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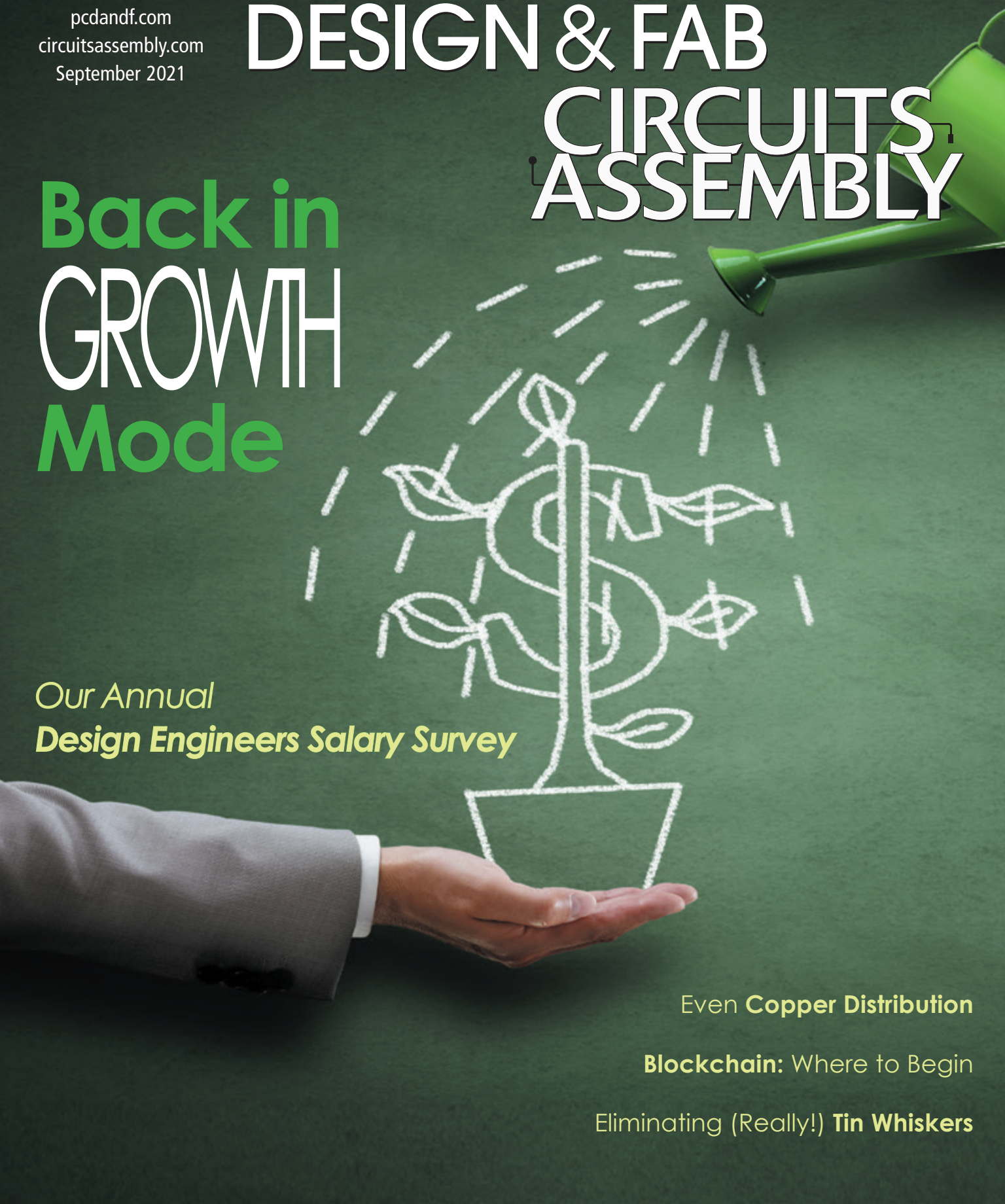


