

pcdandf.com
circuitsassembly.com
October 2026

PRINTED CIRCUIT DESIGN & FAB CIRCUITS ASSEMBLY

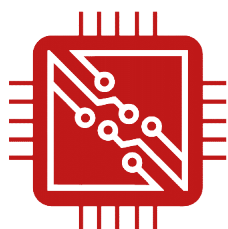
BETTING *on the* RIGHT HAND

The Annual NTI-100:
Which Tech Will Win?



This issue of PRINTED CIRCUIT DESIGN & FAB/CIRCUITS ASSEMBLY is brought to you by:

Want an Instant **FULL TURNKEY** Quote online?



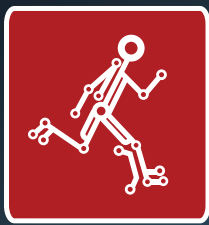
PCB TRACE

20 YEARS OF MANUFACTURING
EXPERIENCE WITH BLIND AND BURIED
VIAS, RIGID FLEX & FLEX PCB

Visit [PCBTrace.com](https://www.pcbtrace.com) and
get up to **\$1500** in discounts.

[Click to learn more](https://www.pcbtrace.com)

PCB Trace provides instant quotes on multiple sets
of quantities within minutes.

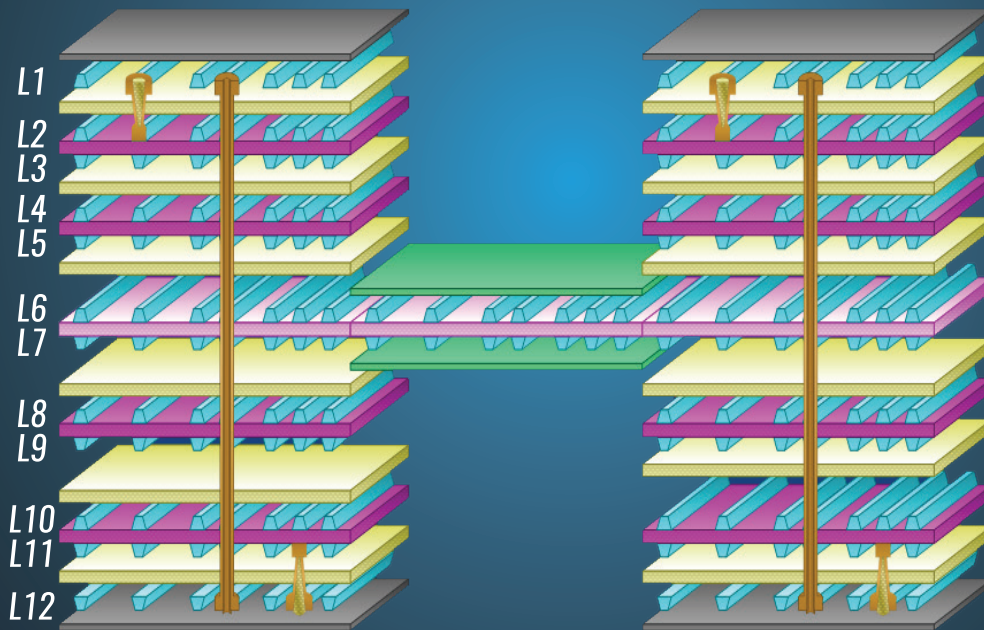


RUSHPCB

20 YEARS OF MANUFACTURING EXPERIENCE WITH
BLIND AND BURIED VIAS, RIGID FLEX & FLEX PCB
ELECTRONIC DESIGN, & QUICK TURN CIRCUIT
BOARDS, ASSEMBLY & FULL TURNKEY

Multilayer PCB Stackup

12 Layer Flex Rigid, 0.030" Thick Rigid, 0.008" Thick Flex
Blind Via L1-L2 & L11-L12, 0.003" Hole, Resin Filled,
0.002"/0.002" Trace/Space, Controlled Impedance



Manufactured on August 2016

When you're in a rush call **RUSH PCB**

Affordable Pricing ★ Satisfaction Guarantee ★ Fast Response ★ Free Quote ★ Fast Shipping
HDI Boards ★ Stacked Micro Vias ★ 2 mil line & Space ★ Flex & Rigid Flex

Located in the Silicon Valley
PCB up to 12 Layers in 3 days
PCB Assembly Same Day Turn
Full Turnkey Service

Certified: ISO9001/ITAR/UL

www.rushpcb.com | Sales@rushpcb.com | 1 408 496 6013
Rush PCB Inc, 2149-20 O'Toole Ave, San Jose, CA 95131, U.S.A

FIRST PERSON

CAVEAT LECTOR

The balance has shifted.

Andy Shaughnessy

MONEY MATTERS

ROI

UHDl changes the rules.

Peter Bigelow

BOARD BUYING

Earn the Mercedes treatment.

Greg Papandrew

FOCUS ON BUSINESS

AI needs adult supervision.

Susan Mucha

TECH TALK

DESIGNER'S NOTEBOOK

Make every micron count.

John Burkert, Jr.

ECAD TIPS & TRICKS

Prevent late-stage part surprises.

David Haboud

MATERIAL GAINS

Software still needs hardware.

Alun Morgan

THE FLEXPERTS

Design decisions drive cost.

Nicholas Koop

TECHNICAL ABSTRACTS

DEPARTMENTS

AROUND THE WORLD**PCEA CURRENT EVENTS****MARKET WATCH****OFF THE SHELF**

PRINTED CIRCUIT DESIGN & FAB CIRCUITS ASSEMBLY

FEATURES

NTI-100 (COVER STORY)**AI is Reshaping the PCB Industry**

Advanced substrates and high-layer-count boards for AI hardware have replaced smartphones and PCs as the PCB industry's primary growth engine, rewarding fabricators that invested early in the right technologies and capacity.

by DR. HAYAO NAKAHARA

VIA MANAGEMENT**Managing Vias in Very High Data-Rate Differential Pairs**

Careful selection, placement and modification of via structures can limit signal degradation and help very high-speed differential pairs operate reliably at data rates reaching 56Gb/s.

by LEE RITCHEY

ELECTRICAL ORIGINS**The Electron: A Biography and the Emergence of Soldering**

The story of the electron traces how discoveries in electricity and electromagnetism led to advances in telegraphy, telephones and electric lighting while laying the scientific and technological foundation for modern soldering.

by RONALD C. LASKY

CONNECTED PRODUCTION**How Electronics Complexity Is Changing SMT Manufacturing**

Connected equipment, automated inspection, material management and production data are transforming SMT manufacturing as assemblers respond to denser designs, smaller components and increasingly complex product mixes.

by SCOTT ZERKLE

SMARTER MONITORING**Building Your Own IoT: Equipment Monitoring for New and Legacy Systems**

PCB fabricators can combine affordable IoT monitoring with AI-assisted development to track equipment behavior, troubleshoot installations, identify emerging problems and create useful operating records for both new and legacy systems.

by SEAN PATTERSON



ON PCB CHAT (PCBCHAT.COM)

 **PCB Chat**

HDP USER GROUP ANNUAL UPDATE

with MADAN JAGERNATH

THE HIDDEN CAUSES OF ADHESION FAILURE

with DAVID DWORAK

DESIGN GUIDE

cādence®

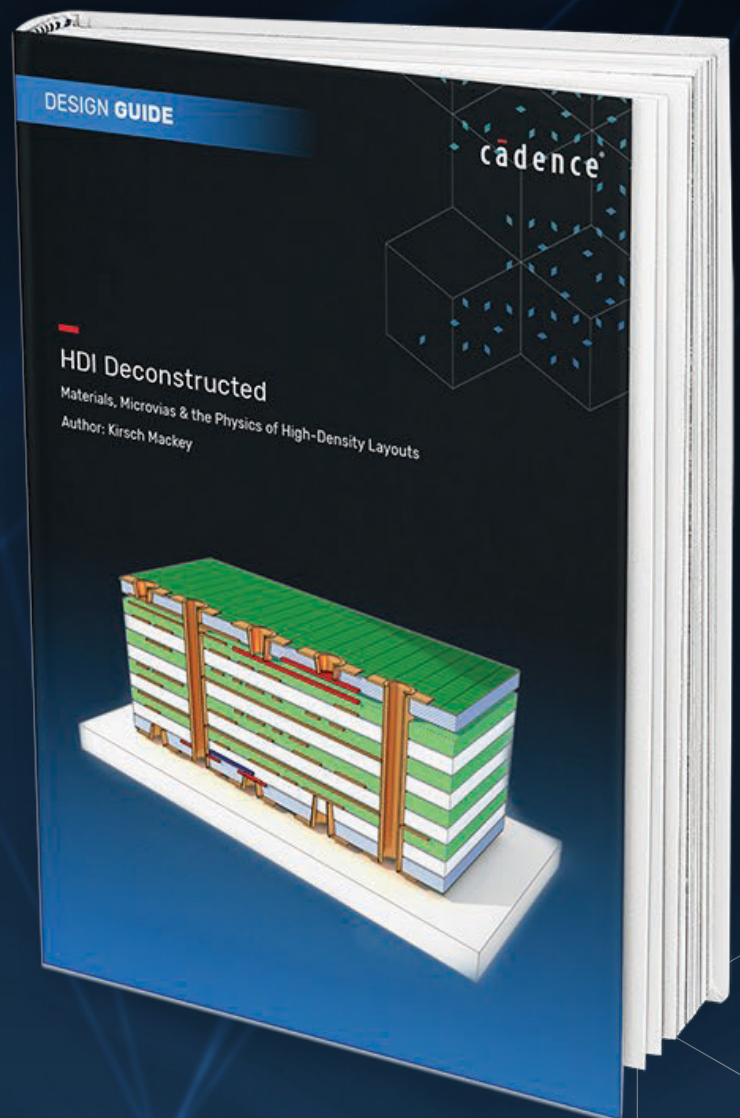
HDI Deconstructed

Materials, Microvias & the Physics
of High-Density Layouts

Get the “why” behind HDI design challenges.
Learn the critical tradeoffs that influence
reliability, performance, yield, and
production success.



Read the HDI Guide Now >>





Printed Circuit Engineering Association

PCEA
PO BOX 237
PORTSMOUTH, NH 03802

PCEA BOARD OF DIRECTORS

Stephen V. Chavez, CHAIRMAN
Susy Webb, VICE CHAIRMAN
Justin Fleming, SECRETARY
Anaya Vardya, TREASURER

MEMBERS

Jim Barnes
Michael Buetow
Tomas Chester
Douglas Dixon
Juan Frias
Richard Hartley
Matthew Leary
Charlene McCauley
Eriko Yamato

PCEA.NET

THE PRINTED CIRCUIT ENGINEERING ASSOCIATION, INC. BRANDS:

PUBLICATION

PCD&F/Circuits Assembly.....digital.pcea.net

WEBSITES

PCD&F.....pcdandf.com

Circuits Assembly.....circuitsassembly.com

NEWSLETTER

PCB Update.....pcbupdate.com

PODCASTS

PCB Chat.....pcbchat.com

EVENTS

PCB West.....pcbwest.com

PCB East.....pceast.com

EDUCATION

PCEA Training.....pceatraining.net

Printed Circuit University.....pcea.net/pcu

AWARDS PROGRAMS

Service Excellence Awards.....pcea.net/sea-awards

NPI Awards.....pcea.net/npi-awards

PRINTED CIRCUIT DESIGN & FAB CIRCUITS ASSEMBLY

pcdandf.com

circuitsassembly.com

MANAGEMENT

PRESIDENT

Mike Buetow 617-327-4702 | mike@pcea.net

VICE PRESIDENT, SALES

Brooke Downey 404-316-9018 | brooke@pcea.net

SENIOR DIRECTOR, STRATEGIC ACCOUNTS

Frances Stewart

PCD&F/CIRCUITS ASSEMBLY EDITORIAL

MANAGING EDITOR

Ryann Howard 912-803-9780 | ryann@pcea.net

CONTENT ARCHITECT

Andy Shaughnessy 770-315-9901 | andy@pcea.net

COLUMNISTS AND ADVISORS

Jeffrey Beauchamp, Dan Beaulieu, Peter Bigelow, Robert Boguski, John Burkert, Jr., Stephen V. Chavez, Mark Finstad, Nick Koop, Jake Kulp, Alun Morgan, Susan Mucha, Greg Papandrew, Hemant Shah, Chrys Shea, Jan Vardaman, Gene Weiner

PRODUCTION

ART DIRECTOR & PRODUCTION

blueprint4MARKETING, Inc. | production@pcea.net

Nathan Hoeller | nathan@pcea.net

SALES

VICE PRESIDENT, SALES

Brooke Downey 404-316-9018 | brooke@pcea.net

SENIOR SALES EXECUTIVE

Will Bruwer 404-313-1539 | will@pcea.net

EVENTS/TRADE SHOWS

EXHIBIT SALES

Brooke Downey 404-316-9018 | brooke@pcea.net

TECHNICAL CONFERENCE

Mike Buetow 617-327-4702 | mike@pcea.net

WEBINARS

Andy Shaughnessy 770-315-9901 | andy@pcea.net

EVENTS MANAGEMENT

Leah Spinks 912-239-7730 | leah@pcea.net

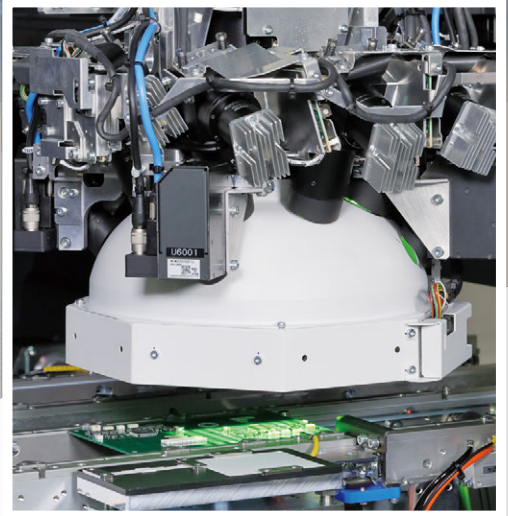
PRINTED CIRCUIT DESIGN & FAB/CIRCUITS ASSEMBLY is distributed without charge to qualified subscribers. To subscribe, visit pcdandf.com or circuitsassembly.com and click on Subscribe. For changes or cancellations to existing subscriptions: subscriptions@pcea.net



PRINTED CIRCUIT DESIGN & FAB/CIRCUITS ASSEMBLY is published monthly by Printed Circuit Engineering Association, Inc., PO Box 237, Portsmouth, NH 03802. ISSN 1939-5442. GST 124513185/Agreement #1419617.

© 2026, Printed Circuit Engineering Association, Inc. All rights reserved. Reproduction of material appearing in PRINTED CIRCUIT DESIGN & FAB/CIRCUITS ASSEMBLY is forbidden without written permission.

REDUCE PROGRAMMING TIME AND DEFECTS WITH YAMAHA'S AI ENHANCED AOI



- + Fastest 3D Automated optical inspection on the market today!
- + Resolution for narrow pitch 0201mm devices.
- + New co-axial lighting system for finding defects on reflective surfaces.
- + AI Automatic Secondary Inspection reduces false call rates and operator interaction
- + AI Based **Automatic Data Generation and Auto Component Programming** dramatically reduces the time to create new inspection tasks.



◀ **SCAN THE QR CODE®
FOR MORE INFO**
Messaging and data
rates may apply.



Yamaha can meet the challenges of almost any product that is on the market today.

DON'T MISS THE OPPORTUNITIES FOR THESE NEW TECHNOLOGIES!

Learn more at www.yamaha-motor-im.com
For inquiries: y-sales@yamaha-motor.com



China and Taiwan Expand Lead in PCB Fabrication

This month, Nakahara's NTI-100 breaks down the revenue for the world's top fabricators.

IT'S FALL, AND our thoughts turn to pumpkin spice, Halloween decorations and Dr. Hayao Nakahara's NTI-100.

Many of us look forward to the NTI-100. It provides a detailed snapshot of the biggest companies in the PCB fabrication segment that you just can't find anywhere else. No one but "Naka" has this much information, in this much detail, about so many fabricators around the world. Naka has followed these data since America was a world leader in PCB fabrication, and he can relate these new data back to the historical trendlines that got us here.

Naka estimates global bare-board output around \$104 billion for 2025, with total output expected to hit \$135 billion this year. A total of 168 fabricators cracked \$100 million in 2025 revenue, totaling \$101.8 billion, but the top 30 alone pulled in 61.6% of that. The top 60 earned nearly 80%.

The list of top players is top-heavy. China alone produced \$69.5 billion worth of PCBs, plus another \$20 billion from Taiwanese-owned plants. TTM is the lone standard-bearer for the US. Naka also notes that these 168 fabricators still represent only 7% of the world's 2,500 fabricators.

The US and Japan stand out for their absence near the top of the list, and China and Taiwan are running the show now. Naka illustrates just how far the mighty have fallen when he compares his newest numbers to his data from 26 years ago.

Looking back at the NTI-100 in 2000, I'm reminded of the theme from *All in the Family*, "Those Were the Days." Back in 2000, American and Japanese fabricators were the envy of the world. In 2000, only four fabricators cleared \$1 billion in revenue, split evenly between the US and Japan. Today, Taiwanese and Chinese fabricators dominate the top ranks of billion-dollar fabricators.

Last year, 29 fabricators hit that number, and only two of them – TTM and AT&S – are not Asian. Of the Top 30 fabricators from 2000, 13 are gone or acquired. The US fell from eight spots in the Top 30 to just one: TTM. Japan went from 12 down to four, losing \$1.4 billion in revenue to Taiwanese and Korean buyers over the years.

Also, this year, the NTI-100 confirms what many of us suspected: PCs and smartphones aren't the biggest drivers in PCB manufacturing anymore. AI is now the No. 1 growth driver in this segment. In 2025, the biggest growth in PCB

fab came from advanced IC substrates and high-layer-count boards destined for AI hardware required by hyperscalers like Google, Meta, AWS and Microsoft.

AI boards are eating up capacity at the most advanced PCB fabricators, and it's not likely to stop anytime soon. If these hyperscalers don't double their demand for AI hardware PCBs in 2027, I'll be surprised. Some of you are no doubt thinking, "AI is taking over by way of PCB capacity. We're doomed!"

Remember that this is all relative. These numbers pale in comparison to the revenue on the chips side of things. As Naka says, analysts expect semiconductor output to hit \$1.5 trillion in 2026. That's 1.5 Elons.

Yes, our industry has changed quite a bit since 2000. US fabricators are no longer the world leaders in revenue they used to be. But American fabricators, though few in number, tend to be focused on advanced, high-tech PCBs. They've survived multiple downturns and Covid. They have solid business plans, and they're investing in new technology without expanding too fast or taking on too much debt. They're avoiding the self-inflicted wounds that crippled many of their former competitors. Congress and the White House finally seem to understand the importance of a strong domestic PCB fab base.

But for now, as sportscaster Red Barber would say, China and Taiwan are sitting in the catbird seat.



ANDY SHAUGHNESSY is content architect of PCD&F/Circuits Assembly; andy@pcea.net.

Built for change.

The world is constantly changing. Now faster than ever. From rapid tech shifts to climate pressure. From geopolitical uncertainty to new production methods. Today, stability comes from agility. That means having a supply chain that can adapt to your needs - fast. And PCB production is no exception.

NCAB is built for change. For over 30 years, we have been producing PCBs and taking full responsibility — without owning any factories. Instead, we constantly source, qualify and develop the most optimal ones across three continents. And we only use them where they excel.

In other words: You will always have more than one option for your PCB production. So when things change, you can too. Fast.

Reliable PCBs. Resilient supply chain.

Read more here:
ncabgroup.com/sustainable-business/



Element Solutions, Solstice Terminate Merger Agreement

MIAMI – Element Solutions and Solstice Advanced Materials have mutually terminated their proposed merger following shareholder feedback and discussions between the companies.

The companies' boards determined that operating as separate businesses would better serve their respective shareholders. Neither company will make a termination payment under the agreement.

Element Solutions said it will continue its strategy centered on operational execution, capital allocation and product development. The company supplies specialty chemicals for semiconductor fabrication, computing, automotive, communications, aerospace and industrial applications. 

Calumet Opens \$55M Organic Substrate Facility

CALUMET, MI – Calumet Electronics has opened its \$54.7 million Center for Advanced Substrate Technology, a panel-level organic substrate manufacturing facility that the company says is the first dedicated operation of its kind in the United States.

The facility includes Class 1000 cleanrooms and combines semi-additive processing and embedded trace technologies on a single platform. It will produce advanced substrates for radar, electronic warfare, AI computing and 5G/6G communications.

The project was developed with more than 25 industry, government and education partners and is intended to expand domestic substrate production while reducing reliance on overseas suppliers. 

ICTC Philippines Opens Manufacturing Facility in Laguna

BIÑAN, PHILIPPINES – Interconnect Cable Technologies Corporation has opened a manufacturing facility in Laguna Technopark to expand its electronics manufacturing capacity in the Philippines.



Figure 2. ICTC Philippines' new electronics manufacturing facility in Laguna Technopark.

ICTC Philippines provides cable and wire harness assembly, PCB assembly, box-build testing and product integration services for commercial and industrial applications. The facility will provide additional capacity and resources as customer requirements expand.

A formal inauguration is scheduled for Oct. 23 and will include members of ICTC's global team, customers and industry partners. 

SEL to Invest \$150M in Idaho Manufacturing Plant

NAMPA, ID – Schweitzer Engineering Laboratories plans to invest more than \$150 million in a 103,000-sq.-ft. manufacturing plant in Nampa, with operations scheduled to begin in 2027.

The company expects the facility to create approximately 250 jobs initially while increasing production capacity and shortening lead times for products used to protect electrical grids and improve power-system reliability.

The Nampa operation will join SEL's existing Idaho manufacturing facilities in Lewiston and Moscow and represents the company's fourth major manufacturing expansion in two years. 

Ondas Acquires Gate, Bron Technologies for \$205M

WEST PALM BEACH, FL – Ondas has acquired Gate Technologies and Bron Technologies for \$205 million, expanding its electronic safe-and-arm and fuzing capabilities for defense applications.

Gate develops electronic safe-and-arm devices and fuzing technologies for UAVs, loitering munitions, missiles and rockets. Bron adds manufacturing and certification operations in Poland, giving the combined business a NATO-based production presence in Europe.

Ondas expects the acquired businesses to generate \$65 million in revenue in 2026 and \$180 million in 2028. The agreement includes up to an additional \$185 million in performance-based consideration tied to financial targets through 2028. 

Syrma SGS, Elemaster Form India Manufacturing JV

BENGALURU, INDIA – Syrma SGS Technologies and Elemaster have formed a joint venture to establish an electronics manufacturing operation in Bengaluru.



Figure 3. Syrma SGS and Elemaster form a joint venture to establish an electronics manufacturing facility in Bengaluru, India.

The venture, Syrma SGS Elemaster Pvt. Ltd., will operate a 20,000-sq.-ft. facility in the Bommasandra Industrial Area with SMT, through-hole technology and box-build assembly lines.

The operation will serve railway, industrial and medical electronics customers, combining Syrma SGS's manufacturing capabilities with Elemaster's design expertise and European OEM relationships. 

Flex to Acquire EPC Power for \$4.4B

AUSTIN, TX – Flex has entered into a definitive agreement to acquire EPC Power for \$4.4 billion, adding power-conversion technologies for AI data centers, energy storage and grid applications.

EPC Power develops hardware, software and control systems supporting rectifiers, DC-DC conversion and next-generation 800V data-center architectures. The company has more than 15GW deployed across 62 countries and expects US manufacturing capacity to exceed 30GW in 2027.

The transaction is expected to close in the fourth quarter, subject to regulatory approvals. EPC Power will join Flex's Cloud and Power Infrastructure segment, which Flex plans to separate into an independent publicly traded company in early 2027. 

Microscreen Opens Connecticut SMT Stencil Facility

OXFORD, CT – Microscreen has opened an 8,000-sq.-ft. manufacturing facility in Oxford to expand SMT solder stencil production and service capabilities in the northeastern United States.



Figure 4. Microscreen's new 8,000-sq.-ft. SMT solder stencil manufacturing facility in Oxford, CT.

The facility offers 24-hour stencil turnaround and places customers from Maine to Philadelphia within one-day ground shipping range. Equipment includes a Tannlin T11 laser capable of cutting approximately 10,000 to 15,000 apertures per hour and a Watt Laser SE12 Pro for inspection, step welding and aperture measurement.

The site manufactures multiple frame and foil systems, including VectorGuard, Apshen, QTS Wizard and rework stencils. 

Kitron Plans New Denmark Manufacturing Facility

HORSENS, DENMARK – Kitron plans to build an 8,850-sq.-m. electronics manufacturing facility in Horsens to support anticipated growth and demand for localized production.

The company-owned plant will replace Kitron's existing Horsens operation and feature a manufacturing layout designed to improve production efficiency and workflows for regulated and high-reliability markets.

Construction is expected to begin in January 2027, with operations scheduled to start in early 2028. Kitron plans to increase staffing at the location from approximately 150 to 250 employees once the plant is fully utilized. 

TFE Acquires Tekena USA

SCHAUMBURG, IL – TFE has acquired Tekena USA, expanding its North American portfolio of particle-removal and surface-cleaning technologies for precision manufacturing.

The acquisition adds sheet and web cleaning systems, contact-cleaning equipment, adhesive rolls, manual products, consumables and related services. The technologies remove dust, fibers and other contaminants that can affect product quality, process consistency and yield.

Applications include PCB manufacturing, SMT, coating, lamination, battery production, printing and solar manufacturing. Tekena customers and distributors will receive continued product and technical support through TFE's existing teams. 

MBK, FormFactor Complete \$661M FICT Acquisition

LIVERMORE, CA – A consortium led by MBK Partners has completed its acquisition of Japanese PCB manufacturer FICT from Advantage Partners in a transaction valued at approximately \$661 million.

MBK acquired an 80% interest in FICT, while FormFactor invested approximately \$60 million. Formerly a Fujitsu subsidiary, FICT manufactures high-density printed circuit boards for high-speed data transmission, semiconductor and high-performance computing applications.

The investors expect FICT to benefit from increasing demand for AI data centers, advanced packaging and high-speed communications. FormFactor said the investment will also secure access to technologies used in advanced probe cards. 

NCAB Expands into Australia with IMP Acquisition

ADELAIDE, AUSTRALIA – NCAB Group has agreed to acquire the operations of IMP Electronics Solutions, expanding the PCB supplier's presence into Australia and New Zealand.

The transaction includes IMP's 12 employees in Australia and China and is expected to close in the fourth quarter. Founded in 1964, IMP supplies printed circuit boards to industrial and defense customers and generated approximately \$9 million in sales during its 2026 financial year.

NCAB will pay an initial \$4 million plus a performance-based earnout. The acquisition is expected to contribute positively to the company's results in 2027 through supplier, logistics and sales synergies. 

TM Soldering Solutions Opens Process Development Lab

SPOKANE VALLEY, WA – TM Soldering Solutions has opened a Selective Soldering Process Development Lab at its 10,000-sq.-ft. manufacturing facility in Spokane Valley.

