EVENTS CHAPTER NEWS

Missouri. The new Missouri chapter will sponsor a talk on DfA by Dale Lee, staff DfX process engineer at Plexus, on Jan. 15. For details, visit https://attendee.gotowebinar.com/register/506313452873561692.

Portland, OR. John Johnson from American Standard Circuits shared his insights on Design Guidelines for Unique RF Features at our Nov. 21 meeting. Also, we are asking chapter members if their CAD software supports advanced formats like IPC-2581 or ODB++ without having to buy and upgrades or licenses. Share your comments with Stephan Schmidt, stschmidt@pcea.net.

MARKET **WATCH**

Electronics Companies Spurring US Construction Boom

BANNOCKBURN, IL – Manufacturers are investing in new facilities at a record pace, according to IPC, some 2.3 times the 2019 (pre-Covid) levels. Much of this is likely attributable to the Chips Act, which has spurred billions in capital investment over the past 24 months.

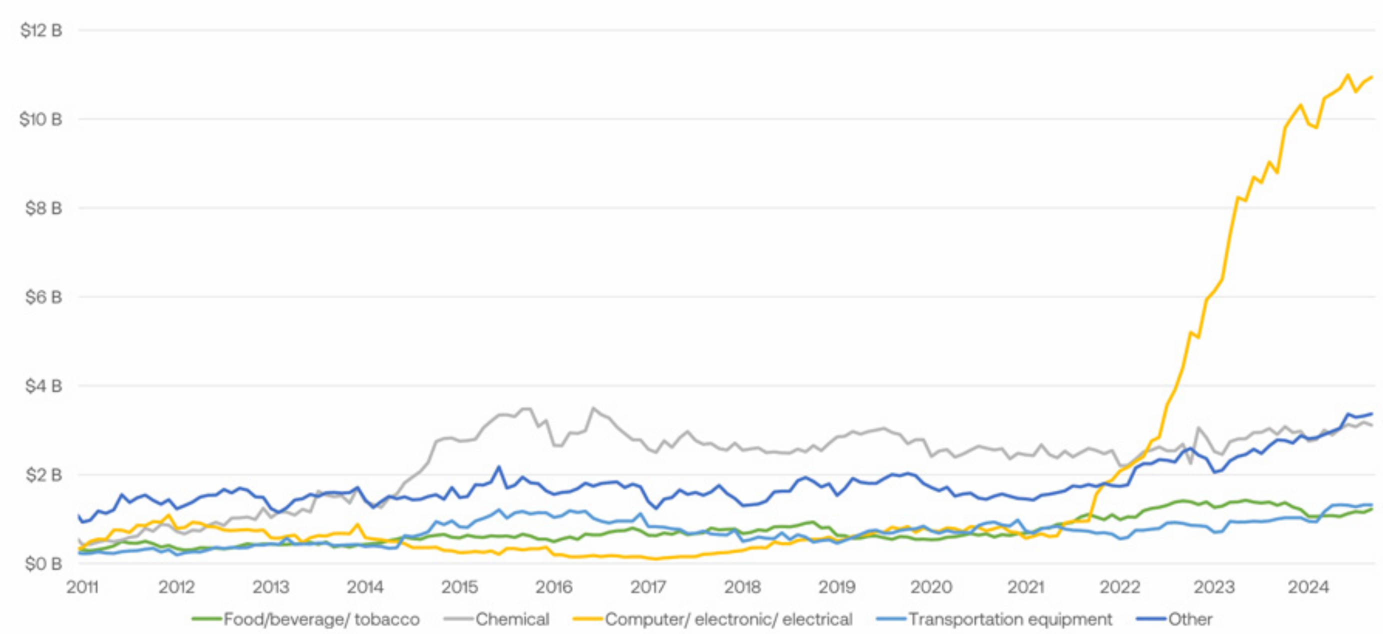


Figure 1. Electronics manufacturing is driving the construction demand.

Speaking in an open webinar in November, IPC's Shawn DuBravac added that electronics manufacturing is "nearly 55% of the manufacturing construction spend."

The outlook for GDP growth in the US in 2025 has improved from summer to fall, settling at 2.1% in November, up from 1.7% in January. That suggests a dip from the forecast of 2.7% growth in 2024, but a recession is "unlikely," according to IPC.

DuBravac added that price inflation has stabilized at around 0.2% but service inflation remains elevated at 3.5%, with prices up 20% over 2019.

Hiring at manufacturers is slowing, and the sector has lost 50,000 spots in the past year, but open jobs persist, DuBravac said. More than a quarter of those employed in computers and electronics products manufacturing are over 55, while the average manufacturing age is 44.

Bytes and Lights

Trends in the US electronics equipment market (shipments only)

	% CHANGE			
	JUL.	AUG.[r]	SEPT.[p]	YTD
Computers and electronics products	0.2	0.0	0.6	1.0
Computers	2.3	-1.0	-1.4	21.5
Storage devices	7.4	0.2	1.2	5.1
Other peripheral equipment	0.6	3.6	-2.0	6.8
Nondefense communications equipment	0.2	-1.1	1.2	0.8
Defense communications equipment	-1.0	2.6	-0.5	-2.6
A/V equipment	4.3	-1.2	0.4	-2.2
Components[1]	-0.7	2.2	0.0	5.0
Nondefense search and navigation equipment	0.5	0.2	4.0	3.4
Defense search and navigation equipment	1.2	1.3	-1.2	5.4
Electromedical, measurement and control	0.1	-1.3	0.6	-1.7

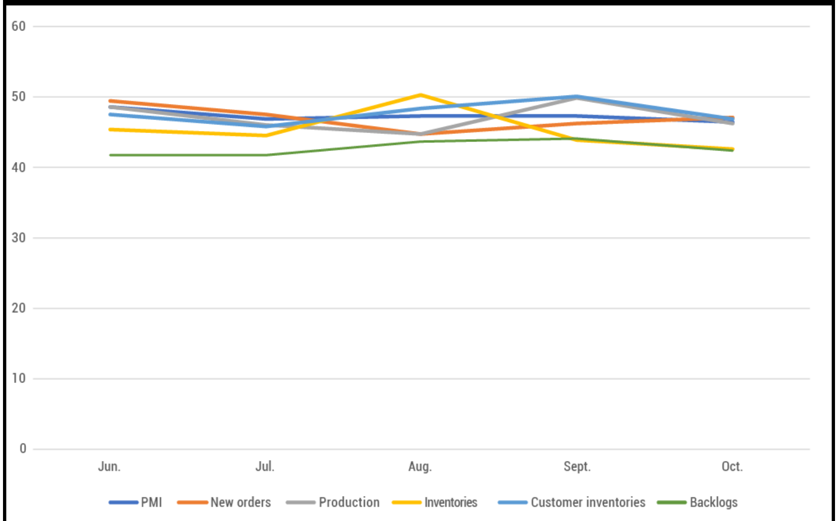
[r]Revised. [p]Preliminary. [1]Includes semiconductors. Seasonally adjusted.
Source: US Department of Commerce Census Bureau, November 4, 2024

Key Components

	JUN.	JUL.	AUG.	SEPT.	OCT.
EMS book-to-bill[1,3]	1.32	1.21	1.27	1.26	1.25
Semiconductors[2,3]	18.3%	18.7%	20.6%	23.3%	TBA
PCB book-to-bill[1,3]	0.95	0.99	0.99	1.05	1.09
Component sales sentiment[4]	98.9%	103.4%	108.4%	98.8%	97.1%

Sources: [1]IPC (N. America), [2]SIA, [3]3-month moving average, [4]ECIA

US Manufacturing Indices



Source: Institute for Supply Management, November 4, 2024

Hot Takes

China could surpass Taiwan to become the world's largest producer of PCBs in 2024, with a 33% share predicated on an output value of $26.8 billion, up 17% from 2023. (Taiwan Printed Circuit Association)

India's electronics manufacturing industry faces a deficit of 10 million trained professionals, while the sector's 25-30% compounded growth rate is expected to generate 12 million jobs by 2027-28. (TeamLease Services)

Malaysian electronics exports in October grew 7.6% year-over-year while accounting for more than 41% of total exports. (Ministry of Investment, Trade and Industry)

India's fiscal 2024 has seen a **decline in electronic imports,** thanks to the nation's Make in India campaign. (Economic Times)

Worldwide **tablet shipments** grew 20.4% in the third quarter, totaling 39.6 million units. (IDC)

Worldwide **smartphone shipments** are forecast to grow 6.2% year-over-year in 2024 to 1.24 billion units. (IDC)

The global **hardcopy peripheral market** rebounded in the third quarter, growing 3.8% year-over-year. (IDC)

Japan has unveiled a $65 billion plan to boost the country's **chip and artificial intelligence industries** via subsidies and other financial incentives.

Global semiconductor sales rose 23.3% year-over-year to $166 billion in the third quarter. (SIA)

North American EMS shipments in October were up 14.7% year-over-year and 3.4% sequentially. Bookings rose 6.6% from a year ago but fell 4.5% from the previous month. (IPC)

October **North American PCB shipments** dropped 11.1% year-over-year but grew 20.4% sequentially. Bookings rose 3.5% from a year ago and slipped 3.7% from the previous month. (IPC)

Electronic design-automation providers stand to gain $6 billion through 2030. (Bloomberg Intelligence)


Hmm, what is recommended **minimum distance for copper to board edge?**

Prepping for 2025

What are you going to do next year that is different from the past?

IT IS HARD to believe we are rapidly approaching the end of another year. Reflecting and looking forward, it certainly appears that the more things change, the more they stay the same. The many challenges remain the same, namely adding critical technology, increasing sales, recruiting and adding and developing much-needed staff to both grow and replace those approaching retirement. And yes, doing all profitably. So what will you do this year that is different – and more importantly – better than you did last year or in past years? How will you commit your time, talent and treasure to outperform the industry or accomplish your goals? The time is now to figure out what you want to accomplish and how you will do it. If you want or need to make the new year an extraordinarily great one, here are a few suggestions for where to start.

Planning. It sounds trite, looks easy and at times feels like a waste, but it has been proven over and over that success begins by planning and continues through continuous work on the plan. In its most basic form, planning is simply thinking through what you want to – and with the available resources, can – do. As with any "to-do" list, it is essential to make sure that you are reaching for an attainable goal, that you have an idea of the cost in both dollars and man-hours, and you know how you will measure success or failure.

Sit down with your staff and advisors – the sooner, the better – and talk through what you want to accomplish this coming year and what resources you will need to get it done. Write down in the simplest terms what you want to get done and how you will measure success. Most of all, keep it simple. If you plan to increase sales by 10%, don't spend 50 pages saying it – just write down "Objective 1 is to increase sales by 10%."

Even a one-man operation needs to plan the allocation of resources – most importantly time – on what is important. This means that if your "Objective 1" is to increase sales by 10%, then you need to elaborate on how you will make it happen. Again, when you commit the plan to paper, keep it simple – just tell it like it is. Equally, if you want to achieve Objective 1, then simply say that, for example, you will "increase sales 10% by adding a salesperson/representative for a new geographic territory/market . . ." or whatever action will most effectively accomplish the goal.

Planning is not about producing a slick document; rather, it is going through the process of thinking through what is *really* important, committing to that goal, and allocating the resources needed to make it happen. And, finally, for those who do not believe planning is that important and instead look at certain companies or individuals as just having luck, all I can say is that more often than not, "luck is good planning carefully executed."

Networking. It is easy to get stuck behind a desk or in a rut and see the same people over and over. Networking is committing to improvement by meeting new people. Networking is committing to share with others. Networking is about finding the next good idea, outstanding employee or cutting-edge technology. And most importantly, networking is about being positive and not looking for excuses!

Over the past few Covid-influenced years, networking has gone through a massive transition. Often, opportunities to network now are via online meetings using Teams, Zoom, etc. The good news is that users can now access outstanding content from subject matter experts across the globe via this online technology. Online opportunities should be added to the mix of how and with whom you and your team network.

Equally, a number of traditional "in-person" venues are available for networking. Local organizations such as the Chamber of Commerce or regional manufacturing or technology development hubs are great for discussing generic cost reductions such as health care and business insurance or taxes. Local networking can also be a great source for locating talented employees. Regionally, some organizations focus on everything from family business issues to technology development to workforce training and development. No matter where you are, there are local and regional organizations that can offer a wealth of information and ideas to improve your business.

Industry-specific networking is another way to grow. Local chapters of PCEA, the publisher of this journal, and the SMTA, to name just two, attract local attendees specifically from our industry. Attending regional and national industry-focused trade shows is possibly the best venue for meeting and networking with the entire supply chain within our industry.

Communication. No matter how well you think you communicate, it is never good enough! Once you have prepared a plan – formal or not – and whenever you step out of your comfort zone to network with new people, communication is essential. The most important people to communicate with are your employees and advisors, but what you communicate to each may not be the same message or presented in the same way. Equally, communication is not a one-time affair. It needs to be consistent and supported in word and deed. You need to walk the walk, not just talk the talk, to effectively communicate.

Action. One of the best I ever worked for would send handwritten notes or clip articles that were of interest or relayed/confirmed a message. One I remember well was an article that said it does not matter how much you know if you do not take that knowledge, communicate it and take action with or because of it. His message was clear, especially as he had a bias toward action. Taking action, however, requires a plan – one that is based on knowing what is going on within the industry and includes what will be done by whom, how and with what resources. The plan must be communicated to those who might need to approve it, such as investors, banks, advisory or corporate boards, etc. Most of all, the plan must also be communicated to those who will implement it – your employees.

What are you going to do next year that is different from the past? The time is now to plan, network, communicate and take action to achieve your goals in 2025 and beyond.

PETER BIGELOW is president of FTG Circuits Haverhill; (imipcb.com); pbigelow@imipcb.com. His column appears monthly.

What's Your 2025 PCB Buying Strategy?

The industry will face old and new challenges in the new year.

THIS YEAR'S SUPPLY chain issues and looming economic uncertainty have many PCB buyers wondering about 2025.

Here are the top three challenges the PCB industry will face next year. How prepared are you?

Precious metals. The price of gold is up nearly 30% this year, hitting another all-time high last month. As a consequence, PCB buyers should expect a price bump in board pricing for both new and repeat orders.

Heightened concerns about inflation and economic stability continue to make gold an attractive safe haven. Even with hopes of a better economy next year, don't expect prices to drop to 2023 levels any time soon.

Board buyers should alert customers and seriously consider alternative metal finishes for their PCBs. While ENIG is one of the most popular, do you need it on every board your company buys? And does your PCB really require hard gold fingers (or as I call it, "jewelry"), or will the lower-cost ENIG fingers suffice?

Assemblers should consider using metal finishes like HASL, LFHASL, OSP or tin. Silver is another possibility, but as a semi-precious metal, its pricing – while much lower than gold – is likely to fluctuate as well.

PCB buyers need to discuss with their production and process personnel which products could use a less costly metal finish to offset any price increases. Once determined, buyers need to contact the PCB supplier to issue the appropriate engineering change notices to implement the new process.

Out of China. Geopolitical tensions, along with the supply chain concerns that have come about during and since the Covid pandemic, have forced many OEMs and EMS companies to look outside of China to source their PCB needs. But it's a task that is easier said than done.

India, Malaysia, Thailand and Vietnam are trying to mimic China's success; however, they fall short when it comes to higher-mix, lower-volume (HMLV) and higher-technology PCB manufacturing. That said, since early 2022, many prominent PCB manufacturing companies from China, Hong Kong and Taiwan are planning to build or are currently building PCB manufacturing facilities in those nations.

But the number of available manufacturers that can produce HMLV in a timely manner is not as plentiful outside China. This will continue to be a serious challenge for PCB buyers if and when tariffs and geopolitical tensions force them to look elsewhere for board manufacturing.

Without tariffs, PCBs manufactured outside China in nations such as India, Malaysia, Thailand and Vietnam average 10-15% higher than boards built inside China. In addition, the average time to ship orders is much longer, averaging five to eight weeks. In comparison, China ships most product in three to four weeks or less.

So it's not as simple as just moving production to another country. And even if tariffs higher than 25% are imposed and PCB manufacturing in China no longer makes sense, board prices in the US *and* other countries are highly likely to go up because of capacity limits.

Everyone will be paying more and waiting longer for their boards.

The next 18 to 24 months will determine how successful out-of-China PCB manufacturing will become. The strength of the world economy and the politics that are put into play will determine the outcome.

Component obsolescence. Those in the sustainability industry predict next year will be a challenge when it comes to component obsolescence. This is a risk that may prevent many OEM or EMS companies from completing their assemblies, or result in them being stuck with partial builds in inventory until the original component becomes available.

When a semiconductor component becomes obsolete or has a lead time beyond 52 weeks, finding a direct replacement that fits the existing system's footprint can be challenging.

A product redesign might be necessary if a lifetime buy of a component that is about to become obsolete is not available. A costly redesign at the system level may not be needed, however, if the redesign can be performed at the component level with a PCB interposer or adapter.

An interposer (also known as a daughterboard) is a small electronic assembly that has a custom-designed PCB with components that mimic the function(s) of the original IC. That PCB contains the I/O interconnect that emulates, or is an upgrade of, the performance of the original IC.