Our Annual
Design Engineers Salary Survey

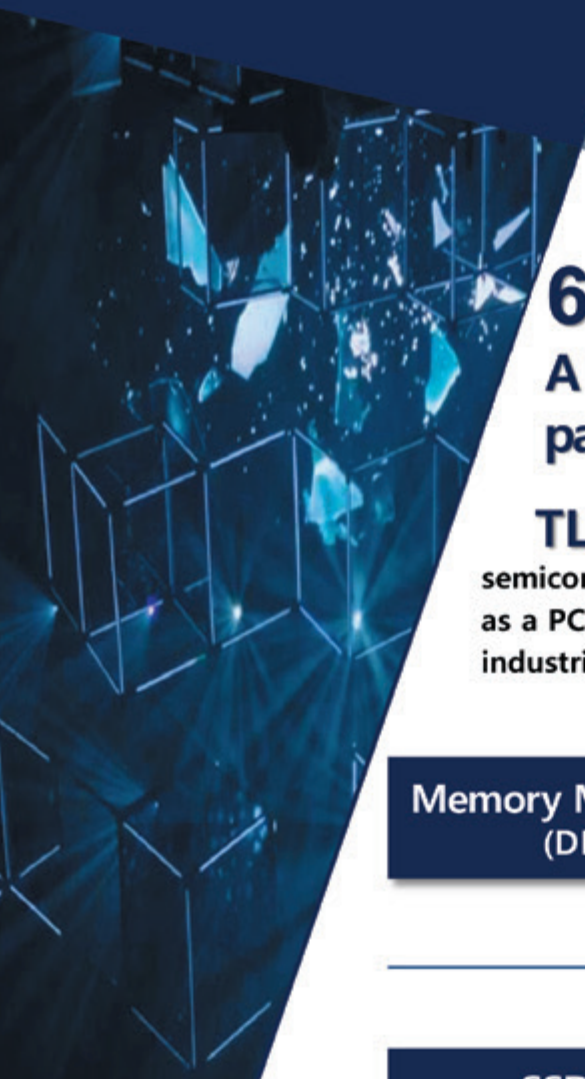
Even **Copper Distribution**

Blockchain: Where to Begin

Eliminating (Really!) **Tin Whiskers**

TLB

Semiconductor Total Solution Manufacturer



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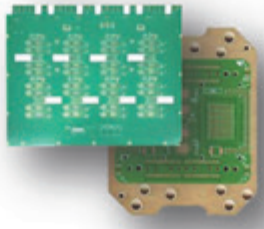

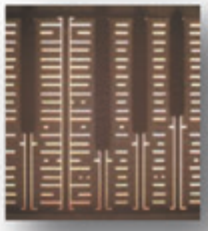

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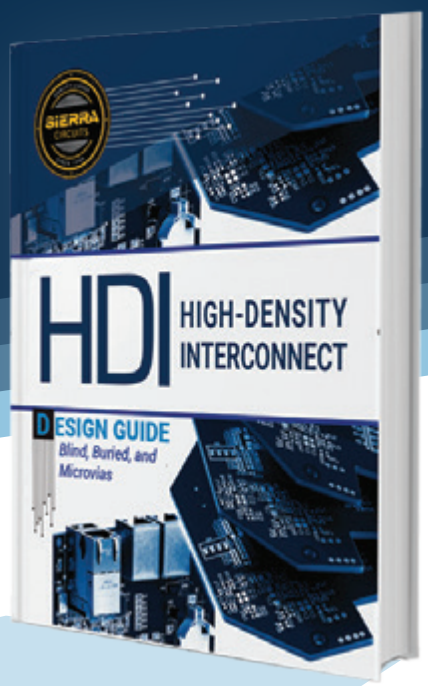
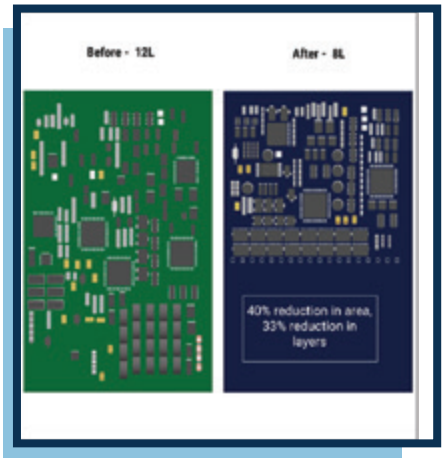
THE HDI DESIGN GUIDE



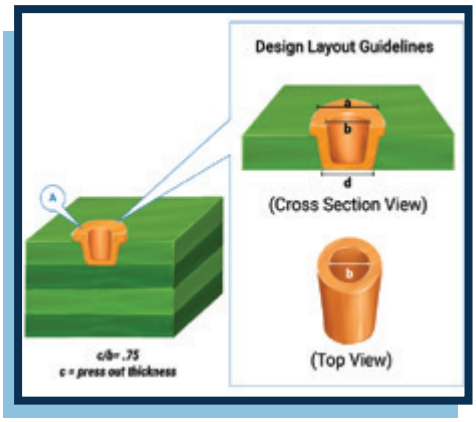


The how-to guide for your blind and buried via technology

- Plan your stack-up and microvia structure
- Choosing the right materials
- Signal integrity and controlled impedance in HDI
- Manufacturing considerations for higher yieldsimpedance in HDI

Get expertise on HDI material selection

- Is your high-speed material suitable for sequential laminations?
- Materials will affect the electrical performance of the signal traces.
- The dielectric loss plays a vital role in material selection.



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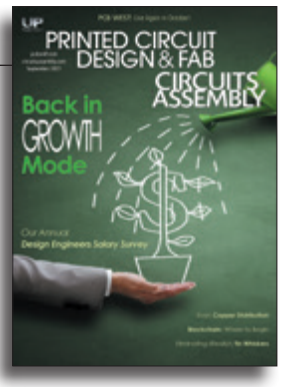
FEATURES