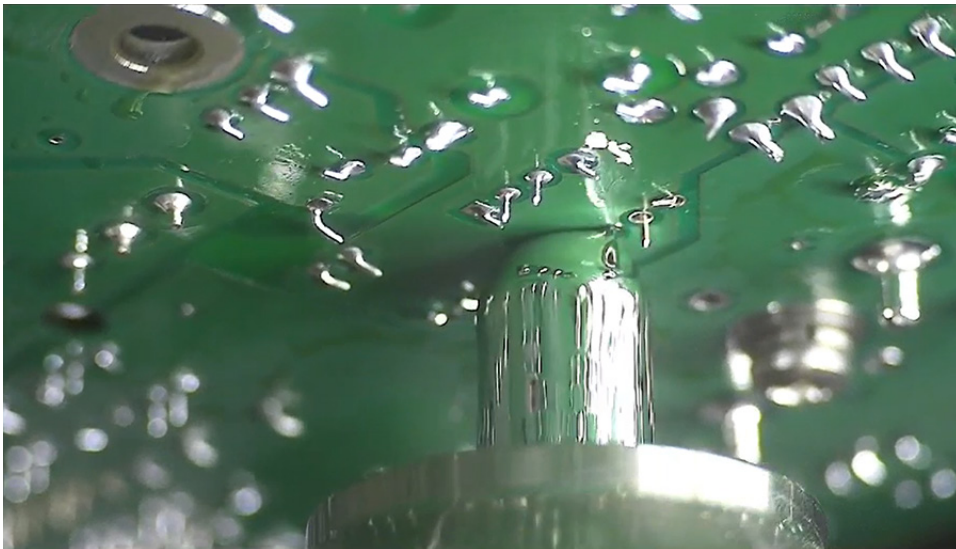


Figure 1. TM Soldering Solutions' new Selective Soldering Process Development Lab in Spokane Valley, WA.

The lab will allow customers to test circuit boards, troubleshoot manufacturing challenges and develop selective soldering processes with support from former ACE Production Technologies engineers, builders and technicians.

TM initially operated as a parts and service provider specializing in replacement parts, repairs and refurbishment for KISS Gen 1 and Gen 2 selective soldering machines. Its team has collectively designed, built, installed and supported more than 1,200 machines. 

PCD&F

Arxis acquired **StratEdge**, a manufacturer of specialized semiconductor packages for aerospace, defense, medical and industrial applications.

AT&S and **Marvell Technology** expanded their collaboration to support next-generation AI infrastructure.

Gold Circuit Electronics plans to invest approximately \$436 million in a new PCB manufacturing plant at Taiwan's Zhongli Industrial Park.

Morimaru raised \$15 million to develop chip-based passive components for AI networks.

TracXon is scaling production of hybrid printed electronics and flexible circuits using an additive manufacturing process. 

CA

Absolute EMS installed a **Pillarhouse** Jade S-200 MKII selective soldering system at its Santa Clara, CA, facility.

Aimtron Electronics secured a pilot order from **Curtiss-Wright** for electronics manufacturing and engineering services.

Aimtron's US arm reported \$11 million in orders.

AMC Robotics plans to enter trial production at its Vietnam manufacturing facility buildout, which is targeting \$30 million in annual production capacity.

Arch Systems secured \$30 million from **Vistara Growth** to accelerate its agentic AI manufacturing intelligence platform.

Escatec established in-house BPA-free plastic component manufacturing at its Johor Bahru facility.

Microscreen and **AGI Corporation** launched the **Microscreen AGI Alliance**.

Miltronik invested in a **Yamaha Robotics** YRi-V 3D AOI system.

Neoway Technology partnered with **Zetwerk** for made-in-India IoT manufacturing, including SMT production.

OSI Systems received approximately \$8 million in orders for electronic assemblies used in test and measurement solutions.

Pillarhouse USA appointed **BRL Marketing & Sales** as its manufacturers' representative for Illinois and Wisconsin.

Promex Industries added a **Koh Young** Zenith Alpha 3D AOI system.

Renesas opened a physical AI and robotics laboratory in Beijing.

Scanfil implemented a fully automated electronics testing cell at its Wutha, Germany, production facility.

Seho Systems named **NMTronics** its distributor in India.

SK Hynix is reportedly in discussions with **Intel** to manufacture memory chips in the United States.

YFore opened a US manufacturing facility in Georgia. 

SIEMENS

AI-enabled electronic systems design

Xpedition

Harness one integrated flow from schematic to manufacturing-ready

HyperLynx

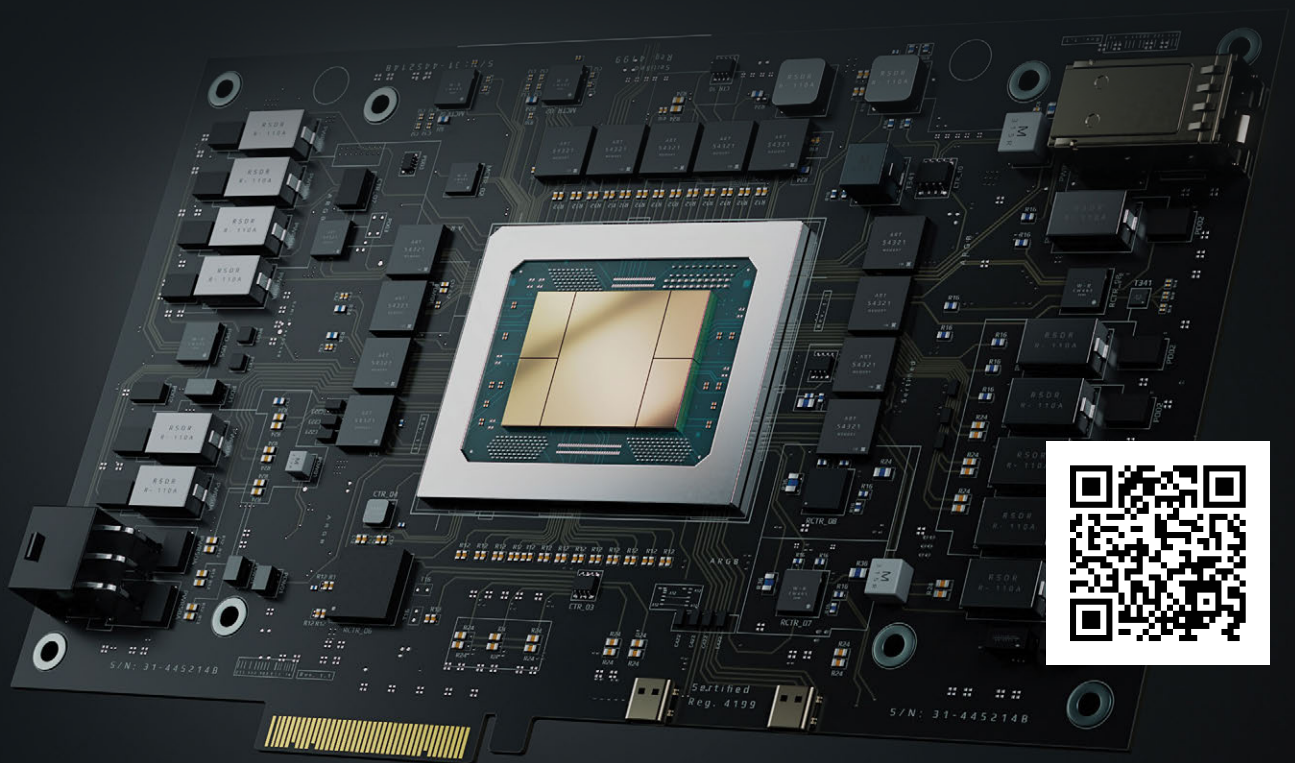
Ensure a first pass success with high-speed signal and power integrity analysis

Valor

Bridge the gap with a digital thread from design to manufacturing

The #1 solutions provider for your most complex designs*

* Figure P 1, Pedestal Research, Feb 2025



PCDF



Eli Yaffe



Ron Freund



Kevin Pelletier



Tara Taylor



Marissa Oskarsen



Joseph Bates

Anduril Industries promoted **Rio Schad** to staff radar PCB designer.

Eltek CEO **Eli Yaffe** will retire Sept. 23, with CFO **Ron Freund** succeeding him as CEO while continuing as CFO until the company names a replacement.

Infineon Technologies (Wuxi) named **Kevin Pelletier** sustaining product engineer.

Intuitive Machines named **Tara Taylor** PWB designer.

Omni PCB named **Marissa Oskarsen** supply chain manager.

Quilter named signal integrity expert **Eric Bogatin** its first technical fellow.

Rockwell Collins named **Joseph Bates** principle ECAD engineer. 

CA



Mandeep Chawla



Corinne Baker



Kanhu Panda



Loïc Biarez



Rafael Matute

Celestica named **Mandeep Chawla** group president, global markets, and **Todd Ankenmann** will succeed him as chief financial officer.

Jabil promoted **Corinne Baker** to senior director supply chain management.

Koh Young America appointed **Brent Johnson** Western regional sales manager.

Kyzen named **Kanhu Panda** regional manager for India.

Luminovo has named Buymanager founder **Loïc Biarez** to its ambassador network.

ViTrox appointed **Rafael Matute** service manager for Mexico. 🇲🇽

THE **NEXT** REVOLUTION OF SOLDER



Durafuse[®] LT

- ✓ Low-temperature reflow to help eliminate HIP & bridging on large size BGAs
- ✓ Enhanced thermal cycle reliability in harsh conditions
- ✓ Reflow temperature 205–260°C



Durafuse[®] HR

- ✓ Enhanced thermal cycling performance
- ✓ Superior voiding performance
- ✓ Reflow temperature 235–260°C



INDIUM 12.9HF

- ✓ Engineered for fine-pitch assemblies, delivering high transfer efficiency & superior SPI yields
- ✓ High oxidation resistance to eliminate graping in air reflow
- ✓ Low BGA, CSP, LGA, and QFN voiding



indium.com
**From One Engineer
To Another[®]**

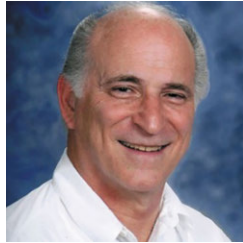
©2026 Indium Corporation



Ferrari, Hartley, Nakahara and Webb Named PCEA Lifetime Achievement Winners



Rick Hartley



Gary Ferrari



Susy Webb



Hayao Nakahara

SANTA CLARA, CA – PCEA named Rick Hartley, Susy Webb, Gary Ferrari and Hayao Nakahara recipients of the PCEA Lifetime Achievement Award.

The award is presented in recognition and with great appreciation for their years of loyalty and dedicated service to the printed circuit industry, advancing technology through shared knowledge, leadership, and collective excellence.

The announcement was made at the PCEA annual meeting in conjunction with the PCB West conference and exhibition.

Hartley was one of the cofounders of PCEA in 2020 and was the first chair of its Conferences Task Group. He also reviewed much of the reference material in the Education section of PCEA's website. In his 50 years in the electronics design industry, Hartley has become a go-to for training on signal integrity, noise control and EMI. He is the most popular speaker in the history of the PCB West conference and coauthored the Certified Printed Circuit Engineer curriculum.

"Rick Hartley's name is synonymous not only with design engineering but, even more importantly, with sharing what you know with your industry peers and colleagues," said Mike Buetow, president, PCEA, in announcing the awards. "He is a bright example of the power of determination and positivity, and he embodies the best in what PCEA offers its members and the industry."

A senior PCB designer with 40 years of experience, Webb is synonymous with PCB East and PCB West, where she has taught for nearly 20 years. She is a former writer and columnist for PCD&F, a chapter author for Clyde Coombs' *Printed Circuits Handbook*, and a judge for the annual Siemens TLA competition.

For PCEA, Webb is vice chairman of the Executive Board and a member of the Education Committee and

Conferences Task Group. She has been one of the most popular presenters in the history of the PCB East and PCB West technical conferences and a significant contributor to the PCEA Training Design Certification curriculum.

“For going on four decades, Susy Webb has epitomized what giving back to the industry is all about,” Buetow said. “Name the job in the printed circuit industry, and Susy has done it. Her utmost professionalism, her willingness to help anyone at any time, and her ability to always think in terms of both the short and long term have been invaluable, and she is a strong leadership voice and mentor across the organization.”

Ferrari is also one of the founding members of PCEA. His experience promoting the design profession dates to the early 1990s and the formation of the Designers Council, of which he was executive director for more than a decade. He later charted the path that became PCEA and was key in developing the organization’s charter and mission.

“Gary Ferrari is perhaps the person most responsible for PCEA’s early credibility, and he was a strong voice that PCEA be open to working with anyone,” Buetow said. “For two generations, Gary was the go-to for designers worldwide, and his energy and passion for the industry will likely never be matched.”

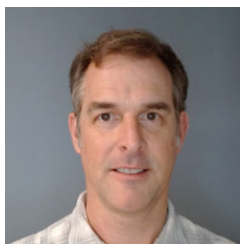
Nakahara is the leading authority on the printed circuit marketplace, visiting scores of board shops across four continents each year. For more than 30 years, he has produced the NTI-100 list of the largest board fabricators, along with reams of additional data on the market. His annual report is one of the most-read publications in *PCD&F/CIRCUITS ASSEMBLY* each year.

“Hayao Nakahara’s market research has been an invaluable service to business leaders and marketers for planning and strategy,” Buetow said. 

Dodd, Leary and Burns Receive 2026 PCEA Leadership, Membership Awards



Ed Dodd



Matt Leary



Michael Burns

SANTA CLARA, CA – The Printed Circuit Engineering Association in September announced Edward Dodd and Matthew Leary as recipients of the annual PCEA Leadership Award for their development of the PCB design roadmap for the US government.

PCEA also named Michael Burns the recipient of the fifth annual PCEA Membership Award for his dedication toward growing the PCEA membership.

The announcement was made at the PCEA annual meeting in conjunction with the PCB West conference and exhibition.

Dodd and Leary led the development of the PCB Design Roadmap, a document prepared for the PCB Executive Agent to the Undersecretary of the Navy. The document details the current and projected status of design technology and workforce over the next 10 years, identifying gaps, needs, and recommendations.

“Ed Dodd and Matt Leary have given the PCB design community a voice it has long been missing,” said Mike Buetow, president, PCEA, in announcing the award. “For too long, printed circuit design has been invisible in Washington. The roadmap puts the discipline in front of the people who set national priorities for electronics, and gives lawmakers a clear picture of what it takes to keep design talent and capability in the US. That is leadership in the truest sense.”

Burns is leader of the PCEA Richmond (VA) chapter. He launched the chapter in 2025 and has spearheaded regular meetups for hardware engineers and designers.

“Michael Burns has been a great ambassador for PCEA. Growing a professional community takes persistence, one conversation and one meeting at a time, and Michael has put in that work. It gives me great pleasure to recognize him with the PCEA Membership Award,” Buetow said. 

‘PCB Basics’ Now Available in Spanish

PEACHTREE CITY, GA – The sixth edition of *PCB Basics: An Introduction to the PCB Industry*, is now available in Spanish, Printed Circuit Engineering Association announced.

The book is available for free download to all PCEA members.

The new edition includes a chapter on high-density interconnect (HDI) and ultra high-density interconnect (UHDI). There is also a chapter on artificial intelligence and its applications – and potential applications – in PCB design, fabrication, assembly, test, inspection and procurement.

First published over 40 years ago, *PCB Basics* is a primer for anyone just getting involved with the industry: recent graduates, technicians, operators, sales and marketing professionals, procurement teams, and anyone else whose work involves PCBs.

To download *PCB Basics: An Introduction to the PCB Industry*, [click here](#). 



ASSOCIATION NEWS

PCB East 2027 booth sales are open. The one-day exhibition will take place Apr. 28, while the four-day technical conference will take place Apr. 27 – 30. All events will be held at the DCU Center in Worcester, MA. Attendance at the PCB East 2026 conference and exhibition rose nearly 48% year-over-year. Contact Brooke Downey at brooke@pcea.net for details or visit pcbeast.com.

On Oct. 20, process engineer Kevin Dial of ASC/Sunstone will present “Coin-Style PCB Heat Sinks,” a one-hour webinar starting at 1:00 PM EDT. Click [here](#) to register.

On Oct. 21, Judi Emerson of Milwaukee Tool will present “How to Be a GREAT Designer” from 1:00 PM to 2:30 PM EDT. Click [here](#) to register.

On Nov. 4, senior PCB design engineer and instructor Susy Webb will present “Designing the Signal Routing to Control Energy in Digital PCBs,” a 3.5-hour webinar running from 11 AM to 2:30 PM EST. Click [here](#) to register.

On Nov. 17, Yash Sutariya of Saturn Electronics will present “Sourcing PCBs Globally,” a one-hour webinar beginning at 1:00 PM EST. Click [here](#) to register.

New Corporate Members

- Cybord

Recent Discord Chatter

Overheard on the PCEA Discord server:

- Transition via placement
- Applying standards as reference documents
- Pressfit connectors

Want to join? Send a note to membership@pcea.net. 

CHAPTER NEWS

National.

Upcoming webinars:

- Oct. 20 – “Coin-Style PCB Heat Sinks,” with Kevin Dial, ASC Sunstone ([register here](#))
- Oct. 21 – “How to Be a GREAT Designer,” with Judi Emerson, Milwaukee Tool ([register here](#)).
- Nov. 4 – “Designing the Signal Routing to Control Energy in Digital PCBs,” with Susy Webb ([register here](#)).
- Nov. 17 – “Sourcing PCBs Globally,” with Yash Sutariya, Saturn Electronics ([register here](#))

Upcoming PCEA Training Certified Professional Circuit Designer (CPCD) training and certification classes will be held:

- Sept. 28 – Oct. 2 (live abridged class, taught in-person in conjunction with PCB West)
- Oct. 16, 23, 30, Nov. 6, 13

Orange County, CA. Thanks to Justin Fleming for his talk in September on implementing accurate and standards-compliant footprints.

Richmond (VA). We are holding a series of PCB open discussion sessions around the region. Our next stop is the Richmond Public Library Main Branch at 101 East Franklin Street on Oct. 6. Drop in any time between 5 and 7:30 p.m. to discuss PCB design, schematics, layout, component libraries, manufacturing, design challenges, or ECAD workflows. Bring a project you’re working on, a question you’ve been stuck on, or just stop by to meet other engineers and designers in the area.

We will have a laptop with KiCad and Altium installed, and attendees are welcome to bring other tools and projects to share. Whether you’re an experienced designer, a student, a hobbyist, or simply curious about PCB design, you’re welcome to come by.

No presentation, agenda, or commitment required. Come for 15 minutes or stay the whole evening. Optionally, you can [sign up](#) or email burns.mikec@gmail.com. 

Low Void Soldering Maximized Throughput

Book a VIP meeting with us at SMTAI

Booth 2521

Short Cycle Vacuum Reflow



Smooth Profile

Heated Vacuum Chamber
for Flexible Manufacturing



Low Void

Vacuum Closed-Loop
Stepped Control for Improved Quality



Exclusive Patent

Innovative Multi-Stage
Speed-Adjustable Conveyor System



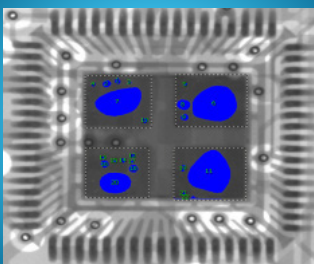
Doubled Throughput

Achieve the Shortest Cycle
Time to Up Your Production

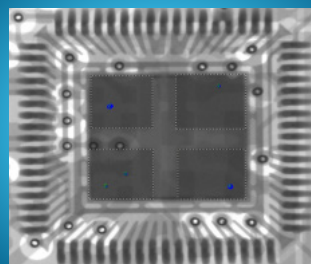


Reliable Vacuum Design, Achieve $< 1\%$ Void

Normal
Reflow



Vacuum
Reflow



By 2030, China Aims to Become a Global Automotive Powerhouse

BEIJING – Beijing wants you to believe the future of the automobile is already decided. On Sept. 10, nine Chinese ministries – from the National Development and Reform Commission down to the Cyberspace Administration, because nothing in China’s industrial policy gets one signature when nine will do – rolled out the 15th Five-Year Plan for Intelligent Connected New Energy Vehicles. The headline: by 2030, China intends to lock up “global automotive power” status for good.

The numbers, as always with these documents, are precise to the point of theater. New energy passenger vehicles at 70% of domestic sales, commercial at 40%. Autonomous driving “at scale.” Fuel economy down to 3.3 liters per 100km for combustion vehicles, 11.5kWh per 100km for EVs. Highways and “some” urban roads handling highly automated driving. Labor productivity up 15% over 2025. A handful of homegrown automakers cracking the global top 10 in sales, and parts suppliers cracking the top 100. Carbon peak by 2030. Safety systems that beat human drivers, stated as fact rather than target.

It’s an impressively tidy plan for an industry that, in the rest of the world, doesn’t move in straight lines. Supply chains don’t hit five-year checkpoints on schedule, and “highly autonomous driving” has a way of staying five years out no matter which five years you’re in. What the plan does confirm, whether China clears every bar it set for itself, is the direction of travel: state resources aimed squarely at owning the vehicle electronics and software stack, not just the sheet metal. For anyone in PCB fabrication, EMS, or component supply watching China’s share of automotive electronics demand, that’s the part of this release that matters more than the fuel-economy decimal points.

The industry will spend the next four years finding out how much of this is delivered and how much is aspiration wearing an official seal. Worth watching either way.

D-Day

Trends in the US electronics equipment market (shipments only)

	% CHANGE			
	MAY	JUN. ^r	JUL. ^p	YTD
Computers and electronics products	1.0	2.5	-1.2	7.6
Computers	1.6	0.3	-0.1	16.3
Storage devices	0.2	-1.8	1.9	14.3
Other peripheral equipment	2.0	-10.4	1.1	37.9
Nondefense communications equipment	2.1	2.0	0.8	25.1
Defense communications equipment	4.4	6.4	4.4	5.2
A/V equipment	0.2	-2.4	2.5	-9.8
Components ¹	2.2	1.7	-0.1	6.0
Nondefense search and navigation equipment	-0.5	-0.9	-1.1	4.9
Defense search and navigation equipment	0.1	3.7	-1.7	13.9
Electromedical, measurement and control	0.5	5.1	-3.3	1.5

^rRevised. ^pPreliminary. ¹Includes semiconductors. Seasonally adjusted.

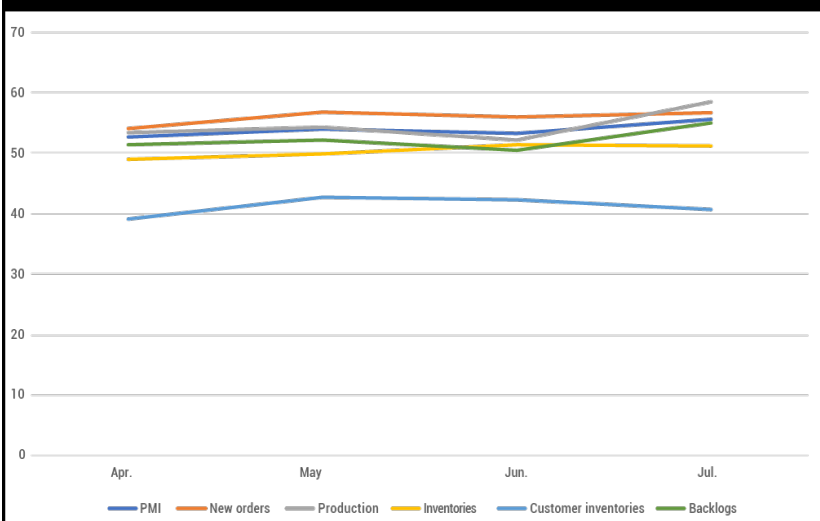
Source: US Department of Commerce Census Bureau, Sept. 2, 2026

Key Components

	APR.	MAY	JUN.	JUL.	AUG.
Semiconductors ^{1,3}	93.9%	104.1%	123.6%	135.0%	TBA
PCBs ^{2,3}	1.24	1.60	1.49	1.46	TBA
EMS ^{2,3}	1.36	1.36	1.33	1.29	TBA
Electronics mfg. orders ²	118.0	115.0	118.0	119.0	TBA
Electronics shipments ²	115.0	117.0	117.0	119.0	TBA
Component sales sentiment ⁴	146.6%	146.6%	154.1%	141.6%	136.7%

Sources: ¹SIA, ²GEA, ³3-month moving average, ⁴ECIA

US Manufacturing Indices



Source: Institute for Supply Management, Sept. 2, 2026

Quick Hits

The **worldwide server market** reached a record \$166.3 billion in vendor revenue in the second quarter, surpassing the previous high of \$125.3 billion set in the fourth quarter 2025. The result marks a 52% year-over-year increase and a 35.7% sequential gain. (IDC)

Vietnam is moving to strengthen domestic **electronics and semiconductor supply chains** after exports reached an estimated \$101 billion in the first eight months of 2026. (Vietnam Electronic Industries Association)

The global **specialty chemicals** market for PCB pulse plating is projected to grow to \$483 million by 2032 from \$221 million in 2025. (QYResearch, Inc)

Global **semiconductor sales** reached \$146 billion in July, up 6% sequentially and 135% year-over-year. (SIA)

Factory activity expanded across much of Asia in August as strong demand for semiconductors, computers and other AI-related hardware boosted manufacturing in China, Japan and South Korea. (S&P Global's Eurozone Manufacturing Purchasing Managers' Index)

The **global PCB assembly** market is projected to grow from \$102 billion in 2025 to \$168 billion by 2035. (SNS Insider)

Philippine electronics exports could reach a record \$54 billion in 2026, and the annual growth forecast rose to 10%. (SEIPI)

Surging AI demand is crowding out upstream material capacity for display panels, which is expected to drive total TV panel costs up 4-7% sequentially in the fourth quarter. TV panel demand by unit is projected to decline 4% in the period. (TrendForce)

Worldwide hardcopy peripherals shipments declined 7% year-over-year to 17.2 million shipments in the second quarter. (IDC)

Semiconductors for AI will grow to \$1.5 trillion by 2031 (Yole Group) 

Onshore, Nearshore or Offshore, We've Got the Right Solution



Product Lifecycle Management
Supply Chain Management
Traceability
Project Status Visibility
Outsourcing
Tariff Mitigation
Manufacturing
Responsiveness
Lowest Total Cost
Lean Six Sigma
IP Protection
Logistics Support

Developing a sustainable outsourcing strategy can be challenging. Tariffs. Supply chain constraints. Less predictable market demand. You need a responsive partner with the systems, processes and expertise to give you flexibility in manufacturing sites, expertise in supply chain management and visibility into production status from raw material to finished goods en route to their end destination. SigmaTron International is that partner. Our global facility network gives you choices which can change as your manufacturing needs evolve. Our expert team provides DFX recommendations and utilizes Lean manufacturing principles to ensure superior quality and an efficient manufacturing process.

SigmaTron's advantages include:

- Tariff mitigation options via our 3 USMCA-certified Mexico manufacturing facilities
- U.S. manufacturing options to support Assembled in USA requirements
- A Vietnam facility to provide a low cost manufacturing option within SE Asia
- Two China facilities capable of supporting domestic as well as exported manufacturing
- 24/7 visibility into project status around the globe via our proprietary SCORE™ system
- A global supply chain management strategy that supports electronic and precision engineered products

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

We have built our business around mid-to-high volume accounts who want Tier One caliber solutions, customized service and responsiveness. All our facilities are registered to ISO 9001 and those building mission critical products are also registered to ISO 13485 and IATF 16949. Our U.S. facilities are also ITAR registered. You will have access to global manufacturing options that support onshore, nearshore and offshore strategies plus a trusted partner who values your business.

Contact us today at **510-477-5004** or email: info@sigmatronintl.com.

Visit www.sigmatronintl.com/ad to download our new white paper: **Optimizing Regional Sourcing Strategy to Mitigate Tariffs.**

Let us show you how our options can help your company thrive in a changing world.

ONE SOURCE. GLOBAL OPTIONS.®

SIGMATRON
I N T E R N A T I O N A L

Rethinking Inspection for the UHDI Era

Increasing circuit density is pushing traditional inspection, verification and validation methods to their limits and creating a need for new approaches.

WHEN DOES TECHNOLOGY advance to such a degree that the industry needs to pause and rethink how it produces products and then verifies and validates that those products will reliably perform as intended and marketed?