More importantly, it is manufactured with the same footprint as the original IC, can be shipped in tape-and-reel or a JEDEC tray and attaches using conventional SMT assembly processes.

An interposer provides a flexible, cost-effective and efficient solution to the challenge of semiconductor obsolescence or unavailability.

The PCB interposer acts as a bridge between the new component and the old system, permitting the integration of modern semiconductors into legacy systems without the need for extensive redesign.

By permitting the integration of newer semiconductor technologies into older systems, adapters and interposers ensure these systems continue to function and remain relevant, despite the original components being phased out or not immediately available.

Implementing an adapter is typically faster than undertaking a full system redesign. This speed is crucial for industries where time to market and system uptime are critical factors, as interposers eliminate the need for extensive technical re-evaluation and redesign, simplifying the upgrade process.

Interposers also offer PCB buyers and engineers more options. They are often more economical than redesigning the entire system or product to accommodate new semiconductor components, saving time and money.

Custom-made interposers also prevent costly last-minute or risky gray-market buys.

Of course, 2025 will also pose the usual challenges every supply chain faces. We may be dealing with fuel surcharges, labor strikes and material availability issues. But I believe the three I've outlined here will complicate those challenges. Do you have a carefully planned 2025 PCB buying strategy? If not, now is the time to develop one.

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 DirectPCB (directpcb.com) and can be reached at greg@directpcb.com.

FOCUS ON BUSINESS

Natural Disasters and Impact on EMS Forecasting

2025 could bring demand spikes and component availability tightening. Are you prepared?

HURRICANES HELENE AND Milton delivered unprecedented damage throughout the Southeast US. Rebuilding efforts will take years in some locations. In western North Carolina, some people lost their homes, their families and their employers. In those cases, it isn't a matter of just rebuilding a home; they are rebuilding their entire lives. Sadly, while everyone contributes when the disaster is in the news, those contributions stop when the news cycle moves on.

So, before I start my column on the business upside of natural disasters, I encourage everyone to remember the impacted communities. Personally, I'm budgeting to keep giving to charities helping those areas for the next several months. I'm also buying from companies in North Carolina to help local businesses stay in business.

While disasters are devastating for those they impact, there is an upside when rebuilding starts because a lot of things need to be replaced. Utility infrastructure, traffic signals, power management equipment, appliances, vehicles, mobile phones, computers, entertainment systems, production equipment, solar panels, point of sale equipment, security systems, restaurant equipment, industrial refrigeration systems, medical equipment and agricultural equipment are just a few of the products likely to exceed their historical replacement numbers in 2025 as result of these disasters. What does that mean for the EMS industry?

First, while materials availability has improved, there has been some tightening of late and capacity isn't increasing due to recession fears. A spike in demand is going to tighten availability more. Based on past disasters, some other dynamics are also in play.

- Demand will be driven by insurance and disaster relief reimbursements which may take months. Manufacturers won't know what demand is until orders come in because not all losses will be reimbursed. Buyers will want products quickly because they've already been waiting months while their claims are being processed. EMS providers are the folks at the end of that information stream who must figure out how to build quickly to a changing forecast.
- Manufacturers may opt to temporarily focus on selling lower-priced products to have the widest appeal to people rebuilding. That may change forecasts on configure-to-order builds or temporarily make some component inventory inactive, so just adding some pad to existing forecasts isn't always the best solution.
- The program management job is going to be a lot more difficult in 2025.

That said, there is a bright side. Manufacturing revenue has been dropping and this will improve it for many EMS providers. Program managers need to approach this proactively:

- Have a serious discussion about 2025 forecasts with your customers. Make sure they know material availability may not be all puppy dogs and unicorns once there are spikes in historical demand.
- Discuss contingency plans relative to product offerings in 2025. Are any factory retooling discussions going on to better shift to the replacement product need? Will that impact the models you are building?
- Identify components for which availability may be tightening. Identify alternates and get them approved. Help customers by providing quarterly updates on changes in materials availability.
- Discuss the results of your forecast conversations with customers internally. Review options for addressing upside surprises in the production schedules. Reconcile any forecast changes against internal plans to draw down inventories. Make sure the supply-chain team is sharing anticipated forecast trend changes with critical suppliers. Also, review whether existing contracts adequately protect against inactive inventory if forecast changes make some models inactive. Internally, discuss whether there should be inventory cost-sharing negotiations if this happens.

Replacement orders will help improve next year's EMS economic picture. A proactive approach is necessary, however, to ensure this unpredictable demand can be addressed rapidly through normal planning rather than through costly expedites and overtime.

Post-Covid, EMS companies developed strong skills for managing unpredictable demand. Those skills haven't been needed much this year. It is time to hit the gym and start toning up that skillset because 2025 will likely have the chaotic mix of demand spikes and component availability tightening that requires them.

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

Learning to Fly

Four important lessons gleaned over a three-decade design career.

THERE'S AN OLD saying among test pilots: "Any landing that you can walk away from is a good landing." They also know that there are old pilots, there are bold pilots, but no old, bold pilots – or so the saying goes. If you want to hang around as a PCB designer, you can only hope to walk away from your mistakes with your career intact. So, this is a chance to learn from my mistakes from 35 years of design work.

Going all the way back to the '90s finds me in my first PCB design role. I had just taken an internal transfer to the commercial side of the business after a couple of years of feeding from the government trough. My manager on the mil-spec side, Merrill, was a father of a dozen children and was an all-around nice guy, perhaps a bit of a pushover.

Before applying for the transfer, I wanted to talk with Merrill, so I came up behind him and asked if he wanted to go to Armadillo Willy's, a local barbecue place, for lunch. I didn't see that he had a sandwich in his hand and was about to take the first bite. Instead, the sandwich hit the desk with a thunk, and we were off to the restaurant. Such was his dedication to his people.

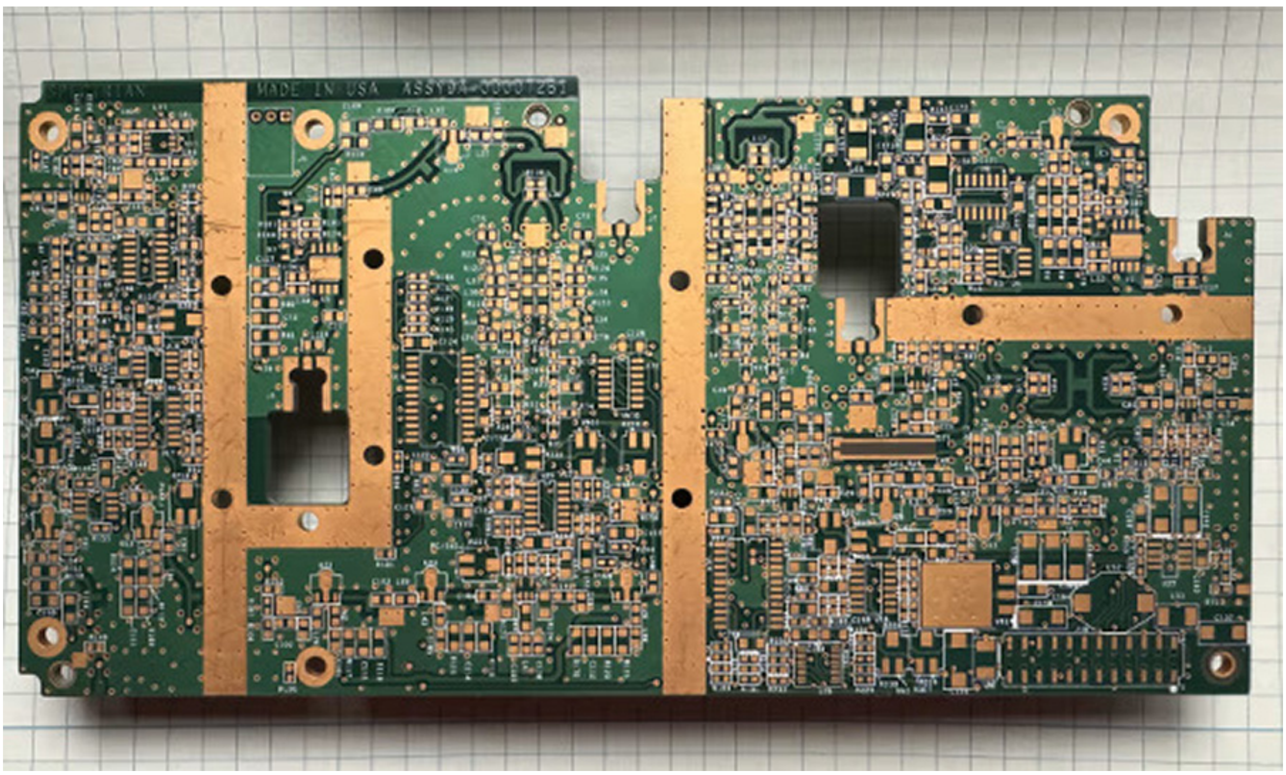


Figure 1. A multilayer control board for RF amplifiers circa 1999. By that time, I had done many of these and could turn them around quickly.

A little background: A recent audit from the Army had raised many concerns. I was fresh out of a six-month program at the Copper Connection, a local PCB/CAD trade school that taught the Department of Defense drawing standards along with AutoCAD. I knew my stuff well enough that one of our mechanical engineers asked me if I had a photographic memory. No, I had just put in the six months to study the *Drawing Requirements Manual*.

My drawings were cleanest among the several CAD designers, with only two flags on my drawing package. One was about hardware callouts. I was labeling threaded holes with a commercial designation. So I called out a 4-40 UNC-2B threaded hole when it should have been 0.112-40 UNC-2B. That leading "4" was the same issue we all had where the auditors wanted a diameter value instead. That was an easy one.

1. Assembly drawings do not tell you how, only what. The other issue was with what the auditors called "methodized drawings." At the time, Merrill asked me what that meant. My reply was to mention the design reviews where the manufacturing engineer would request a list of notes to add to the assembly drawings. The intention was to have a single document that the assemblers could use to place components. I reminded Merrill of all the times I had pushed back on those requests but was overruled. Lesson learned.

The noble idea was to keep assembly workspaces tidy. It also made the drawings (what is) into a procedure (how to). The government has reasons to avoid entangling the two.

The outcome of that audit was that, from that day on, I was tasked with checking everyone's drawings for compliance with the manual. I had already spent time doing quality control inspection of PCBAs on the assembly line and eventually bare PCBs in the receiving inspection lab. This checker distraction is going to cut into my productivity!

Even before looking at the first drawing, I knew this would be a thankless job. As the newest, most junior person, I wasn't going to endear myself to anyone by nitpicking their work. So, in the end, that decision to put my name in the Checked By box was a wedge that had me looking over the cubicle wall toward the other team that was enabling 3G wireless technology for the masses.

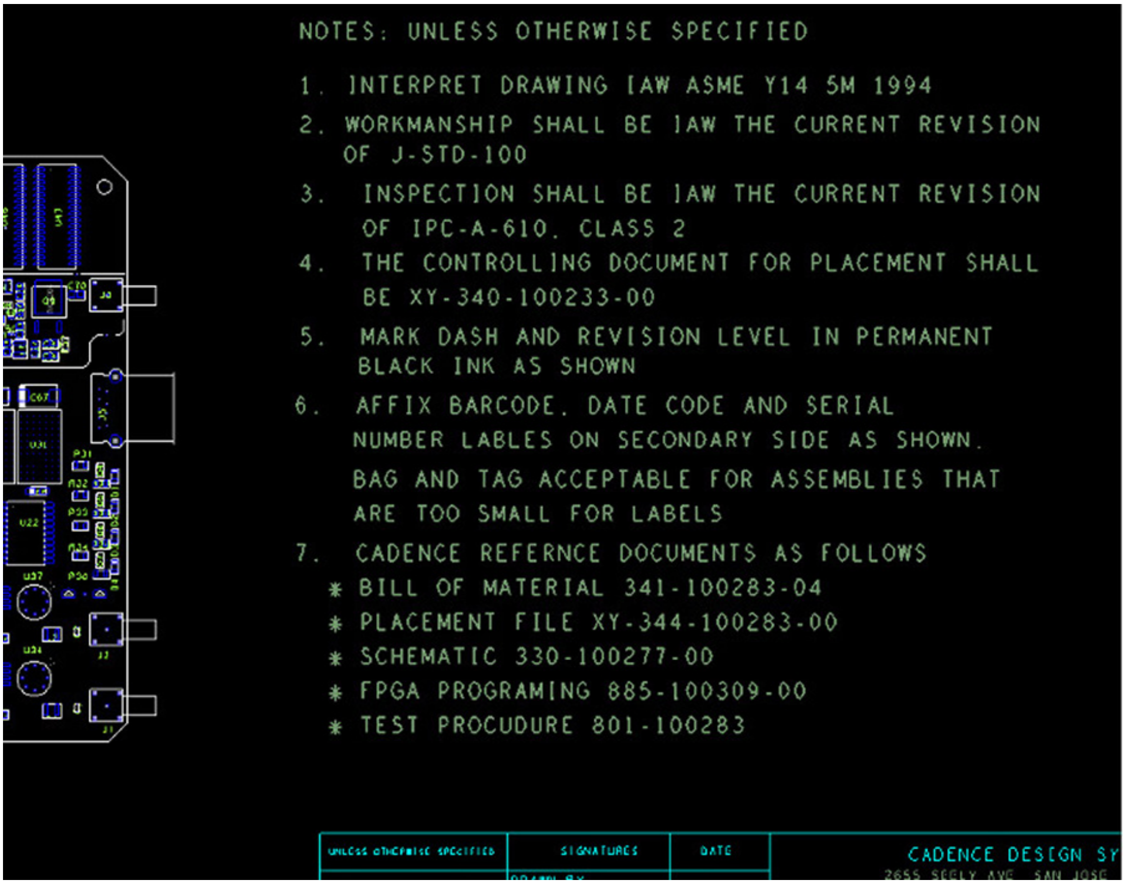


Figure 2. My idea of what makes up an appropriate list of notes. Any instructions on the assembly drawing should be verifiable by checking the condition of the PCBA. How would we know, for instance, if the assembler used its ESD strap and ionizer while doing the job?

Looking back, I should have brought my *Drawing Requirements Manual* to the design review and bookmarked the section about drawings vs. procedures for reference. Having solid facts from a reliable source is better than "just my opinion." Now, we have the internet, where getting that kind of information is trivial.

Merrill was unable to talk me out of applying for the transfer, though he tried. My new manager, Ed, approved and I moved to the other side of the building. As an aside, the new job was doing multilayer boards, where everything on the DoD side was single-sided power amplifier boards. The control boards were always outsourced from either side. That was about to change, and I was going to be the one to make it so.

2. Crowding components is bad no matter whose idea it is. My buddy Joe warned me that "Ed don't take no sh*t," and I was like, "Why should he?" Then he relayed that when Ed was asked what would happen if I could not design multilayer boards, his reply was, "Then I'll fire him." Right there is a useful data point. After three days of training on some actual PCB design software, I was cut loose on my first four-layer job. I taped out four layers, no mask, no silk, no clue! That all came together on my second control board.

The commercial group was growing and hired a big-brain kind of guy named Dave for that second board. Note that Dave was eventually promoted to VP of engineering. He had a persuasive nature and convinced me that two resistors had to be super close or the PLL circuit would not work. I wanted it to work, so I nudged them closer and closer until Dave said, "That's good."

Dave was wrong, and by listening to him, I was also wrong. I've told this part of the story before, so it may seem familiar. Ed calls me into his carpeted office and tells me to shut the door and sit down. It went something like this.

Ed: Manufacturing is reporting solder issues with a couple of parts on your board. Do you know that we need a solder dam between every pin?

Me: Um, yes.

Ed: So, why do these two parts have their pads too close for that?

Me: Oh, Dave told me that is necessary for the PLL …

Ed: (cutting me off) If I want Dave to design the board, then I don't need you. These boards have to be manufacturable or there's no point.

Me: *Gulp* OK.

Ed: Alright, go back to work but don't ever do this again.

At least I kept my job for another eight years. And that never happened again. Not at that first job, nor any subsequent job over the following three decades. Working for startups is all I did until Qualcomm bought one of them. That is where big company processes (and politics) come into play.

3. Learning big company politics the hard way. I was having a hard time getting guidance on shield footprint standards. I had hit up the San Diego-based manager of the mechanical engineering team hoping to learn more. Enough time had passed that I sent a second message letting her know that I was feeling left out about the lack of feedback.

That message totally backfired. It was something I picked up in a course called Managerial Interpersonal Effectiveness (MGMT101). We were instructed not to use a "You" message but rather an "I" message to let the other party know how their behavior is affecting you. That mechanical engineering manager "schooled" me on etiquette and bcc'd my manager. Yep, another call to the carpet when a simple phone call may have done the trick. I did not see that one coming.