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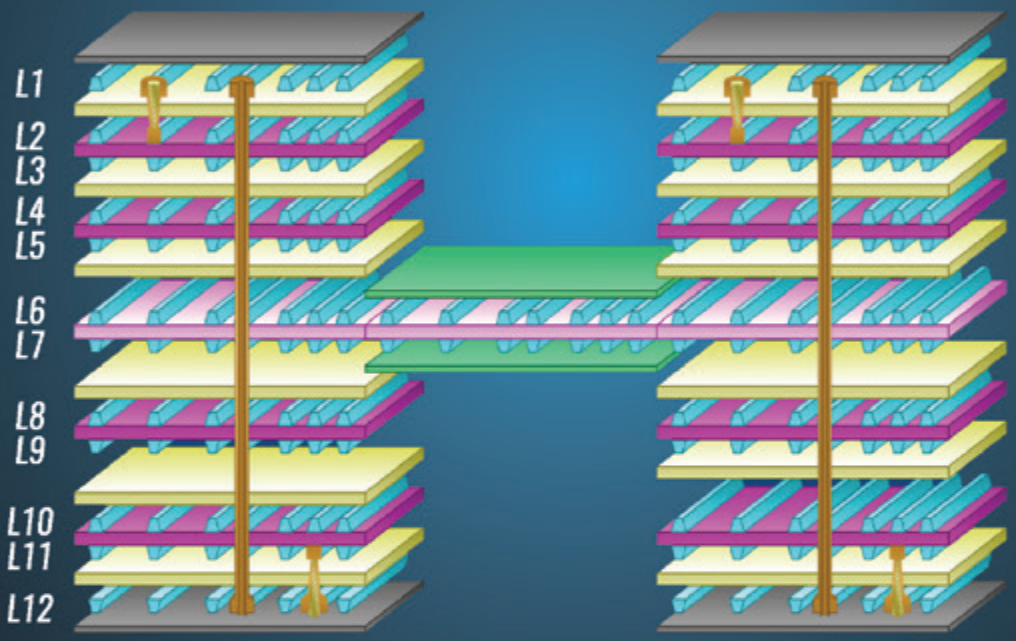

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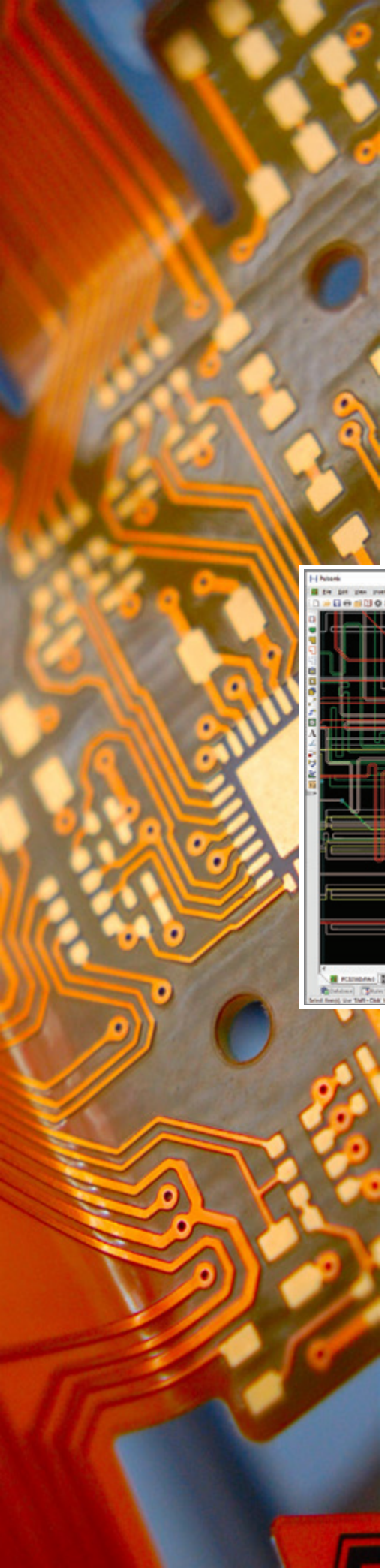

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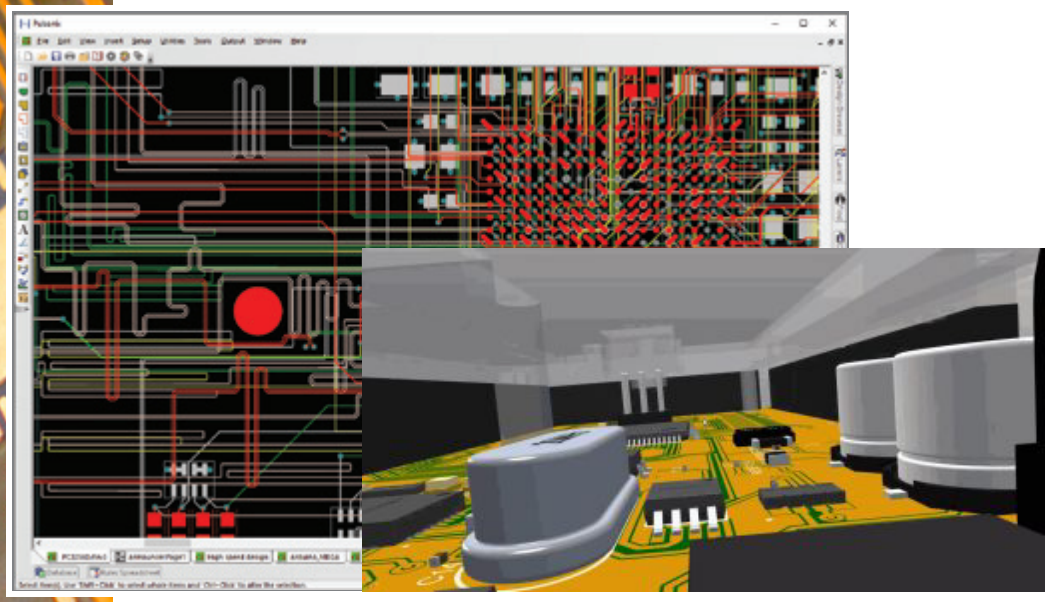

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MIKE BUETOW
EDITOR-IN-CHIEF

A Pair of Antidotes to a Complex Environment

YEARS AGO, AHEAD of a US election, I used this space to pen an open letter to the new president. I wrote that the race for office was heated and intense, but the winner should put aside any ill feelings and work toward the betterment of all Americans.