Over the decades I have spent in the electronics industry, I have marveled again and again at the technological advances – and the pace of those advances – that continually take place in our industry. From single-sided circuit boards in the late 1950s to multilayer boards, then microvias, high-density interconnect (HDI) circuits, and emerging ultra-high-density interconnect (UHDI) and organic substrates, the pace of innovation has seemed breathtaking. And this pace is not limited to circuit boards; memory has transitioned from circuit cards in the 1960s to high-density chips that are now common and continue to advance technologically.

The demand for more capability in smaller packages drives the innovation that enables continually advancing technology. And as technology advances and package sizes shrink, the industry keeps asking for more of both. While design engineers keep advancing designs and material suppliers keep developing newer and more advanced materials to enable those designs, manufacturing processes and verification and validation methods too often remain unchanged and simply get pushed to greater extremes.

One example of product verification and validation can be seen in most quality departments in our industry. On a shelf in the back corner of the room sit optical microscopes that can magnify up to 60x. Next to those may sit one that can magnify up to 200x. However, at workspaces where employees perform inspection measurements, electronic microscopes can provide magnification of 1000x or more. The technology is basically the same, but with the small features of current technologies, the old 60x and 200x microscopes just don't cut it.

The same can be said for many other longstanding verification and validation methods, such as cross sections. The process of making a cross section is the antithesis of what the electronics industry is about. The process involves taking a circuit board, cutting a piece with a saw, placing it in a mold and pouring resin over it, grinding and polishing it after the resin sets, cleaning what is referred to as a “puck,” and then examining and measuring it. So how well does this inspection technology, or the use of ever-increasing microscope magnification, work to verify and validate processes or products in the world of ultra-high-density circuitry? Most likely, marginally at best.

Very possibly, the level of technology that our industry is producing and further developing has reached a point where, together as an industry, we need to pause and rethink verification, validation and quality inspection: why we

do it, how best to do it, and what new tools we should develop to assure consistency.

For such a paradigm shift to take place, the industry must start by reviewing why it does what it does. With advances in technology, what needs verification: reliability, robustness or consistency? Considering a product's size, thickness and materials, what is its most vulnerable attribute, requiring the greatest focus and effort to verify and validate?

Do different types of technology require radically different test procedures and equipment? The industry has inspected microvia printed circuit boards using basically the same equipment and processes as traditional multilayer circuit boards. Possibly, the too-frequent microvia failures result in part from the processes and equipment used to inspect the circuit.

As more high-density and ultra-high-density technologies become mainstream in electronics, using equipment and inspection processes developed for standard products to verify and validate them may miss critical failures, similar to what has occurred with microvias. Possibly, the entire inspection, verification and validation process needs development not after a product has been designed, but while the product is being developed.

The same can be said about in-process inspection. As circuit density, especially on innerlayers, increasingly tightens, the industry should rethink traditional visual and cross-section analysis. The cutting or grinding tolerances involved in creating a cross-section alone may be greater than the area under inspection. Equally, the time required for traditional in-process inspection delays corrective process changes.

So, how will our industry assure reliability, consistency or robustness as the technologies it produces become ultra- or ultra-ultra-dense? A wide variety of sensors and the ability to more easily create software are now available that simply did not exist a decade or several decades ago when the industry established traditional test, verification and validation protocols. Now would be a good time for the industry, working together, to pause, rethink and create a better inspection paradigm for the increasingly dense and small technologies of today and the future. 

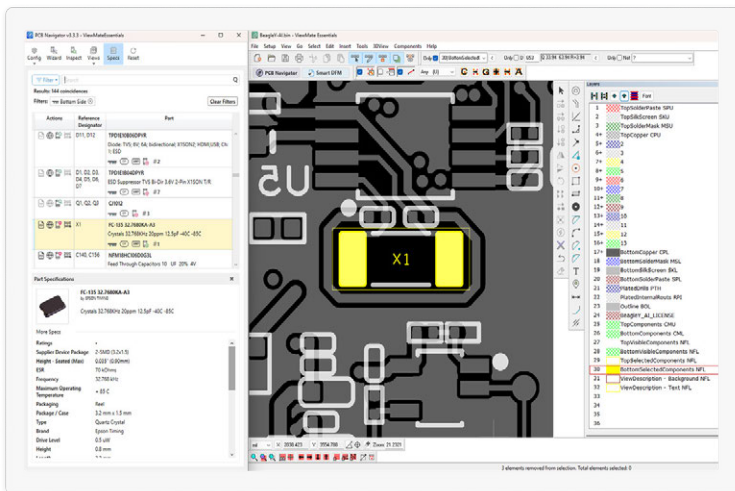


PETER BIGELOW has more than 30 years' experience as a PCB executive, most recently as president of FTG Circuits Haverhill; peterbigelow@msn.com.



ViewMate Essentials

The Designer's Edge – CAM Made Simple, Smart



Integrating ViewMate Essentials into the PCB workflow catches errors early, optimizes files for manufacturing, reduces costly rework, and improves collaboration with standardized outputs.

ViewMate is the industry standard CAM software, trusted by PCB Designers worldwide for decades.

Get your CAD data ready for PCB Fabrication and PCB Assembly

- ✓ CAM Editor for Gerber Files & Drill Data
- ✓ SmartDFM with Custom Rule Checks
- ✓ PCB Navigator with Views and Reports

→ **Download a free trial
or book a custom demo!**

+1 (800) 238-1920

pentalogix.com

How to Be a Good PCB Customer

See how clear communication, fair negotiations and timely follow-through can turn an ordinary buyer into a valued manufacturing partner.

I AM A PCB broker, a middleman who buys and sells printed circuit boards. Not only does my company have to meet the needs of our customers, but we also must accommodate the needs of the manufacturers in Asia that we work with. Otherwise, quality product do not ship on time.

I have always regarded feedback as a gift, especially when it leads to better service and relationships with my manufacturing partners that I can depend upon.

I get that important feedback by asking my suppliers not so much what I should do but what they would prefer me *not* to do.

Here are some of the things I've been told over the years:

Do not assume that just because you have a purchase order, the factory is desperate for your business. With current market challenges such as material shortages, tariffs and the demands of the AI boom, factories are not actually in need of just any customers. But they do need and want good customers. Until you can prove you will be a good PCB customer, they will likely view you as more of a liability.

Don't delay in awarding business. Signing an NDA, requesting multiple quotes and asking engineering questions is fine, but there must be business awarded and soon. A PCB buyer may think they are doing proper due diligence, but the factory sees all of this as unpaid sales time, free engineering work and an opportunity that could have gone to a "real" customer.

Asking for a free qualification run is understandable, but don't treat that sample like it costs nothing. There are over 100 manufacturing steps required to make a quality PCB. The factory agrees to a qualification run in hopes of winning your business. But if feedback on the sample (good or bad) is not received in a timely manner, your company will be remembered as a risk.

Tough price negotiation is expected, but it must be done honorably. Waiving a fake competitor's quote and demanding a much lower price will not win a supplier's heart. The factory not only sells the final product but also the engineering, labor and machine time to build that quality PCB. Pushing the supplier to a lower price could lead to substitute (cheaper) materials being used, production delays and relaxed quality oversight. And when that happens, is it the factory's fault or the buyer's unreasonable downward price push that engineered their own quality of service problems?



Figure 1. Strong PCB partnerships are built on consistent communication, realistic expectations and mutual respect.

There are customers and then there are good customers, and factories are rating them constantly. A customer not regarded as a good one gets treated as low priority. They won't get their quotes returned immediately, email requests may be delayed and pricing isn't always as favorable. A good customer gets the best quotes and preferential treatment during holiday rushes. That good customer is also forewarned of material delays. In addition, their product gets sent to the freight forwarder immediately upon completion.

Funny story: When I was a young buyer on one of my first trips to Asia, the factory sent a car to pick me up from the hotel. I was greeted by the international sales manager who invited me to ride in the provided transportation. It was a Mercedes complete with a chauffeur, privacy curtains on the side windows and bottles of ice-cold water for the drive. I arrived at the factory and was treated like a king upon entry, with my name in lights welcoming me to the plant.

Unfortunately, during my tour of the facility, both the supplier and I realized my proposed business was not a good fit for this manufacturer.

My departure was cordial enough, but the supplier had called a taxi to take me back to my hotel. A good customer would have again gotten the Mercedes. To paraphrase Julius Caesar: I came, I saw, I was hailed a cab."

Today's PCB buyer must constantly prove to be a strategic partner by being clear and consistent in communications, issuing regular purchase orders, providing realistic forecasts and, most importantly, paying on time. Buyers with this "good customer" mentality gain offshore manufacturing partners willing to invest in the growth of the relationship.



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

Innovation, Assembled

Our experienced team works closely with customers to deliver reliable PCB assembly with the flexibility to meet changing production needs.

20+ Years
PCB Assembly
Experience

50,000+
Designs
Assembled

24-48 Hour
Quote
Turnaround

Double-Sided SMT

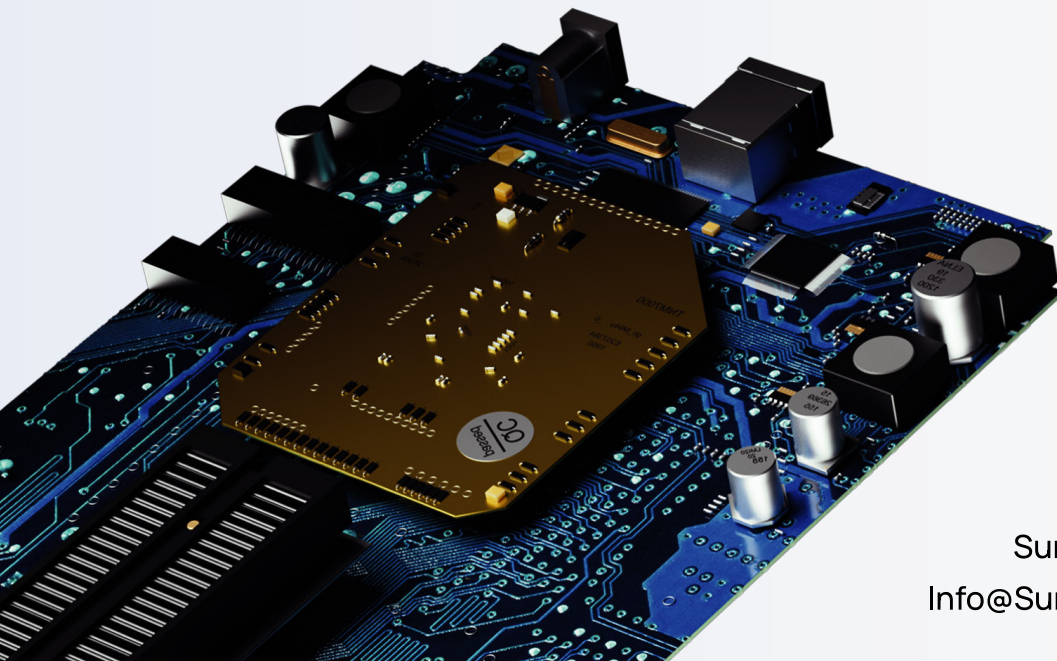
Fine-Pitch BGA

01005 Passives

Flying Probe

3D BGA X-Ray

RoHS & Leaded



Artificial Intelligence and the EMS Industry

AI can improve productivity across EMS operations, but effective governance is critical for managing information security, ethical use and output quality.

ARTIFICIAL INTELLIGENCE (AI) is a game changer for increasing productivity and organizational oversight. However, as it is deployed more widely across organizations, the downsides are also becoming visible. The three biggest downsides I've seen are the increase in information exposure risks, ethical challenges and failure to thoroughly review the quality of output.

The biggest driver of information exposure in AI use is the lack of AI governance policies. The number of AI tools grows every day. Tell your organization to adopt AI tools as quickly as possible, and people will grab what they know, or they think they know. AI models learn by analyzing information shared by the companies using them, and in a mandated "increase productivity through AI" environment, employees may experiment with tools that don't restrict shared information to the company. Having clear training on information sharing, which internal tools represent a secure environment and which information can be shared, helps limit information exposure. A central AI governance point that approves tools and continuously assesses risks is also an important check and balance. While it is nice to think that tools advertised as secure are secure, AI models are making headlines, rewriting their rules every day.

Information that may not be appropriate to share in any model includes:

- Detailed customer contact lists, particularly if associated with specific projects;
- Customer documentation or IP covered by an NDA;
- Sensitive employee information.

A central point of AI governance, along with corporate policies on appropriate AI use, is also critical to ensuring ethical AI use. From a sales standpoint, AI tools can profile potential customers to the nth degree, learning far more than they are likely to share. A deep dive in this pool will help you figure out leverage points, interests, behavior patterns, networks and other information that can help build the relationship. The challenge becomes: how much is too much? I've seen prospects get angry simply finding out that their email opens, clicks and pass-along activity is tracked. Sharing the fact that you know personal information that a prospect doesn't believe they are sharing publicly can end a deal. More importantly, gathering information a person hasn't agreed to share may break privacy laws in some geographies. Those laws are continuing to tighten, so corporate governance needs to anticipate future legal constraints as well as current laws.

Outcome quality is another potential downside. I use AI extensively as a search tool and do my best to refine my prompts to get accurate information. That said, I often find the information that comes back in a search is questionable when I refine the prompt. One humorous example I've had was when a client questioned data I'd written in a report about EMS quote-to-win rates. I've developed my assumptions about quote-to-win metrics over 45 years of studying them.

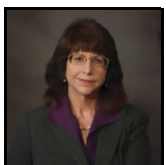
The client wanted me to document this by citing outside sources. I did an AI web search and found multiple sources with the same data, which satisfied the client. The problem? I've been a prolific speaker and writer. The wording on most of those citations told me the information had likely been pulled from articles I'd written or my book. So I satisfied the client by citing sources that quoted my past work without attribution. I've seen worse examples in marketing. A salesperson used AI to write a whitepaper and carefully attributed key sections to appropriate sources.

The problem? All the attributions led to competitors' websites. AI is great for writing report summaries on action item completion or activities. However, unedited, those reports tend to be repetitive and bland, which can reflect poorly on the person generating them. Similarly, when AI writes marketing emails, it can be pretty obvious, especially if the tool customizes information it finds about the recipient as an introductory icebreaker. This is another area where a customer can be offended either by the information shared or by the fact that the information the AI tool thought was appropriate shows a total lack of understanding of that business. What works well with consumers doesn't necessarily work well in business-to-business communication when you delegate it entirely to an AI tool.

So, where is AI really good?

EMS is controlled chaos with more information flow than most team members can fully absorb. AI tools can take exception-based reporting to the next level, helping teams start each week with shortage reports aligned with production schedules. Capacity planning can be enhanced. AI tools can help cut programming time on non-recurring engineering activities such as test programming. Virtually any information or trend analysis task can be sped up with AI tools, as long as the information shared fits within corporate governance guidelines. Industry 4.0 lines incorporate a mix of machine learning and AI when fully leveraged.

AI can offer significant benefits to organizations that adopt it with careful planning. What are appropriate uses? How secure is information shared with the proposed tool? Will uses stay aligned with trends in privacy laws? Where is information flow outpacing our team's ability to analyze it? What trend analyses should we be doing to improve productivity, quality, or return on investment? How do we balance AI assistance with overdependence on AI? Is the output accurate and well written? Companies and associated users who ask these questions as they adopt AI will come out ahead of those who don't. 



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.



RECOGNIZING THE BEST

New Electronics Assembly
Equipment, Materials & Software



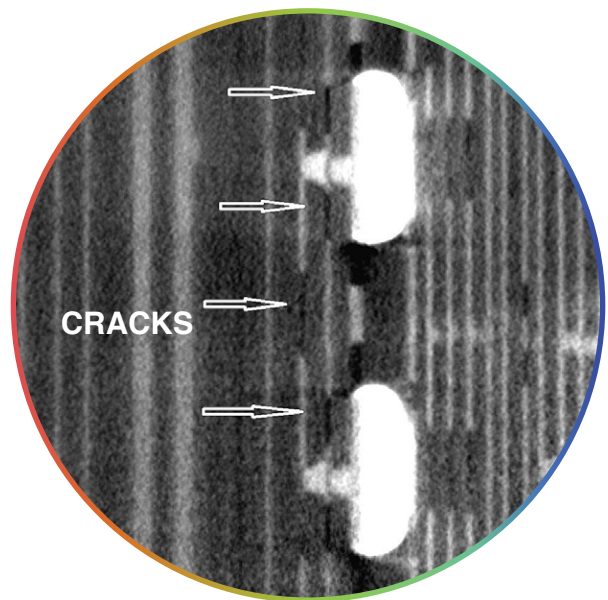
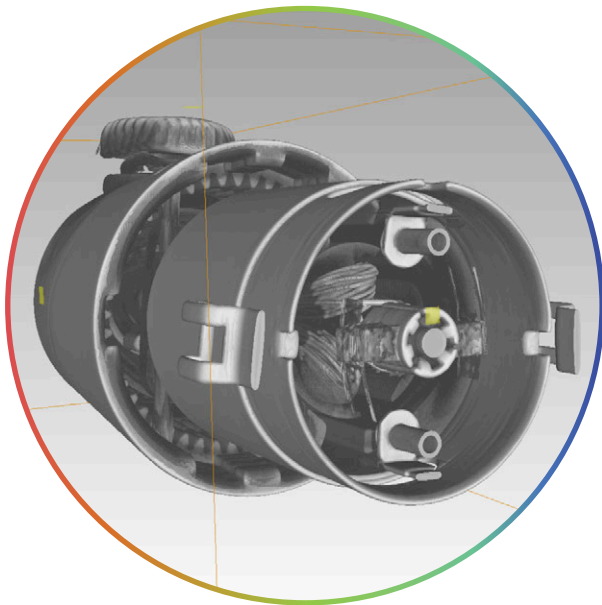
Nomination Deadline
December 4, 2026

Sponsored by
**CIRCUITS
ASSEMBLY**

DATEST

DON'T GUESS. CT SCAN IT.

*IF YOU COULD SEE INSIDE THE PART,
YOU'D ALREADY HAVE YOUR ANSWER.*



FINDING WHAT OTHERS *MISS*

INTERNAL DEFECTS & POROSITY

CRACKS & DELAMINATION

VOID ANALYSIS

ASSEMBLY VERIFICATION

DIMENSIONAL MEASUREMENT

REVERSE ENGINEERING

**TEST ENGINEERING.
FAILURE ANALYSIS. ANSWERS.**

WWW.DATEST.COM

HDI Design Strategies

HDI techniques use strategic component placement, microvias and via-in-pad technology to create compact, reliable, high-performance circuit boards.

PRINTED CIRCUIT BOARD design sometimes involves the editing of previous circuits. Other times, the board is an empty polygon waiting for you to populate it with virtual symbols. Next, connect them with the graphical version of traces and shapes. All of this effort creates a digital twin of the product. PCB designers have figured out that connecting the dots is a small part of the day-to-day saga of product development.

The PCB designer's task is to create that above-mentioned twin based on a number of competing factors, including:

- Meeting DfX requirements within IPC specifications for the class
- Capturing design intent as rule-driven constraints for validation
- Reserving the space required for FCC immunity
- Thermal performance/battery life
- Ever-decreasing form factors
- Progressively shorter timelines

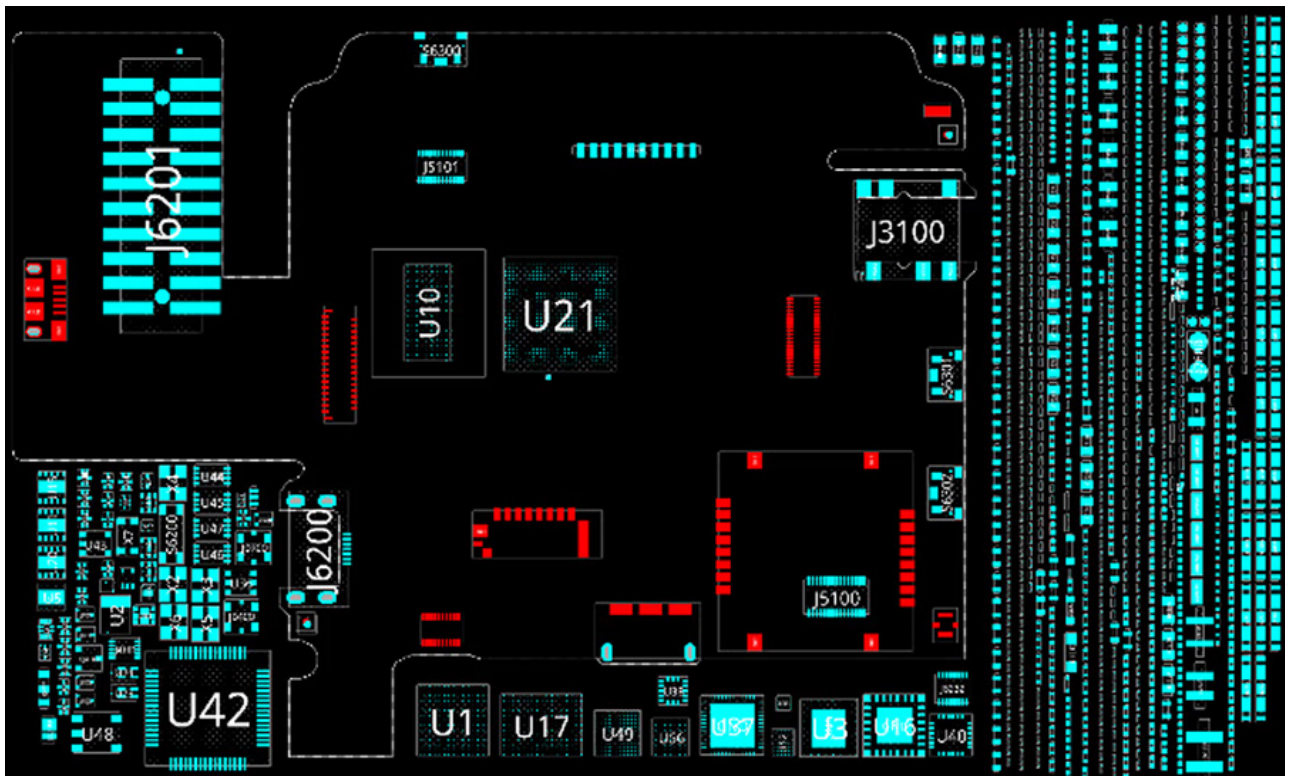


Figure 1. Step one of the placement study is to confirm that all parts are in the library. The components that are already placed were largely predetermined by the outline drawing. It gives confidence that we can place the board, but there will be parts on both sides. The outline drawing requires double-sided component placement to begin with. That gives us a lot more real estate. The critical check will be how much headroom we have on the far side. Keep-out areas are often reserved for cables and other features. (All images credit: Author)

The pressure is on from day one. To gamify the process, there are elements of chess, jigsaw puzzles, Tetris, connect-the-dots, SimCity, and even Grand Theft Auto, where designers have to take space from one thing to provide for something else. Different interests can have you feeling a bit like King Solomon, wondering how to divide up the finite space on the board during the even more finite schedule.

Size Matters: The Smaller, the Better

Some things we can control, and others we can only hope to influence. Asking for more room halfway through hits differently than when you make the case right away. New boards feature new connectors and other items that need to bubble up through the library to the layout.

“Clean that up before making copies all over...”

If that’s your job, build them as well as you can to help with things like organizing silkscreen. The “Wizard” will build errors into the library footprint. One is creating zero-width silkscreen over pads. Clean that up before making copies all over the board. If routing under a certain kind of part is a problem, solve it at the component level with a route keep-out. A little extra work on the library pays

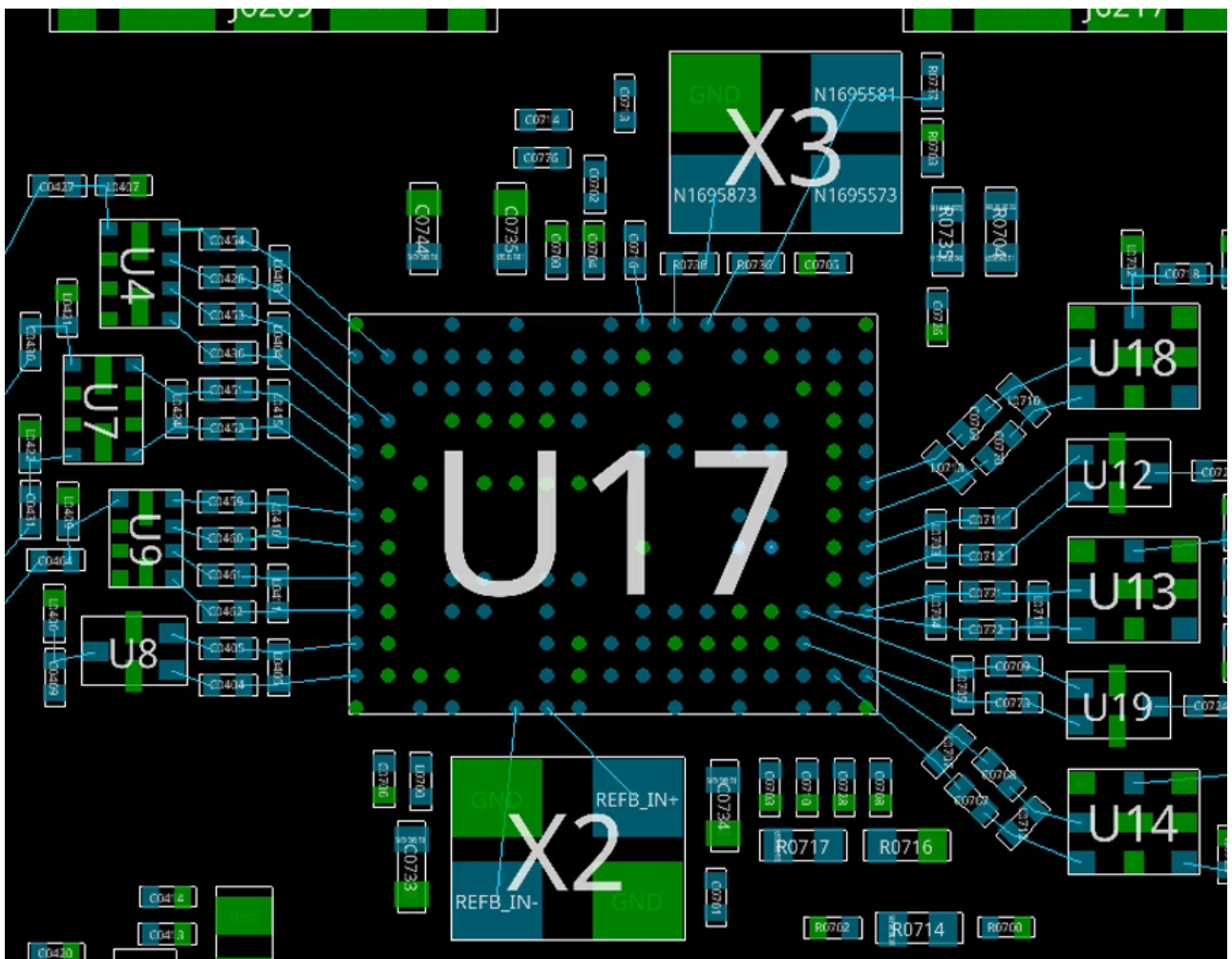


Figure 2. This is a classic example of the connections driving the placement. Matching networks, switches and diplexers are among the ancillary components that find their way into an analog block. Placement details favor trace flow more than the assembly house's preference for consistent component orientation. The shortest trace is the best trace.

For placement, it makes sense to start with parts like connectors, where the location is already determined. If ESD suppression diodes are involved, it's a no-brainer to place them close to the connector pins. Not everything is that simple to discern, but the schematic can offer clues. Setting up automatic cross-probing is pretty easy.