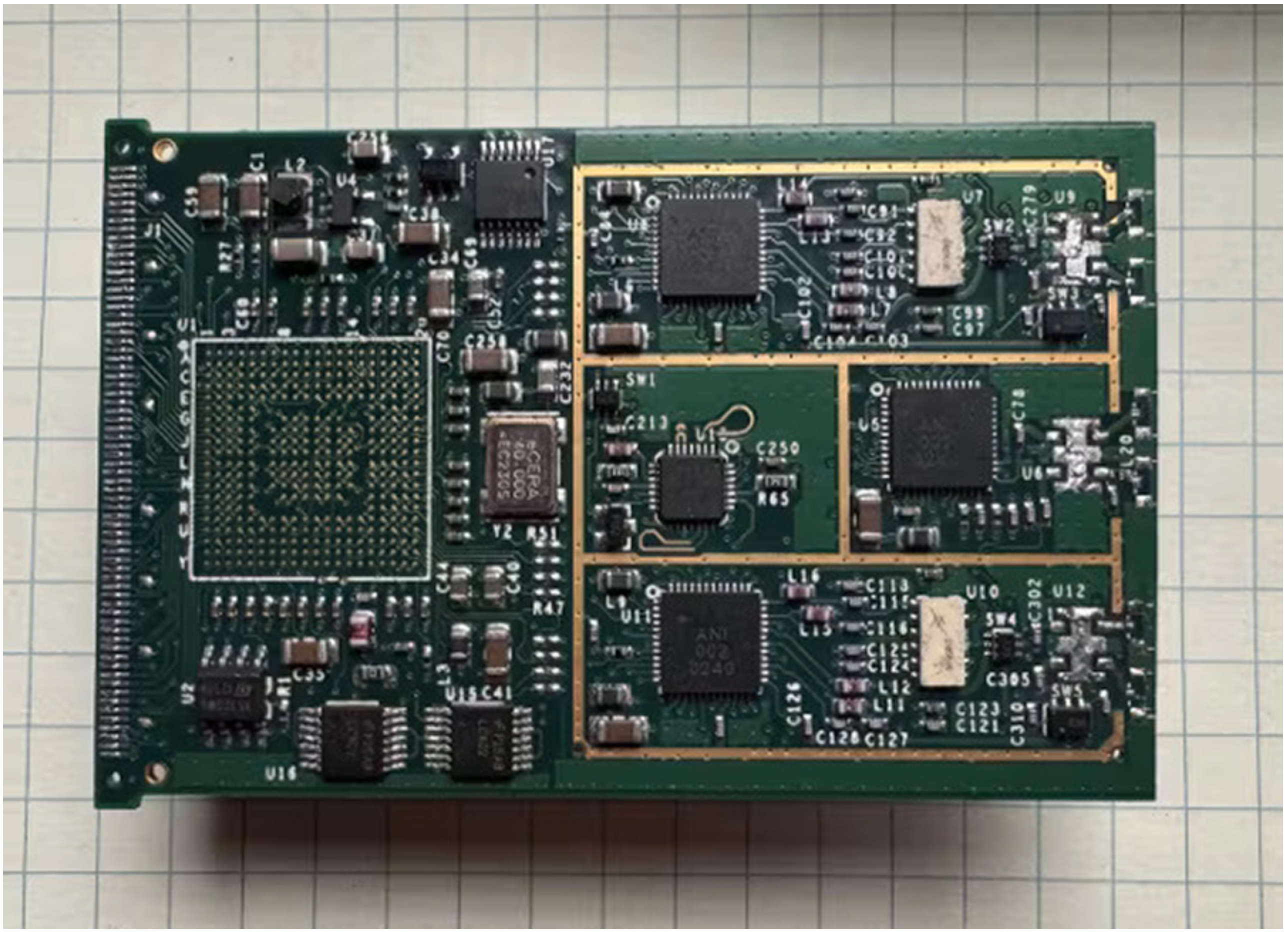


Figure 3. A PCIe-based MIMO radio PCB featuring a multi-chamber EMI shield

Following that incident, a lot of good things came out of working six years for Qualcomm. One was that they had an exceptional offshore PCB vendor. I'll name names. It was Plotech. They had the chops to deliver on smartphone-grade PCBs. They were, at that time, a top 100 global PCB vendor but far enough down the list that they were not monopolized by one of the mega-players in the industry. They would treat us well even though Qualcomm was only doing pilot programs to generate reference designs.

4. Using a Taiwan-based vendor without understanding customs processes. My next opportunity was at Google's Chrome OS hardware team. Not long after arriving, the procurement person moved to a different division. We were told to do our own purchasing until the role was filled. I had a radio board that would be perfect for Plotech, so I contacted them to save some money over what the local shops would charge. Even though my email ended with @google, they asked if my company had a website to see if we were legit. Yeah, you might have heard of us!

So, we set up a nondisclosure agreement and I got the quote and ordered a batch of bare boards. I circled back to them a few days after the boards were supposed to ship to get a status on the order. That's when I learned about customs. You have to lay the groundwork before you can import electronics to the US. In hindsight, a local vendor would have been just fine; it's not like the company didn't have the money to spend. That cost the development team about a week where a one-day slip is still a failure.

A bonus mistake that I could walk away from was the time I did a favor for a coworker by cleaning up the reference designators for the silkscreen and the assembly drawing. I pulled the design from the repo and wrote a script while I organized the text, and then pushed my script to the repo so he could straighten it all out by repeating my work on his database.

Well, the find filter had changed between my pulling and pushing, and instead of moving the text, it moved almost every part on the board. He had the “stretch” command going, so it also contorted the traces while it was at it. Of course, he saved first, but we let it run its course so we didn’t hang up the license server. It was a good time to go get some of that free food, although watching it destroy the layout was hilarious!

This could easily have been five or 10 problems I’ve caused. The general idea is that communication is important. If you’re uncomfortable with something, share your discomfort, but don’t surface a problem without offering a solution or two. Circle back with the team early and often to make sure you stay on track. Educate yourself on what the vendors can and can’t do. Use nice words in case you must eat them later. This all should be part of your nature if you like doing PCB design.

JOHN BURKHERT JR. is a career PCB designer experienced in military, telecom, consumer hardware and, lately, the automotive industry. Originally, he was an RF specialist but is compelled to flip the bit now and then to fill the need for high-speed digital design. He enjoys playing bass and racing bikes when he’s not writing about or performing PCB layout. His column is produced by Cadence Design Systems and runs monthly.

Training the Grid

Wise use of AI could be the key to our sustainability and survival.

AI IS THE technology of the day, and I have commented positively on its properties and potential many times in this column. Building AI into new products and services has become a marketing prerequisite. AI applications in the cloud offer easy access and fast answers to complex computing challenges, delivering great value for commercial organizations and novel services for consumers. And in devices such as PCs, smartphones and wearables, AI is the critical ingredient to enable the kinds of intuitive, human-like interactions people want to have with their tech today.

The AI in our smartphone cameras knows what our photographs should look like and adjusts the settings accordingly – a process that would take experts several minutes using Lightroom now happens inside our phones in milliseconds before we even see the picture. We even have bicycles that can warn the rider of a puncture with a tiny inertial sensor that integrates machine learning to monitor handling, giving the safety of a tire-pressure monitoring system (TPMS) without the expense of tire-pressure sensors.

But AI can be an energy-intensive way to do computing. Neural networks exploit both parallelism and depth to solve complex challenges faster than traditional sequential computers. And although trained models can be highly optimized and will process any given set of inputs only once, the training phase demands vast datasets that require large memory resources and involve processing samples multiple times to fine-tune the model parameters. The emergence of edge AI offers a response predicated on creating lightweight inference engines that use minimal layers and parameters to mimic the output of large, complex models. These can be tailored to the limited power budget of devices such as smartphones, smartwatches and automotive systems.

Despite these concerns about power consumption and other aspects of the technology, AI is essential to our future survival. Nokia says digitalization is essential for decarbonizing industries and accelerating sustainability. Its presentation at the COP28 summit in Dubai, No Green Without Digital, cited AI and other technologies like digital twins as important technologies in the drive to decarbonize.

As we seek sustainability through initiatives like electrification, powered by energy from renewable sources, we need these technologies to help us harvest enough energy to meet our needs and stabilize supply. We know that sources like wind, solar and hydro are weather-dependent and difficult to predict, so grid stability becomes more difficult to maintain. In the developed world, we have come to expect access to the power we need, when we need it. On the other hand, the transition to decentralized, distributed grid networks brings opportunities to improve the delivery of electricity in rural areas and the many regions of the world that could not afford to install traditional power infrastructures. Here, stability holds the key to improving healthcare, education and economic development. With AI to help us model the systems, we can establish the reliability we all need to support our electrified lives, as well as improve performance and efficiency.

If AI is to help us, we need to ensure that using the technology delivers a net benefit, and that the energy saved will exceed the energy needed to train and operate the models that run the grid, noting that data-intensive training will be ongoing as new capacity is added and as demands and usage patterns evolve.

Improvements in computing efficiency could work in our favor. Koomey's law observes that computing efficiency, expressed as the number of compute operations per joule of energy, doubles every 1.57 years. Less well known than Moore's law, it's a trend that equates to a 100-fold increase in energy efficiency over a decade. Although this sounds impressive, our digital lifestyles and the ongoing digital transformation of our businesses demand more and more operations, so the overall energy demand continues to rise. This could help explain why our CO_2 emissions are still increasing despite the huge engineering commitment to keep developing greener, energy-saving technologies like inverterized motor drives, LED lighting, photovoltaic cells, wind turbines, wide-bandgap semiconductors, to name a few.

The International Energy Authority reports that the increase in emissions is slowing, and attributes this to growing clean energy deployment. Indeed, without the shortfall in hydro generation caused by unfavorable weather conditions, the IEA's figures show that global energy-related CO_2 emissions in 2023 would have fallen.

Have we turned a corner? Juniper Research says our smart grids are becoming more effective, especially with technological improvements such as battery energy storage systems (BESS). Its latest report quantifies the potential benefits, suggesting we could save $290 billion in energy costs worldwide by 2029.

But let's not congratulate ourselves just yet. The rapid growth in data centers, driven by exploding demand for their services, is causing wider concerns about sustainability. Energy demand is one aspect, while consumption of other resources like water for cooling those hard-working servers is also increasing rapidly. Usage is coming under scrutiny, particularly in areas affected by droughts. In response, big tech companies have committed to community projects to improve the local water supply, and some are adopting alternative cooling technologies.

We can anticipate an effective technological solution. It's what engineers do. On the other hand, we may need to consider changing our always-on, energy-hungry lifestyles to ensure reliable, sustainable access to the services we all need.

ALUN MORGAN is technology ambassador at Ventec International Group (venteclaminates.com); alun.morgan@ventec-europe.com. His column runs monthly.

Embedded Sensors in Flex Circuits

From glob top to lamination, solutions for sealing parts in flex.

I NEED A flexible circuit with a temperature sensor on one end. I need this area to be as thin as possible and sealed against liquid ingress. How do I accomplish this?

Several ways will do what is described. Each has its own benefits and associated costs. I will cover each of them below.

SMT-mounted sensor with conformal coating. The most straightforward solution is to simply mount a standard surface mount NTC or other sensing device to the flex, then seal it with a conformal coat. The conformal coating is typically an epoxy like 3M 2216. This will seal the component and ruggedize the sensor's solder joints to keep them from damage during assembly or subsequent handling **(Figure 1)**. The downside to this option is the sensor and potting will protrude above the surface of the flex, and depending on the size of the component, this could be significant. Also, the potting is basically a "glob top" where a predetermined dose of epoxy is dispensed over the component and permitted to flow over the top to cover the component and surrounding area. This usually does not produce a perfect circle or oval footprint on the flex, so expect a fair amount of variation. But if there is space above and around the sensor, this is the easiest and least expensive option. Thinner conformal coatings may be used to seal the sensor (e.g., spray-on type), but those will not offer the mechanical protection of epoxy. Potting may also affect the sensor's sensitivity and responsiveness.

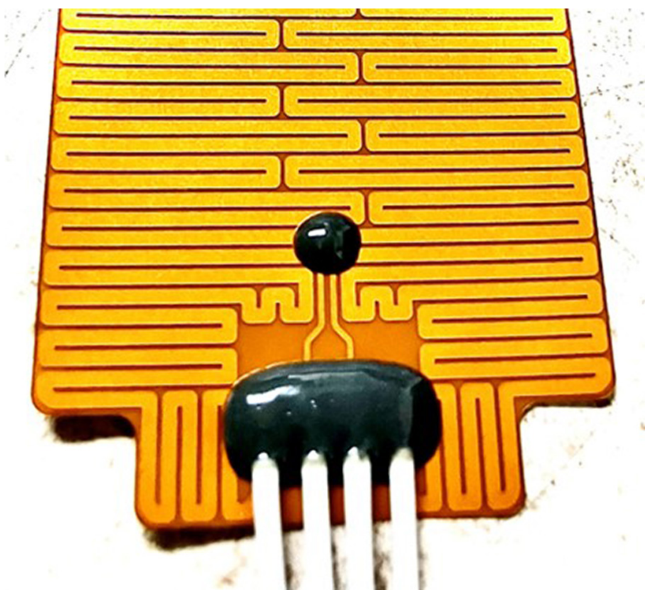


Figure 1. "Glob topping" epoxy is a cost-effective way to ruggedize and seal SMT components and lead wires.

SMT sensor mounted under cover layer. This version would require that the sensors be soldered to the bare-etched flex before applying and laminating the cover layer. This can cause difficulties during SMT because there is no solder mask or cover layer to limit the solder flow to only the SMT pads during reflow. Also, I would recommend this only for very small components (0201 packages or smaller). Even with small components, additional patches of adhesive may need to be manually added (which means more cost) over the components before the cover is applied to ensure adequate adhesive flow to achieve complete encapsulation. The cover lamination temperature must also be carefully monitored to ensure the melting temp of the solder is not exceeded. That would be a mess! The result of this version is a reasonably rugged assembly that is thinner than the glob top version but also a bit more expensive.

A variation to the method above would be to solder the SMT sensor per normal processes onto the completed flex (with the cover layer already laminated). An additional polyimide patch can be added over the top of the sensor to seal and ruggedize it. With both versions of the SMT sensor under the cover, you will need compliant lamination materials with enough cushion to mold around the component while also providing adequate pressure to get good lamination without crushing the component.

Embedded thermocouple. This version requires two to three metal layers, with one or two layers being copper and the other layer being a cupronickel alloy such as Constantan. The simplest way to do this is to use one layer of each metal and connect the two layers with a copper-plated via in the area where the sensor is. The result is a thermocouple junction that is *very* robust and requires no increase in thickness in the sensing area. The difficulty in getting this version to work is that *no* copper plating whatsoever can be deposited on the circuit's copper-nickel alloy side. Many flex manufacturers that use electroless copper plating to metalize vias will not be able to support a two-layer version of this design. A variation to this method is to add a second copper layer (three metal layers total) and sandwich the CuNi alloy layer between the outer copper layers. One of the copper layers will have pads only in the sensor areas. This will permit the manufacturer to add plating to both outer layers without depositing any on the internal CuNi alloy layer. Obviously, adding a third metal layer will have a significant impact on the cost.

Another variation to the above construction would be to start with a single layer of CuNi alloy and then selectively copper-plate the surface of the CuNi in the sensor area. When complete, each location where the copper plating terminates would form a thermocouple junction. This *will* require extreme accuracy on where the copper plating is deposited to ensure that adjacent non-sensing conductors are not plated. Also, while the thermocouple response is very consistent in the variation, it is less predictable and will require the end-user to characterize it over the temperature of their application.

Considering all the variations involved in a design like this, I recommend talking with a flex supplier to find the most reliable and cost-effective solution.

MARK FINSTAD is director of engineering at Flexible Circuit Technologies (flexiblecircuit.com); mark.finstad@flexiblecircuit.com. He and co-“Flexpert” **NICK KOOP** (nick.koop@ttmtech.com) welcome your suggestions.

Semi-Flexible PCBs: Flexibility without the Polyimide Price Tag

Why a relatively unknown technology might be right for static bend applications.

WORKING WITH SEMI-FLEXIBLE PCBs has opened some unique opportunities that I believe are worth exploring. The idea behind semi-flex is simple yet effective: a circuit that can flex without the high cost associated with using polyimide materials, which are typically necessary for full flexibility. This means the PCB can handle moderate bending without the expense of materials traditionally required for a fully flexible circuit. In multiple scenarios, once I've introduced this technology to customers, they've fully embraced it and have incorporated it into their PCB designs many times over, replacing rigid-flex designs for limited or static bend applications.

Despite the advantages, semi-flex is still a relatively unknown technology. A small group of people understand what it is and use it regularly, but for most, it's completely new, and they're often amazed by the possibilities it brings. Many customers light up when they see how a semi-flexible circuit could work in their applications, especially since it brings flex into the rigid realm. This permits flexible applications while leveraging the manufacturing techniques of a typical multilayer or HDI factory. It's a major advantage because, unlike fully flexible PCBs, semi-flexible boards don't require specialized facilities, which can drive up costs and narrow production options.