The column was timed to hit readers' desks in November, just after the election results were announced. Magazine deadlines being what they were, of course, I wrote it in early October – more than four weeks prior to election day. In short, I submitted it to the printer having no clue who was actually going to win.

More than a few readers didn't catch that little nuance, and they filled my inbox with screeds both positive and negative about the outcome, projecting their own biases on my musings and utterly missing the point I was trying to make about leadership.

Since then, I've stayed away – far away – from anything that even hints of politics, sensing it's too charged a subject to use even as a metaphor for a larger point.

So, when an industry friend whom I respect more than he will ever know suggested I write an editorial about electronics companies requiring vaccination, and, in his words, "come out swinging in favor of it," my first reaction was indifference.

Then we conducted a survey of US readers and found just under 60% plan to attend face-to-face events this year, and the top reason for staying home is, of course, Covid-19. That's no way to get business done, not when there's a perfectly good vaccine – more than one, actually – available and in most cases free.

As Covid-19 cases increase across the nation, primarily with unvaccinated persons, it's hard not to be frustrated at the current state of the world. This is a largely preventable disease, provided we choose to prevent it.

Although I will probably pay dearly for using this space as a soapbox for something that goes beyond electronics engineering, I can't keep quiet knowing just how badly it's affecting our industry, not to mention our world.

With that, I strongly encourage all companies – not just US-based ones – to mandate vaccinations for all workers, full-time, part-time and contract-based. Any visitors to their offices should be required to show proof of vaccination too.

I realize that the unvaccinated have their reasons, and I'm not going to argue with them. But let it be known I wholly disagree with their stance. We must ensure we are doing everything we can to protect the health of our employees and each other. It's time to take a stand.

EMS on overdrive. Speaking of health, the EMS industry has posted several straight months of what some consider excessively high book-to-bill ratios. The April peak of 1.62 has only marginally fallen over the past couple months and, as of this writing, was 1.48 in June, the most recent data available. Some are concerned of an overheated market, but conversations with several leading EMS firms suggest instead that OEMs are offering longer forecasts, which are inflating the numerator. For instance, if the typical window was six months, it might be nine or even 12 months now. That pushes more "orders" into the data pile, but it's a mathematical anomaly, not a sign of double-booking. I don't expect the sky to fall, at least this time.

mbuetow@upmediagroup.com
@mikebuetow

P.S. Those able to venture out should be sure to register for PCB West, coming Oct. 4-8 to the Santa Clara Convention Center (pcbwest.com). With a stellar lineup of speakers led by Lee Ritchey and Rick Hartley, and the support of the Printed Circuit Engineering Association, this is a great way to get back to "normal."

But if you can't make it, check out Printed Circuit University (printedcircuituniversity.com), the new online learning platform, with more than 100 hours of design, fabrication and assembly training by industry experts.

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PCDF People

Calumet Electronics promoted **Meredith LaBeau,** Ph.D to chief technology officer. She has a master's and a Ph.D. in environmental engineering from Michigan Technological University and served eight years as the company's director of process engineering and director of R&D.

Peters named **Markus Wieler** global business manager, responsible for OEM management. The industry veteran returns to Peters after a 13-year absence.

PCDF Briefs

Altium's Upverter Modular Electronics Design program focuses on modular board design, allowing students to gain knowledge while applying the fundamental concepts, empowering progressive learning in virtual, hybrid, and in-person classroom settings.

Calumet Electronics announced the addition of 75 new jobs at its facilities in Calumet, MI.

CIPSA Circuits installed a **Ucamco** Ledia direct imager and **Techno System** autoloader.

EMA Design Automation added **Anacom** to its EMA Solutions Partner Program.

EMA Design Automation and **Digi-Key Electronics** have collaborated to release the OrCAD Capture Bundle available on digikey.com. The bundle provides OrCAD Capture; the in-design ability to search and select parts from Digi-Key; a searchable cloud library of schematic symbols connected to Digi-Key parametric data; integrated sourcing tools to procure parts from Digi-Key; and OrCAD e-Learning, including certification opportunities.

Printed Circuits completed installation of the process line and qualification of a **Notion** direct solder mask and nomenclature printer.

Shanaya Environmental Services has completed its previously announced acquisition of printed circuit board manufacturer **CPH** for S$22 million ($16.1 million).

Ventec will take over exclusive distribution of **Taiyo** products in mainland Europe, the UK and Ireland.

New Consortium to Push US Domestic Electronics Production

WASHINGTON – A group of printed circuit board fabricators has established the Printed Circuit Board Association of America (PCBAA) amid rising geopolitical challenges faced by domestic microelectronics manufacturers in the US.

PCBAA is a consortium of US-based companies that support initiatives to advance the US domestic production of microelectronics, specifically PCBs, and the materials that comprise the boards.