Once you do that, every part you click in the layout tool shows up on the schematic. After you've used cross-probing that way, it's going to be in play for all of your placement and power delivery decisions. I feel like I have a hand tied behind my back without it. Sometimes, an engineer will leave local notes on the schematic with instructions. That's another reason to look for context when placing components.

The chip maker wants you to adhere to the diagram or assume the risk.

Of course, another nice-to-have is a quick link to the data sheet for the various chips. App notes will provide placement diagrams for optimal performance. The chip maker wants you to follow the diagram or assume the risk if the device fails.

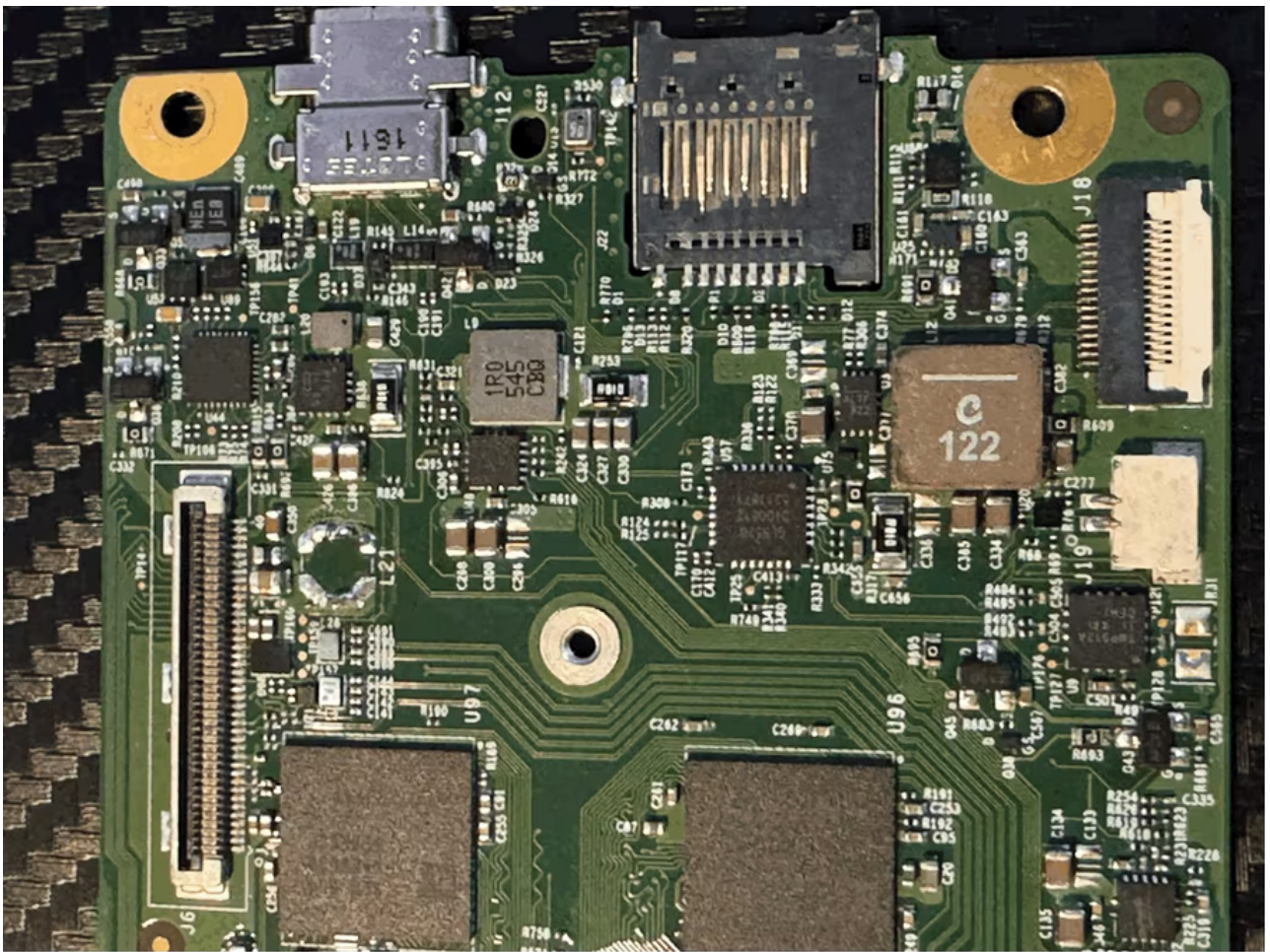


Figure 3. HDI PCBs support the microelectronics common in today's computers and other electronic devices. The thickness of the bare board is 1mm, saving some space in the z-axis. We like thin computers with lots of batteries. This holds true for almost everything.

Do it their way, or you're on your own. In reality, you have more parts than the diagram shows, and the data sheet may include hole-tolerance callouts beyond the fabricator's capacity. For layout-dependent devices, placement will be negotiated as those little parts get shuffled around to fit the limited space.

If there is no existing work to copy, I like to create an ideal layout for a device outside the board outline before putting it on the board. The little parts often reveal the full context of the routing.

Other than that, placement is about walking down the schematic page, picking symbols and having that part's footprint appear under my cursor in the layout tool. Again, using cross-probing to place components or using the highlight command to colorize a page's worth of components keeps things in focus. That will be handy if you've already run a quick place to see what you're working with page by page.

With the biggest chip in the middle and the connectors on the edge, all that's left are the smaller groups clustered around the board outline in their rainbow of highlight colors. Of course, the memory is going right next to the processor chip. Some choices are obvious, but there's also a grey area where it would be nice to keep it close to the device. Count on having more ancillary devices than "storefront" around the primary devices.



Figure 4. A cluster of 0201(imperial) caps and resistors plus a few test points support a processor on the opposite side of the board. Silkscreen was omitted from many of the components as there wasn't sufficient room.

The bottom of the board is often the best side for applying bypass caps. They're small and numerous. When a chip is 10mm or more across, the bottom side could get much closer to the inner grid where power and ground pins are fairly common. The inductive loop will be measurably shorter. This is especially good for capacitors measured in picofarads, like 22 or 47pF, for example.

Big bulk caps can use the top side and do their thing at a distance. There's lumped capacitance, and then there are distributed elements. We have those and usually some ferrite beads to split up the power domains. It's common to start with lots of filters and capacitors, then try to depopulate certain ones to see if they are really needed. We can't remove anything from the board until we fill it up.

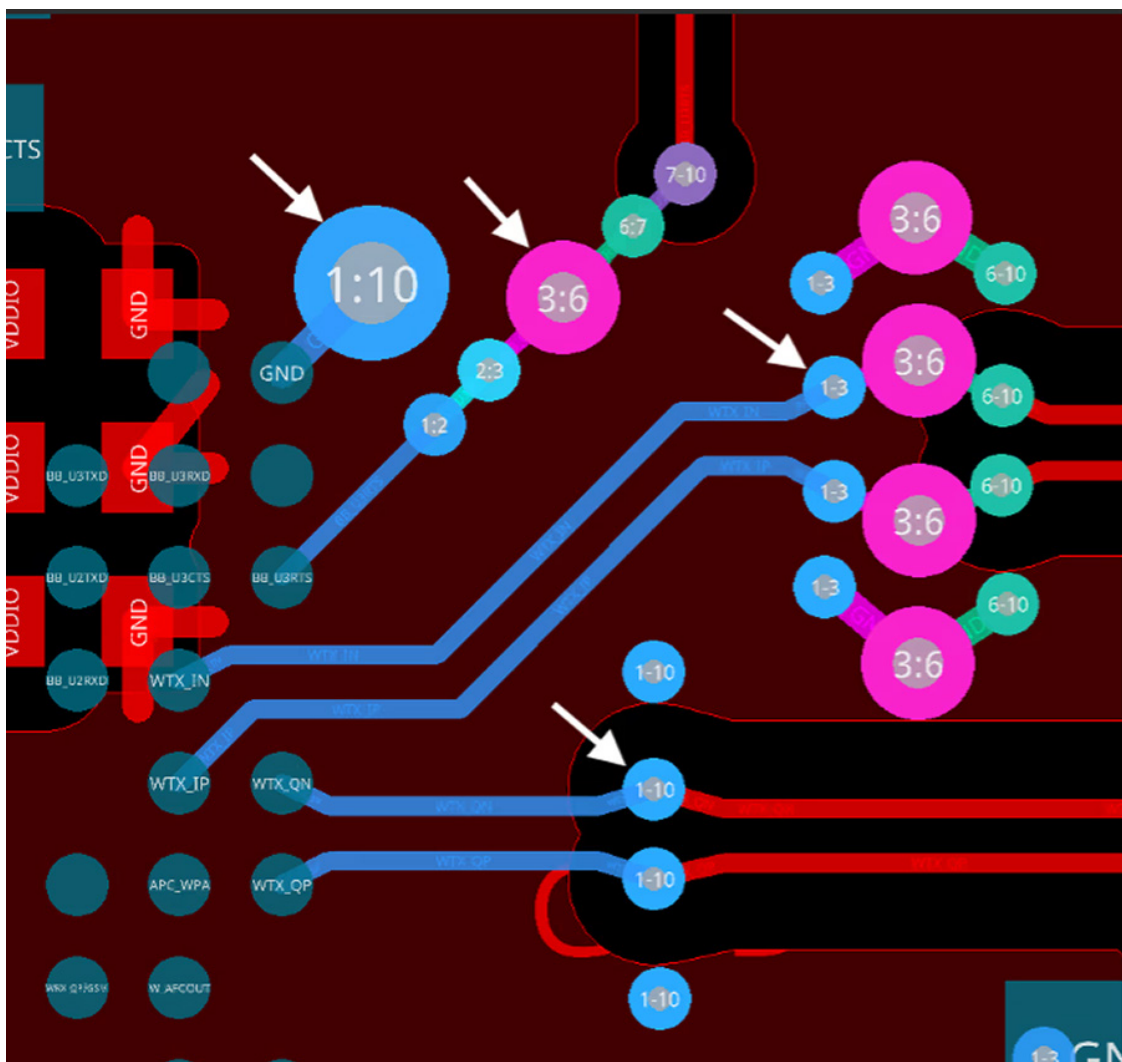


Figure 5. The component placement spacing will be influenced by the routing topology. Around the horn, we have a plated through-hole via followed by staggered microvias with a buried via, then over to the diff-pairs using stacked microvias with buried vias, and finally a full stack of microvias. This fan-out study also proves the copper pour rules that give extra space to the differential pairs.

The advantages of HDI PCBs:

- No additional space is required for fan-out by using via-in-pad technology. Minimum component spacing is generally sufficient all around.
- The smaller microvias are lower in impedance, and that helps with signal integrity.
- Back-drilling is unnecessary as the via can go from one layer to any other layer with the exception of buried vias.
- HDI boards may be the only option with many of the leading-edge devices on the market. Fine-pitch parts are usually the first package out of the gate for new silicon.

Creating HDI boards requires more than a traditional single-lamination cycle. Each sequential layer pair takes as long to laminate as a complete through-hole board. The press is both expensive to buy and is the bottleneck in the typical fab shop. The result is higher labor costs and longer lead times for high-definition interconnect circuit boards. As they



JOHN BURKERT, JR. is a principle PCB designer in retirement. For the past several years, he has been sharing what he has learned for the sake of helping fresh and ambitious PCB designers. The knowledge is passed along through stories and lessons learned from three decades of design, including the most basic one-layer board up to the high-reliability rigid-flex HDI designs for aerospace and military applications. John's well-earned free time is spent on a bike, or with a mic doing a karaoke jam.

*“My view is there’s no bad time
to innovate.”*

-Jeff Bezos

*ok, e-commerce guru --
super-de-duper rich
with NO hair!!!*



Invest in Innovation



Register Today!

Comprehensive PCB Design Training

NEXT CLASSES:

Oct. 16, 23, 30, Nov. 6 & 13



Check the website for more classes added throughout the year.

pceatrainning.net



WEST 2027

Conference & Exhibition

Conference & Exhibition Info

Coming
SOON

Software-Defined Warfare Meets the Hardware Supply Crunch

Today's software-defined military systems need incredibly powerful hardware, and its intensifying competition for components and materials.

ESTABLISHING THE TECHNOLOGICAL upper hand has always taken priority for military forces. In today's data-driven, AI-powered world, superiority comes from faster decision-making, seamless interoperability between systems, and real-time adaptability.

This is software-defined warfare, and the shift is happening after civilian applications have shown that software-defined technologies such as cellular radio-access equipment (SDR) can deliver agile architectures that respond quickly to new specifications and changing user demands through over-the-air updates. Indeed, as defense departments have transitioned their practices and systems to this more flexible approach, SDR has been described as the digital backbone of the battlespace. It provides the key to multi-domain integration and enables rapid, seamless connections between national systems of allied forces.

Moreover, SDR is a critical technical enabler of signals intelligence, comprising communications intelligence (COMINT) and electronic intelligence (ELINT), which analyses transmissions from non-allies. While COMINT is rooted in codebreaking to intercept content like speech, text and data, ELINT focuses on non-communication emissions like pulse patterns and RF power levels to infer equipment capabilities, modes and intent. Knowing what types of systems are present and how they operate gives strategists the basic information needed to counter them.

The enormous flexibility and real-time adaptability of SDR are central to making software-defined warfare work, enabling transmission and reception across a wide range of frequencies and quick responses to new and previously unseen sources entering the RF landscape.

As military SDR moves beyond its origins in classical radio technology, it's becoming software-defined sensor-compute platforms that can detect, digitize, classify and combine data from multiple sources. It can adapt in real time as adversaries change their tactics and technology.

Hence, software-defined warfare has come to describe a multi-domain and multi-sensor environment, and there are clearly exciting opportunities for those designing and building the next generations of equipment. But software can only manipulate what the hardware can pick up and it's extremely challenging to create a platform that is broadband and powerful enough to provide a suitable generic environment for the software to do its magic. This is intensifying demands to massively increase the hardware's front-end RF bandwidth while ensuring linearity. Designers are also

under pressure to increase embedded computing power for tasks like real-time waveform recognition and create ever-faster system interconnects.

The coming generations of military SDR will have far greater capabilities than any previous civilian systems, but achieving the required performance calls for high-end components: ultra-wideband analog front ends, GPU accelerators, high-bandwidth and high-density memory, high-capacity MLCCs and high-speed optoelectronics. Advanced resins, e-glass and copper foils are also needed for high-density packaging, interposers for chiplets and low-loss, high-speed PCB substrates. If this sounds familiar, these are the items already in high demand for hyperscale data-center expansion and, in many cases, strictly available on allocation. The AI-accelerated sensor platforms needed to power software-defined warfare are thus running straight into the same bottlenecks currently facing the AI-server ecosystem.

With the weight of government behind them, militaries can push hard for access to the resources they need. On the other hand, globalized markets and supply chains are dominated by trillion-dollar cloud companies with huge purchasing power and commitments already in place. Materials like ABF, as well as advanced resins and foils, come from only one or a few sources worldwide.

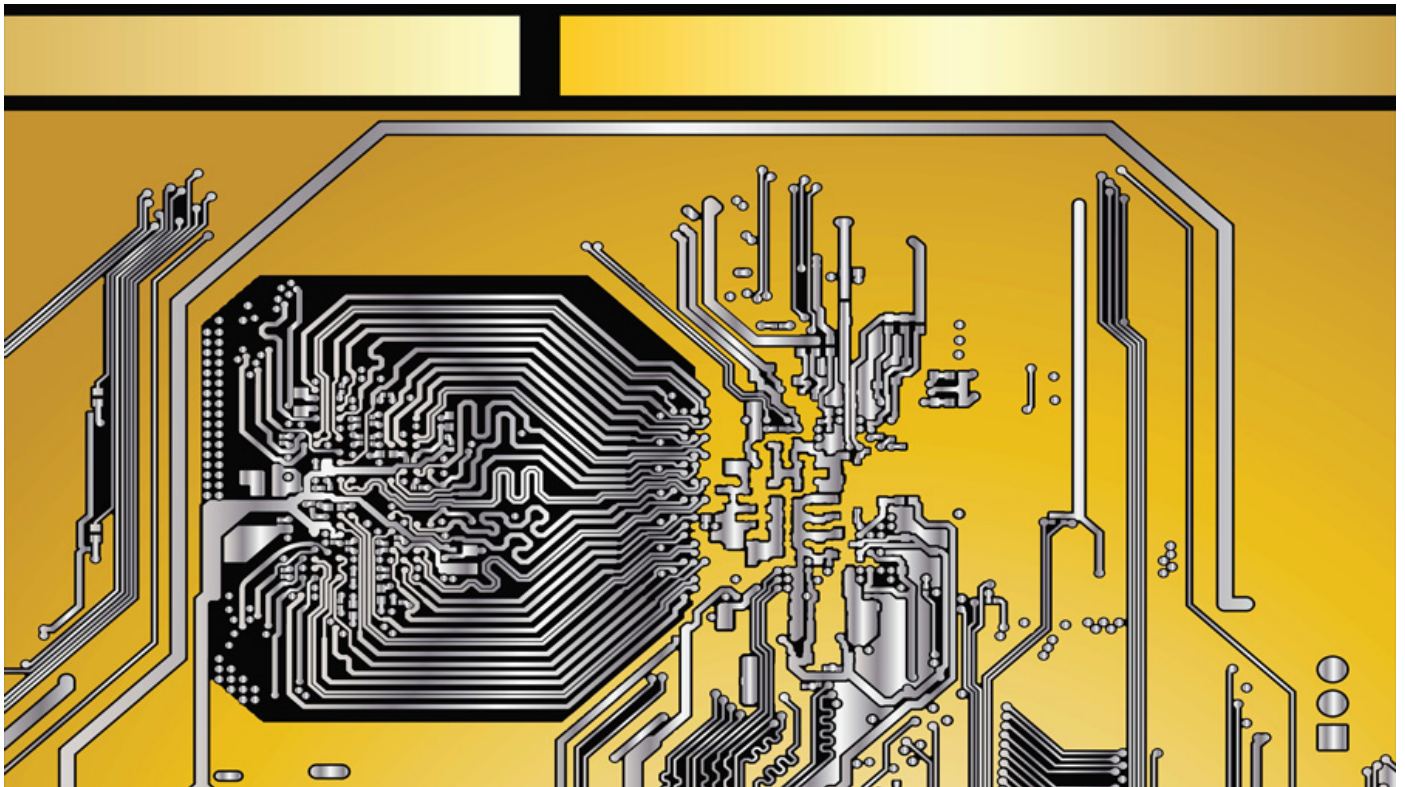


Figure 1. Next-generation software-defined military systems are increasing demand for high-performance components, advanced PCB materials and high-density interconnect technologies.

We are seeing a scramble to re-establish sovereign supply chains for critical materials and components that have been outsourced over time as the demands of the commercial electronics sector have shaped the industry. It's true, however, that the US has retained significant military-related manufacturing capabilities. In PCB manufacturing, over 50% of PCBs made locally are for defense applications. But the design expertise and manufacturing capabilities needed to realize high-performing PCBs for software-defined warfare systems are becoming increasingly advanced. Trace

dimensions are becoming comparable to signal wavelength, which calls for tighter manufacturing tolerances.

It is becoming vitally important to simulate new designs before committing to manufacture and to use techniques such as digital twins to evaluate performance effectively. However, increasing both know-how and production capacity, while establishing secure supplies of the most advanced components and materials needed, will demand persistence and sustained investment.

While demands for cutting-edge capabilities and performance – within compact and portable form factors that are critical to ensure ease of use in the field – are intensifying, the military will always demand high ruggedness and reliability. It will be important for them to find suppliers that not only can provide the required components and materials but also maintain AS9100-certified quality management systems.

And while the military may be able to insist on access to supplies, those wielding the power must also recognize that the nation's data centers are the places where the AI models needed to drive software-defined warfare will be trained. The enormous capabilities and expertise amassed in the private AI sector are beyond anything authorities can build exclusively for themselves. Thus, these facilities must now be viewed as critical national security assets. The hyperscalers and the military must thrive together because, in many ways, the outcome of future wars will be determined in these data centers. 



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

Why Become a **PCEA Corporate Member?**



- ✓ Information, opportunities & marketing channels to **highlight your brands, products & services** to buyers & users worldwide
- ✓ Inclusion in the **PCEA Member Directory**, a product & service guide for buyers & users
- ✓ **Free advertising** of your products & services to more than 50,000 design engineers, fabricators & assemblers
- ✓ **Discounts** on trade shows, technical conferences, online learning platforms & webinars



Join today:
pcea.net/pcea-membership

Offering price points to meet every company's budget and needs!

Understanding Flex Circuit Cost Drivers

Part geometry, material selection, layer count, via strategy and final finish are among the key design decisions that determine flex circuit costs.

EVERY DESIGNER IS tasked with creating a design that meets all performance criteria. A flex circuit must interconnect a variety of components and inputs and outputs within the envelope of the finished product. It must achieve size, weight and power goals while also meeting cost targets. When trying to balance all that, it is good to know where the cost drivers are. The early design tradeoffs will define at least 80% of the final cost.

So, let's talk about some of the main cost drivers. While this won't answer all the possibilities, it should provide a feel for some of the bigger considerations.

Part size and shape is one of the biggest drivers. Plain and simple, the more parts the manufacturer can get on a panel, the lower the cost. In North America, the most common manufacturing panel size is 18×24". Usable area for parts is about 16×22", give or take. This accounts for tooling and coupons. So, selecting a part size that fits well on the panel with high utilization is key. Sometimes flex circuits have arms or appendages that stick out one side or the other of the main body. This may impact the panel layout. An appendage may be able to extend from more than one place and still meet design requirements. One of these geometries is likely to positively impact panel utilization. The part outline should be reviewed to determine how efficiently it fits on a panel.

Material choices matter. For flex laminates, the cost rises as the polyimide film gets thicker. In fact, the costing is more sensitive to the polyimide thickness than it is to the copper weight. The same goes for coverlay and bondply. For coverlay, 0.001" polyimide film is the lowest cost. Anything thicker or thinner increases cost. For rigid laminates and prepreg, the same rule of thumb applies to rigid-flex as it does to rigid PCBs. Higher-performance materials cost more. However, they may be an enabling choice when it comes to things like impedance and high speed and frequency.

Layer count is a cost driver too. Obviously, more layers equal more material and more processing, which adds to cost. It usually leads to a thicker PCB, driving up the drilled-hole aspect ratio of depth to diameter. Also, as layer count goes up, the challenge of aligning all the layers to each other and meeting annular ring requirements increases.

There can be reasons to add layers to manage costs. For example, in some cases, adding a layer or two may allow for larger pads, wider traces and wider spaces. This can improve yields, especially if feature sizes go from advanced or leading edge back to something more middle of the road. An extra layer or two may also allow for simplification of the outer layers. Since these are plated layers, moving them one layer inside leaves them unplated and easier to etch.

It should also be noted that, in general, going up from an odd number of layers to an even number, such as nine layers to 10, can be a minimal cost adder. This is because most laminates are procured as double-sided clad. If a stack has an odd number of layers, it is likely that one of the cores will have one side etched off completely. This means paying for the copper and then paying to have it etched away. Conversely, increasing from an even number of layers, say 10 to 11, is a bigger cost jump because it adds more material to the stackup.

The via strategy is a key cost driver. Combinations of through vias, blind vias, buried vias and microvias definitely impact cost. Each via type requires a separate process to form the hole and a separate set of processes to plate it. In addition, various via structures will drive sequential lamination processes.

Some hole types will require nonconductive via filling. Buried vias are filled to avoid embedding an air pocket inside the PCB. Blind vias are filled to protect the via and board from subsequent processing. Some through vias need via fill as well if the via is located in a surface-mount pad. These vias in pad need to be copper cap plated to create a planar SMT pad. This is called via-in-pad plated over (VIPPO). Via filling and planarizing tend to be expensive processes and, in some cases, lead to yield loss.

Microvias are often copper plated full for one of two reasons. Internal microvias are copper filled to allow for the next level of microvia to be plated on top of them. Exterior microvias are filled because they are usually in an SMT pad.

Combining various via types and terminating them on the same layer will result in multiple plating operations on that layer, which will make etching that layer more difficult. It also makes imaging that layer more difficult because the different via types have different alignment origins. It can be difficult to align the image and meet annular ring requirements for all via types. Extra pad diameter may be needed to mitigate the risk.

While some of these via structures can add to cost, they are essential in most HDI products. In fact, avoiding some mixture of microvias and buried vias in favor of through vias only can result in a design that is actually too difficult to build. The resulting yield may be so low that a buried via and microvia combination can be the lower-cost option.

Final finish can drive costs in several ways. Some finish types, such as gold, can be more expensive given the fluctuating cost of gold. Thicker coatings will also drive up cost.

Electrolytic finishes like nickel and gold require electrical connections. This means either using the finish as the etch mask or having tie bars that may or may not need to be removed after plating and etching. These will impact yield and add extra steps. This has been a major reason designers have shifted to ENIG and ENEPIG finishes.

Requiring more than one finish adds costs for both finishes. There are also a number of operations to mask and unmask for each finish that drive up costs. Consideration must be given to where finishes may overlap or need to be segregated.

Certainly, some designs require one or more of these cost drivers to meet end-product performance requirements. The key is to consider tradeoffs to maximize performance while simultaneously staying within cost boundaries. When in doubt, a trusted supplier can provide guidance on choices that optimize the design and manage costs. 



NICK KOOP is director of flex technology at TTM Technologies (ttm.com), vice chairman of the IPC Flexible Circuits Committee and co-chair of the IPC-6013 Qualification and Performance Specification for Flexible Printed Boards Subcommittee; nick.koop@ttmtech.com. He and co-“Flexpert” **MARK FINSTAD** (mark.finstad@flexiblecircuit.com) welcome your suggestions.

Thank You!

TO OUR PCEA CORPORATE MEMBERS

 **ACCURIS**

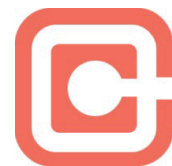

all flex
SOLUTIONS

 **AllSpice.io**

 **ASC**

BEST
Technology

BOARDERA




CHESTER ELECTRONIC DESIGN

 **cofactr**

Cybord 


DirectPCB[®]

 **ELECTRONIC
INTERCONNECT**
THE PCB EXPERTS

 **elyca**

EMA | Design
Automation™

ESPEC

FINELINE
EXCELLENCE IN PCB

 **FREEDOMCAD**
ELECTRONIC PRODUCT DEVELOPMENT

GFE

 **luminovo**

MC
Millennium Circuits Limited

 **NCAB
GROUP**

25
Newgrange Design
Celebrating 25 years

PCEA CORPORATE MEMBERS



Learn more: **Will Bruwer** Senior Sales Executive • 404-313-1539 will@pcea.net

Managing Vias in Very High Data-Rate Differential Pairs

Managing via structures can minimize signal degradation and enable differential pairs to operate at data rates as high as 56Gb/s.

by LEE RITCHEY

Vias are the plated through-holes in a printed circuit board used to connect device signal pins to the traces in the PCB. As shown in **Figure 1**, for signals whose frequency content is below three gigahertz, the effects of these vias are visible but not significant. The dip in the signal is caused by the via's parasitic capacitance. (This plot was used to show that a right-angle bend does not cause a signal integrity problem.)