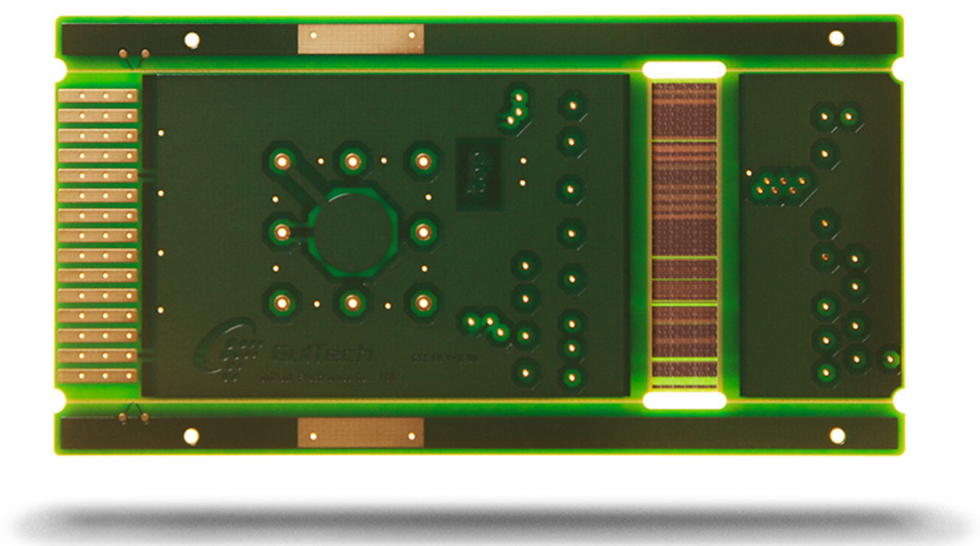


Figure 1. For applications that need only small portion of flex in specific areas, semi-flex is a cost-saver.

Some technical challenges come with semi-flexible PCBs, however, especially around durability in bending areas. For one, traditional solder masks just aren't made to handle bending; they will crack and flake because solder mask isn't designed to flex. We've found that using a flexible solder mask (usually a flexible LPI, or liquid photoimageable solder mask) allows us to build semi-flex circuits that can bend without the solder mask chipping off or cracking in these high-stress areas.

One example I remember well is a project that required a specific solder mask color. The original board design was red, which looked great, but we soon found that most of our factories didn't have UL approval for red flexible solder mask. To get around this, we had to do a red board with a green flex mask in the bend areas. The result was a bit Christmasy – red and green aren't exactly a subtle color combo – but it got the job done while staying within UL requirements. This sort of color compromise can be one of the challenges with semi-flexible tech; it's not always the prettiest solution, but it's sometimes what we need to work to meet regulatory guidelines and achieve functional, flexible designs.

Another interesting aspect is the use of coverlay versus solder masks in traditional flexible PCBs. Unlike semi-flexible PCBs, fully flexible circuits don't always need solder masks; they often use a coverlay, typically amber in color, instead of a green solder mask. I've had customers assume the amber look is a standard color for flexible PCBs. In reality, it's a coverlay we use because, unlike solder mask, it handles flexing well without cracking. On semi-flexible circuits, we'll often have green solder mask on the rigid areas and flexible solder mask in the bend areas. Sometimes we can also use a coverlay film, but it is a more expensive option and, in my experience, does not significantly improve the durability of flexibility of the bend area. If you look at the PCB, you can see where the green mask stops and the amber coverlay begins; that's where the board can bend.

There are limitations on the number of bends, number of layers in the bending area and bend angle. One major consideration is the thickness and number of layers in the bend area. For example, while two layers in the bend area work well, pushing it to six layers or a 0.063″ board thickness simply isn't feasible. It's just not going to bend the way a thinner board would. We try to keep it to two layers in the bend area for the best results, and our design guidelines permit up to three, but we know from experience that adding more layers creates more mechanical stress. The more material in the bend area, the fewer bending cycles it can withstand. This is one of those critical factors where understanding the limits of the material is essential to avoid failures in the field. The bend angle is limited to 90°, so keep that in mind in the design as well.

One specific project involved designing a semi-flex board that would bend in just one area. This board had a reinforcement layer added to prevent any peeling or cracking on the backside of the bend area. The reinforcement permitted the board to flex only where needed without risking damage to the other parts. By using these design techniques, we could build a semi-flexible PCB that would bend and still stay durable.

In my experience, semi-flexible PCBs have a lot of potential, especially if you're looking for a cost-effective way to add flexibility to a design without fully committing to a flexible PCB. For applications that need only a bit of flex in specific areas, it's a technology worth exploring. Just be aware of the limitations: stay mindful of layer counts, use flexible solder masks where needed, and keep an eye on UL approvals when dealing with color-sensitive requirements.

It's important to be mindful when choosing a supplier. Although there is more manufacturability compared to rigid-flex, not every rigid factory can produce these. And remember, semi-flex won't be as flexible as a fully flexible board, but it's a fantastic middle ground that bridges some of the gaps between rigid and flexible PCB technologies.

JEFFREY BEAUCHAMP is director of technology & engineering at NCAB Group USA (ncabgroup.com); jeffreybeauchamp@ncabgroup.com. He started his career in the PCB industry in 2003 at PD Circuit, now part of NCAB Group, and works with PCB customers to provide optimal solutions.

CONSORTIA

Collaborating Across the Industry

The High Density Packaging User Group drives innovation through active partnerships.

by TYLER HANES

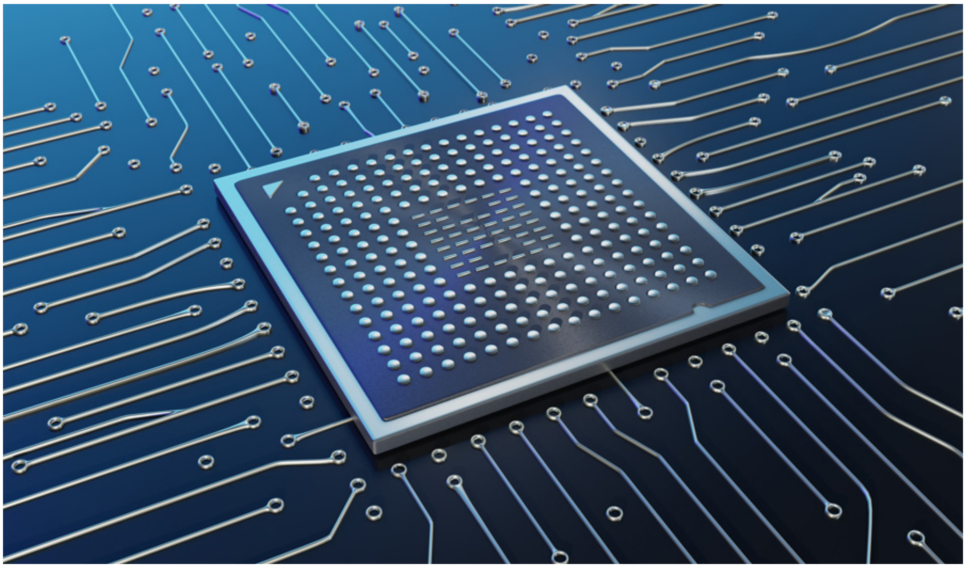
For more than 30 years, the High Density Packaging User Group has facilitated innovations in the electronics industry supply chain, encouraging collaboration to solve some of the industry's critical problems.

We sat down with HDP project facilitator Karl Sauter during PCB West 2024 to learn more about the group and some of its ongoing and completed projects.

Sauter said the group's primary focus is to permit companies to collaborate on large joint research projects that would otherwise be too costly or require too many resources for a single company to conduct independently.

Many large OEMs are not as vertically integrated as they once were, so conducting a research project that goes up and down the supply chain often requires working with multiple companies along each step, he added.

One recently completed project led by Intel involved eight laminate manufacturers who supplied samples of their materials as part of the study, and also looked at the effects of different materials, copper routing densities and manufacturing processes on coplanarity to minimize dielectric variation under large BGAs.



One recent HDP User Group project examined various impacts on coplanarity to minimize variation under large BGAs.

Other ongoing projects include looks at improved copper surface roughness modeling, defects and anomalies in backdrilled vias, improving microvia reliability, low-loss materials and copper foils, as well as improving SIR test methods.

The results of projects are shared among members, but HDP periodically publishes its findings in academic papers, with the aforementioned project led by Intel winning IPC Apex's Best Paper Award in March.

Other completed projects this year included a noncontact foil profile project that brought together 10 copper foil manufacturers and three laser microscope manufacturers to complete statistically significant testing to enable measurement standards and ultra-low profile foil classifications, as well as a thermal analysis methodology evaluation that highlighted the need for a better understanding of test methods and potential improvements required when analyzing next-generation PCB materials.

Some of the group's ongoing projects are examining the measurement of copper surface thickness and examining the coefficient of thermal expansion and how temperature affects expansion across the X and Y axes, Sauter said.

A Fine-Tuned Process

With its decades of experience in the field, HDP has fine-tuned its process for defining projects and seeing them through to completion. Each project starts in the idea phase, in which members and nonmembers can voice their proposals to determine if there is sufficient interest.

If interest is sufficient, the project moves to the definition phase, in which HDP gathers as much information as possible from members and across the industry to develop a project plan, choose a project leader, finalize its scope and timeline and secure resources, and under the implementation phase, the project is conducted by HDP members.

This approach allows participation of all members who may be interested, and it ensures members are not committing resources to a nonviable project, Sauter said.

Research always has some risks, and HDP works to make sure that at every point a project can be stopped or discontinued as early as possible if warranted. Then as more resources get committed to a project, HDP has already worked to maximize the chances of success, he said.

HDP currently has 50 members, including large OEMs, material suppliers and test facilities, and having a mix of companies that specialize in different areas is important to ensure research stays up to date and a broad set of resources is available.

"You don't have to be a major OEM to be a member," he said. "You can be a supplier, you can be a test facility, and you will get visibility from participating in the projects."

HDP company membership has benefits, with members being able to share costs that they would incur while conducting research on their own, whether it's adding new equipment or technology. And project team members also determine which final results of a project are only shared among members, Sauter said.

"We don't publicly share all the results," he said.

With HDP board of directors approval, HDP project members may decide to at least let the industry know that there's a better way. HDP may not share all the details, but it can be in the interest of HDP membership to let the industry know that there's a better way.

Sauter said HDP continues to look for potential new members as technology advances into new territories, and as the industry landscape changes through consolidations and mergers.

"We're open for new members and we do have areas of technology that we're looking to work toward," he said.

He said the industry continues to see growing interest in HDI and ultra-HDI, and the group has a large enough presence that some members encourage their suppliers to join and add to the effort of tackling some of the challenges they are seeing.

Other areas of interest among members include new substrate materials and packaging innovations, Sauter said. While there may not be active projects in those areas, companies can encourage new members and new research directions.

"If something is not currently covered and a company wants good research done where collaboration would be cost-effective, that company can join so that good research can be done." he said. "The HDP value-add is to improve their member companies' ability to serve their customers in the electronics industry."

TYLER HANES is managing editor of PCD&F/CIRCUITS ASSEMBLY; tyler@pcea.net.

TESTING **DEVELOPMENT**

How to Run a Design of Experiments

A review of the six fundamental steps behind scientific process development.

by PATRICK VALENTINE

Design of experiments (DoE) is an efficient method for planning experimental tests so the data obtained can be analyzed to produce valid and objective conclusions. Designed experiments are commonly used for product and process design, development and improvement. Here we review the history of designed experiments, experimental design, common design of experiments and experimental steps.

Aristotle (384-322 BC) laid the foundation for the scientific method. At the beginning of the 19th century, science was established as an independent and respected field of study, and the scientific method was embraced worldwide. The scientific method is a five-step process. These five steps are 1) make observations, 2) propose a hypothesis, 3) design and conduct an experiment, 4) analyze the data, 5) accept or reject the hypothesis, and, if necessary, propose and test a new hypothesis. Early experiments were one-factor-at-a-time (OFAT). These designs would vary only one factor or variable at a time while keeping the others fixed. But in 1922, things changed.

In 1922-23, RA Fisher **(Figure 1)** published essential papers on designed experiments and their application to the agricultural sciences. Fisher is revered as the godfather of modern experimentation. Then, in 1932-33, the British textile and woolen and German chemical industries began using designed experiments for product and process development. In 1951, Box and Wilson started publishing fundamental work using designed experiments and response surface methodology (RSM) for process optimization. Their focus was on the chemical industry. The applications of designed experiments in the chemical industry began to increase. From 1975 through 1978, books on designed experiments geared toward engineers and scientists began to appear. In the 1980s, various organizations adopted experimental design methods, including electronics, aerospace, semiconductor and the automotive industries. Taguchi's methods of designed experiments first appeared in the United States. In 1986, statisticians and engineers visiting Japan saw firsthand the extensive use of designed experiments and other statistical methods. During the early 1970s through the late 1980s, proprietary design of experiment software began to emerge (Minitab, JMP and Design Expert). In 2011, Jones and Nachtsheim introduced the definitive screening design of experiments.[1,2]

Figure 1. Sir Ronald Fisher

In the 1950s, product and process improvement designed experiments were introduced in the United States. The initial use was in the chemical industry, where the power of designed experiments became widely harnessed. This is one reason why the US chemical industry has remained one of the most competitive in the world.

The spread of designed experiments outside the chemical industry was relatively slow until the late 1970s and early 1980s, when many Western companies learned that their Japanese competitors had been systematically using designed experiments since the 1960s. Japanese companies used designed experiments for new process development, process improvement and reliability improvements. This discovery catalyzed extensive efforts to introduce designed experiments in the engineering field and academic engineering curricula.

Experimental Design

With an experiment, we deliberately change one or more input process factors to observe the changes' effect on the response variables. An application example is shown in **Figure 2**. Design of experiments is an efficient method for planning experiments so that the data obtained can be analyzed to produce valid and objective conclusions. Design of experiments begins with determining the experiment's objectives; designed experiments are commonly used for product and process design, development and improvement. Process factors and levels are then selected for the study. Knowledgeable Six Sigma Black Belts and process engineers understand and harness the power of DoE.

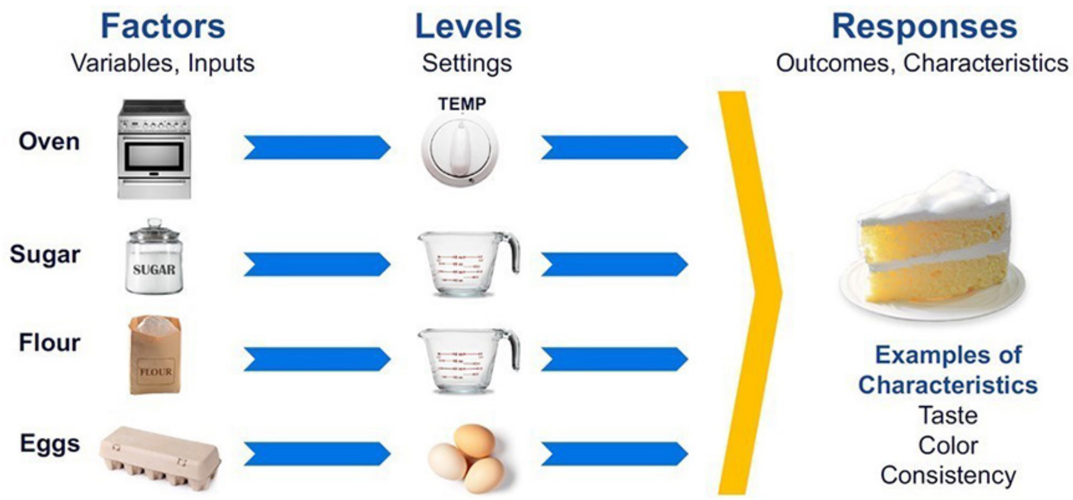


Figure 2. Usual applications for design of experiments.

An experimental design is the creation of a detailed experimental plan before experimenting. Properly chosen experimental designs maximize the information that can be obtained for the given amount of experimental effort. Two-level factorial and fractional factorial designs are typically used for factor screening and process characterization. The most common model fit to these designed experiments is a linear form. Response Surface designs are typically used to find improved or optimal process settings, troubleshoot process problems and weak points, or make a product or process more robust against external and noncontrollable influences. The most common model fit to these designed experiments is a quadratic form.

Experiments commonly need to account for some uncontrolled factors (noise) that can be discrete (different shifts or operators, etc.) or continuous (ambient temperature or humidity, etc.). Noise factors may be identified or unidentified and can change during the experiment. The presence of noise factors is called a Black Box process **(Figure 3)**.