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

PCBAA is taking action in Washington to improve conditions for US domestic manufacturers of PCBs and their US domestic supply chains. These actions are guided by PCBAA's three main mission objectives: supporting domestic production of PCBs; enhancing domestic supply chain security; and advocating for initiatives that create fair market conditions.

The association strives to educate, advocate, and legislate to raise awareness with decision-makers in Congress, the White House, the Department of Defense, and the rest of the Executive Branch about the domestic capabilities and resiliency of the PCB and assembly industry for national security and economic purposes.

Isola, Summit Interconnect, and TTM Technologies are among the founding members. To join, visit PCBAA.org/join. (CD)

Royal Circuit Acquires South Coast Circuits

HOLLISTER, CA – Royal Circuit Solutions in August acquired South Coast Circuits, expanding its quickturn printed circuit board fabrication services. The deal marks the second acquisition Royal Circuit Solutions has completed as it continues to expand its PCB manufacturing operations and market reach.

Financial terms were not disclosed.

Based on the terms of the merger, which involved South Coast Circuits and Royal Flex Circuits, a subsidiary of Royal Circuit Solutions, the facility in Santa Ana, CA, will continue to conduct business as South Coast Circuits. Victor Hemingway, current president of Royal Flex Circuits, will become president of South Coast Circuits, reporting to Milan Shah, owner and cofounder of Royal Circuit.

"This is a very exciting transaction that will create an even larger, more dominant PCB manufacturing group," said Shah in a press release. "It is a landmark deal for the PCB industry and another step forward in Royal Circuits' mission to help design engineers bring new product designs to market as quickly as possible."

Founded in 1982, South Coast Circuits has a diverse, loyal customer base in a variety of industries, including computer, communications, ATE, aerospace, networking test & measurement, medical, and consumer electronics. The tenured staff has helped the company build a solid reputation for delivering quality, high-end technical circuit boards. This merger also allows Royal Circuit Solutions to further expand its service offerings for the ATE industry.

"The alignment in company values and culture between the companies made this a great opportunity for our employees and customers," said Chuck Benson, former president, South Coast Circuits. "Together, South Coast Circuits and Royal Circuit Solutions will be able to achieve rapid expansion while delivering the quality, speed and service that our customers have come to rely on."

South Coast Circuits provides rigid, flex and rigid-flex circuit board fabrication and PCB assembly for prototypes to mid-volume production quantities. (MB)

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CA People

CalcuQuote said **Steve Vecchiarelli** is joining the company in an advisory capacity. He has 40 years of distribution experience, and will facilitate among the EMS industry, CalcuQuote, and customer needs for digital transformation.

Cogiscan named **Michael Ho** director – business development. In his more than 30 years in electronics, Ho has been a software engineer for Universal Instruments and Nordson, among others.

Enics appointed **Denis Laxague** chief procurement officer.

Mek (Marantz Electronics) has appointed **Austin Jones** sales engineer, North America. He has a bachelor's from the University of Florida and worked for Leidos.

Naprotek appointed **Jim Apfel** senior vice president of business development. He has over 30 years' experience in sales and business development with Spartronics, Benchmark Electronics, Realtek & SwitchCore, Diamond Multimedia, and Rockwell.

TT Electronics named **Emma Darke** group sustainability director.

CA Briefs

AbelConn Electronics opened a 110,000 sq. ft. facility in Maple Grove, MN, where the wholly owned subsidiary of **Celestica** will provide rapid prototyping, volume manufacturing, and engineering support for the defense and aerospace industries.

Akyumen Technologies is being sued for failing to live up to announced plans to build a 200,000 sq. ft. smartphone assembly plant in Gary, IN.

Buy American requirements would be tightened under a new proposal from the Biden administration.

Circuit Technology Center purchased an **Oxford** 980 X-Strata series XRF system.

Compal Electronics in August acquired **Cal-Comp USA (Indiana)** for an undisclosed sum. Compal plans to manufacture car electronics at the site.

Creation Technologies to Buy IEC for $174M

NEWARK, NY – IEC Electronics and Creation Technologies have signed a definitive merger agreement under which Creation will acquire all outstanding shares of IEC for $15.35 per share in cash, making the deal worth approximately $174 million.

The transaction, which has been unanimously approved by both companies' boards, includes a "go-shop" period during which IEC will actively see alternative acquisition proposals, which the EMS could select over the Creation offer.

The transaction is expected to close by early October. Upon completion of the transaction, IEC will become a privately held company, and shares of IEC's common stock will no longer be listed on any public market.

The deal represents a fully diluted equity value of about $173.8 million and an aggregate enterprise value of $242.3 million, based on net debt of $68.6 million. Creation will finance the transaction through a committed debt financing package provided by JPMorgan Chase Bank and Citizens Bank.

The "go-shop" period is 35 days after signing the merger agreement, ending Sept. 16, 2021.

The two companies are heavily vested in the electronic manufacturing services market, IEC as a high-complexity, low-to-medium volume provider focused on the aerospace and defense, medical and industrial end-markets in the US, and the larger Creation Technologies focused on medium-volume, high-reliability customers in the same markets.