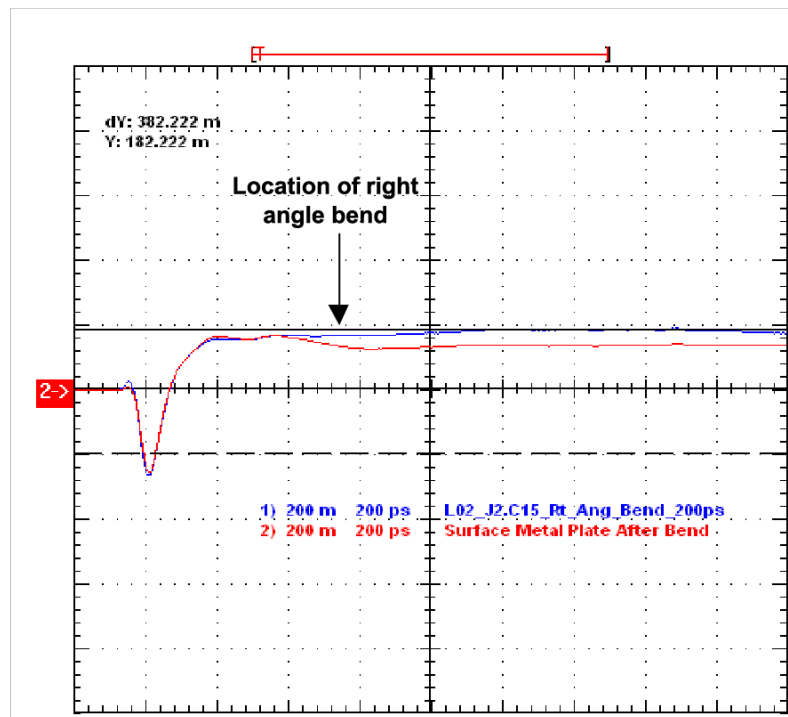


Figure 1. Reflection from the via used to access a signal net below 3 gigahertz.

For signals with useful frequencies above three gigahertz, the foregoing may not be true. In fact, not knowing about these via effects and doing something to minimize them can result in signal degradation so severe that the data path does not function. This article explains why this happens and how to minimize these effects. For data rates as high as 56Gb/s, it's necessary to use low-loss laminates.

Figure 2 is a loss vs. frequency plot of two eight-inch-long traces routed in two different signal layers on the same 16-layer PCB. As shown, up to about 3GHz, the loss vs. frequency is about the same for both traces. Above 3GHz, the trace represented by the blue curve develops a very large amount of loss (44dB at 8GHz) and, if something isn't done to minimize the effect of the vias on this trace, it will not operate correctly.

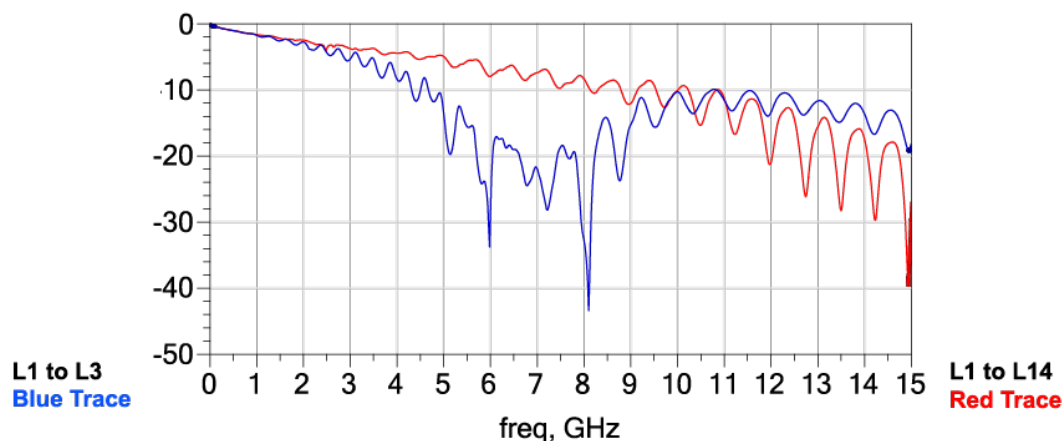


Figure 2. Loss versus frequency for two eight-inch traces on different signal layers.

Next, as shown, when the signal travels the length of the via, as the red trace does, the via's effect on the loss curve is minimized. This is one solution to the problem. However, it only works when these traces can be routed on the signal layers near the bottom of the PCB.

Figure 3 is loss vs. frequency for three traces, all routed on the same signal layer. The red and green traces have only a via at each end to connect to signal pins. The vias on the red trace have the unwanted part of the via extending below the trace layer drilled away using a technique called backdrilling. This method adds additional cost to PCB fabrication. Plus, it requires careful monitoring so the PCB is not made unusable as a result of backdrilling. The blue trace has an additional via along its length, which might be used to change signal layers. It has not been backdrilled.

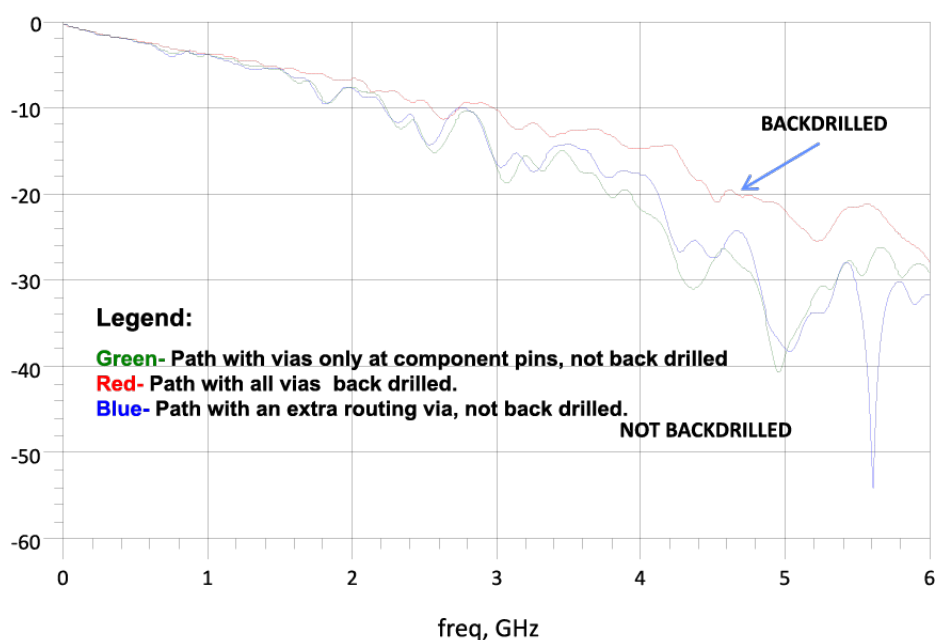


Figure 3. Loss versus frequency for three traces routed on the same signal layer.

This article illustrates two methods for minimizing the effect of vias on transmission lines. There are a total of four methods that can be used. They include:

1. Routing the signals on layer one and using no vias.
2. Routing the signals on layer two and using blind vias to access the trace. **Figure 4** illustrates this method.
3. Routing the signals on layers near the bottom of the PCB.
4. Routing the signals on layers not near the bottom of the PCB and backdrilling away the unwanted portion of the via.

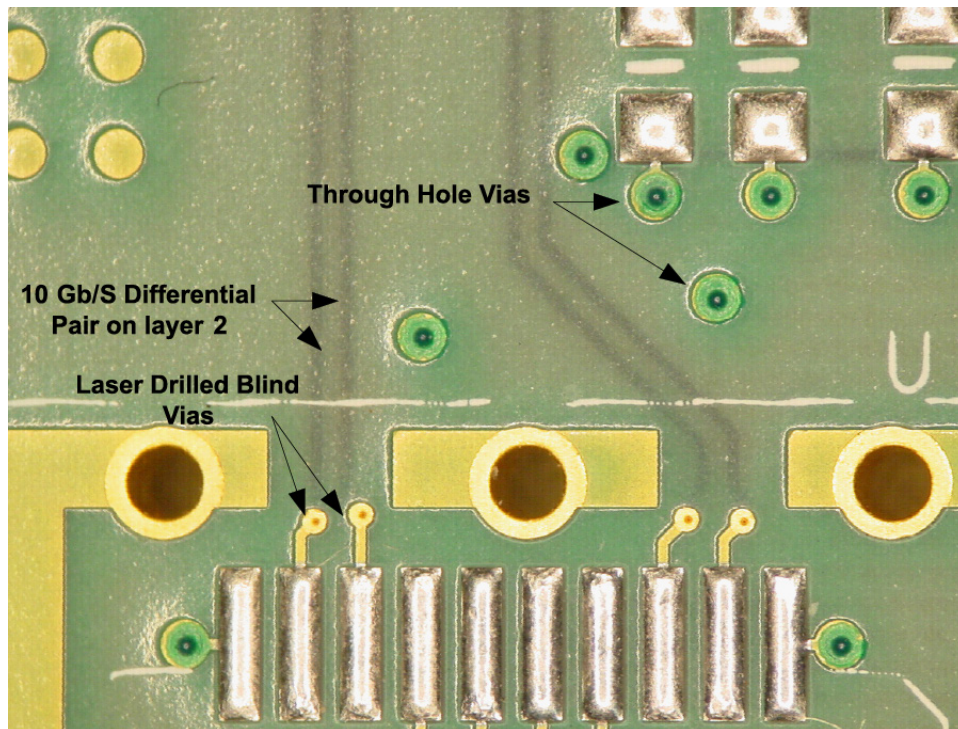


Figure 4. Routing signals on layer two and accessing the trace with blind vias.

All four routing methods described above have disadvantages. Methods one, two and three only work when the number of signals to be routed will fit in the space available on their respective layers. Method four carries with it the added cost of backdrilling and the risk that a drill may penetrate too deep and sever the connection between the via and the signal trace.

Routing only on layer one has the disadvantage that the outer layers have the poorest impedance control of all the signal layers in a PCB.

Figure 5 is an illustration of backdrilling. Some designs, such as backplanes, may require several different drill depths depending on which layer signals are routed.

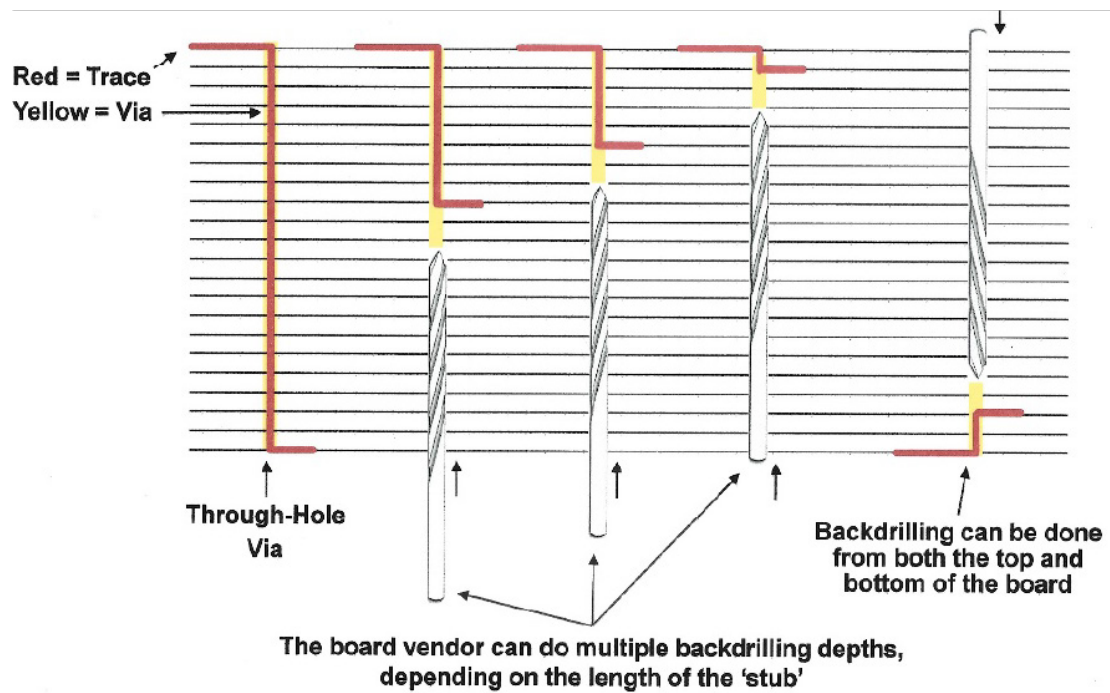


Figure 5. Backdrilling removes the unused portion of a via below the signal layer.

With careful management of the vias used to connect signal pins to each other, it is possible to achieve data rates as high as 56Gb/s in PCBs. 

LEE RITCHEY is president of Speeding Edge (speedingedge.com); lritchey49@aol.com.



PCB Chat

pcbchat.com

Recent Chats:

■ **HDP User Group Annual Update**
with MADAN JAGERNAUTH

■ **The Hidden Causes of Adhesion Failure**
with DAVID DWORAK

The PCB Podcast

AI is Reshaping the PCB Industry

Advanced substrates and high-layer-count boards, not smartphones and PCs, are now the growth engine.

by DR. HAYAO NAKAHARA

How things change in just one generation. If we look back 25 years or so, computers and networking systems were pushing technology and fabricator revenues, with smartphones showing signs of a coming shift. There were four billion-dollar printed circuit board fabricators, two each from the US and Japan.

Last year, however, some 29 fabricators cleared the \$1 billion mark, and all but two, TTM and AT&S, were based in Asia.

The data point to a decisive shift in what's driving PCB demand: after decades in which PCs, tablets and especially smartphones set the pace, growth is now concentrated in advanced IC package substrates and high-layer-count multilayer boards feeding AI hardware for hyperscalers like Google, Meta, AWS and Microsoft. Taiwan and China, home to the bulk of global chip packaging and assembly capacity, continue to widen their lead over Western and Japanese fabricators, several of which have been acquired or absorbed in recent years. Global PCB output will reach \$135 billion in 2026, driven largely by continued investment in substrates – although ballooning capacity and looming materials and technology shifts could test the durability of the current boom.

Before diving into the data, the author must regretfully note that it is getting harder to put together NTI-100 data every year. Five years ago, he told himself it was the last time he'd write this article. Sadly, it's an addiction. So, here we go.

Many individuals and trade organizations helped the author with the data in the main table. Special gratitude is due to CPCA, without which it would have been impossible to put this story together. As always, there are probably errors caused by the author's judgment. He takes full responsibility for any errors. But in his defense, who can pull off such article? Ranking is important for many PCB fabricators to see where they stand. However, everything is relative.

Exchange Rates

Revenues are converted to US dollars using 2025 exchange rates based on local currency including 2024 revenues for the purpose of seeing the growth rate of each fabricator in the list (**Table 1**). In 2025, the RMB, baht and Euro gained slightly against the US dollar. As yen to dollar exchange rate is floating at about 160:1 throughout 2026, fewer Japanese entries will make next year's list.

Table 1. Average Exchange Rate History: US Dollar vs. Local Currency

Currency	2019	2020	2021	2022	2023	2024	2025
China Yuan (RMB)	6.910	6.903	6.402	6.732	7.072	7.196	7.039
Japanese Yen	109.01	106.77	108.98	131.43	141.70	151.53	149.60
Taiwan NTD	30.93	29.47	27.64	28.98	31.15	31.31	31.35
Korean Won	1,165.70	1,180.00	1,136.00	1,292.00	1,306.00	1,364.00	1.42
Thai Baht	31.03	31.27	31.76	35.06	34.77	35.29	32.90
Singapore D	1.364	1.380	1.333	1.379	1.343	1.336	1.308
Malaysia Ringgit	4.123	4.203	4.11	4.40	4.56	4.58	4.287
Vietnam Dong	23,202	23,200	22,879	23,121	23,815	25,060	25,455
Indonesia Rupiah	13,798.61	14,559.25	14,195	14,851	15,238	15,861	16,484
Canada D	1.327	1.34	1.224	1.302	1.35	1.37	1.40
Indian Rupee	70.39	71.12	73.36	78.01	82.57	83.68	87.13
Mexican Pesos	19.25	21.50	20.13	20.12	17.74	18.30	19.23
Russian Rouble	64.69	72.41	73.12	76.50	85.31	85.82	81.28
Swiss Franc	0.99	1.38	0.967	0.99	0.90	0.88	0.812
UK Pound	0.78	0.78	0.721	0.812	0.805	0.782	0.76
Euro	0.894	0.868	0.839	0.952	0.924	0.924	0.877
Euro	0.844	0.894	0.868	0.839	0.952	0.924	0.924
2025.01.03, NTI Summary from www.exchangerates.com							

Rankings

The NTI-100 this year contains 168 entries. **Tables 2** and **3** highlight the findings based on the 60 largest companies. **Tables 4-7** contain the remaining 108 companies. Readers will see the purpose of doing this.

Table 2. 2025 World's Largest PCB Fabricators, 1-30

Rank	Company	Local Name	Nationality	2024	2025	% Change
1	Zhen Ding Technology	臻鼎科技	Taiwan	5,483	5,822	6.2%
2	Unimicron	欣興電子	Taiwan	3,685	4,186	13.8%
3	DSBJ	東山精密	China	3,520	3,640	3.4%
4	Shennan Circuits	深南電路	China	2,543	3,359	32.1%
5	TTM Technology,Inc	TTM Technologies, Inc.	US	2,443	2,906	19.8%
6	WUS Group (TW+CN)	楠梓電子(滬士電子)	Taiwan	1,956	2,810	43.7%
7	Victory Giant	勝宏科技	China	1,521	2,741	79.8%
8	Compeq	華通電腦	Taiwan	2,314	2,550	4.9%
9	Kyocera	京セラ	Japan	1,940	2,393	23.3%
10	Tripod	健鼎科技	Taiwan	2,102	2,341	11.5%
11	Mektec	메ктеック	Japan	2,472	2,235	-9.6%
12	Kinwong	景旺電子	China	1,794	2,175	20.9%
13	AT&S	AT&S	Austria	1,813	2,042	12.6%
14	Gold Circuit (GCE)	金像電子	Taiwan	1,239	1,905	54.0%
15	HannStar Board	瀚宇博德	Taiwan	1,330	1,825	37.5%
16	Kingboard PCB	建滔集團	China	1,568	1,733	10.5%
17	Ibiden	イビデン	Japan	1,314	1,626	23.7%
18	SEMCO	삼성전기	S. Korea	1,431	1,619	13.1%
19	Meiko	メイコー	Japan	1,396	1,608	15.2%
20	Young Poong Group	영풍그룹	S. Korea	1,468	1,461	-0.5%
21	Shengyi Electronics	生益電子	China	666	1,349	102.6%
22	Nanya PCB	南亞電路	Taiwan	1,031	1,281	24.4%
23	BH Flex	베에이치플렉스	S. Korea	1,234	1,261	2.2%
24	Kinsus	景碩科技	Taiwan	975	1,255	28.9%
25	AKM Meadville	安捷利美維	China	1,125	1,251	12.1%
26	LG Innotek	LG이노텍	S. Korea	988	1,210	25.5%
27	Suntak	崇達科技	China	892	1,072	20.2%
28	Hongxin Electronics	廈門弘信電子科技	China	835	1,039	58.8%
29	Shenzhen Fast Print	深圳興森快捷電路	China	828	1,022	23.7%
30	Simmtech	심텍	S. Korea	866	959	10.7%
Top 30 Total				52,772	62,676	18.8%
In US\$ millions. N.T. Information Ltd., August 2026						

Table 3. 2025 Largest PCB Fabricators, 31-60

Rank	Company	Local Name	Nationality	2024	2025	% Change
31	Nitto Denko	日東電工	Japan	904	947	4.8%
32	Sumitomo Elect Ind.	住友電気工業	Japan	706	813	15.1%
33	Shinko Electric Ind.	新光電気工業	Japan	820	805	1.8%
34	Olympic	世運電路科技	China	713	792	11.0%
35	Aoshikan (ASK PCB)	奧士康	China	649	786	21.1%
36	Delton Technology	広州広合科技	China	623	779	46.9%
37	ISU Petasys	이수페타시스	S. Korea	589	765	29.9%
38	Daeduck Electronics	대덕전자	S. Korea	627	749	19.5%
39	Flexium Technology	台群科技	Taiwan	844	713	-15.5%
40	Founder PCB	方正印刷電路	China	480	694	44.4%
41	Mutara Manufacturing	村田製作所	Japan	650	670	3.1%
42	CMK	日本シーエムケー	Japan	636	670	5.3%
43	Sun & Lynn	深聯電路	China	549	665	21.2%
44	SZ Deren Electronics	得潤電子	China	610	640	-4.9%
45	Dynamic Electronics	定穎電子	Taiwan	566	622	10.0%
46	Taiwan Techvest (TPT)	志超科技	Taiwan	566	596	3.7%
47	Fujikura	フジクラ	Japan	690	586	-15.7%
48	Unitech	耀華電子	Taiwan	592	578	-12.3%
49	Ellington	依頓電子	China	498	572	14.8%
50	Kingshine	広東科翔電子	China	482	528	9.6%
51	Red Board	紅板	China	384	522	36.1%
52	Bomin Electronics	博敏電子	China	464	519	10.6%
53	Chin Poon	敬鵬工業	Taiwan	522	502	-3.7%
54	Somacis	Somacis	Italy	257	452	75.9%
55	CCTC	汕頭超声印制板	China	394	448	8.8%
56	China Eagle (CEE)	中京電子	China	417	446	7.1%
57	Linkstech (GBM Japan)	リンクテック	Japan	400	420	5.0%
58	Sanmina Corporation	Sanmina Corporation	US	380	400	5.3%
59	Gul Technology	Gul Technology	Singapore	342	387	13.2%
60	ASE	日月光	Taiwan	260	380	46.0%
31 to 60 Total				16,614	18,446	11.0%
In US\$ millions. N.T. Information Ltd., August 2026						

As shown in Table 2, the top 30 fabricators' output accounts for 61.6% of the aggregate \$101.8 billion by the 168 fabricators with revenues of \$100 million or more in 2025.

The next 30 fabricators' output accounts for 18.1% of the total. In other words, the top 60 fabricators' output accounts for nearly 80% of the NTI-100. Seeing the two tables, one may conclude that the big get bigger and faster. A total of 29 fabricators had revenue exceeding \$1 billion in 2025! TTM and AT&S were the only Western fabricators among them.

In the 1990s through 2020, semiconductors and PCBs used by PCs including tablets and smartphones were the growth locomotive. That has changed completely today. While the growth of these products is stagnant or even declining,

AI-related semiconductors, GPUs, CPUs, HBMs, and PCBs assumed the role. Particularly over the past few years, the semiconductor narrative has centered on GPU, HBM, CoWoS, EMIB, and now CPU, advanced process nodes and high-speed interconnects. By the second half of 2026, however, the resource allocation triggered by AI is spreading well beyond the highest-end AI components and into conventional DRAM, PCs, smartphones and the broader electronics supply chain.

From the PCB viewpoint, advanced IC package substrates (hereafter “substrates”) and high-layer count (“HLC”) multilayer boards became the driving force. If one examines the PCB fabricators that grew by large percentage from 2024 to 2025, he will notice that they are either substrate fabricators and/or HLC multilayer board fabricators (MLB). Their biggest end-customers are typically so-called hyperscalers such as Google, Meta, AWS and Microsoft.

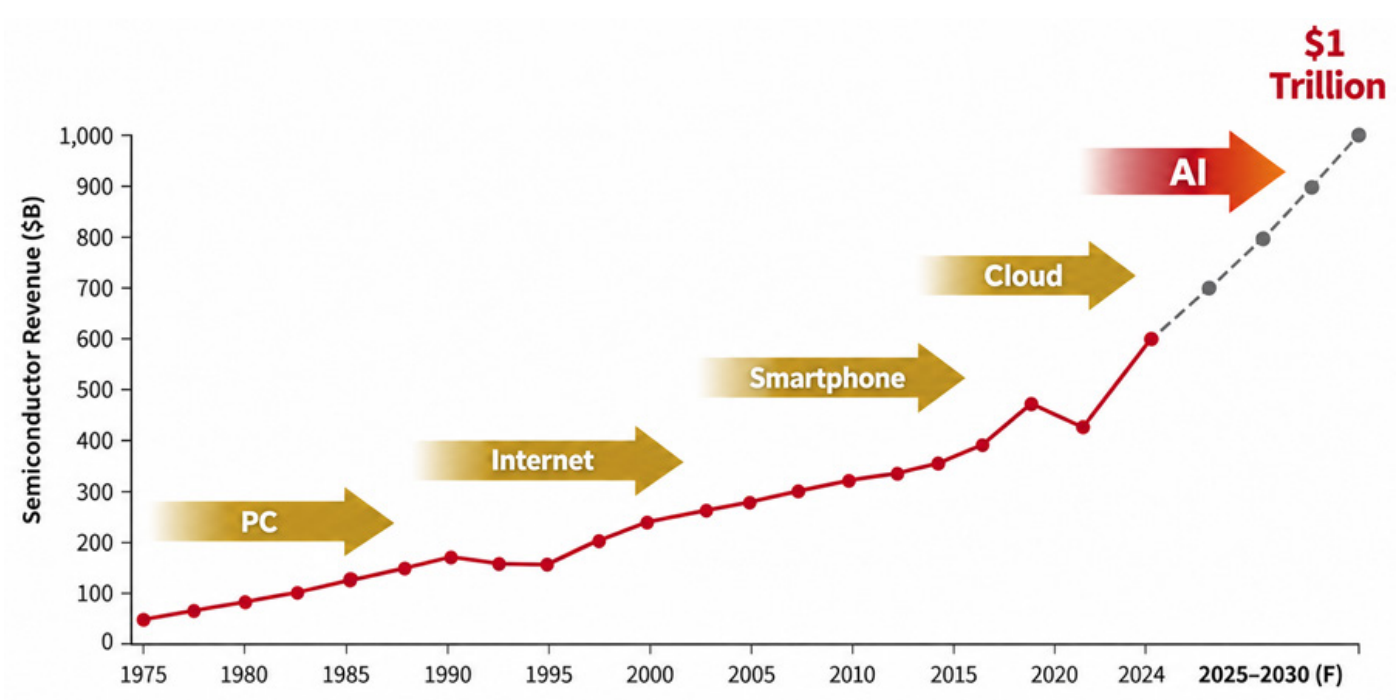


Figure 1. Semiconductor drivers and outlook.

Taiwanese PCB fabricators have tremendous advantages as TSMC makes about 70% of the global chips and many OSATs are Taiwan-based. The CEOs of two large semiconductor companies, Nvidia and AMD, Jensen Huang and Dr. Lisa Su, respectively, both came to the US from Taiwan. The CEO of Intel is Lip-Bu Tan, of Chinese Malaysian origin. These may not have anything to do with the strength of Taiwanese and Chinese PCB fabricators, but the author sometimes wonders. Major OSAT companies, which assemble chips into packages, operate in Taiwan, China and Southeast Asia. ODM/EMS companies such as Foxconn, Pegatron and Wistron, to name a few, are Taiwan-based although they operate globally. This may relate somewhat to the strength of Taiwanese and Chinese PCB fabricators.

What top PCB fabricators have in common is that they invested tremendously in the right direction and ensure delivery confidence to their clients. In terms of importance to mega-users of PCBs, “price” comes first, followed by “delivery,” which means capacity or investment, technology notwithstanding. These relate to cost of manufacturing. Asia Pacific provides all of these.

Table 4 shows the remaining 106 fabricators with revenues of \$100 million or more in 2025.