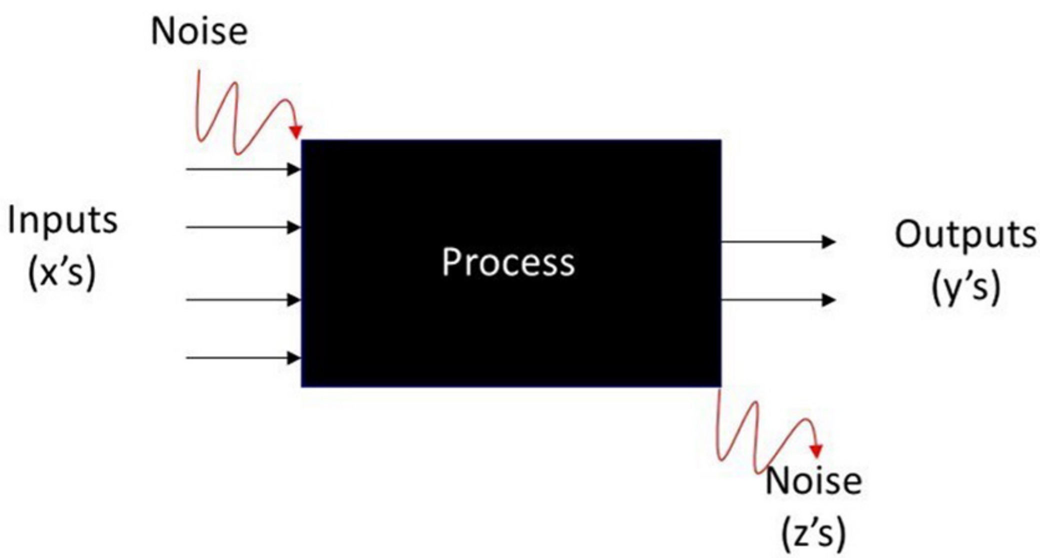


Figure 3. A Black Box process model schematic.

Noise factors can be tolerated when they are managed correctly and disastrous when they are not. Managing noise factors is accomplished by randomization.

Randomization is a schedule for running DoE combinations so that the conditions in one run do not depend on the conditions of the previous run, nor do they predict the conditions in the subsequent runs. The importance of randomization cannot be overemphasized. It is necessary if conclusions drawn from the experiment are to be correct, unambiguous and defensible.[3]

The design of experiment resolution is a term that describes the degree to which estimated main effects are confounded with estimated two-level interactions, three-level interactions, etc., and is commonly identified in Roman numerals. If some main effects are confounded with two-level interactions, the resolution is III. Full factorial designs have no confounding and have a resolution of "infinity." A resolution V design is excellent for most purposes, and a resolution IV design may be adequate. Resolution III designs are functional as economical screening designs.[3]

Common Design of Experiments

ANOVA: The analysis of variance design has two primary subcategories. The one-way supports one numeric or categorical factor at ≥2 levels, and the two-way supports two numeric or categorical factors at ≥2 levels. These designs are extensions of the t-test.

Combined designs: An excellent choice when working with mixtures in combination with categorical and continuous factors. These designs support factors at >3 levels and identify significant main effects, all interactions and quadratics. You can add constraints to your design space, for instance, to exclude a particular area where responses are known to be undesirable.

Definitive screening designs: Incorporate mid-levels for each factor, allowing individual curvature estimation. They efficiently estimate main and quadratic effects for no more and often fewer trials than traditional designs. They can be augmented to support a response surface model. They are an excellent choice for screening multiple factors.

F-test: One numeric or categorical factor at two levels. Used to test if the variances of two populations are equal. A typical application tests if a new process or treatment is superior to a current one.

Full and fractional factorials (2^k) designs: Numeric and categorical factors at two levels. Estimation of main effects and interactions and can detect curvature by adding center points. Full factorials measure responses at all combinations of the factor levels. In contrast, fractional factorials measure responses for a subset of the original full design. This reduces the total runs, but the tradeoff is design confounding.

General factorial designs: Numeric and categorical factors at ≥2 levels. Identifies main effects, all interactions and quadratics. Measures responses at all combinations of the factor levels. These designs become very large with ≥5 factors and are generally not cost- or time-efficient.

Irregular fraction designs: Numeric and categorical factors at ≥2 levels. Estimation of main effects and two-factor interactions. These are resolution V designs with unusual fractions like 3/4 or 3/8. They are also known as space savers, reducing runs by 25%. These designs are a great choice as they reduce runs and are still resolution V.

Minimum run resolution IV and V designs: Numeric and categorical factors at ≥2 levels. Estimation of main effects and some interactions. Suitable for screening, designed for ≥5 factors. It's a good choice if interactions are unlikely.

Mixture designs: Components from 2-50, expressed as either proportions (from 0-1) or values (pounds, ounces, grams). Designs include simplex centroid or lattice and extreme vertices. Design points are arranged uniformly (lattice) over a simplex (a generalization of a triangle or tetrahedron to an arbitrary dimension). Can add points to the interior of the design space.

OFAT: One-factor-at-a-time designs vary only one factor at a time while keeping the others fixed. OFAT designs are useful in some situations but should not be the first choice. They become invaluable with complex systems and extremely hard-to-change factors, such as varying the copper level in an electroplating via fill tank. Randomization is impossible, however. OFATs are best analyzed with partial least squares regression.

Optimal designs: Numeric and categorical factors at ≥2 levels. These designs are known as alphabet optimality. Designs are generated based on a particular optimality criterion (D, G, A, E, I, L, C, S) and are generally optimal only for a specific statistical model. D and I-optimal are the most common. Optimality is either maximized or minimized. Optimal designs are excellent for regions of constraints and costly runs. Designs are not orthogonal by nature.

Plackett-Burman designs: Numeric and categorical factors at two levels. Can estimate main effects. Good for screening ≥7 factors. Useful for ruggedness testing (validation) where it is hoped to find little or no effect on the response due to any factors.[4] The 12-run design has a unique attribute: there is a weak correlation among the factors, so confounding is minimized, and the interactions are uniformly dispersed over all the experimental runs.

Randomized blocked designs (RBD): Supports two factors at ≥2 levels, but interest lies in only one factor. Used when a noise factor is known and controllable, but you do not intend to make claims about the differences between the levels of the noise factor. Typical noise factors are raw material lot numbers, locations, plants, operators, etc.

Response surface method (RSM): Primarily numeric factors at ≥3 levels, but categorical factors can be added. Identifies main effects, all interactions and quadratics. The RSM family includes central composite, Box-Behnken and 3^k designs. They can become enormous with ≥4 factors.

Split-plot designs: Numeric and categorical factors at two levels. Estimation of main effects and two-factor interactions. Excellent designs for hard-to-change factors (HTC). Hard-to-change factors are challenging to randomize due to time or cost. These designs range from resolution III and higher.

Taguchi designs: Numeric and categorical factors at ≥2 levels; can run mixed levels, too. Can identify main effects and interactions. Suitable for screening ≥4 factors, also capable of robust parameter designs. The alias structure (confounding) for these designs can be very complex.

t-test: One numeric or categorical factor at two levels. Used to test if two population means are equal. A typical application tests if a new process or treatment is superior to a current one.

Experimental Steps

DoE has six fundamental steps: 1) state the problem, define the objectives, 2) design the experiment, 3) run the experiment, 4) analyze the experiment, 5) confirmation runs and P_{pk}, and 6) report and recommendations.

State the problem, define the objectives. Do we have a clear understanding of the problem? Why are we doing this DoE? What is the desired outcome for the response? Typically, either better (e.g., reliability, aesthetics), faster (e.g., drying, curing), cheaper (e.g., lower cost, less reaction time), or positive outcome (e.g., marketing, advertising). A team discussion best determines the objectives of an experiment. The group should discuss the key objectives and which are "nice but not necessary." All the objectives should be written down.

Design the experiment. Successful experimental designs incorporate both process knowledge and sound statistical procedures. Process knowledge is invaluable in the design stages and in interpreting the results. Experimental design is commonly an iterative approach – rarely does one run a single large comprehensive DoE in which final conclusions are made. Choose factors and reasonable ranges for each. Determine appropriate responses and how to measure them. Select a design, know your pros and cons and review runs. Check the factor settings for impractical or impossible combinations. The choice of an experimental design depends on the experiment's objectives and the number of factors to be investigated. Generally, we use resolution III designs to screen several main factors and resolution IV or above for interactions. A DoE design guide is shown in **Figure 4**.

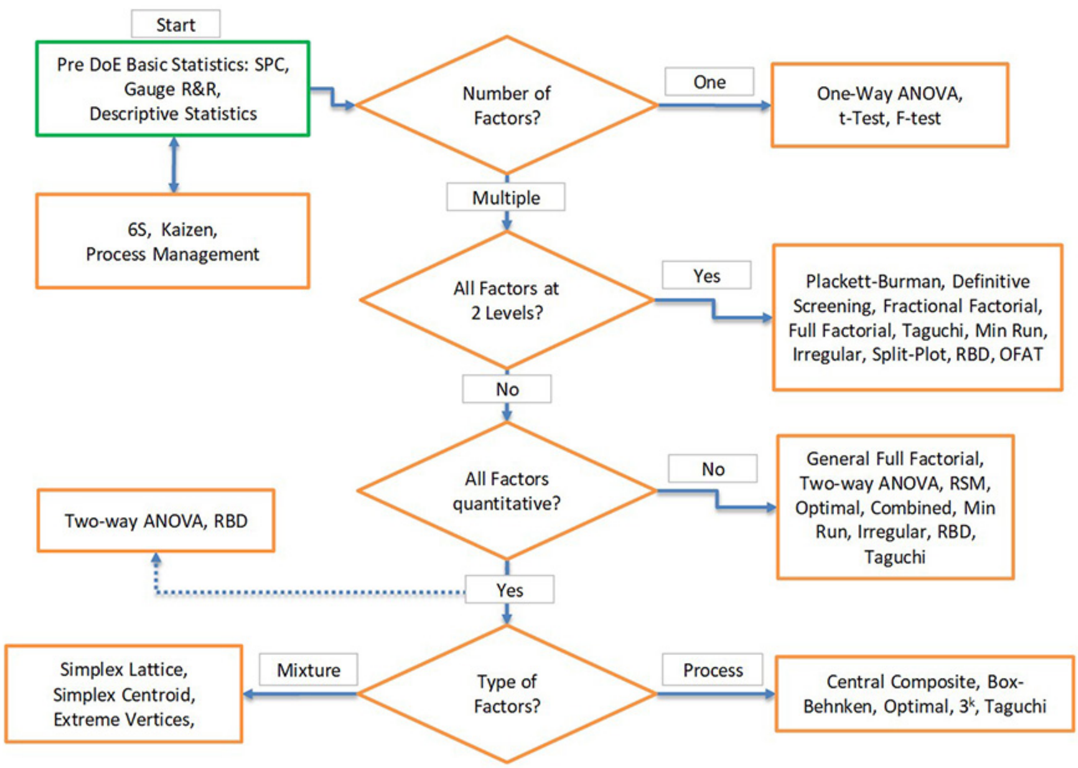


Figure 4. A DoE design guide.

Run the experiment. There are five cardinal rules: 1) Be involved, 2) Keep an eye on everything, 3) Don't guess or make assumptions, 4) Block out known sources of variation, and 5) Randomize the runs. Noise variables, uncontrolled and unobserved variables that change during the experiment and might affect the response, can confound one or more of the study variables. Randomization helps protect against noise variables but doesn't compensate entirely for their effect. Randomization will desensitize an experiment to the effects of noise variables and more accurately predict the real differences between treatment means.

Analyze the experiment. Multiple steps are required when systematically analyzing experimental data **(Figure 5)**. Errors can be introduced into an experiment in four ways: 1) A significant factor(s) was/is missed, 2) There is an error in the measurements, 3) Unknown noise factor(s) were present during experimentation, 4) Excessive variation (inherent in the process itself – lack of statistical process control, poor controls during experimentation, etc.).

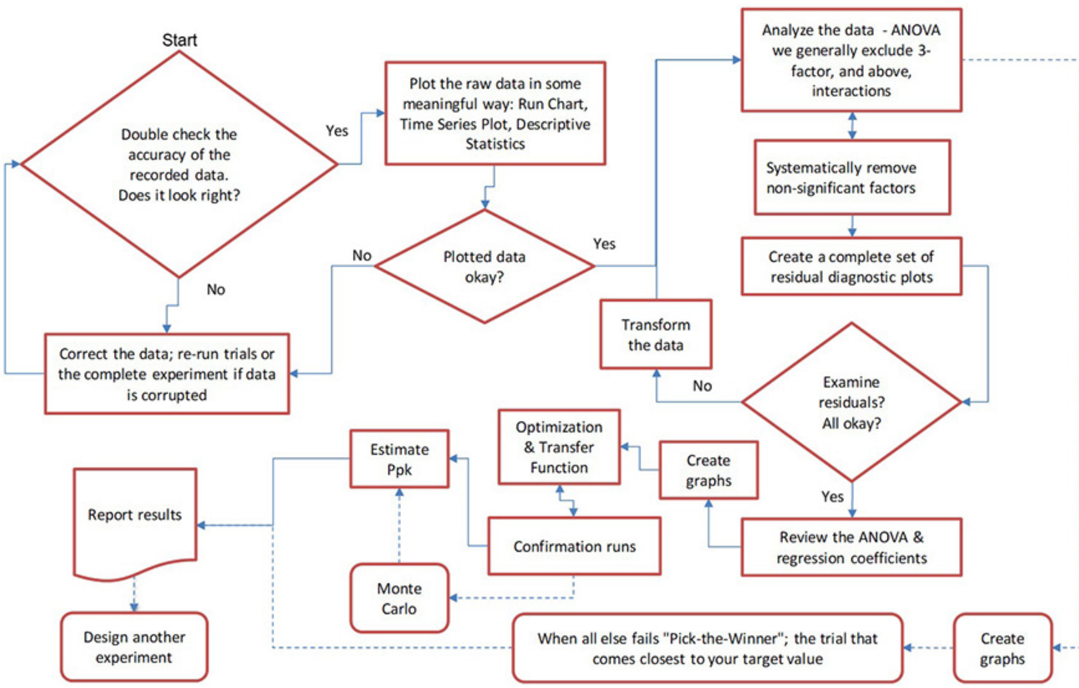


Figure 5. A DoE analysis flowchart.

Confirmation runs and P_{pk}. When the experiment analysis is complete, one must verify that the predictions are reasonable. This is accomplished through confirmation runs. These runs ensure nothing has changed and the response values are close to their predicted values. The number of runs depends on the cost per run, the time per run, product reliability concerns, and whether the runs will generate production (saleable product). As a rule of thumb, 4 to 20 runs are typical. Still, do enough runs to confidently estimate the mean and standard deviation.

The P_{pk} index provides an estimate of the long-term actual performance. Actual performance is based on the process average and the standard deviation. This overall variation is comprised of both common cause and assignable cause variation. The P_{pk} index estimates the total variation and accurately tells us "what the customer feels."

Report and recommendations. Put recommendations upfront. State them clearly and concisely and back up the reasons. Provide the P_{pk} for the confirmatory runs. Review the DoE design and analysis. Know the audience: Provide clear and easy-to-follow statistics, an ANOVA table, regression coefficients, graphs, pictures, etc.

Conclusions

Design of experiments is commonly used for product and process design, development and improvement. An experimental design is the creation of a detailed experimental plan before experimenting. There are dozens of different designed experiments; choosing the right one is a mix of experience, process and statistical knowledge. There are six fundamental steps to creating, running and analyzing a design of experiments. Knowledgeable Six Sigma Black Belts and process engineers understand and harness the power of DoE.

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PATRICK VALENTINE is technical and Lean Six Sigma manager for Uyemura USA (uyemura.com); pvalentine@uyemura.com. He holds a doctorate in Quality Systems Management from Cambridge College, a Six Sigma Master Black Belt certification from Arizona State University, and ASQ certifications as a Six Sigma Black Belt and Reliability Engineer.

ASC GOES ULTRA

American Standard Circuits' Push for UHDI is On

After new technology investments, the flagship operation of the Chicago-based fab is primed for growth.

by MIKE BUETOW

As the US electronics manufacturing industry braces for the next wave of technological advancements, American Standard Circuits is positioning itself as a key player in the ultra-high-density interconnect (UHDI) space. Yet, the looming question remains: Could UHDI follow the same path as HDI, where slow domestic investment permitted Asia to dominate?

Years ago, HDI production was overtaken by Asian manufacturers, as the US didn't invest fast enough. UHDI could follow a similar trajectory, especially as the demand signal for the technology remains unclear, particularly in defense. As circuit board investment ramps in India, Thailand and Vietnam, it adds pressure on North America's ability to compete for next-generation products. ASC, however, recognizes that PCB manufacturing should be viewed as critical infrastructure, akin to roads and buildings – integral to defense, medical, automotive and communications sectors.

Earlier this year, PCD&F/CIRCUITS ASSEMBLY profiled ASC's operations in the Pacific Northwest, the former Sunstone Circuits. Its editors followed that up in the summer by visiting the company's flagship plant in West Chicago, IL.

ASC's customer base is diverse, but defense (35-40%) and medical (5-10%) stand out as significant contributors. The fabricator also sees demand from the automotive, communications and semiconductor sectors. Flex UHDI is driving a large portion of demand, and the company's production is split nearly evenly between rigid and flex PCBs.

Figure 1. ASC has received several patents for its process developments.

A key move for ASC was its acquisition of Sunstone, which chief executive Anaya Vardya notes had two main objectives: To give customers the ability to use higher technology while still experiencing the service Sunstone is known for, and to retain Sunstone's existing customer base, both domestic and offshore. The strategic purchase, terms of which were not disclosed, permitted ASC to expand its UHDI capabilities while also servicing a broader customer base.