Creation and IEC combined will have more than 4,000 employees in facilities located in the US, Canada, Mexico and China, and annual revenues between $750 million and $800 million, according to CIRCUITS ASSEMBLY estimates. The merger will augment IEC's existing production capabilities with access to Creation's existing low-cost manufacturing facilities in Mexico, the firms said.

"IEC is excited about joining the Creation family. The transaction presents our stakeholders with immediate value while providing our customers a broader platform for continued growth," said Jeffrey T. Schlarbaum, president and CEO of IEC, in a statement.

"A combination of IEC and Creation creates a leading medium-volume, high-reliability electronics manufacturer with a customer service driven culture," said Stephen P. DeFalco, chairman and CEO, Creation. "Furthermore, IEC and Creation's complementary geographic footprints create a premier full-service North American supply chain for both companies' customers."

The purchase price represents a premium of approximately 47% to IEC's closing share price on Aug. 11, the last full trading day before the announcement. The tender offer is subject to customary closing conditions, including the tender of at least two-thirds of the total number of IEC's outstanding shares and the expiration of the applicable waiting period under US antitrust law.

Following the closing of the tender offer, a wholly owned subsidiary of Creation will merge with and into IEC. (MB)

Mycronic to Acquire Chinese OEM

TABY, SWEDEN – Mycronic has signed an agreement to acquire Shenzhen Huan Cheng Xin Precision Manufacture, an OEM of screen printers and pick-and-place machines.

The transaction is expected to be finalized in the fourth quarter of 2021. Other terms have not been disclosed.

Shenzhen Huan Cheng has about 120 employees and annual revenues of almost SEK 100 million ($11.3 million).

Mycronic said screen printers account for 80% of Shenzhen Huan Cheng's sales and placement machines the remaining 20%. China is the company's dominant market, accounting for 95% of sales.

"With this acquisition we strengthen and broaden [our] product portfolio and are

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Davlec plans to expand its EMS business thanks to a loan from the **Development Bank of Wales.**

Flexible Circuits purchased an **Essemtec** FOX2 pick-and-place and dispensing system.

Foxconn has purchased a 6-inch wafer fabrication plant from **Macronix.**

Hentec Industries/RPS Automation published a technical paper on techniques for selective soldering demanding components.

India's electronics manufacturing sector is poised to become a major focus area for business employment in Uttar Pradesh, and the state government has chalked out a comprehensive plan to that end.

Intel is announcing a major expansion of its Intel AI for Workforce Program to help educate the next generation of US technologists, engineers and inventors – and to help them land careers in their chosen fields.

Inventec's board of directors approved a $76 million investment plan to build new production lines for servers in Mexico.

Keerthi Industries received board approval to proceed with a plan to update its EMS site in Hyderabad.

A new **Kurtz Ersa** subsidiary in Bangalore houses an equipped demo center with soldering systems and provides technology training and short-term realization of production lines.

Lockheed Martin has completed construction of an advanced manufacturing facility at its Palmdale, CA, campus and headquarters. The aerospace OEM says the "intelligent, flexible factory has digital foundations to incorporate smart manufacturing components, embrace the Internet of Things and deliver cutting edge solutions rapidly and affordably."

PVA relocated its Cohoes, NY, facility to a new global headquarters and production facility in Halfmoon, NY.

Singapore has set a target for 2030 to increase its electronics manufacturing 50%, with an eye on semiconductor development.

TestEquity acquired test and measurement company **MCS Test** for an undisclosed sum.

Thal Technologies installed an **Autotronik** AP1200 screen printer, **Essemtec** Puma placement machine, and **Zonda** convection reflow oven.

able to offer a more complete and attractive solution to our customers," said Ivan Li, senior vice president, High Volume, Mycronic. (MB)

USPAE Overcomes Covid, History to Get DoD Eyes on Electronics Sector

WASHINGTON – Face-to-face meetings have been scarce in the past year, but historically even rarer have been sessions between US electronics industry leaders and their counterparts in the US Department of Defense.

That made the July meeting even more meaningful for the large assembly of representatives who made time for the annual US Partnership for Assured Electronics meeting in Washington.

Some 55 USPAE members met with 12 representatives from the Department of Defense, including the Defense Microelectronics Cross-Functional Team, Research and Engineering, Industrial Base Analysis and Sustainment, the Defense Logistics Agency, and Roger Smith and Craig Herndon of the DoD Executive Agent.

Attending members included owners, CEOs and engineers from PCB fabricators, EMS companies, distributors, materials providers, and academia.

The main objective for this first meeting was simple: to establish a dialogue in a way that hasn't previously happened among government, industry and academia on how to strengthen US electronics manufacturing.

For many of those companies attending, it was the first time they came face-to-face with the DoD.

Future technologies were discussed but in a broad sense and were secondary to the bigger picture of how to compete on low-volume, high-mix (LVHM) products for aerospace and defense.

The recent emphasis on the US microelectronics industry by the US government has not gone unnoticed. Witness the much-publicized commitment of $50 billion by the Biden administration to boost domestic semiconductor manufacturing. But made clear in the meeting was that the DoD and Congress need to pay attention to the entire electronics ecosystem, including design and assembly of PCBs. While $50 billion isn't peanuts to semi companies, a single state-of-the-art wafer fab costs three times the entire value of the US bare board manufacturing industry. Even a fraction of that would be a game-changer for PCB suppliers. Follow-on meetings are being set to continue that discussion between USPAE members and key government agencies, which are described as keen on access to trusted and assured microelectronics, including PCBs and assemblies.