Table 4a. 2025 Largest PCB Fabricators, 61-90

Rank	Company	Local Name	Nationality	2024	2025	% Change
61	APEX International	泰鼎電路	Taiwan	398	370	-6.8%
62	GD Champion Asia	広東駿亜電子	China	333	359	8.0%
63	DAP	디에이피	S. Korea	358	358	0.0%
64	KCE	KCE Electronics	Thailand	404	356	-11.9%
65	Kingsignal Technology	金信諾	China	311	355	14.1%
66	Ichia Technology	毅嘉科技	Taiwan	304	346	13.9%
67	SI Flex	에스아이플렉스	S. Korea	223	342	53.4%
68	Toppan Printing	凸版印刷	Japan	307	321	4.6%
69	Summit Interconnect	Summit Interconnect	US	280	310	10.7%
70	First Hi-Tech	高技企業	Taiwan	133	308	130.8%
71	Jinagsu Transimage Tech	江蘇伝芸科技	China	301	305	1.3%
72	Maruwa	マルワ	Japan	288	301	4.5%
73	ACCESS	珠海越亜半導體	China	238	297	24.8%
74	Camelot PCB	金淥電路科技	China	227	293	28.7%
75	Kyoden	キョウデン	Japan	280	280	0.0%
76	AdvancedPCB	AdvancedPCB	US	250	280	12.0%
77	Shihui Fushi	四会富仕電子科技	China	201	274	36.7%
78	Brain Power	欣強科技	Taiwan	140	273	185.0%
79	SZ Jove Enterprise	深圳中富電路	China	206	267	29.2%
80	Shenzhen Sunshine	深圳明陽電路	China	221	264	19.4%
81	Inno Circuits Ltd	四川英創力電子	China	104	261	150.3%
82	FICT	エフアイシーティー	Japan	213	255	11.8%
83	Palwonn	競華電子	Taiwan	167	254	53.0%
84	Sun Create Electronics	四創電子	China	180	248	38.0%
85	Onpress	安柏電路	China	204	239	17.2%
86	Ji'An Munkan	吉安滿坤科技	China	180	234	30.0%
87	Amphenol PCB	Amphenol PCB	US	210	230	9.5%
88	Glorysky	惠州市特創電子	China	167	221	32.4%
89	Aikokiki	愛工機器	Japan	168	220	25.2%
90	Top Reach	深圳至誠合電子	China	177	219	15.9%

In US\$ millions. N.T. Information Ltd., August 2026

Table 4b. 2025 Largest PCB Fabricators, 91-120

Rank	Company	Local Name	Nationality	2024	2025	% Change
91	Welgao	江西威尔高電子	China	145	219	51.2%
92	Forewin FPC	福萊盈電子	China	186	211	13.5%
93	Sichuan Ruijienxin	四川省杰鑫電子	China	140	210	33.4%
94	Jiangxi Union Gain	江西聯益電子科技	China	193	209	8.1%
95	Minzhenhong	広東明正宏電子	China	183	207	13.3%
96	Taihong Circuit Industry	台豊印刷電路工業	Taiwan	197	207	7.2%
97	Schweizer Electronics	Schweizer Electronics	Germany	144	197	19.8%
98	Tianjin Printronics	天津普林	China	160	196	22.2%
99	Shirai Denshi	シライ電子	Japan	194	195	0.5%
100	Fuchangfa	信豊福昌発電子	China	146	193	32.0%
101	Changzhou Auhong	常州澳弘電子	China	184	192	4.3%
102	Longteng Electronics	湖北龍騰電子	China	152	187	22.6%
103	Forewin FPC	福萊盈電子	China	126	182	44.6%
104	NBC	エヌビーシー	Japan	157	182	15.9%
105	Cetc Potevio Sci & Tec	中電科学普天科	China	164	180	9.6%
106	PCB Technology	PCB Technology	Israel	150	180	20.0%
107	Career Technology	嘉聯益科技	Taiwan	232	173	-25.7%
108	Kunshan Huanxing Grp.	昆山華新電子集團	China	149	170	9.1%
109	Longyi Group	広東龍宇新材料	China	126	170	35.0%
110	Kunshan Huaxing	昆山華新電子	China	149	170	9.1%
111	Gangzhou Kingshun	贛州金順科技	China	136	169	24.2%
112	Jiangxi ZLE	江西中絡電子	China	155	168	8.6%
113	KS Wangyuantong	昆山万源通電子	China	148	168	13.6%
114	Xusheng Electronics	江西旭昇電子	China	147	166	12.6%
115	Kyosha	京写	Japan	175	165	-5.7%
116	Intflex (SZ Zecheng Elec.)	深圳則成電子	China	195	161	-21.2%
117	Jinagsu Difeida	江蘇迪飛達電子	China	141	160	13.6%
118	Edadoc	深圳一博科技	China	126	160	27.0%
119	Daisho Dennshi	大昌電子	Japan	151	160	6.6%
120	NTK	日本特殊陶業	Japan	147	160	8.8%

In US\$ millions. N.T. Information Ltd., August 2026

Table 4c. 2025 Largest PCB Fabricators, 121-150

Rank	Company	Local Name	Nationality	2024	2025	% Change
121	Song Shan Electronics	松山電子	Taiwan	137	158	15.7%
122	STEMCO	스템코	S. Korea	158	158	0.0%
123	SZ Konka PCB	深圳康佳電路	China	152	156	2.2%
124	Würth Elektronik	Würth Elektronik	Germany	180	154	-14.4%
125	CHPT	中華精測科技	Taiwan	115	153	33.3%
126	Dongguang Hongyuen	東莞康源電子	China	130	148	14.1%
127	Synopex	시노펙스	S. Korea	148	148	0.0%
128	Hyunwoo	현우	S. Korea	145	145	0.0%
129	Meizhou Ding Tai	梅州鼎泰電路板	China	131	142	8.8%
130	Yongxinglong Electronics	黄石永興隆電子	China	126	139	-4.5%
131	Stariver (Galaxy)	深圳市星河電路	China	130	139	7.0%
132	Henghe Dingfu (Suzhou)	恒赫鼎富(蘇州)電子	China	89	139	56.0%
133	Xingzhinguang Circuit	惠州市星之光科技	China	128	139	8.1%
134	Jiangsu Xiehe Electronics	江蘇協和電子	China	126	139	10.4%
135	Concord Electronics	江蘇協和電子	China	126	139	10.4%
136	FTG	Firan Technology	Canada	116	136	17.8%
137	Shenzhen QD Circuit	深圳強達電路	China	123	135	20.2%
138	Linangjincheng	聯錦成科技	China	127	133	4.7%
139	APCB	競國實業	Taiwan	164	133	-18.5%
140	Liang Dar	良達科技	Taiwan	139	133	-4.1%
141	Zhejiang Leuchtek	浙江羅奇泰克科技	China	126	132	4.7%
142	SZ Trustech Electronics	深圳全成信電子	China	96	131	36.0%
143	TLB	티엘비는	S. Korea	127	127	0.0%
144	Jiangsu Suhhang	江蘇蘇杭電子集團	China	133	125	-6.7%
145	Jinangsu Allfavor Int. Ckt.	江蘇本川智能電路	China	85	124	47.0%
146	New Flex	뉴플렉스	S. Korea	124	124	0.0%
147	Kungshan Wanshen	昆山万正電路板	China	96	117	21.8%
148	Oki Printed Circuit	沖PC	Japan	110	117	6.4%
149	Haesung DS	해성디에스	S. Korea	106	115	8.5%
150	Sierra Proto	Sierra Proto	US	100	115	11.5%

In US\$ millions. N.T. Information Ltd., August 2026

Table 4d. 2025 Largest PCB Fabricators, 151-168

Rank	Company	Local Name	Nationality	2024	2025	% Change
151	Xiamen Guangpu Elec.	光苒電子股份	China	100	114	14.5%
152	Jiangxi Asurung	江西愛升精密電路	China	112	114	1.7%
153	Yidong Electronics	奕東電子科技	China	96	114	19.0%
154	Ronghui Group	江西榮暉電子	China	111	113	1.9%
155	Zhejiang Oulong	浙江歐瓏電氣	China	87	112	28.7%
156	SZ Kiabg Chuang	深圳聯創電路	China	103	112	8.3%
157	SZ Hopesearch PCB Mfg.	深圳豐達興線路板	China	79	109	38.7%
158	Theme Int'l Holdings	榮暉集團	China	98	109	5.5%
159	SZ Xinyu Tengye	深圳新宇騰跌電子	China	80	108	35.0%
160	Jinangmen Belinda	江門市奔力電路	China	89	107	21.0%
161	Shinko MFfg Co., Ltd	伸光製作所	Japan	104	107	2.9%
162	Mutualtek	常熟東南相互電子	China	98	106	8.8%
163	Rayben	榮健科技	China	99	106	7.1%
164	Anhui Dai You Elect.	安徽徽大洋電子科技	China	88	104	18.8%
165	Gangzhou Beyond PCB	贛州超跌科技	China	93	104	12.2%
166	Jiangxi Xiongyi	江西祥益鼎盛科技	China	94	103	9.7%
167	Shenzhen Kingbrothers	深圳金百澤電子科技	China	97	100	2.6%
168	Gorilla Circuits	Gorilla Circuits	US	95	100	5.3%
Total				87,561	101,773	16.2%
In US\$ millions. N.T. Information Ltd., August 2026						

Summary of 2025 Top Fabricators

A total of 168 fabricators reported revenues of more than \$100 million in 2025 (**Table 5**). Let's look a little closer at that that entails. For example, the entire European production “in Europe” in 2025 is estimated at about \$2 billion. A large portion of European PCB production is made by AT&S, mainly in China although its Malaysian production seems to rise continuously. AT&S sold its plant in South Korea to Italy-based Somacis. Likewise, a substantial portion of American PCBs are made in China by TTM.

Table 5. Top Regions in 2025

Region	No. Entry	2024	2025	% Change
China	89	31,304	38,368	22.6%
Taiwan	26	25,591	29,874	16.6%
Japan	23	14,254	15,280	7.2%
S. Korea	15	8,592	9,541	11.0%
America	8	3,663	4,014	9.6%
Europe	4	3,261	3,773	15.7%
SE Asia	2	746	743	-0.4%
Middle East	1	150	180	20.0%
Total	168	87,561	101,773	16.2%
In US\$ millions. N.T. Information Ltd., August 2026				

It's not shown here, but the total production of PCBs made in China in 2025 is estimated to be about \$69.5 billion, of which Chinese "nationals" accounted for about \$44 billion (there are more than 1,000 Chinese fabricators), with another \$20 billion by Taiwanese companies, and \$6 billion by other foreign transplants (TTM, AT&S, Mektec, Meiko, CMK, Gultech, ISU Petasys, and a dozen others). Dynamic, Palwon, Brain Power, etc., are Taiwanese fabricators but have no plants in Taiwan. Zhen Ding Technology has a Chinese subsidiary registered on the Shenzhen Stock Exchange called Avary Holdings. It has another subsidiary in China, LIST (Leading Interconnection Semiconductor Technology), specializing in substrates (\$387 million revenue in 2025).

Unfortunately, several Chinese fabricators that should be in the NTI-100 are not accounted for because the author could not obtain their 2025 revenues. Assuming they output at least about the same amount as in 2024, the number of Chinese entries would have been about 95 and the output may have exceeded \$39 billion. The author knows several South Korean fabricators whose output was also hard to obtain, so he used the same output as in 2024, but the total quantity is not large enough to influence the total output by top fabricators.

Bare Boards and Assembled PCBs

Separating the values of assembled PCB (by PCB fabricators) from the total output is problematic. In China, more than 700 PCB fabricators claim to be "one-stop-shops," from design to fabrication and assembly and even box-build. Suppliers of flexible PCBs (FPC) to iPhone assemblers are said to assemble boards at their plants where the FPC is fabricated before shipment to the customer. Approximately 40% of the shipped FPCs are "bare boards." The component value is 40% and the cost of assembly is 20%.

TTM, Compeq, SCC, Meiko and many other large PCB fabricators engage in assembly, and some engage in equipment businesses, too. The best estimate of this author is that about \$10 billion of the estimated \$115 billion PCB output made by about 2,500 fabricators worldwide – including the \$20 billion made by 2,300 fabricators that are not in the NTI-100 – are assembled boards. If this estimate is decent, the author concludes that the "total global bare PCB output" in 2025 was about \$104 billion. Remember, the 168 fabricators listed in Table 4 are merely 7% of the total 2,500. Many PCB reports are floating around. The author has no idea how they come up with their numbers and forecasts.

Comments on Certain Fabricators

Taiwan's Unimicron purchased Ruwel Werke of Germany and Clover Electronics of Japan. Taiwan's GBM, a subsidiary of HannStar Board, purchased the PCB segment of Elna Corp. of Japan several years ago. Then, in 2024, it purchased Lincstech (formerly a PCB arm of Hitachi Chemical, which is now the core of Resonac). Kyoden was sold to Carlyle Group Japan. Eastern Co. was bought by Simmtech of South Korea. FICT was purchased by MBK Partners of South Korea (a 20% share was purchased by one of FICT's customers, FormFactor). FICT's Vietnam subsidiary was acquired by Taiwan's Tripod. The total revenue of these "former Japanese fabricators" is about \$1.4 billion. That is, Japan lost \$1.4 billion PCB revenue as a nation. Shinko Electric Industry remained a Japanese fabricator as a thanks to the Japanese government fund organization (which holds an 80% share, with 15% held by Dainippon Printing and 5% by Mitsui Chemical) for security reasons.

As mentioned, Somacis bought AT&S Korea. As a result, its revenue jumped on top of its exiting subsidiaries in the UK, US and China, which also grew in 2025. In 2026, its revenue will top \$540 million because it acquired ACB Group in France and Belgium in early 2026. TTM bought ILFA in Germany and GS in Switzerland. Victory Giant Technology (VGT) bought APCB Thailand from its Taiwanese parent. VGT gutted the plant, rebuilt and is expanding. Many more such deals have taken place in recent years, particularly in China.

The author has more than 800 Chinese PCB fabricator files accumulated over the past 30 years. Many of their websites are very confusing. When a Chinese fabricator buys a fabricator in China, the original name of the purchased company seems to remain the same. Such practice is very confusing to researchers like this author.

A Chinese fabricator may have several plants. Its website shows pictures of equipment. It doesn't say anything about which of the several plants the equipment belongs to.

A Quarter Century Later

Table 6 is modified from the original the author made in 2001. Compare Table 9 with Tables 2-4, which show the world top PCB fabricators in 2025. Some 13 of the top 30 fabricators in 2000 have disappeared, either completely or partially (through acquisition by others). TTM did a very good job in growing by acquisition. Acquisitions are not so easy because the buyer must shape the acquired organizations into a coherent corporate culture.

Table 6. World Top 30 PCB Fabricators in 2000

Rank	Maker	Region	Revenue	Comments
1	Sanmina	US	1,550	Sanmina closed 3 shops, but buying SCI
2	Viasystems* (TTM)	US	1,250	Closed Richmond & Puerto Rico. Sold Swedish plant
3	CMK	Japan	1,112	Built two plants in China and one more in China
4	Ibiden	Japan	1,083	Substrate plant in Philippines and HDI plant in Beijing
5	Hitachi Group*	Japan	973	Tackling fiber-optic backplanes
6	Nippon Mektron	Japan	905	German JV is now a subsidiary. Closed US shops
7	Compeq	Taiwan	802	A major supplier of Intel substrates, A plant in China
8	Multek (DCBJ)	US	780	Closed Austin plant. Building 2 new plants in China
9	Fujitsu*	Japan	624	Vietnam plant expanding microvia capability
10	Tyco PCB* (TTM)	US	600	Closed 3 shops in the US and bought Microser of Spain
11	Shinko Denki	Japan	550	A major supplier of Intel substrates
12	Daeduck Group	S.Korea	480	A plant in the Philippines
13	DDi* (TTM)	US	450	Aggressive acquisition. Sales office in Japan
14	IBM*	US	450	Spending \$300M in Shanghai for substrate manufact.
15	Matsushita MACO*	Japan	445	ALIVH doing well. Subsidiaries in Taiwan & Thailand
16	Nanya PCB	Taiwan	440	Built first plant in Kunshan, China
17	Photocircuits*	US	403	Philippines plant still waiting
18	WWEI (Unimicron)	Taiwan	400	Merging with Unimicron and Bestmult, both of Taiwan
19	Samsung E-M	S.Korea	400	Plannig a plant in China
20	Wus	Taiwan	390	Closed Singapore plants (ex-Motorola plants)
21	MGC Group (TCI)	Japan	382	Plants in Japan, Taiwan and China
22	Honeywell ACI (TTM)	US	360	3 plants closed and reorganized
23	LG Electronics	S.Korea	340	Plant in Brazil planned?
24	Elec & Eltek	Hong Kong	320	Building a new backpanel plant in China
25	Korea Circuit	S.Korea	310	Bought a small flex/flex-rigid maker in California
26	Sony	Japan	305	Sony Neagari & Sony Chemical combined
27	Toppan Printing	Japan	295	A new plant in Poway, CA
28	AT&S	Austria	295	Building a new microvia plant in Shanghai
29	NEC	Japan	291	Busy with microvia activities
30	Fujikura Corp	Japan	268	4 plants in Thailand and two new ones in China planned
Top 30 Total			17,253	Top 30 in 2025: \$62,676, +363% in 25 years
In US\$ millions. N.T. Information Ltd., July 2001				
*Completely gone or purchased by other companies				

In 2000, eight of the top 30 were US-based companies. Today, only one: TTM. Twelve of 30 were Japan-based. Today, only four.

The following tables may be interesting to see. **Table 7** shows production values by region/country whereas **Table 8** shows the output by nationality. America includes North (the US, Canada and Mexico, the latter of which is very small) and South, mainly Brazil. ROW includes Middle East, Africa and Russia estimates.

Table 7. Preliminary Estimate of World PCB Output

Region	2021	2022	2023	2024	2025E
N. & S. America	3,400	3,520	3,210	3,340	3,550
Europe	2,025	2,160	1,980	2,000	2,100
Middle East & Africa	145	155	200	220	250
West Total	5,570	5,835	5,390	5,560	5,900
China	54,205	56,720	54,000	62,120	69,520
Taiwan	10,900	11,930	10,200	11,000	11,700
Japan	5,945	6,560	5,590	5,600	6,250
S. Korea	7,220	8,570	7,760	7,950	8,320
Thailand	3,175	3,350	3,050	3,450	5,450
Vietnam	3,110	3,200	2,900	3,200	4,200
Other Asia+India	1,250	1,340	1,200	1,620	2,400
Asia Total	85,805	91,670	84,700	94,940	107,840
World Total	91,375	97,505	90,090	100,500	113,740

In US\$ millions. N.T. Information Ltd., August 2026

Note: Approximately \$10B comes from assembly by PCB fabricators.

Russia not included (\$250M-300M, estimated but uncertain). If \$300M, then world is \$114.04B.

In China, Chinese makers: \$44B, Taiwanese makers: \$20B, Japanese: \$2B, US: \$1.6B, ROW: \$2.1B/2025

Table 8. World PCB Production by Nationality (\$ million)

Nation	Output	Share
China	44,000	38.7%
Taiwan	31,500	27.7%
Japan	14,350	12.6%
S. Korea	11,200	9.9%
America	5,800	5.0%
Europe	4,620	4.1%
S.E.Asia	980	0.9%
India	800	0.7%
ROW	450	0.4%
Total	113,700	100.0%

Source: N.T. Information Ltd., August 2026

Expectations for 2026

Looking at the available statistics, the global 2026 PCB output may reach \$135 billion.

Semiconductor chips must be “packaged,” and packages must be “mounted” on PCBs to implement final products. So, there is a strong correlation between chips and PCBs. For many years, for every \$1 semiconductor output, the PCB output has been around \$0.15, or, 15%. The 2025 semiconductor output was about \$800 billion, thus 15% (for PCB) equals \$120 billion. In 2026, WSTC expects that the semiconductor output may be \$1.5 trillion. Using the 15% rule, the 2026 PCB output would be \$225 billion.

However, this assumption gets carried away, probably. The major growth of semiconductor output this year is coming from memory devices. Since memory prices are shooting up, the “15%” assumption no longer stands correct. The author could see, however, that the 2026 global PCB output may reach \$135 billion as mentioned.

Table 9. Memory Price Forecasts, 4Q25–1Q26

Nation	4Q25	1Q26E revised
PC DRAM	DDR4&DDR5 blended: up 38~43%	DDR4&DDR5 blended: up 105~110%
Server DRAM	DDR4&DDR5 blended: up 53~58%	DDR4&DDR5 blended: up 88~93%
Mobile DRAM	LPDDR4X: up 48~53% LPDDR5X: up 43~48%	LPDDR4X: up 88~93% LPDDR5X: up 88~93%
Total DRAM	Conventional DRAM: up 45~50% HBM blended: up 50~55%	Conventional DRAM: up 90~95% HBM blended: up 80~85%
Enterprise SSD	up 25~30%	up 53~58%
Total NAND Flash	up 33~38%	up 55~60%
Source: TrendForce, February 2026		

In 2026 through 2027, PCB output growth will be driven by advanced substrates and HLC MLBs. About \$30 billion has been invested in advanced substrates since 2022 by major players such as Unimicron, Kinsus, Nanya PCB, LIST, Ibiden, Shinko Electric, Toppan, SEMCO, LG Innotek, AT&S, SCC, Fast Print, ACCESS and a few more fabricators. Due to the scarcity of materials such as T-glass, essential for high-speed, low-loss signal transmission in systems which are made with PCBs carrying substrates and other components, certain substrates and PCBs are on allocation, boosting selling prices, despite the author’s earlier comments on price. Many analysts claim that the current boom will last, but some cynics believe that overcapacity is imminent. The question is, when?

Table 10. Multilayer Board Specifications of Mainframe Computers in the 1980s

Computer Maker	IBM ES-9000	Fujitsu M-780	NEC ACOS-3900	Hitachi M-880	DEC VAX-9000	Unisys 2200-900	Cray C-90	Siemens 7500-H90
Dielectric Material	Brominated epoxy glass	Polyimide glass	Polyimide glass	Maleimide Styryl	BT/Epoxy glass	Cyanate ester	Cyanate ester	Epoxy glass
Dielectric Const	NA	4	4.6	3.6	NA	2.7	2.8	4.5
Dimension (mm)	600x700	540x488	446x477	534x730	626x626	622x648	360x560	460x480
Thickness (mm)	7.4	7.3	8	7	5.4	7.7	3.3	4.3
No. Layers	22	42	42	46	24	50	22	28
Cond. width (μm)	81	60	70	70	100	120	100	100
Cond. height (μm)	43	50	30	65	40	45	NA	40
Channels/crid	4/2.5mm	2/1.2mm	2/1.27mm	2/1.35mm	2/1.27mm	2/2.4mm	NA	2/1.5mm
PTH Diameter (mm)	0.46	0.35	0.6/0.3	0.56/0.3	0.45	0.53	0.3	0.6/0.4
Aspect ratio	16/1	21/1	27/1	23/1	1-Dec	15/1	1-Nov	1-Nov
No. PTHs/Pnl	42000	80,000	17,000	100,000	18,000	86,000	30,000	60,000
No. IVHs	8000	150,000	11,000	NA	24,000	250,000	50,000	24,000
No. MCMs	6	338 VLSI	NA	20	16	196 VLSI	NA	9
No. Pins/MCM	2,772	180	11,540	2,521	NA	243	NA	1,840
Innerlayer pattern formation method	Additive pattern plate on 5μm Cu	Galvanic pattern plate on 9μ Cu	Additive panel T&E on 12μm Cu	Additive pattern plate on 12μm Cu	Galvanic pattern plate on 18μm Cu	Galvanic panel T&E NA	Galvanic Pattern Plate NA	Galvanic pattern plate on 18μm Cu
Outer layer pattern formation	Additive Panel T&E	Galvanic pattern plate	Additive pattern plate	Additive pattern plate	Galvanic pattern plate	Galvanic pattern plate	NA	Galvanic pattern plate
Impedance (Ω)	80±10	65±5	60±6	NA	60	50	60	52
Source: Compiled by Hayao Nakahara, N.T. Information, Ltd., 1991								

An Investment Warning?

Four decades ago, only eight fabricators (all captive) could make HLC MLBs. Today, more than 50 fabricators worldwide handle fabrication of such boards “in volume.”

In 1990, IBM Yasu made a first sizable BGA substrate to assemble “one not so high-density chip” with lines/spaces of “sensational” 100μm. It was sensational. Today, the size of advanced substrates is becoming larger, exceeding 150mm x150mm with lines/spaces down to 3μm, mounting up to six chips and 50 or so HBMs. Some experts speculate that the size may reach 250mm x 250mm and layer count may exceed 30 layers in the future.

At the same time, lots of noise is heard that warping and the heat extraction capability of organic substrates is becoming problematic and eventually they will be replaced by glass core substrates for cost reasons as well as technical ones. At this moment, however, no one claims ongoing mass production of glass core substrates, including Intel which pushed the technology in 2023. If and when glass core substrates replace organic ones, what will happen to the \$30 billion investment made by the current leaders in package substrates?



Figure 2. The Ohno plant (for Nvidia) and Gama plant (for Intel, etc.), at a total investment of \$3.5 billion.



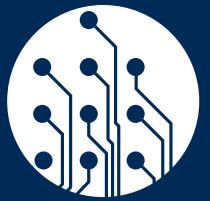
Figure 3. The \$2.2 billion Kulim substrate plant of AT&S Malaysia.

Figures 2 and 3 show some of the multi-billion plants being built. And these are just the tip of iceberg. 

DR. HAYAO NAKAHARA is president of N.T. Information and a contributing editor to PCD&F/CIRCUITS ASSEMBLY; nakanti@yahoo.com. He is the world's foremost authority on the worldwide printed circuit board market.

Stay connected

to top **PCB Leaders** with **PCU**



*Rick Hartley
Susy Webb
Lee Ritchey
Gary Ferrari
& more*



printedcircuituniversity.com

It's like having a second brain.

 **PRINTED CIRCUIT UNIVERSITY**

Online courses and webinars for the printed circuit engineering community.

The Electron: A Biography and the Emergence of Soldering

The electron's story traces how discoveries in electricity and electromagnetism helped drive the development of telegraphy, telephones, electric lighting and soldering.

by RONALD C. LASKY

Folks, the following post is some of what I presented at SMTA PanPac February 2-6, 2026 with a little of the history of soldering added.

My interest in the history of electronics was piqued when I attended a mid-1990s lecture by Nobel laureate Arno Penzias on the same topic. Penzias was a co-discoverer of the cosmic microwave background, which strongly supports the Big Bang creation theory of the universe.

A striking feature of Penzias's talk was when he said: "In 1972, one megabyte of computer memory cost \$1 million. That is about what a small apartment building, in New Jersey, cost back then. Today (1994), a megabyte of memory could not buy a hinge on a door in the apartment building."

Wow, what a striking statement! I often return to this thought when thinking about the rapid advances in electronics. These advances have led to today's \$1,000 smartphone having several times the computing power of the fastest supercomputer of 1995 and more than the computing power of all supercomputers of 1990. But I'm getting ahead of myself.

Let's start with a simple question: What defines modernity? The smartphone? TV? The internet? The electric light? I think the answer is simpler: Electricity. Electricity enables it all.

But let's start at the very beginning: the birth of the electron.

The most useful particle in physics – the electron – was born about 13.8 billion years ago, in the first moments after the Big Bang. It emerged alongside roughly 10^{80} fellow electrons and an equal number of protons, the raw material from which all ordinary matter would eventually form. Over billions of years, that matter condensed into as many as a trillion stars in the observable universe. So vast is this number that if every star were represented by a single grain of sand, the grains would blanket the entire Earth to a depth of about a meter.

Figure 1 shows a deep space image from the James Webb telescope. The small red galaxies formed less than a few

hundred million years after the Big Bang. Therefore, we are seeing the galaxies a short time after they formed. They contain the youngest electrons ever seen. The galaxies are red because they are redshifted as they speed away from us.



Figure 1. The Webb telescope deep-space image. The red galaxies are only a few hundred million years old in this image. (Image source: NASA, CSA and STScI; Processing by E. Siegel)

Humans would not learn to exploit the electron until 1820. But it would be a mistake to minimize this diminutive particle's role in everything that came before. All matter in nature is held together by electrical force, from the smallest virus to the most massive star; without the electron's properties, nothing material could exist.

Serious experimentation with this mysterious force didn't begin until 1752. That summer, Benjamin Franklin flew a kite into a Philadelphia thunderstorm and showed that lightning and the static electricity raised by rubbing a glass rod were one and the same. It was one of the earliest instances of real science conducted in America, and it feels like a fitting place to begin our story: someone brave, or foolish, enough to reach out and touch the electron's power directly, decades before anyone understood what was actually being touched.