UHDI Capabilities

ASC's director of business development John Johnson notes a growing demand for UHDI in mainstream product due to increased use of high-density BGAs and RF. The fabricator is targeting applications of sub-25µm, and uses multiple processing approaches, including tin foil and Averatek's semi-additive process (A-SAP). UHDI isn't exclusive to low-layer-count product, however: Currently ASC can produce UHDI boards with up to 20 layers.

With capabilities such as 50µm through vias on flex, 50-75µm copper-filled vias, and 2.5 mil solder mask clearance, ASC is well-positioned to meet demand for UHDI in both flex and rigid applications.

The company has adopted advanced cleanroom practices for UHDI processing, particularly for handling materials with 12.5µm thickness.

Fabrication and Technology Investments

Beyond its UHDI advances, ASC is making substantial investments in fabrication to stay ahead of the curve. Recent additions include two Integrated Process Systems (IPS) VRP 200 Flasher etcher and developers, cupric chloride and ammonia etch lines, and a Pluritec X-Cut S1 x-ray drill and bar code system **(Figure 2)** that was being tested when we visited.

Figure 2. The West Chicago plant's new Pluritec X-Cut S1 drill and bar coder.

Walking the shop floor, we saw several high-speed, six-head mechanical drills, including a Schmoll system for controlled-depth drilling, plus three Lenz routers and a Vega Technology router. An Excellon Cobra hybrid laser (CO_2 and UV) rounded out the drill room. Surface preparation is performed on Plasma Etch and Nordson March plasma machines.

ASC is adding a copper-filled via plating line, which will be automated later, and new testing capacity. Automation is the key, according to Johnson. Notably, ASC created its own racks for electroless plating and the LPI dip station. Fixtures are used because the material is too thin (0.5 mil dielectric materials) to handle conveyor to conveyor.

Inspection is performed with a CIMS Galaxy AOI (with 30µm capability) and Orbotech Ultra Dimension 800 laser AOI.

Its facility also features a Milltronics VM3018 CNC for milling, XRF tools for material analysis, and tracking systems powered by ERP and barcodes. Other services it offers include laser scribing on metals, copper sputtering, HiPot testing (AC and DC), and impedance testing (Polar Instruments). CAM engineering is conducted both in the US and India.

Looking ahead, ASC plans to add an LED machine and a dual-stage vacuum laminator.

ASC's current 52,000 sq. ft. facility is set to expand, with a planned addition that could bring the total space to between 75,000 and 100,000 sq. ft., depending on customer demand and funding availability.

Challenges Ahead

One of the most pressing issues for the US PCB manufacturing industry is workforce development. Finding skilled workers who are willing to work in manufacturing is a constant challenge. "Workforce development is critical," says ASC, and without a robust pipeline of talent, the industry's competitiveness may falter.

The path forward for UHDI manufacturing in the US is fraught with challenges. Besides the mixed demand signals, the risk of overcapacity looms large, especially with government funding being funneled into select companies. The question remains: Will the rest of the industry move as fast as ASC to carve out a sustainable market in UHDI, or will it be overwhelmed once again by overseas competitors?

MIKE BUETOW is president of PCEA (pcea.net); mike@pcea.net.

RECOGNITION

PEACHTREE CITY, GA – CIRCUITS ASSEMBLY in October announced the winners of its 32nd annual Service Excellence Awards (SEAs) for electronics manufacturing services (EMS) providers and electronics assembly equipment, materials and software suppliers.

CIRCUITS ASSEMBLY recognized companies that received the highest customer service ratings, as judged by their own customers, during a ceremony at the SMTA International trade show in Chicago.

In the EMS category, the overall winners were **Creation Technologies** (sales over $500 million), **Mack Technologies** (sales of $100 million to $500 million), **Silicon Forest Electronics** (sales of $20 million to $100 million), and **XLR8 Services** (sales under $20 million).

The EMS companies with the highest scores in each of seven individual service categories also received awards. (Overall winners were excluded from winning individual categories.)

In the small-company category, **RBB Systems** won for responsiveness; and **Kodiak Assembly** won for dependability/timely delivery, manufacturing quality, technology, value for the price, flexibility, and overall satisfaction.

For companies with revenue between $20 million and $100 million, **Absolute EMS** won for dependability/timely delivery; **Concisys** won for technology; and **Electronic Systems Inc.** won for dependability/timely delivery, manufacturing quality, responsiveness, value for the price, flexibility, and overall satisfaction.

For firms with revenue between $100 million and $500 million, **Vexos** won for dependability/timely delivery, manufacturing quality, responsiveness, technology, value for the price, flexibility, and overall satisfaction.

For EMS companies with revenue over $500 million, **Kimball Electronics** won for dependability/timely delivery, manufacturing quality, responsiveness, technology, value for the price, flexibility, and overall satisfaction technology.

Electronics assembly supplier award winners were **Inovaxe** for component storage systems, **Europlacer Americas** for screen printing; **Europlacer Americas** for placement equipment; **Kyzen** for cleaning/processing materials; **Koh Young** for test and inspection; **Datest** for test laboratories; and **Win Source** for representatives/distributors.

CIRCUITS ASSEMBLY has sponsored the awards program for 32 years.

For more information about the Service Excellence Awards, click here.

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MECHANICAL **STRENGTH**

Filling the Gap: Underfill Materials Dispensing for Electronics

The benefits of capillary flow underfills on solder joint reliability.

by **NATHAN PRESLAN**

In electronics manufacturing, underfill refers to a material that is applied to fill the gap between a semiconductor device, such as flip-chip assemblies, ball grid arrays (BGA), or chip-scale packages (CSP), and the substrate, such as a PCB or flex circuit. It is also important in 3-D ICs and advanced packaging technologies that involve stacking multiple chips or integrating multiple functions into a single package.

Underfill materials are essential in modern electronics manufacturing and are used extensively to enhance the reliability, performance and longevity of electronic assemblies. These materials improve mechanical strength by enhancing the physical bond between the chip and substrate, reducing the risk of solder joint failure due to mechanical stress.

In applications where it is important for the assembly to withstand thermal cycling, underfills improve thermal cycling performance by reducing the risk of failures due to thermal expansion and contraction. Another key benefit of underfills is the protective barrier the provide against moisture, contaminants, and other environmental factors.

Underfills can be categorized into four different types: capillary flow and no-flow underfills, molded and wafer-level underfills. Here, the focus is capillary flow and no-flow underfills in dispensing applications.

Dispensable Underfill Materials

Capillary flow underfills (CUF) are dispensed along the edges of the component after reflow soldering **(Figure 1)**. The material flows by capillary action to fill the space between the chip and substrate and is typically thermally cured, depending on the resin system. Capillary flow underfills usually show excellent thermal cycling performance and are a good choice for high-reliability applications.

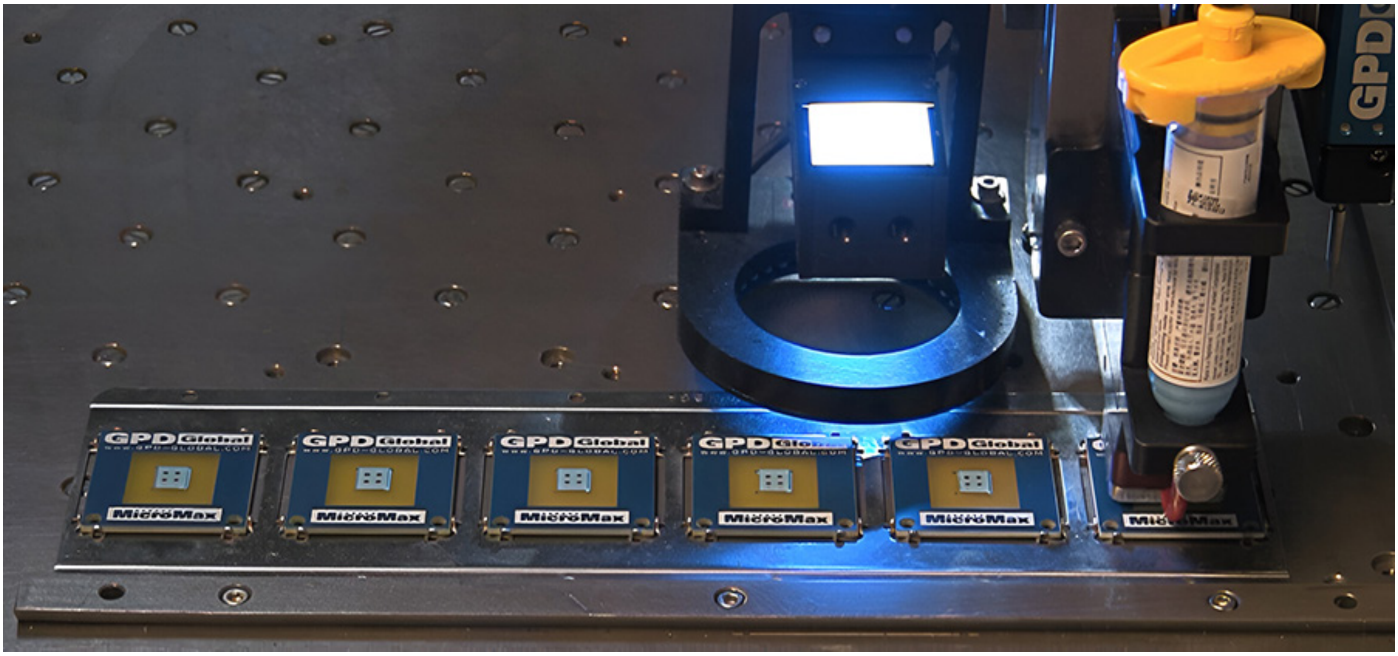


Figure 1. Capillary flow underfills (CUF) are dispensed along the edges of the component after reflow.

No-flow underfills (NFU), on the other hand, are applied before component placement. During the reflow process, the underfill flows and cures simultaneously with the solder joints. By combining the soldering and underfilling steps, it streamlines the process, reducing the overall assembly time. The disadvantages include increased process complexity, potential for voids and incomplete coverage, limited material choices, and potentially lower thermal and mechanical performance compared to capillary flow underfills. Capillary flow underfills, while requiring an additional process step, generally provide better control, flexibility and reliability for high-performance applications.

No-flow underfill is preferred over capillary flow underfill in certain applications where its unique characteristics and benefits align well with the manufacturing process and performance requirements. In high-volume production environments where throughput and efficiency are critical, no-flow underfill can simplify the manufacturing process by reducing the number of process steps and handling operations. In highly automated assembly lines, this can lead to significant time and cost savings.

Where space is at a premium, such as in mobile devices, wearable electronics and other compact consumer electronics, the ability to apply underfill in a single step can be advantageous since the reduced handling and processing can also help maintain the integrity of small and delicate components. For BGA and CSP components, no-flow underfill can also be a benefit. Its ability to flow and cure in the same step ensures that all fine-pitch connections are properly encapsulated without additional process complexity.

The mechanical strength and thermal cycling performance of capillary flow underfills make them often the first choice for environments with extreme thermal and mechanical stress, such as automotive applications, aerospace and defense electronics, where reliability under harsh conditions is critical.

For high-density interconnect (HDI) applications where components are closely spaced, resulting in numerous small gaps, capillary flow underfills can effectively fill these spaces to enhance mechanical stability.

In AI-driven server and data center applications, where large high-power chips are common, capillary flow underfills help manage thermal expansion and improve the reliability of solder joints in these systems.

Underfill Material Properties

Several key properties should be considered when choosing a capillary flow or no-flow underfill. One of the most important properties of an underfill is its viscosity, as it is essential for ensuring the material spreads uniformly and fills the gaps between components and the substrate. The curing mechanism is equally important; for instance, no-flow underfills must cure during the reflow soldering process, meaning the material must withstand soldering temperatures without degrading.

Good thermal conductivity of the underfill helps dissipate heat generated by the electronic components, which is critical for maintaining performance and reliability. Ideally, its CTE should match that of the components and substrate to minimize thermal stress and prevent delamination or cracking during thermal cycling. Adequate adhesion to the component and substrate ensures the assembly's integrity, especially under mechanical and thermal stress. The underfill should also be capable of absorbing mechanical stress without causing damage to the components.

Underfill Material Types

Epoxy-based resins are most commonly used for both capillary flow and no-flow underfills. They offer strong adhesion to various substrates, a high Young's modulus, good thermal conductivity, and material stability.

Acrylate-based resins also provide good adhesion; these underfills can be formulated to have low viscosity and they cure fast. Silicone-based underfills typically have a low Young's modulus, thermal stability, and resistance against moisture and chemicals. Hybrid underfills combine properties of different resin systems, such as epoxies, acrylates and silicones, to achieve a balance of desirable characteristics, including enhanced thermal conductivity, flexibility and faster curing times.

Thermoplastic materials are also used in some no-flow underfill formulations. They are reworkable but usually have a lower modulus compared to thermoset resins such as epoxy.

Optimizing Dispensing

Underfill materials are applied either with traditional nozzle dispensers **(Figure 2)** or jetting, a process similar to inkjet printing that offers precise control over shot size. Although jetting can be somewhat more complex to set up and requires slightly higher initial costs, it is more precise, reduces material waste and is significantly faster than traditional dispensing. This makes it the preferred method for high-volume production, especially for smaller, fine-pitch components or complex geometries found in mobile devices, wearable electronics and advanced packaging. Additionally, in applications where the proximity of the nozzle to the component risks direct contact and potential component damage between the part and the dispenser, jetting serves as a viable alternative to traditional nozzle dispensers.

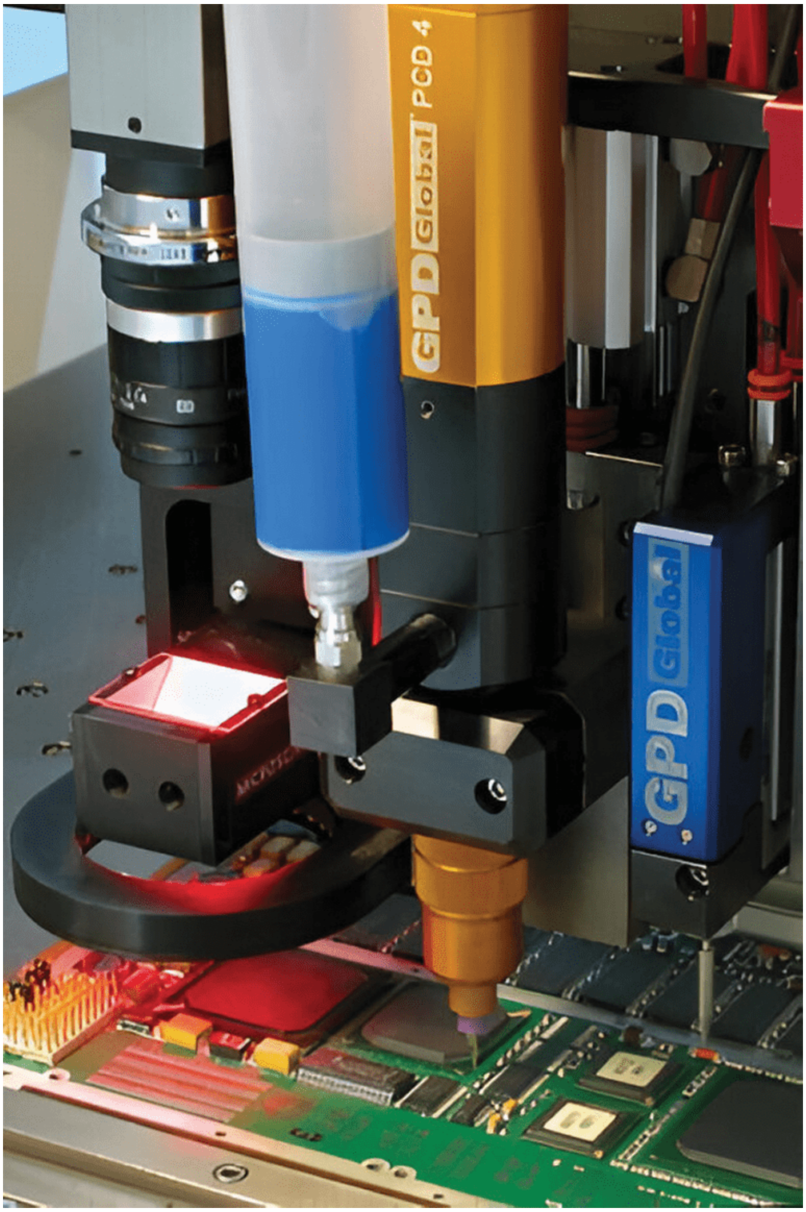


Figure 2. Application methods include traditional nozzle dispensers (shown here) or jetting.

Dispensing underfill materials in electronics manufacturing presents several challenges. Achieving uniform coverage without voids or gaps demands precise control over the dispensing process. Advanced dispensing equipment with accurate flow control ensures consistent application by managing the viscosity of the underfill material to match specific dispensing conditions, thereby improving flow and reducing risk of void formation. Highly accurate integrated weight scales are used for mass flow calibration through software control, automatically adjusting the dispense timing and flow rate with high-resolution pump controllers to compensate for variations in flow rate due to viscosity changes over time or from slight differences from batch to batch to prevent voiding.