While dialogue between the DoD and industry has always occurred, typically it has been directed through the prime contractors. Those large OEMs, in turn, filtered information going up and down the supply chain.

Through these government-industry meetings, the DoD hears from lower-tier suppliers. In doing so, the agencies are exposed to potential supply-chain risks it otherwise might not be aware of, for instance, the inability to source certain critical materials onshore.

An update on legislative activities, provided by Chris Mitchell of IPC, centered mostly on high-level budget and section 224 of the 2021 National Defense Authorization Act (NDAA), which covers trusted supply chain and operational security standards, and expectations for the 2022 NDAA.

As events, macro and micro, emerge, Congress's attention is easily diverted. The USPAE faces the ongoing challenge of keeping the leadership in Congress focused on the entire electronics ecosystem.

With that in mind, although USPAE has no face-to-face meetings planned at present, a couple upcoming events involving the defense supply chain and key DoD representatives include the Defense Manufacturing Conference in Phoenix (dmcmeeting.com), and the Parts & Material Management Conference (formerly the Diminishing Manufacturing Sources and Materials Shortages) (dmsmsmeeting.com) in Aurora, CO. Both meetings are in December. (MB)

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Trends in the US electronics equipment market (shipments only)	% CHANGE APR.	MAY	JUN.	YTD%
Computers and electronics products	0.7	-0.6	-0.2	8.0
Computers	0.7	0.4	-2.2	2.4
Storage devices	9.0	5.5	2.6	32.3
Other peripheral equipment	11.6	-9.8	-7.0	8.9
Nondefense communications equipment	-2.3	0.7	0.4	13.5
Defense communications equipment	-3.6	5.1	3.1	3.3
A/V equipment	2.3	6.4	-12.9	-1.6
Components[1]	-0.6	-1.8	-1.2	7.0
Nondefense search and navigation equipment	4.4	-3.0	1.7	2.0
Defense search and navigation equipment	1.2	-1.6	0.1	2.9
Medical, measurement and control	0.4	-0.6	0.1	8.7

[r]Revised. *Preliminary. [1]Includes semiconductors. Seasonally adjusted.
Source: U.S. Department of Commerce Census Bureau, Aug. 3, 2021

US MANUFACTURING INDICES

	MAR.	APR.	MAY	JUN.	JUL.
PMI	64.7	60.7	61.2	60.6	59.5
New orders	68.0	64.3	67.0	66.0	64.9
Production	68.1	62.5	58.5	60.8	58.9
Inventories	50.8	46.5	50.8	51.1	48.9
Customer inventories	29.9	28.4	28.0	30.8	25.0
Backlogs	67.5	68.2	70.6	64.5	65.0

Source: Institute for Supply Management, Aug. 1, 2021

KEY COMPONENTS

	FEB.	MAR.	APR.	MAY	APR.
Semiconductor equipment billings[1]	32.4%	47.9%	50.3%	53.1%[r]	58.4%[p]
Semiconductors[2]	14.7%	17.8%	21.8%	26.2%[r]	29.2%[p]
PCBs[3] (North America)	1.29	1.22	1.16	1.11	1.15
Computers/electronic products[4]	5.20	5.18	5.18	5.24[r]	5.28[p]

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

Report: Shortage of FC-BGA Substrates to Persist through 2025

AUSTIN, TX – Despite capacity increases this year, and additional plans through 2025, demand for FC-BGA substrates is outstripping supply, says TechSearch International. The gap between manufacturing demand and capacity will continue through 2025.

What's driving the insatiable demand? Larger substrates are required to support high-performance applications, including silicon interposers larger than reticle size and large-area fan-out, says the firm.

With 7, 8, 9, or 10 build-up layers required on each side, more manufacturing capacity is needed to meet package demand for servers, AI, and network switching applications.

Hot Takes

- **Chromebook shipments** in the second quarter grew 68.6% year-over-year, with volumes reaching 12.3 million units. (IDC)
- **The top four Asian PCB players** – China, Taiwan, Japan, and South Korea – accounted for nearly 90% of the global PCB output. (TPCA)
- **The US market for home automation systems** is forecast to grow from $9 billion in 2021 to $15.8 billion by 2026, a CAGR of 12% from 2021 to 2026. (Research and Markets)
- **The Germany region PCB industry** grew 19% in the first quarter, and the book-to-bill was 1.13. (ZVEI)
- **The tablet segment** grew 4.2% year-over-year in the second quarter, with shipments totaling 40.5 million units. (IDC)
- **Smartphones** saw overall shipment volumes up 13.2% year-over-year in the second quarter. Vendors shipped a total of 313.2 million devices during the period. (IDC)
- **The 5G in IoT market** will approach $272.4 billion globally by 2026, a 17.6% CAGR. (Research and Markets)
- **The worldwide shortage of semiconductors** is expected to last for years to come amid increasing risk and supply constraints. Significant shortages will continue through the first quarter of 2023 at a minimum. (Supplyframe)
- **Worldwide shipments of traditional PCs** (desktops, notebooks and workstations) reached 83.6 million units during the second quarter, up 13% year-over-year. (IDC)
- **Shipments by North American EMS companies** in June were up 14% compared to the same month last year and 31% sequentially. EMS orders for the month rose 61% year-over-year and 44% from the previous month. (IPC)
- **China's electronics assembly value** reached a new high of nearly $346.3 billion in 2020, nearly half of the entire Asia/Pacific market. (New Venture Research)
- **Worldwide revenues for the AI market,** including software, hardware and services, is estimated to grow 15% year-over-year in 2021 to $341.8 billion. (IDC)
- **Thirty two of the 33 IC product categories** are expected to experience sales growth in 2021, with 29 product categories expected to see double-digit growth. (IC Insights)
- **The global smart wearable devices market** will reach $137 billion by 2030, growing 14.7% annually over 2020-2030, with a CAGR of 18.6% for unit shipments. (Research and Markets)
- **Thailand's manufacturing production index** is expected to grow 4 to 5% this year, on higher exports of circuit boards and electronics parts.
- **Economic growth in the US in 2021** is expected to be 6.6%, while 2022 GDP growth is forecast to be 4.5%. (IPC)
- **The overall component average sentiment index,** which peaked at 157.7 in March, slowed to 128.7 in July, with concerns related to the US economy and inflationary pressure coupled with parts shortages thought to account for the change. (ECIA)