Figure 2. "Benjamin Franklin Drawing Electricity from the Sky," oil painting by Benjamin West, c. 1816. Franklin's 1752 kite experiment showed that lightning and electricity were the same phenomenon. (Image source: Philadelphia Museum of Art / Wikimedia Commons)

Why is 1820 important? It was, in that year, by accident, that Hans Christian Ørsted made the discovery that led to useful applications of electricity. He was giving a public science lecture at the University of Copenhagen on the heating effects of electricity. He was using a battery, invented in 1800 by Volta. During the lecture, Ørsted was surprised that when a compass was held near a wire in which current was flowing, the compass needle was deflected. This discovery showed that electricity and magnetism were related. Subsequent work by André-Marie Ampère, Michael Faraday, and eventually James Clerk Maxwell led to the codification of electromagnetic (EM) theory into Maxwell's Equations by 1865. These equations have not been improved upon today and are the foundation for the design of essentially all electrical devices.

Soldering was older to Julius Caesar (100–44 BCE) than Caesar is to us. The earliest evidence of soldering dates to about 3500 BCE, making the technology more than 3,400 years old in Caesar's lifetime. In contrast, pioneering electrical researchers such as Hans Christian Ørsted and Michael Faraday relied primarily on temporary electrical connections rather than soldered joints. They commonly used binding screws, clamps, twisted wires or even mercury cups, into which they immersed the ends of wires to make reliable but easily reconfigurable electrical connections during their experiments.

The Telegraph, Telephone and Electric Light

However, well before Maxwell's Equations in 1865, inventors were putting electromagnetism to work. One of the first inventions was the telegraph. Samuel F. B. Morse perfected it and chose the founder of my alma mater, Ezra Cornell, as a partner to implement it. It would be difficult to overstate the importance of the telegraph. With the railroad and photography, it made the American Civil War the first modern war. President Lincoln was a regular at the Washington, DC, telegraph office, using telegraphy to direct the war, far from the battlefields. The Union's use of trains to transport troops and supplies was unprecedented and far outstripped the South's capabilities. The North's use of these two modern tools helped secure its victory. Meanwhile, photographers like Mathew Brady brought the horrors of war home to the people.

The invention of the telegraph gave birth to electric soldering, as wires and components now needed a permanent bond. Tinsmiths of the day performed the soldering using techniques they had developed. Tin-lead solder of 60/40 composition, close to the 63/37 formulation most recently phased out of the commercial world, was used. Soldering irons were made of a copper block shaped to a point and heated in burning coals, much like a blacksmith's tools. Electric soldering irons did not arrive until the 1890s. Solder in bar or wire form was used as shown in **Figure 3** and **Figure 4**.



Figure 3. Bar solder was used in soldering for the telegraph industry starting in the mid-1800s.



Figure 4. Wire solder used in this period was little different from the bar and wire solder of today.

Thomas Jefferson once mused that, given how enormous the Louisiana Purchase was, it would take 25 generations to settle it. He could not have been more wrong. And the telegraph played a part.

The telegraph's true impact emerged when it married the train in the transcontinental railroad. The railroad men pleaded with Congress for money to build the line from sea to shining sea, claiming they could not do such a massive undertaking without government financial help. A pliant Congress agreed, but only if the railroad would install telegraph lines alongside all the rail tracks. The transcontinental railroad was finished in 1869 to much fanfare and had a stunning effect on the development of the American West.

The "49ers" traveling from New England needed up to 8 months to get to the California gold fields. By 1870, the trip could be made in 4 days, and a telegraph message could reach friends and family instantly, letting them know you were coming. Never in history has change been so dramatic. In 1850, it could take months to get a message from New York City to San Francisco. In 1870, minutes.

By 1877, the theory of electromagnetism saw its first practical application in a telephone line from Boston to Somerville, MA, a distance of three miles. By 1900, there were close to 1.5 million phones in the United States. Telephones increased the demand for soldering. By this time, soldering with solder wire and an electric soldering iron was becoming more common.

We could overstate the importance of telegraphy and telephony as compared to electric lighting. In the mid-1800s, whale oil was often the best choice for home lighting. It burned clean and bright, but stank and cost hundreds of today's dollars per month. Kerosene was a welcome replacement, especially with John D. Rockefeller's Standard Oil. But inexpensive electric lighting replaced all of these stinky and dangerous lighting technologies. The implementation of electric lighting set off the War of the Currents: Edison versus Tesla and Westinghouse, so well documented in a motion picture, "The Current Wars." Spoiler alert: Tesla's AC current won. All of these advances created the need for more and more soldering with solder wire and soldering irons.

Meanwhile, Back in the Lab...

While Edison, Tesla and Westinghouse were busy wiring up cities and fighting the War of the Currents, something curious was happening a few steps behind them: nobody actually knew what an electron was. As late as 1895, most physicists still thought of electricity as some kind of fluid, sloshing through wires like water through a pipe. Engineers had been soldering telegraph lines, stringing telephone cables and lighting entire cities for the better part of 50 years without anyone being able to say, with any confidence, what was actually flowing through the wire.

That changed in 1897, when the English physicist J. J. Thomson, shown in **Figure 5**, built a modified cathode ray tube, illustrated in **Figure 6**, and showed that the mysterious "cathode rays" streaming inside it were actually a stream of individual particles, each carrying a negative charge and possessing only a small fraction of the mass of a hydrogen atom. Thomson's method was elegant: he first balanced electric and magnetic forces to find the particles' velocity, then balanced the magnetic force against the centripetal (mechanical) force needed to curve their path, allowing him to calculate the particles' charge-to-mass ratio, e/m . For the first time, humanity had proof that electricity was not a fluid, but a stream of discrete particles. Thomson had discovered the electron.



Figure 5. J. J. Thomson (1856–1940), who showed in 1897 that electrons are discrete particles and measured their charge-to-mass ratio. (Image source: Wikimedia Commons)

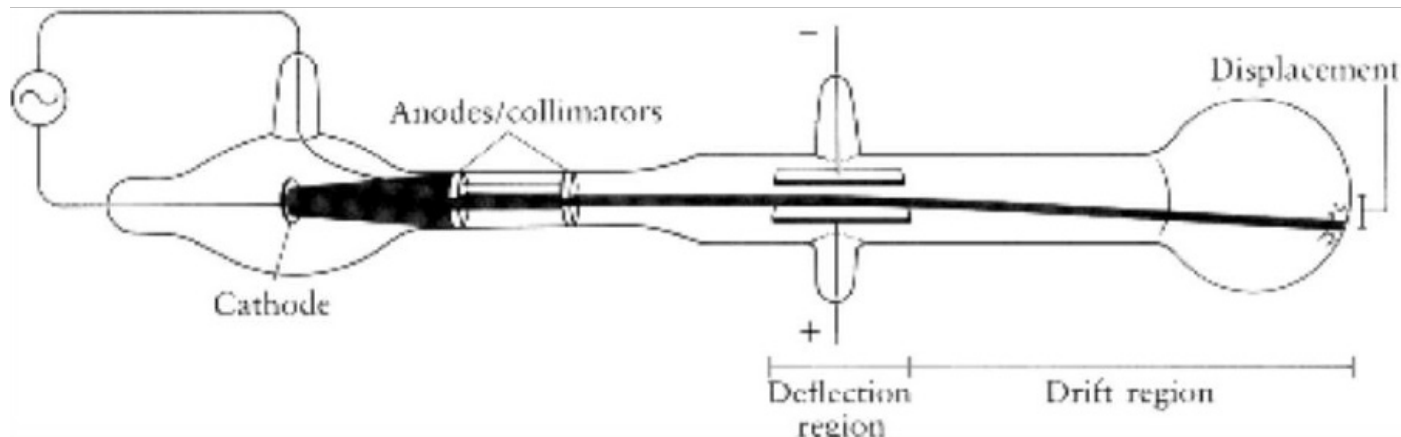


Figure 6. Thomson's cathode ray tube. An electric field from the plates and a magnetic field from coils placed outside the tube deflected the particle beam, letting Thomson calculate its charge-to-mass ratio.

Thomson could measure the electron's charge-to-mass ratio, but he could not isolate the charge or the mass alone. That took another thirteen years and a rather cleverer piece of glassware. In 1910, American physicist Robert Millikan sprayed a fine mist of oil droplets between two charged parallel plates, as shown in **Figure 7**, and adjusted the electric field until it exactly balanced gravity, leaving individual charged droplets suspended in mid-air. By carefully measuring the field needed to hold each droplet still, Millikan found that the charge on every droplet was always a whole-number multiple of one fixed, tiny amount: the elementary charge, e . The electron finally had a measured identity, a mass, a charge, and, for the first time, a name that meant something specific and real.

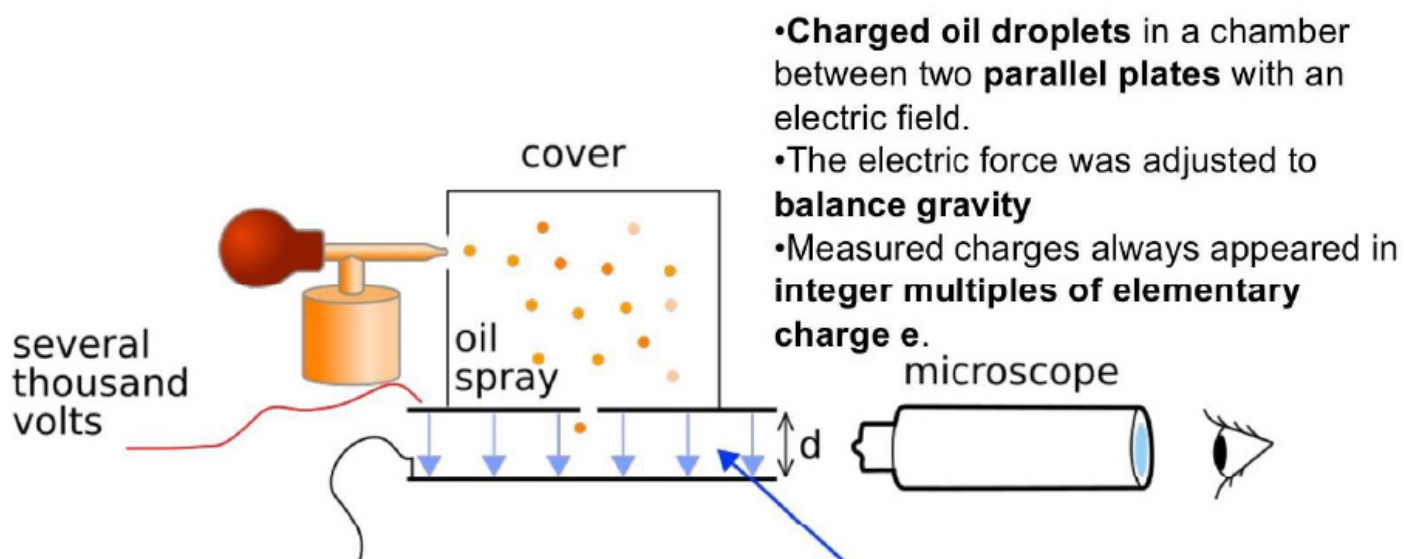


Figure 7. Millikan's oil-drop apparatus. Charged oil droplets were suspended between two plates by balancing gravity against an adjustable electric field, revealing that charge always comes in whole-number multiples of e .

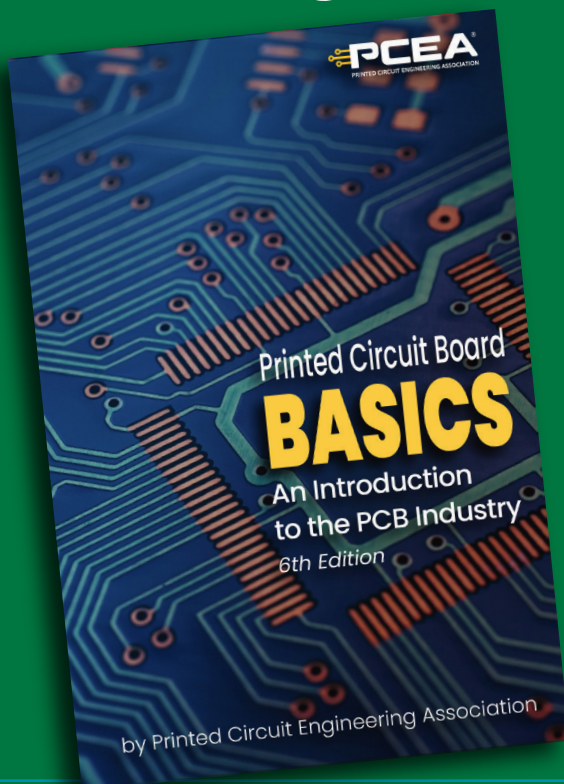
It is a fun bit of irony that the practical engineers of the 19th century were decades ahead of the physicists. The telegraph, the transcontinental railroad, the telephone, and the electric light bulb were already reshaping the world before anyone could prove, in a laboratory, that the electron even existed as a distinct particle. Practice, it turns out, does not always wait for theory.

Now that science had finally caught up with engineering, and given this little particle a name, a mass, and a charge, it was time for the electron to be put to work in a whole new way. Next time, we'll see it amplifying whispers into a roar, inside a simple glass tube, and giving birth to radio. 

RONALD C. LASKY, PH.D., P.E., is a senior technologist at Indium Corporation and a professor of engineering at Dartmouth College.

*Controlled
Impedance?*

Speak "PCB" with confidence.
No degree required.



The handbook for
anyone new to PCBs.
In plain words.

*Download Your
FREE Copy Today!*



PCEA[®]
PRINTED CIRCUIT ENGINEERING ASSOCIATION

How Electronics Complexity Is Changing SMT Manufacturing

Connected equipment, inspection, material management and production data are reshaping SMT manufacturing for increasingly complex electronics.

by SCOTT ZERKLE

Electronics developers continue to pack more functionality into smaller, more sophisticated designs. This progress creates a more demanding production environment for PCB manufacturers. Denser board designs and smaller components leave less room for variation, while manufacturers are being asked to support a broader range of products without sacrificing quality or throughput.

Growing product complexity is being felt across manufacturing. In a [recent survey](#) of manufacturing leaders, 67% described their products as very or extremely complex, up 20 percentage points from the previous year.

For PCB assemblers, this complexity extends beyond the design itself. Production lines must accommodate a wider range of products, materials and assembly requirements while continuing to deliver consistent quality and throughput.

Those technical requirements are accompanied by changing production demands. Smaller lot sizes, faster turnaround times and greater schedule flexibility are changing requirements on the production floor. Manufacturers also need to accommodate varying products and production volumes while managing the materials, equipment and processes required for each build.

These demands are changing what manufacturers need from surface mount technology (SMT) assembly. While speed remains critical, it is no longer the only measure of production performance. Today's assembly operations also need the precision to work within tighter process requirements and the flexibility to accommodate varying products and production volumes.

As PCB assemblies become more complex and product variation increases, SMT technologies are evolving to meet tighter process requirements while maintaining quality and throughput.

Smaller components raise the bar for precision. Component miniaturization is fundamentally changing PCB assembly requirements. Fitting more functionality into smaller form factors requires denser designs, putting greater pressure on the earliest stages of assembly.

That pressure begins before placing a component. Solder paste printing, for example, depends on consistent positioning and deposition. As process requirements tighten, printing technology must combine accuracy with productivity.

Current printing technology demonstrates how closely those requirements can coexist, with one implementation delivering a 12-second printing cycle time and $\pm 3.8\mu\text{m}$ repeated positioning accuracy. Automation is also extending to tasks surrounding the print cycle, including model changeover, solder transfer and supply, cleaning and maintenance monitoring.

For example, current printing systems can automatically retrieve solder remaining on the mask after printing and transfer it to the mask for the next model. Unit cleaning can also be incorporated into each cycle, while real-time solder paste monitoring can optimize maintenance timing and environmental conditions.

Placement presents a similar balancing act. Equipment must handle changing PCB and component requirements while maintaining speed and accuracy. Current placement technology uses approaches such as lightweight heads, higher X-axis acceleration and shorter spindle strokes to increase output and precision while supporting diverse production needs. In one current implementation, these advances support placement speeds of up to 104,000 components per hour while maintaining $\pm 25\mu\text{m}$ placement accuracy.

The progression is also measurable across equipment generations. In one implementation, an updated placement platform improved throughput by 10% and accuracy by 25% compared with the preceding generation, while extending its component range down to 0.3015mm microchips.

However, printing and placement do not determine assembly quality on their own. As process windows tighten, a change at one stage can influence the results measured at another. This makes inspection an increasingly important part of process control.

Inspection is becoming part of process control. As printing and placement requirements become more precise, inspection is playing a greater role in the production process. Advanced process control (APC) uses machine-to-machine communication between printing, placement, and inspection equipment, allowing inspection data to inform adjustments elsewhere on the line.

Solder paste inspection (SPI) data, for example, can be fed back to the printing process to correct solder-volume errors. That information can also feed forward to placement equipment based on position data captured during solder inspection. After placement, automated optical inspection (AOI) provides another feedback point. AOI-measured position data can return to the pick-and-place machine to correct component offsets. Manufacturers can make these adjustments in real time without operator intervention.

This expands how inspection data can be used during production. Rather than remaining at the inspection stage, measurement data can move between printing, placement and inspection processes to inform adjustments as production continues.

This type of process control becomes especially important across a changing product mix. Maintaining performance involves more than making adjustments during a single production run. Manufacturers also have to manage the materials, equipment setup, and changeover requirements that come with moving from one product to another.

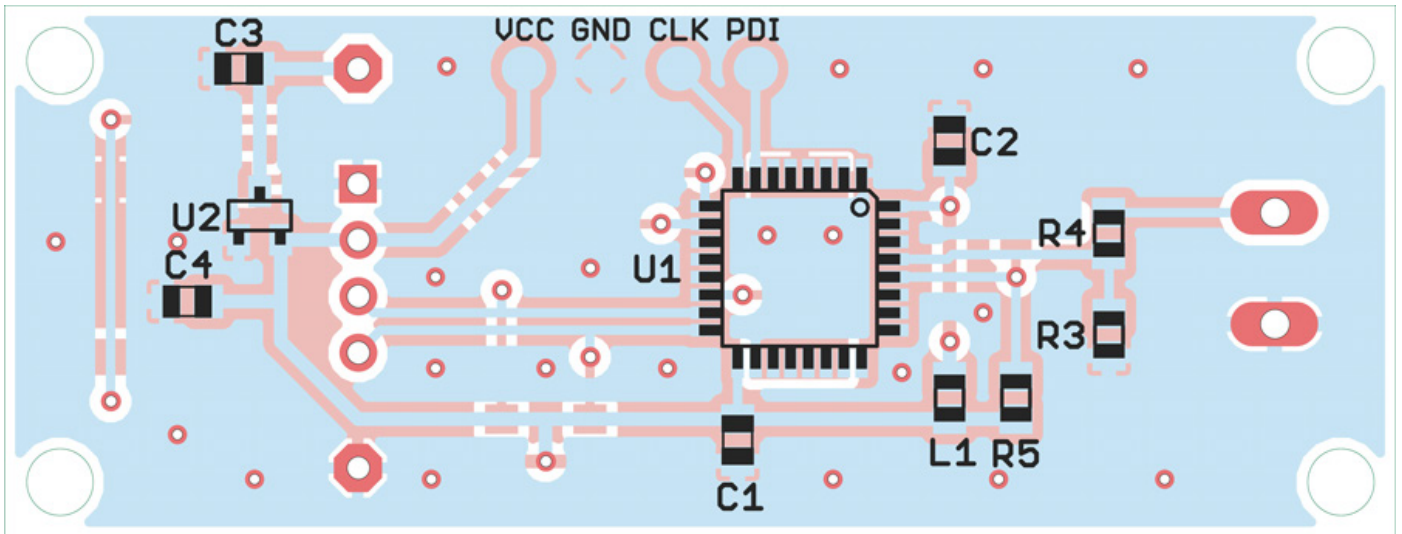


Figure 1. Connected SMT production systems integrate printing, placement, inspection and production data to manage increasingly complex assembly requirements.

High-Mix Production Changes the Productivity Equation

SMT manufacturers operate across a wide range of production environments, from high-mix, low-volume operations to high-volume manufacturing. As product mix changes, so do the components, feeder setups, board configurations, and equipment preparation required for each build.

In this environment, productivity involves more than placement speed. Material supply, setup and changeover can also affect how efficiently production moves from one build to another.

One measurable example of this is feeder technology. In one implementation, automated tape setting reduces the preparation time for a new part from approximately 90 seconds with the prior conventional feeder design to roughly 30 seconds. In the same implementation, a loading unit can automatically load subsequent parts without splicing. While that comparison is specific to those feeder technologies, it demonstrates how automation can reduce the time associated with component supply.

Material readiness also extends beyond the feeder itself. Before production begins, verification software can validate that the correct components have been loaded. During production, the same type of system can support splicing and warn as parts approach exhaustion.

Some materials require additional control. Moisture-sensitive devices (MSDs), for example, must be monitored against their allowable exposure time. Material-control software can track MSD exposure and support inventory management, helping manufacturers keep the right materials available for production.

Material control can extend further into how components are allocated and prepared for production. Unique barcodes can be used to locate materials, while FIFO rules can support component allocation and preparation for product changeover. The same systems can track real-time shelf life, provide notifications as components approach expiration and prevent expired MSDs from being used in production.

Another consideration is changeover. Manufacturing execution system (MES) software can configure and automate line changeover, including product downloads and equipment preparation. This can extend automation beyond placement to some of the work required to prepare the line for the next product.

For high-mix production, these functions have the same objective: having the correct materials and equipment ready for the product being built. While placement speed and accuracy remain fundamental, material supply, verification and changeover are other variables in keeping production moving across a changing product mix.

Traceability connects the assembly to its production history. As manufacturers manage more products, materials, and production requirements, they rely on traceability to record what happened during assembly. With current MES platforms, they can track and record information about the panel, product, machine, and reference designator throughout production.

That record can also extend to the materials and placement activities associated with an assembly. Component-to-panel and placement-to-panel traceability links those production details to the panel being produced. Additionally, barcode readers can automate identification capture as materials and products move throughout production.

This level of traceability gives manufacturers access to production records when addressing issues such as defects, recalls, or regulatory requirements. Rather than depending on information from a single stage of production, teams can trace the panel, components and placement activity associated with the assembly.

Manufacturers also need production monitoring to provide real-time visibility into what is happening on the line. With tools like centralized monitoring and notification systems, they can track production events as they occur, while automated KPI capture and event-resolution detection provide additional information about production status.

Production information can also extend beyond the individual line. MES data can be shared with other factory systems, including information on traceability, production counts, scrap, completion, inventory and material consumption.

Together, traceability and production monitoring offer both a historical record of the assembly and visibility into current production activity. This information becomes foundational for the next step: using production data to inform action.

From production data to process response. Collecting production data is only one part of the equation. Manufacturers must also use that information to understand where to focus and pay attention across the line.

One strategy is to monitor the factors that impact production more broadly. Advanced process control can manage the Five M's (Man, Machine, Material, Method and Measurement) using real-time monitoring to support quality, uptime

and yield across the line.

One example of how this information can inform action is maintenance. Current SMT equipment supports predictive and targeted maintenance functions, while maintenance software can track assets, schedule maintenance, manage work orders and maintain records for equipment and spare parts. Based on an asset's operating conditions, maintenance can also be automated.

At the machine level, diagnostic functions can monitor conditions such as flow sensors, air-blow and vacuum circuits, and Z- and theta-axis loads. Operators can test manually or schedule tests, using results to indicate whether maintenance is required. When integrated with manufacturing software, a head identified as NG can also be prevented from being used on the production line.

This type of diagnosis helps identify placement-head performance issues before they lead to breakdowns. By connecting diagnostic results with manufacturing software, equipment condition can also be used to determine whether a head remains available for production.

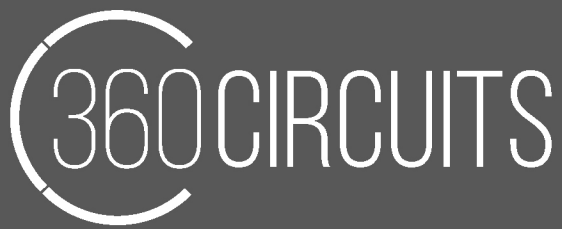
These capabilities expand the role of production information beyond monitoring alone. Equipment conditions can inform maintenance, while software can help coordinate the work required to keep equipment operating. As SMT production becomes more complex, connecting production information with these responses gives manufacturers another way to manage performance across the production line.

Preparing SMT operations for the next generation of electronics. Complex electronics are redefining SMT manufacturing requirements. Precision remains essential, but speed alone is no longer enough.

Modern assembly operations must coordinate equipment, materials, inspection, traceability and production data across the entire manufacturing process. Advanced process control, automated material management, integrated software and predictive maintenance help manufacturers meet these increasingly complex requirements.

As product designs continue to evolve, manufacturers will need production environments that can support any mix and any volume without compromising quality, uptime or yield. The future of SMT manufacturing will depend not only on faster equipment, but on more connected and intelligent production ecosystems. 

SCOTT ZERKLE is associate director of technical operations for Panasonic Connect Process Automation.



Full-Service
Marketing Agency

⋮ WITH A PASSION FOR ELECTRONICS ⋮

Top Services

Graphic Design



Content Writing



Industry Consulting



*Photorealistic Imagery,
Animations and Interactive Media*



Building Your Own IoT: Equipment Monitoring for New and Legacy Systems

PCB fabricators can pair IoT monitoring with AI to track equipment behavior, troubleshoot setups and build useful operating records.

by SEAN PATTERSON

Walk through a printed circuit fabrication shop and ask how people know the equipment is running normally. Some machines have useful displays and records. Others depend on an operator checking a gauge, writing down a reading, or hearing something that doesn't sound right. A lot of knowledge lives with the person standing next to the machine.

That works until a problem develops between checks or the person who usually catches it isn't there. A drilling machine stops, a press needs attention and now production has to work around it. Later, someone asks when the problem started, and there may not be much of a record to check.

If you've priced a monitoring system, you know the costs can include hardware, installation, and ongoing software fees. Older equipment can add another expense when it needs custom work to connect.

A separate sensor and a small computer may give you a simpler place to start. AI can help your team identify what works best for your system and can help you work through the setup. This becomes a basic example of the Internet of Things, or IoT, when the monitoring device connects to a network so its readings can be collected or reviewed. For this article, we're talking about watching equipment your shop already owns.

Working With the Equipment You Have

A PCB shop may have newer drilling equipment alongside a lamination press that has been in service for years. The press joins the layers of a multilayer board using heat and pressure. It may still do its job well without offering an easy way to collect and review its operating data.

Replacing useful equipment just to get better information is a hard expense to defend. And even a newer machine may not make the reading you need easy to find or compare over time.

The people operating and maintaining these machines can usually tell you where more information would help. One machine stops more often than the others. Another has started making an unfamiliar noise. Everyone knows about it, but nobody is sure when it changed or how often it happens. Ask them what they wish they knew sooner. They may be more concerned about repeated stops than a measurement you thought was important.

Depending on the equipment, a separate sensor can collect a measurement without connecting to the machine's controller. That might be temperature, vibration, or electrical current. Vibration monitoring can require faster measurements and more careful sensor mounting than a simple temperature log. The right choice depends on the question you're trying to answer and what can be measured reliably.



Figure 1. Low-cost sensors and small computers can give PCB fabricators greater visibility into equipment operation without replacing legacy machinery.

What You're Building

A basic monitor collects a reading, saves it, and alerts someone when it needs attention. The sensor measures, the computer keeps the record, and a program handles the logging and alerts.

For a PCB shop, the question might be whether a machine's motor is vibrating differently than usual, or how often equipment is running versus sitting idle. Those are different questions and may need different setups. If you use electrical current to estimate running and idle time, check those patterns against what the machine is actually doing. Start with the problem your team already spends time on.