Another challenge is the potential for underfill material to cure prematurely during the dispensing process, which can lead to clogging and inconsistent flow. This issue can be mitigated by carefully managing temperature and humidity conditions in the manufacturing environment. Using materials with tailored curing profiles that provide sufficient working time before curing can help. Underfills are applied more quickly and accurately in a heated environment compared with room temperature, which is why advanced dispensers incorporate inline preheating stages. These stages bring the substrate and components to the desired temperature before starting the underfill application, thereby improving throughput.

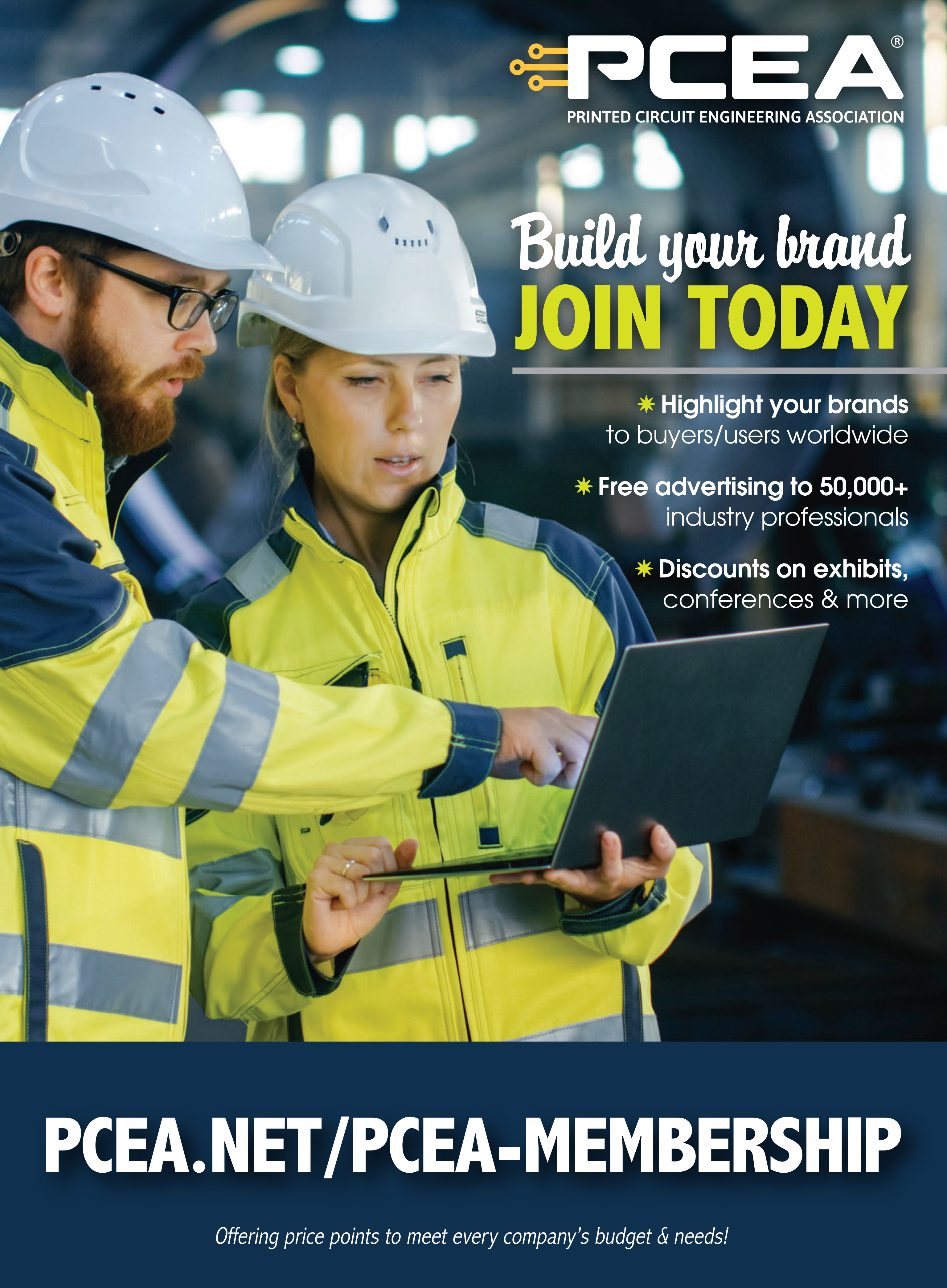
Continuous temperature monitoring, such as with IR cameras, ensures the underfill is applied within the appropriate process window. Ensuring proper adhesion between the underfill material, component and substrate is critical. Inadequate adhesion can lead to delamination and mechanical failure. Surface preparation techniques to enhance bonding can include plasma cleaning or applying adhesion promoters. Selecting underfill materials with good inherent adhesion properties tailored to the specific substrate material is also important to improve reliability.

A key concern for high-volume production is maintaining throughput while ensuring quality. Automated dispensers with real-time monitoring and feedback controls can help maintain high production rates without compromising quality. Implementing inline post-process inspection techniques such as automated optical inspection (AOI) or x-ray inspection can identify and address defects, ensuring consistent product quality.

Conclusion

Underfill materials are essential in modern electronics manufacturing for their ability to enhance mechanical strength, thermal management and environmental protection of electronic assemblies. Each type of material serves specific purposes, such as bonding, protecting, insulating and conducting, and therefore should be selected based on the requirements of the application. They play a crucial role in ensuring the reliability and performance of high-density and high-performance electronic packages, making them essential in the production of advanced electronic devices. Understanding and overcoming the challenges in dispensing underfill materials through precise and intelligent process control, environmental management and surface preparation is crucial to enhance effectiveness and reliability.

NATHAN PRESLAN is senior applications engineer at GPD Global (gpd-global.com); npreslan@gpd-global.com.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PASTE CHEMISTRY

Ensuring Optimal Performance of Solder Paste in Challenging Environments

Heat and cold can prematurely degrade incorrectly handled materials.

by GAYLE TOWELL

Solder paste is an elaborate mixture of metal powders, acids, thixotropes, solvents and a variety of other chemicals. When combined, the reactions and interactions can be extremely varied and complex. When designing solder paste chemistry, key considerations include not only its in-process performance but also how to maintain the stability of that performance against the rigors of time, temperature fluctuations and usage.

Stencil printing is a pivotal process on the assembly line, foundational to the entire assembly. A quality print can significantly reduce the need for rework, whereas a poor print almost certainly necessitates it. Print quality, and the PCB assembly process in general, are susceptible to various external influences like environmental conditions, setup alterations and operator variability, emphasizing the need for consistent solder paste performance to minimize manufacturing discrepancies.

Controlling the Conditions

The first link in the chain is the solder paste's manufacturing process and its constituent materials. Powder is manufactured and stored under extremely tightly controlled conditions. Flux medium raw materials require controlled storage, and the flux medium is also produced under tightly controlled conditions, with an abundance of quality control measures. The slightest anomaly in flux production can generate unacceptable results on the SMT assembly line.

The powder and flux medium are blended in an exacting process, after which responsibility for minimizing variability begins to shift from the paste manufacturer down the chain to packaging, shipping, distribution and the end-user.

During product development, solder pastes are characterized against typical time, temperature and usage conditions to ensure product stability. But their performance can be profoundly impacted by influences beyond the developer's lab. Consistent solder paste functionality on the production line relies on a robust chain of custody from raw materials to the stencil printer. Any break in that chain can adversely impact performance.

Packaging and Supply Chain Integrity

Solder paste packaging is a labor- and materials-intensive process. Solder paste is kept cool and environmental exposure is limited to a few seconds – from the time the container is filled until the plunger is placed in the jar or the cap is screwed onto the cartridge. It is then packed in carefully engineered packaging to keep the product cool for at least 30 hr. to cover typical transit times.

Solder paste must not be exposed to elevated temperatures; otherwise, the material may not arrive fully intact and will not perform as designed. Higher temperatures increase the chemical interactions within the solder paste that adversely impact every aspect of its performance. These changes may initially be subtle and then worsen over time, making them even more insidious than if the paste had arrived in obviously unusable condition. Minor variations can lead to increased voiding, decreased wetting, clogged apertures and other process variations, forcing engineers to adjust to address faltering print quality, declining end-of-line yields, or both.

Transportation and Temperature Extremes

Solder paste is most likely to experience temperature extremes in transit. According to FedEx, summer temperatures in the cargo area of ground vehicles can reach 30°F higher than the ambient temperature outside the vehicle.

To illustrate the point, in Phoenix, one of the hottest cities in the US, temperatures regularly exceed 100°F (38°C), peaking at 116°F (47°C). Using FedEx's guidelines of +30°F, conditions can climb to 146°F (47°C). This will certainly cause some interactions and may have already activated some of the oxide-reducing agents in the solder paste, literally forcing the paste to interact with itself.

Even International Falls, MN, one of the US's coldest cities, can experience 90° days in the summer. This means unprotected paste could experience temperatures as high as 120°F (49°C), a temperature engineers often use to "cure" prints for SPI golden boards.

Shipping cannot only heat the delicate cargo; it can also freeze it. FedEx says temperatures aboard most wide-body aircraft main cargo compartments vary between 65°F (18°C) and 90°F (32°C). Meanwhile, packages in the bulk department, adjacent to the aircraft's outer structure, might be exposed to in-flight temperatures as low as 0°F (-18°C).

These conditions require extensive measures to ensure the carefully developed and manufactured solder paste arrives at the customer's site with the least amount of shipping-induced variability. **Figure 1** shows the internal temperature of a shipping container, designed to mitigate external temperature extremes, when placed in a thermal chamber for five days at 104°F (40°C).

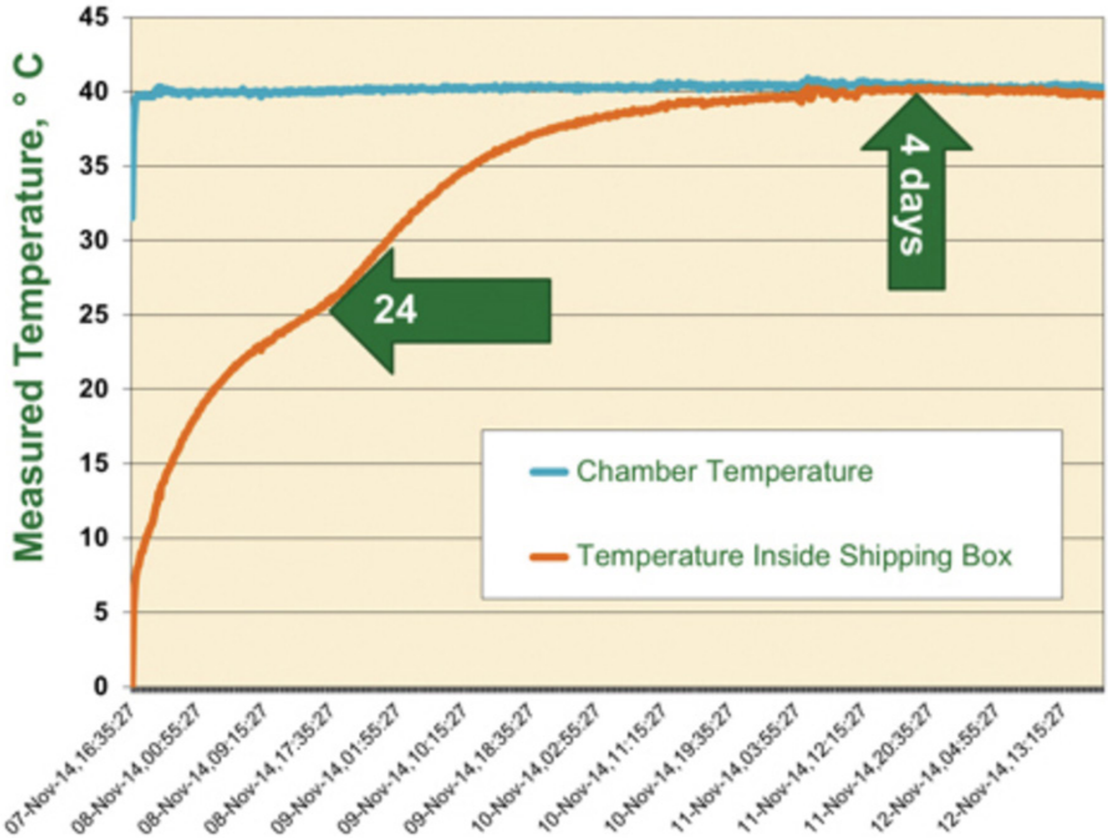

Figure 1. Five-day shipping test (container placed in thermal chamber at 40°C) for solder paste.

End-User Handling and Storage

The final link in the transit chain is the end-user. We can safely estimate that over three-fourths of solder paste handling-related issues occur after delivery to the end-user. These issues can be minimized, however, by implementing the following best practices:

- **Immediate and appropriate storage.** Upon receipt, store solder paste as recommended by the manufacturer, typically under refrigeration. Ensure that receiving dock employees are trained to quickly recognize and properly store these packages. Consider using automatic tracking updates from freight carriers to notify engineers or operations personnel upon the paste's arrival.
- **Inventory management.** Log each paste container upon storage and track when it is removed for use, adhering strictly to the first-in-first-out (FIFO) method.
- **Natural temperature adjustment.** Warm solder paste to ambient temperature naturally before use. Avoid placing paste near heat sources or opening the container prematurely, as moisture condensation can degrade the paste's performance **(Figure 2)**.
- **Preparation before use.** Stir paste in jars per manufacturer's instructions to ensure uniformity and readiness for printing. Note that cartridges typically do not require stirring due to their dispensing mechanism.
- **Avoid mixing different pastes.** Never mix used with unused solder paste. Contaminants from the used

paste can significantly compromise the quality and performance of the remaining material.

- **Controlled production environment:** Maintain the production area within an optimal temperature range of 72° to 80°F and relative humidity (RH) of 40% to 50%. Nevertheless, geography, seasonality and facility capabilities are often beyond the engineer's control. Selecting a solder paste that performs well in select manufacturing conditions is a key to successful outcomes.

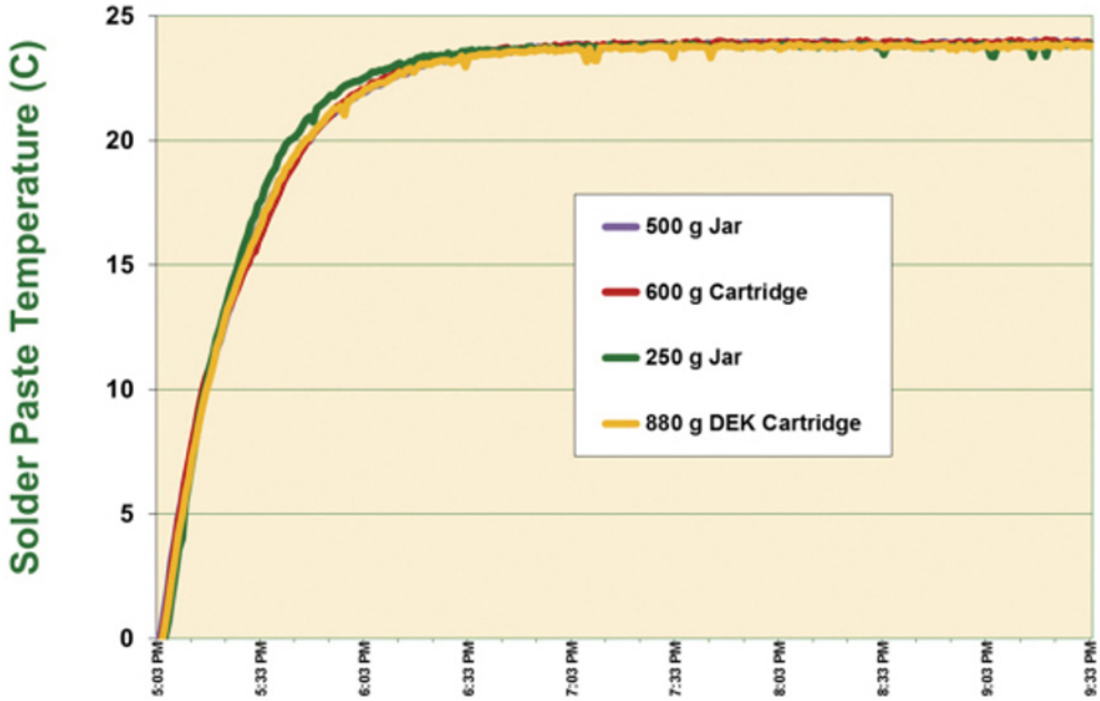

Figure 2. No clean SAC305 solder paste warming time.

From manufacturing to final application, managing the many factors that impact solder paste performance is crucial for maintaining high print quality and efficient assembly lines. By implementing stringent controls throughout the solder paste's life cycle, manufacturers and end-users can significantly reduce variability and enhance overall product reliability.

GAYLE TOWELL is content specialist at AIM Solder (aimsolder.com); gtowell@aimsolder.com.


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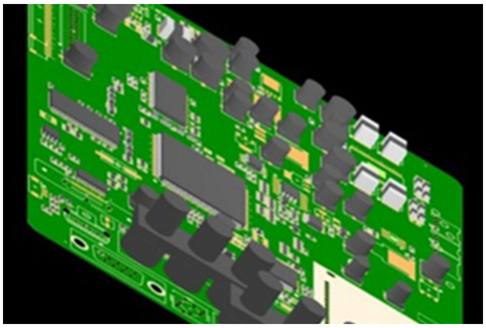


ALTAIR POLLEX FOR ECAD VERIFICATION

PollEx for ECAD streamlines design processes, enhances product quality from the earliest stages and is said to integrate seamlessly with all leading electronic computer-aided design (ECAD) tools. Offers PCB verification capabilities at no cost, permitting them to integrate with leading ECAD tools and transform their PCB design workflows. Is part of the HyperWorks design and simulation platform. Is for design review; analyzing verifying and assessing physical, logical and electrical attributes. Detects potential manufacturing and electrical issues early in design to reduce design iterations and avoid rework. Identifies issues and boosts production yield with ECAD integration.

Altair
altair.com

FAIRVIEW MICROWAVE QUARTZ RELAY SWITCHES

Quartz series surface-mount failsafe electromechanical relay switches offer frequency bandwidth from DC up to 26GHz. Can manage up to 40W average power during hot switching. Built with failsafe actuators and come in 12V and 24V models. Withstand sine vibration to mechanical shock. Gold-plated mounting surface resists oxidation for prolonged and reliable connection. Lifecycle rating of 5M. Frequency bands range from VHF to UHF to K bands. Insertion loss rates as low as 0.2dB max, high isolation exceeds 50dB, and switching time averages 5ms.

Fairview Microwave

infiniteelectronics.com

KYOCERA DUAL-ENTRY CARD-EDGE CONNECTORS

9159-800 series dual-entry card-edge connectors feature compact form factor equipped with four to 20 beryllium copper compression contacts arranged in two rows with a tight 1mm pitch. Have gold-plated compression contacts that enable solderless installation and exhibit up to 2A of current-carrying capacity per contact. Also exhibit low contact resistance and deliver electrical and mechanical performance suited for harsh environments. Support both top- and bottom-entry mating configurations and have recessed through-board mounting to deliver a 3.5mm profile. For automotive, transportation, industrial manufacturing, consumer electronics and white goods applications. Have white, glass-filled, high-temperature, flame retardant (UL94 V-0) and halogen-free insulators and are rated for up to 150VACRMS or the DC equivalent and operating temperatures extending from -40° to +125°C. Can mate with 1.6mm-thick PCBs with gold-plated pads and are UL and RoHS compliant.

Kyocera AVX

kyocera-avx.com

MODELITHICS COMPLETE+3D LIBRARY FOR KEYSIGHT ADS/RFPRO

Complete+3D Library for Keysight ADS/RFPro combines elements of Keysight ADS and RFPro. Collects circuit simulation models for over 28,000 passive and active devices from more than 75 vendors as well as over 300 full-wave 3-D geometry models, for circuit and systems design. Features advanced-feature models, along with electromagnetic layout analysis, to result in accurate model-to-measurement agreement and fewer design iterations, and uses 3-D models to enhance design analysis and capture electromagnetic interactions between components and surrounding elements.

Modelithics

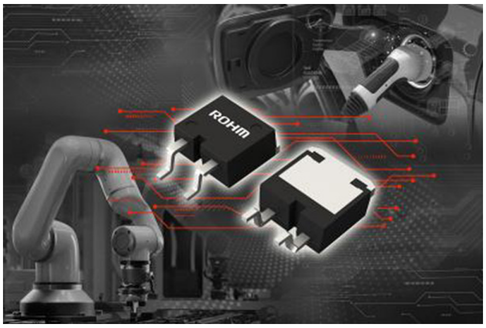
modelithics.com

NANO DIMENSION EXA 250VX DLP 3-D PRINTER

Exa 250vx digital light processing 3-D printer creates high-resolution micro parts at high production throughput. Uses resin-based DLP technology to achieve precise layer heights and exceptional surface finishes for an array of industries and applications, including connectors and other miniaturized components for electronic devices. Features a 100mm x 100mm x 70mm build volume, 7.6µm X-Y resolution, and layer thickness of 10µm.

Nano Dimension

nano-di.com



ROHM SIC SBDS

Surface-mount SiC Schottky barrier diodes (SBDs) improve insulation resistance by increasing the creepage distance between terminals. Original design removes center pin previously located at bottom of package, extending creepage distance to a minimum of 5.1mm, about 1.3 times greater than standard products. Minimizes possibility of tracking (creepage discharge) between terminals and eliminates insulation treatment through resin potting when surface mounting device on circuit boards in high-voltage applications. Can be mounted on same land pattern as standard and conventional TO-263 package products, for easy replacement on existing circuit boards. Comes in two voltage ratings – 650V and 1200V – supporting 400V systems commonly used in xEVs and higher-voltage systems.

Rohm Semiconductor

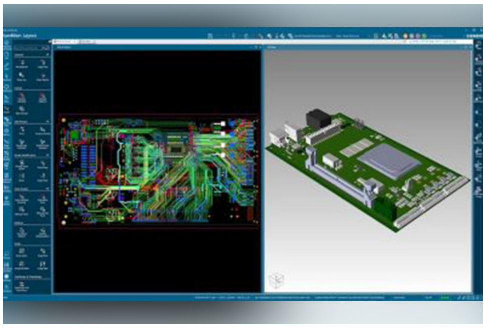
rohm.com

SCHMID HYPER LOOP SYSTEM (HLS) ETCHER

Hyper Loop System for printed circuit board etching combines high efficiency with sustainable benefits. Integrates a unique hybrid nozzle system and eliminates need for external compressed air, for precise and ecofriendly etching of fine structures. Features hybrid nozzles that deliver a thin, even spray pattern. Design promotes precision and reduces maintenance time due to quick nozzle replacement capabilities. Eliminates external compressed air supply, enhancing sustainability and lowering operational costs. Operates without exhaust air treatment requirements, reducing chemical consumption, especially when used with hydrochloric acid, as it eliminates alkali neutralization and minimizes the waste of copper-containing liquids.

Schmid Group

schmid-group.com



SIEMENS AI-ENHANCED DESIGN SOFTWARE

Xpedition, HyperLynx and PADS software are now combined in a unified user experience featuring cloud connectivity and AI capabilities. Adds predictive engineering and new support assistance using AI to enhance engineers' capabilities, and features cloud connectivity to facilitate collaboration and provide access to specialized services and resources. Also brings enhanced integration with Siemens' Teamcenter software for product lifecycle management and NX software for product engineering, allowing for multi-BOM support and tighter collaboration between ECAD and MCAD domains. Offers rigid data access restrictions that can be configured and geo-located, and includes design and verification requirements management for model-based systems engineering support.

Siemens Digital Industries Software

siemens.com

STACKPOLE HCS SERIES SHUNTS

HCS series of shunts offers resistance values as low as 0.1mΩ, for applications requiring high currents while minimizing self-heating during the sensing process. Features power ratings up to 10W at 100°C and is said to deliver reliable operation in demanding environments. Includes a raised resistance element to enhance thermal footprint, reducing PCB and terminal temperatures, with an all-metal construction that provides pulse endurance and supports operation in temperatures up to 170°C.

Stackpole Electronics

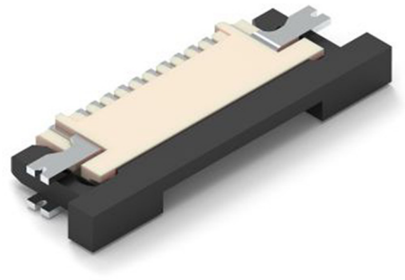
seielect.com

VISHAY TS7 SMD TRIMMERS

TS7 single-turn, surface-mount cermet trimmers are for harsh environments. Feature a 6.7mm x 7mm footprint with a height of 5mm, and are fully sealed to withstand standard board wash processing and ensure reliability in demanding industrial, consumer and telecom environments. Feature a 0.5W power rating at +70°C and come in both top and side adjustment styles. Ohmic range is 10Ω to 2MΩ.

Vishay Intertechnology

vishay.com



WÜRTH WR-FPC ZIF CONNECTOR

WR-FPC ZIF (zero insertion force) connectors are now offered with gold-plated contacts. Offer improved electrical conductivity, wear resistance, corrosion resistance and reliability, and are primarily aimed at connecting flexible printed circuits. Feature identical mechanical properties and polarity to standard series with tin plating, so no design changes are required with upgrade.

Würth Elektronik

we-online.com

CA

EMIL OTTO ETIMOL SW 22 CN STENCIL CLEANER

Etimol SW 22 CN stencil cleaner is a water-based, neutral concentrate developed to promote work safety and cleaning efficiency. Is nonhazardous, simplifying transportation and storage, and is formulated to efficiently remove lead-containing, lead-free, no-clean solder pastes and SMT adhesives on SMT stencils in automatic cleaning systems. Is said to feature good dissolving properties, ensure stable and high-quality cleaning results and rinses well with itself and DI water.

Emil Otto

emilotto.com

GÖPEL MULTI LINE INSPECTION SYSTEMS

Multi Line series of inspection systems support the entire manufacturing process. Modular base system features uniform software interface that reduces training requirements, enables flexible employee scheduling and optimizes knowledge exchange between production staff. Configurable for all inspection tasks throughout the entire manufacturing process: SPI, SMT and THT AOI and CCI. For THT PCBAs, provides flexible transport options, with or without carriers, and all necessary camera modules, as well as THT solder inspection, even during return on the optional lower transport conveyor. Uses 3-D technology to inspect solder joints for quality, shorts volume and pin length without flipping the PCBA. Optional double-sided inspection fully tests SMT assemblies without flipping the PCBA. Comes as an SPI system for inspecting solder paste deposits for shape, height, area, bridges, volume, X/Y offset and coplanarity. For CCI, can automatically inspect protective coatings by making fluorescent coatings glow using UV LEDs of different wavelengths, and features telecentric optics and a color camera to delivers high-contrast images while enabling fast programming using CAD data and coating plans.

Göpel Electronic

goepel.com

INSPECTIS SERIES U50 DIGITAL MICROSCOPE

Series U50 digital camera microscope is a 4K system with 60 FPS for ultra-high resolution applications. Zoom range of 50x, with a sensor for higher sensitivity and a higher dynamic range than previous 4K cameras. Is said to have superior image stabilization. Is compatible with full range of Inspectis accessories and software. For fast-moving inspection or live working tasks.

Inspectis AB

SCIENSCOPE XSPECTION 3120 INSPECTION SYSTEM

Xspection 3120 offline x-ray inspection system is designed for long PCBs. Inspects long or oversized PCBs in a single pass, eliminating need to split inspections across multiple setups and ensuring thorough inspection on all parts of the board. Streamlines inspection process and minimizes need for multiple repositions or manual adjustments, reducing handling risks.

Scienscope

scienscope.com

SCS PRECISIONCURE UVC CURING LINE

PrecisionCure UVC microwave UV curing system now comes in two sizes – 46" and 80". Delivers UV curing performance through programmable profiles, a compact design and Heraeus Noblelight microwave-activated UV lamps. The 46" system is for single-sided curing and is designed to optimize production floor space. Features patent-pending lamp movement trolley for UV exposure control, customizable lamp passes and varying UV dosage across different components of a single board. The 80" unit comes in single- and double-sided configurations for larger production environments. Both models accommodate boards up to 28" long and are equipped with pneumatic inlet/outlet shutters for process control.

Specialty Coating Systems

ULT ACD 400.1 EX EXTRACTION SYSTEM

ACD 400.1 Ex was developed to extract and filtrate dry, flammable and nonflammable gases and vapors in concentrations up to 20% of the lower explosion limit. Comes with an explosion-proof fan in accordance with ATEX Ex II 2G T3, and is a modular, two-stage storage filter device consisting of an M5 dust pre-filter and two adsorption filter modules (activated carbon). Other benefits include quiet operation, low energy consumption and flexibility for changing workplaces or types of emissions. Features electrically conductive filter cassettes with a potential equalization connection and offers a high safety standard for users when changing filters. Also features a T3 blower to ensure safe extraction of gases in temperature classes T1-T3.

ULT

ult-airtec.com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In Case You Missed It

Defect Detection

"MDD-DETR: Lightweight Detection Algorithm for Printed Circuit Board Minor Defects"

Authors: Jinmin Peng, *et. al.*

Abstract: PCBs (printed circuit boards) are the core components of modern electronic devices, and inspecting them for defects will have a direct impact on the performance, reliability and cost of the product. However, the performance of current detection algorithms in identifying minor PCB defects (e.g., mouse bites and spurs) requires improvement. This work presents the MDD-DETR algorithm for detecting minor defects in PCBs. The backbone network, MDDNet, is used to efficiently extract features while significantly reducing the number of parameters. Simultaneously, the HiLo attention mechanism captures both high- and low-frequency features, transmitting a broader range of gradient information to the neck. Additionally, the proposed SOEP neck network effectively fuses scale features, particularly those rich in small targets, while INM-IoU loss function optimization enables more effective distinction between defects and background, further improving detection accuracy. Experimental results on the PCB_DATASET show that MDD-DETR achieves a 99.3% mAP, outperforming RT-DETR by 2% and reducing parameters by 32.3%, thus effectively addressing the challenges of detecting minor PCB defects. (*Electronics*, October 2024, https://doi.org/10.3390/electronics13224453)

Electroplating

"Effect of Matte-Sn Electroplating Parameters on the Thermo-Mechanical Reliability of Lead-Free Solder Joints"

Authors: Abhilaash Ajith Kumar, *et. al.*

Abstract: Most of the Cu/Cu alloy lead-frames of electronic components used for automotive applications contain electroplated matte-Sn terminal finish to improve the wettability of Sn-based Pb-free solders during reflow soldering process. When solder joints are subjected to combined thermal and mechanical cyclic loading, the influence of matte-Sn electroplating parameters can lead to early and brittle failure of the solder joint. To test this hypothesis, a factorial design of experiments (DoE) has been conducted with LFPAK-MOSFET (hereafter referred to as LFPAK) components plated with different matte-Sn electroplating parameters and reflow soldered with two solder alloys (SAC 305 and Innolot). The LFPAK solder joints were then subjected to thermo-mechanical in-phase cyclic loading under different strain amplitudes. No electrical measurement is done to eradicate the effect of electrical current on the

solder joint. The response to the DoE is the crack percentage obtained in the LFPAK solder joints after 1000 and 2000 cycles. Innolot solder joints exhibited lower crack percentages than SAC 305. The level of organic additives in the electroplating process of matte-Sn influences the failure mode of the solder joint. Microstructural investigation attributes the nature of failure to the morphology of the $(Cu,Ni)_6Sn_5$ IMC phase that forms on the component side of the solder joint. (*Journal of Surface Mount Technology*, April 2024, https://doi.org/10.37665/smt.v37i1.46)

Flexible Circuits

"Ambient Printing of Native Oxides for Ultrathin Transparent Flexible Circuit Boards"

Authors: Minsik Kong, *et. al.*

Abstract: Metal oxide films are typically deposited at elevated temperatures by using slow, vacuum-based processes. The authors printed native oxide films over large areas at ambient conditions by moving a molten metal meniscus across a target substrate. The oxide gently separates from the metal through fluid instabilities that occur in the meniscus, leading to uniform films free of liquid residue. The printed oxide has a metallic interlayer that renders the films highly conductive. The metallic character of the printed films promotes wetting of trace amounts of evaporated gold that would otherwise form disconnected islands on conventional oxide surfaces. The resulting ultrathin (<10nm) conductors can be patterned into flexible circuits that are transparent, mechanically robust and electrically stable, even at elevated temperatures. (*Science*, August 2024, https://doi.org/10.1126/science.adp3299)

Soft Electronics

"Soft Electronic Vias and Interconnects through Rapid Three-Dimensional Assembly of Liquid Metal Microdroplets"

Authors: Dong Hae Ho, *et. al.*

Abstract: The development of soft electronics requires methods to connect flexible and stretchable circuits. With conventional rigid electronics, vias are typically used to electrically connect circuits with multilayered architectures, increasing device integration and functionality. Creating vias using soft conductors leads to additional challenges, however. Here the authors show that soft vias and planar interconnects can be created through the directed stratification of liquid metal droplets with programmed photocuring. Abnormalities that occur at the edges of a mask during ultraviolet exposure are leveraged to create vertical stair-like architectures of liquid metal droplets within the photoresin. The liquid metal droplets in the uncured (liquid) resin rapidly settle, assemble and then are fully cured, forming electrically conductive soft vias at multiple locations throughout the circuit in a parallel and spatially tunable manner. The authors' three-dimensional selective stratification method can also form seamless connections with planar interconnects, for in-plane and through-plane electrical integration. (*Nature Electronics*, October 2024, https://doi.org/10.1038/s41928-024-01268-z)