Some installations need only a few inexpensive parts. Others require more protection or professional work. Price the whole job and compare it with an available monitor before deciding to build. The experience of building has value, but the installation still has to make sense.

Keep the monitor separate from the machine's controls and safety systems. Qualified people should review the installation and handle electrical work. Include whoever manages your network and data before connecting the device

or sending readings to an outside service.

Getting Help From AI

The programming is often where a small project gets stuck. Someone has to make the sensor readings reach a file, give them a timestamp, and arrange for an alert. AI can help write that program and explain the setup in language you can follow.

The key is to let the AI ask you questions before it proposes anything. Here is a prompt you can paste in and adapt to your own shop:

<CONTEXT> I work in a printed circuit board fabrication shop. One piece of equipment gives us trouble and doesn't offer an easy way to see what it's doing. Right now we depend on an operator noticing a problem or writing down a reading. I want to build a simple, separate monitor using a sensor and a small computer. I have little or no programming experience.

<ROLE> You are an experienced industrial maintenance engineer who has built low-cost equipment monitors with off-the-shelf sensors and small computers such as a Raspberry Pi. Your goal is a monitor a non-programmer can install, test, and trust, that stays completely separate from the machine's controls and safety systems, and that costs less than the problem it's watching.

<INTERVIEW> Interview me to provide more context to accomplish the task and remove assumptions between us. Ask only one question at a time. For each question, give me options A through E with your recommendation as an expert, and wait for my answer before asking the next one.

<TASK> After the interview, give me: (1) a recommendation for what to measure and which sensor to use, with a short explanation of why; (2) a parts list with rough costs; (3) the program that reads the sensor, saves each reading with a timestamp to a file, and sends an alert when a reading crosses a limit I set, with plain-language comments explaining what each part does; (4) step-by-step setup and test instructions, including how to confirm the readings match a trusted measurement and how I'll know if the sensor disconnects; and (5) a list of anything that should be reviewed by an electrician, our engineering team, or whoever manages our network before we install it. If the program fails when I run it, I'll paste the error back to you along with what I was doing.

Have the appropriate people review what comes back. Your engineering team and equipment requirements still determine what readings are acceptable. AI doesn't get to decide how your process should run.

Expect some back and forth. If the program fails, paste the error into the conversation and explain what you were doing. Try the correction and bring back the result. When it runs, compare the readings with a trusted measurement where practical. Check that timestamps and units are correct, that alerts arrive, and that a disconnected sensor or interrupted connection does not go unnoticed.

We see this in the cohorts we teach with people who have never written code make progress because they keep working through the questions. We remind people that code is simply text. They don't understand every part on the first try, but they learn enough to take the next step and recognize when they need help.

Making Sense of the Readings

Once you've collected enough readings to understand normal operation, you can look for changes. Is the equipment stopping more often? Does unusual reading happen during the same part of a job? AI can help review the record and identify things worth checking.

Give it context about what was running and ask it to explain what the readings support. A change may reflect a different job or a planned adjustment. It may also deserve a closer look from maintenance. The data alone won't always tell you which.

Compare the findings with production and maintenance records before deciding what to do. Equipment readings can help you investigate a problem, but they don't replace the inspection and testing used to confirm board quality.

Over time, the record gives the team something more useful than a recollection that a machine "has been doing that lately." You can see when the change appeared and what was happening around it.

Get the Team Involved

The team will use the information, respond to the alerts, and notice when a reading doesn't match what's happening on the floor. Whoever chooses what to monitor should understand what the reading means and what action it could lead to.

Fit the review into an existing production or maintenance discussion. If something needs follow-up, assign it to someone. Decide who receives alerts and what they're expected to do with them. Otherwise, a useful warning can sit unread while everyone assumes somebody else is handling it.

Keep the first project small enough to finish. Get one installation working reliably and see whether the team finds it useful before adding more. It's easy to start planning a screen for every department while the original machine still isn't being monitored.

Think about the equipment failure that disrupted your last production schedule. What would you have wanted to know before it stopped the job? That question is a reasonable place to begin. A basic monitor may reveal changes worth investigating, but it will not necessarily predict a failure or explain its cause.

You can learn a great deal from one useful installation. Your team gets a better record of the equipment's behavior and some experience building a tool for its own work. That is the point we've kept coming back to in this series: learn how to use AI on a problem close enough to the work that you can judge whether it helped. 

SEAN PATTERSON is an accomplished executive with extensive C-suite experience across CRO, COO, and CTO roles who now specializes in humanizing artificial intelligence implementation in business environments, particularly manufacturing; sean@crossgen-ai.com.

Patterson's unique approach to AI implementation stems from his multifaceted leadership experience in the PCB industry, including serving as COO and CTO & head of AI at Summit Interconnect, various senior positions at TTM Technologies, and CRO of Nano Dimension. He built Amazon's tractor trailer division and healthcare platforms. He currently serves as COO of StartGuides, providing military technology working backwards from the soldier. He is also on several nonprofit AI advisory boards in education.

Patterson brings practical insights into how PCB manufacturers can approach AI adoption strategically. His methodology emphasizes cultural adoption from the top, employee empowerment, and then automation. His approach to AI implementation is captured in his often-quoted principle: "AI adoption is not something a leader can delegate."

Patterson holds a master's in nuclear science and engineering from MIT and a bachelor's in systems engineering with a focus on robotics from the United States Naval Academy.

PCD&F



BINDER M12-A MIDMOUNT PCB CONNECTORS

M12-A angled panel-mount connectors feature a midmount design that positions the connector axis in the plane of the PCB to reduce assembly height in cylindrical housings. Available in four- and five-pin configurations with shielded or unshielded options and support PCB thicknesses from 1mm to 2mm. THR termination permits reflow soldering on existing SMT lines, while an integrated pickup surface supports automated processing. Rated to 60V and operate from -40°C to 85°C, with IP68 protection when mated and locked. For sensors, measuring transducers, fieldbus devices and other space-constrained electronics.

Binder

binder-connector.com



KYOCERA AVX KGU SERIES RF MLCCS

KGU Series RF multilayer ceramic chip capacitors are available in an ultraminiature 0201 case size for high-frequency wireless and communications applications. Feature C0G (NP0) ceramic dielectrics, ultra-low ESR, high Q and high self-resonant frequencies, with ratings from 6.3V to 250V and 0.1pF to 100pF. Operate from -55°C to 125°C and

feature tin/nickel-plated copper electrodes for solderability and high-volume automated assembly. For cellular base stations, WiFi networks, satellite communications and broadband wireless systems.

Kyocera AVX

kyocera-avx.com

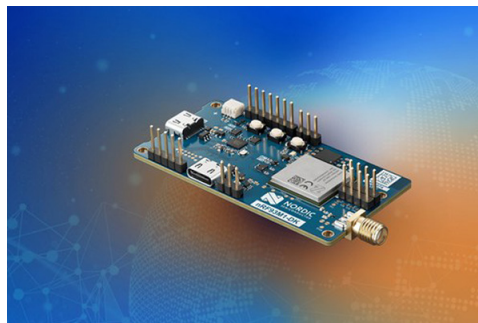


LUXINAR AIONIS 515-50-YB FEMTOSECOND LASER

Aionis 515-50-Yb femtosecond laser delivers 50W of power, pulses below 350fs and pulse energy up to 100μJ. Provides up to five times more power than previous models and features advanced pulse control for increased throughput, cleaner processing and improved process stability. Uses a 515nm wavelength for tighter beam focusing, smaller feature production and reduced thermal impact. For semiconductor manufacturing, glass and brittle material processing, medical device production, photovoltaics and other precision manufacturing applications.

Luxinar

luxinar.com



NORDIC SEMICONDUCTOR NRF93M1 SMART MODEM MODULES

nRF93M1 Cat 1 bis smart modem modules combine cellular connectivity with access to nRF Cloud services for device management, observability and firmware-over-the-air updates. GCF-compliant nRF93M1-LABA supports multiregional deployments, while pin- and software-compatible nRF93M1-LACA adds global-band coverage without requiring PCB or software redesign. Connect to host MCUs through UART or USB and support AT commands and

PPP. Development kit includes an nRF54L15 host MCU, Onomondo SIM, LTE antenna and application examples. For fleet management, asset tracking, point-of-sale terminals, healthcare, gateways, smart energy and metering applications.

Nordic Semiconductor

nordicsemi.com



PATRIOT MEMORY VIPER STEEL 5 INFINITE RGB DDR5 MEMORY KIT

Viper Steel 5 Infinite RGB DDR5 memory kit includes two 16GB modules for a total capacity of 32GB. Reaches speeds up to 7600MT/s with a compatible ASUS ROG motherboard and enabled ROG Certified firmware setting. Supports Intel XMP 3.0 and AMD EXPO profiles at speeds up to 7000MT/s. Features selected memory ICs on a 10-layer PCB, a ROG-styled heat spreader and an Infinite Mirror addressable RGB light bar. Measures 43mm high. For gaming computers and other high-performance desktop systems.

Patriot Memory

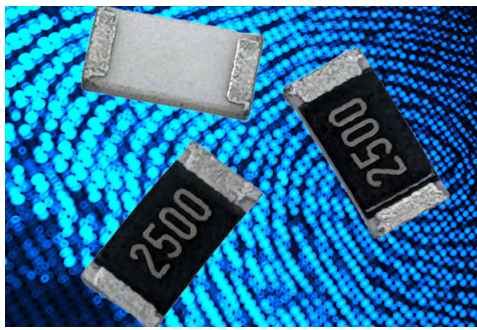
patriotmemory.com

ROHM BH65T41XXXF 650V ECOIGBTs

BH65T41xxx F Series fourth-generation 650V EcoIGBTs combine low conduction loss with high short-circuit withstand capability and are AEC-Q101 qualified for automotive applications. Available in multiple package configurations, with SPICE and PLECS simulation models available to aid circuit design. Additional compact and top-side-cooled package options are planned. For automotive electric compressors, high-voltage heaters, industrial inverters and power supplies.

ROHM

rohm.com

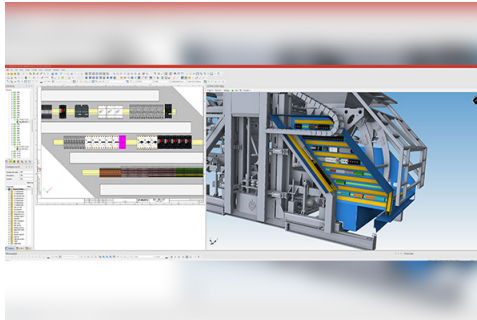


STACKPOLE ELECTRONICS RNAN THIN-FILM RESISTORS

RNAN Series thin-film precision resistors feature aluminum nitride substrates for heat dissipation in high-power industrial electronics. Available in 0603, 0805, 1206 and 2512 sizes, with power ratings from 0.5W to 6W at 70°C. Provide tolerances to 0.1%, TCR as low as 25ppm/°C, resistance values from 50Ω to 30.1kΩ and operating temperatures from -55°C to 155°C. For industrial power supplies, motor drives, robotics, renewable-energy controls and test and measurement equipment.

Stackpole Electronics

seielect.com



ZUKEN E3.SERIES 2027 ELECTRICAL DESIGN SOFTWARE

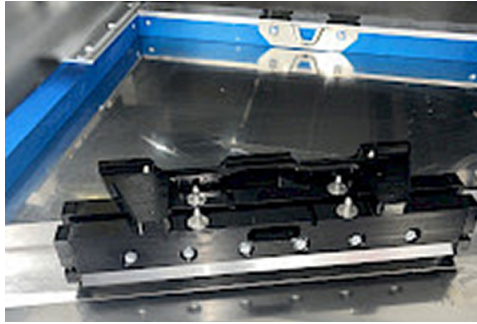
E3.series 2027 electrical design software adds E3.CloudView for browser-based access to project documentation, including 2-D electrical schematics and 3-D panel layouts. Generates complete 2-D Manufacturing Views of enclosures with a single command and adds configuration search, updated Variant and Option handling and simultaneous placement of multiple symbols. E3.3DPanelBridge converts mechanical panel models into native E3.panel design objects, while E3.3DTransformer 2027 adds topology-attribute editing, model-tree search and updated CATIA, Creo and JT format support. For wiring, wire harness, fluid and control systems design.

Zuken

zuken.com



CA

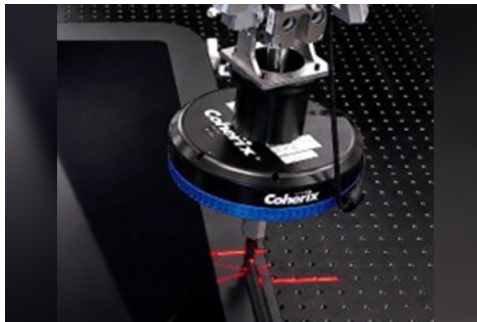


ASMPT DEK TQ AUTOMATED SETUP CHANGEOVER

Automated setup changeover option for the DEK TQ printer platform automates stencil and squeegee changeovers, reducing operator time at the printer from approximately 4 min. to 30 sec. Uses a prepared setup combining the stencil with a consumable cartridge containing the squeegees, while the print head automatically locates and picks up the squeegees and prepares the printing process. Supports automatic solder paste transfer during subsequent stencil changes and stencil identification and verification with the Camera Barcode Reader option. Includes a new print head, squeegees, consumable cartridge, adapter and software. Available for new DEK TQ printers and as a retrofit for existing systems.

ASMPT

asmpt.com



COHERIX 3-D GLASSMASTER TRACKER ADHESIVE DISPENSING INSPECTION SYSTEM

3-D GlassMaster Tracker provides 100% inline, real-time inspection and adaptive process control for adhesive dispensing. Tracks part-to-part geometry variations during dispensing and automatically adjusts the robot path to compensate for changes in glass shape, battery-cover geometry, adhesive viscosity and other manufacturing conditions. Records and verifies the dispensing process for each part to provide traceability for quality audits, warranty investigations and regulatory compliance. For automotive windshield bonding, battery assembly and other safety-critical adhesive dispensing applications.

Coherix

coherix.com



DYMAX BLUEWAVE FX LINE EMITTERS

BlueWave FX Line Emitters provide uniform linear UV/Visible curing for automated production applications. Deliver up to $4.2\text{W}/\text{cm}^2$ intensity at a 25mm working distance and are available in 75mm and 150mm lengths with a 25mm curing width. Offered in 365nm, 385nm and 405nm wavelength options and integrate with FX-series controllers for dual-channel control and flexible wavelength configurations. Are CE and UKCA marked. For adhesive bonding, medical device assembly, printing, lacquers, paints and UV-curable coating applications.

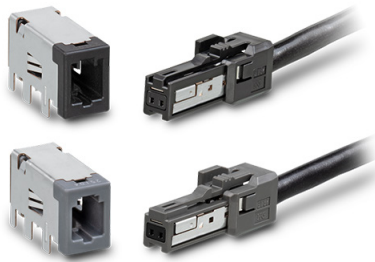
Dymax

dymax.com



GÖPEL ELECTRONIC MULTI LINE AXI 3D-CT X-RAY INSPECTION SYSTEM

Multi Line AXI 3D-CT X-ray inspection system provides 2-D, 2.5-D and 3-D inspection of PCBAs using microfocus X-ray technology and a high-speed flat-panel detector. Features an $810 \times 535\text{mm}$ inspection area, PCBA clearance up to 105mm and transport capacity up to 25kg. Delivers CT imaging in less than 2 sec. with $8\mu\text{m}$ voxel resolution and supports void calculation and THT fill measurement. Integrates with PILOT software, MES and traceability systems and can operate inline, at-line or stand-alone.

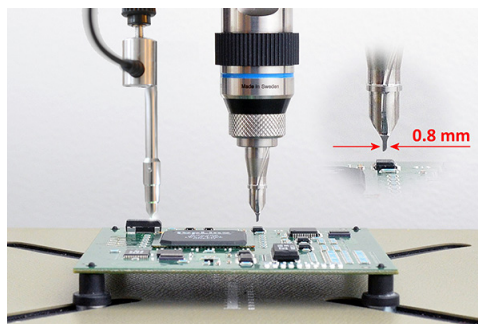


HIROSE GT37 SERIES AUTOMOTIVE ETHERNET CONNECTOR

GT37 Series wire-to-board connector supports 1000BASE-T1 automotive Ethernet connectivity for Gigabit data transmission over a single twisted-pair cable. Features a fully shielded design, impedance matching at the stripped-cable section and a two-position interface measuring $8.6 \times 10.6\text{mm}$. Sleeve design eliminates commercial copper tape during shield termination, while an optimized cable strip length and dual-lock mechanism simplify harness assembly and provide positive mating confirmation. Is compatible with standard automotive harnesses and requires no dedicated processing equipment.

Hirose

hirose.com



INSPECTIS MICRO-SIZE OPTICAL PROBE TIP

Micro-Size Optical Probe Tip for the Inspectis BGA Inspection System provides detailed, noncontact inspection of solder joints beneath BGA packages with limited clearance. Features a 0.8mm-thick stainless-steel tip, 90° viewing angle, integrated illumination and improved optics for sharper images of BGA solder joints. Is fully compatible with the Inspectis BGA Inspection System. For electronics manufacturers, EMS providers and quality-control teams.

Inspectis AB



MEK POWERSPECTOR JSAZ 350 DESKTOP AOI SYSTEM

PowerSpector JSaZ 350 desktop AOI system features a fixed PCB stage for increased mechanical stability during inspection. Includes Selective 3-D Laser Measurement Technology for repeatable component and object height measurements. Can be configured with up to nine cameras, including a high-resolution top camera and eight angular side cameras, with multi-angle LED lighting and Diffused On Axis Light. Supports SMT and THT inspection throughout production and integrates with Mek Catch System for process control and traceability. Features a compact chassis based on the PowerSpector JSaZ 550 platform for a reduced footprint.

Mek

marantz-electronics.com

OVERTON INSTRUMENTS SCORPION-II FAULT-FINDER AUTOMATED TEST SYSTEM

Scorpion-II Fault-Finder automated test system combines test-development components in an integrated desktop package. Features an Intel-based single-board computer with standard peripherals and memory resources and supports Windows and Linux operating systems. Integrates with the company's smart instrument modules and controls connected instruments through an embedded USB hub module. Includes a bed-of-nails test platform available in multiple sizes for PCBAs and other technologies. Includes a Python-based test executive for custom application programming.

Overton Instruments

overtoninstruments.com



PVA DELTAFLEX COATING AND DISPENSING PLATFORM

DeltaFlex large-format coating and dispensing platform is designed for oversized, complex and high-reliability manufacturing applications. Combines the flexibility of the company's Flex Cell platform with a motion architecture that supports larger assemblies and heavier process equipment. Features a ruggedized gantry, dual-driven Y-axis, linear encoder positioning and high-speed motion capability. Is available with standard 800mm and 1,200mm workspaces, increased Z-axis travel and custom oversized configurations. For aerospace, defense, electric vehicle battery manufacturing, telecommunications, industrial electronics and electronics manufacturing services applications.

PVA

pva.net



SAKI 3XI-ZS1EX AUTOMATED X-RAY INSPECTION SYSTEM

3Xi-ZS1EX automated X-ray inspection system provides 3-D inspection of XXL PCB assemblies up to 1,000 × 690mm. Features automatic board warpage correction, high-resolution 3-D CT imaging and AI-based image analysis for detecting small voids and hidden defects. Delivers approximately 1.6 times higher takt time compared with previous Saki models while accommodating large boards within a compact footprint. For AI server, data center and other large, complex PCB assembly inspection applications.

Saki Corporation

sakicorp.com



TEKPAK AUTOMATION TD3/R SERIES PICK-AND-PLACE CELL

TD3/R Series three-axis robotic pick-and-place cell loads or stacks products into trays, cases, cartons, thermoformers or flow-wrapper infeeds. Features robot positional accuracy of $\pm 0.1\text{mm}$ and vision-controlled position tracking, along with rapid size changes and a quick-change gripper for multiple formats. Compact design is suited for cleanroom and space-constrained environments and includes touchscreen controls, gentle product handling and integrated safety functions.

Tekpak Automation

tekpakautomation.com



TM SOLDERING SOLUTIONS PHOENIX SELECTIVE SOLDERING PLATFORM

Phoenix selective soldering platform adds configurable options including a programmable nitrogen de-bridging knife with 360° rotation, 6-in. dynamic solder wave assembly, automatic nozzle tinner and integral N_2 purity analyzer. Dynamic solder wave enables conversion between selective and 6-in. wave soldering processes, while the purity analyzer integrates real-time nitrogen measurements into EmberX software. Available in batch and inline configurations. For PCB assembly and selective soldering applications.

TM Soldering Solutions

tmsolderingsolutions.com



ULT 200.1 MOBILE EXTRACTION UNIT

ULT 200.1 mobile extraction and filtration unit features an expanded filter surface area for increased pollutant storage capacity and extended filter service life. Has a 4m² panel prefilter, up from 0.5m², and an 8kg activated carbon capacity, up from 1kg. ISO 16890-compliant prefilter captures 80% of particles smaller than 1µm, followed by H14 HEPA and activated carbon filtration for gases and odors. Supports up to four extraction elements and features constant negative-pressure control that automatically adjusts extraction performance based on operating conditions and filter loading. For laser processing, engraving, cutting and other high-pollutant applications.

ULT

ult.de



In Case You Missed It

Flex Circuits

“Facile Preparation of High-Precision Flexible Circuits through Combining Inkjet Printing and Template Plating”

Authors: Qing Li, *et al.*

Abstract: Driven by the rapid evolution of electronic devices toward multifunctionality and portability, circuits fabricated on flexible substrates require increasingly higher manufacturing precision to support the integration of high-density electronic components. In this work, a facile strategy combining inkjet printing and template plating was proposed to fabricate high-precision flexible circuits. An adhesive layer was first introduced onto the polyimide substrate to enhance interfacial adhesion and substrate compatibility, followed by inkjet printing of a resin solution to form circuit templates. The uniform template with an average line width of $58.5\mu\text{m}$ was obtained by optimizing the printing parameters. The printed template was chemically modified via alkali treatment and Ag activation, which generates catalytically active sites for selective electroless Cu plating. The uniform Cu circuits with an average width of $63.2\mu\text{m}$ were obtained, exhibiting low resistivity of $8.45\mu\Omega\text{ cm}$, strong adhesion strength of 5B, and excellent fatigue resistance under cyclic bending. Moreover, the Sn circuit was electroplated based on the Cu circuit template. The precision consistency of the Sn circuits was confirmed by electrical fusing tests according to the corresponding national standard (GB/T 9364.4-2016). The Sn circuit also exhibited strong thermal stability during reflow cycles at 220°C . These results demonstrate the enormous application potential of the proposed strategy for the additive manufacturing of high-precision flexible circuits. (*Journal of Materials Science: Materials in Electronics*, vol. 37, number 1900, Aug. 26, 2026, <https://link.springer.com/article/10.1007/s10854-026-18254-0>)

Inspection

Vision-Based PCB Defect Detection Using YOLOv5 and MobileNetV2 with Grad-CAM

Authors: Selva Kumar Chandrasekar, *et al.*

Abstract: Printed circuit board (PCB) defects such as mouse bites and missing holes significantly impact the reliability of electronic devices. Traditional PCB defect inspection technique relies on worker experience and unreliable in accuracy and scalability. This paper presents a hybrid vision-based approach that integrates YOLOv5 for defect detection, MobileNetV2 for defect verifying and reducing false positives, and Grad-CAM for generating visual heatmaps that highlight critical defect regions. YOLOv5 efficiently identifies potential defect locations, while MobileNetV2 acts as a lightweight classifier to ensure only true defects are identified. Grad-CAM provides

interpretability by visually explaining the model's decisions, aiding quality control operators. Performance metrics including precision, recall, and F1-score are employed to evaluate detection performance comprehensively. Additionally, a severity index is computed based on the nature of the defects according to their effect of the PCB's function. The proposed method's advantage in detection accuracy, false positive minimization and effective interpretability is demonstrated. This work improves vision-based PCB defect inspection systems through a reliable and interpretable 3-level machine vision method for PCB defect detection. (*Proceedings of International Conference on Computational Intelligence*, Aug. 2, 2026, https://link.springer.com/chapter/10.1007/978-3-032-31523-6_15)

Materials

“Sustainable Flame-Retardant Self-Reinforced Composites: The Role of mPAO in Fabrication and Recycling”

Authors: Dr. Jin Chul Kim, Dr. Ji-Eun Jeong and Dr. Young-Jae Jin

Abstract: The development of recyclable, high-performance polymer composites are essential to address the challenges of environmental sustainability and carbon neutrality. This study explores the multifunctional role of metallocene poly(α -olefin) (mPAO) in enhancing the rheological, thermal, mechanical, and recycling properties of high-density polyethylene (HDPE)-based self-reinforced composites (SRCs). An ionic phosphorus-based flame retardant (ADK) was incorporated for its environmental compliance and facile removability during recycling. The addition of mPAO not only facilitated a more homogeneous dispersion of ADK within the HDPE matrix but also tailored the melt rheology of HDPE films, improving processability and fiber–matrix interfacial adhesion. Recycling was achieved by sequentially removing ADK using aqueous sodium hydroxide and extracting residual mPAO with hexane, enabling high-purity HDPE recovery. The optimized S-PE-mPAO5-ADK40 composition delivered outstanding mechanical strength and achieved a UL-94 V-0 flame-retardant rating. These findings highlight the potential of mPAO as a multifunctional additive for fabricating sustainable, high-performance, and fully recyclable polymer composites for industrial applications. (*Composites Part B: Engineering*, vol. 312, Mar. 1, 2026, <https://www.sciencedirect.com/science/article/pii/S1359836825012399?via%3Dihub>)

Thermal Managament

“Thermal Management in Electronics: From Conventional Cooling to Hybrid Innovations”

Authors: Bijaya Raj Karki and Aayush Luitel

Abstract: The relentless miniaturization of electronic devices and escalating heat fluxes in data centers, electric vehicles, and aerospace platforms, projected to exceed $1000\text{W}/\text{cm}^2$ in next-generation chips, have intensified the demand for advanced thermal management. This review systematically surveys electronic cooling progress across a normalized set of metrics: junction-to-coolant thermal resistance, heat flux, pressure drop, and power usage effectiveness (PUE). Conventional strategies including natural and forced-air convection, heat sinks, liquid cold plates, phase-change systems, and thermoelectric coolers are evaluated for their capabilities, limitations, and applicability across heat flux regimes. Emerging approaches such as two-phase microchannel cooling, single-phase

and two-phase immersion cooling, jet impingement, spray, and electrohydrodynamic techniques are discussed, with demonstrated performance up to $2000\text{W}/\text{cm}^2$ and PUE values as low as 1.02. Material innovations including graphene spreaders, SiC microchannel substrates and nano-enhanced phase change material (PCMs), alongside computational tools such as topology optimization and machine learning (ML)-augmented computational fluid dynamics (CFD), are identified as enablers of step-change performance gains. Cost, carbon footprint and regulatory considerations, including post-per- and polyfluoroalkyl substances (PFAS) dielectric fluid requirements, are integrated throughout. Open challenges in two-phase flow instability, lifecycle assessment standardization, adaptive workload-driven control, and long-term hybrid system reliability define the critical research agenda bridging laboratory demonstrations and industrial deployment. (*Journal of Electronic Packaging*, June 2026, <https://asmedigitalcollection.asme.org/electronicpackaging/article-abstract/148/2/020905/1233293/Thermal-Management-in-Electronics-From>)  



EAST 2027

Conference & Exhibition

Save The Date!

Conference:

April 27 – 30

Exhibition:

Wednesday, April 28

DCU Convention Center
Worcester, MA

colocated with FPGA Horizons

FPGA
HORIZONS
BEYOND GATE ARRAYS

pcbeast.com