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A Positive Message for Surviving a Pandemic

If ever employees deserved a big "Thank You," now is it.

THE WORLD HAS been through the ringer over the past 18 months. Pandemics have a way of shaking things up in ways no one could possibly imagine. It's sort of like being tossed into the wash cycle of a washing machine, being soaked from every possible direction, only to be rewarded by needing to survive the spin cycle! Covid-19 has brought nothing less. Regrettably, as summer turns to autumn, thanks to the Delta variant the end of this pandemic looks nowhere near.

For too many the disease itself has been devastating, from loss of life to the scores of friends, family and colleagues who fell seriously ill. No words can be said to ease the pain for those who have lost loved ones. For many others, the disease has cost them employment and caused dramatic changes in day-to-day lifestyles. For some, total despair. Indeed, the impact of Covid still can be seen and felt across the globe.

In some industries the impact of Covid has brought a complete change in the cadence of daily life. Rather than adults heading out the door each morning to go to an office to work, the work has moved into their home much like a loved (but unliked) distant relative. Ditto children: Rather than heading to school each day to learn in a classroom and play with friends, they have been confined to home. Parents, children, coworkers and teachers all inhabit limited space and fight for enough bandwidth to handle the seemingly never-ending virtual meetings and lessons. This new Covid paradigm, while enabling people to remain in a safe environment, has still caused displacement, inconvenience, and for many levied an emotional toll.

Within manufacturing the impact is different. Many positions require being in the company facility to perform the job at hand. Day-to-day life for those employees may on the surface appear "normal." Under the veneer, however, lay multitudes of issues. Many have children at home rather than at school, creating childcare issues. Many more may be showing up at the company facility, but with social distancing must perform their job under suboptimal conditions to ensure the work environment remains safe. And everyone is expected to deliver the same volume and quality of work regardless of where it is performed.

A pandemic-complicated phenomenon all businesses are experiencing is finding employees. Many displaced workers either lack the qualifications to change careers or prefer to wait to return to their pre-Covid jobs. Some who want to work are concerned about entering a dense workplace for fear of the risk of catching Covid. We are left with fewer staff, most working in socially distanced, nontraditional or at-home environments, trying to get more work done to meet the demands of employers and customers.

If ever employees deserved a big "Thank You" for dedication, flexibility and determination, now is the time. If ever employees needed the – ahem – shot in the arm of hearing that "Thank You" from their company, employer and coworkers in appreciation of the sacrifices and flexibility that pandemic life has required of all, now is the time!

Under normal conditions it is all too easy to get wrapped around the task at hand or project of the moment and forget the little things. When a seismic event unfolds, distracting and upheaving the normal cadence of work – and home – life, it becomes even harder, but much more important, to remember all those around you who are making sacrifices and deserve – and need – to hear they have not been forgotten and are much appreciated.

As executives and managers grapple with how, or if, to return businesses to a semblance of normal, part of that effort should include thanking all who have adapted to the everchanging pandemic environment. Especially as it appears returning to that normal may get postponed and require further sacrifice and flexibility, appreciation may be the most important ingredient to sustain the months ahead. Executives and managers, now is the time to voice sincere appreciation to all those who are working in such unprecedented times.

And while thanking each and every employee, make sure to give a big shout-out to their families. The children who have experienced school like none of their parents' generation could ever have conceived; the spouse or partner who has shared space at home to work while simultaneously attending to family; the parents, siblings and grandparents who have all been mustered to service to help all do what they need to do to enable parents to work, children to learn and everyone, together, to stay sane and healthy together.

Extraordinary times have required extraordinary efforts by all. Taking positive action and reacting to the unknown of a pandemic has taken its toll on everyone. Despite – or maybe because of – everyone's extraordinary efforts, economies have chugged along, and the technologies our industry does best continue to enable new and exciting products. All this could not have happened without people demonstrating flexibility, tenacity and creativity. Thank you all for your effort! No matter how the coming months unfold, remember to thank those around you who are pulling more than their weight. Together we will eventually lick this pandemic. ▫

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

US PCB Shops Should Look in the Mirror

Buyers will pay more for local products, if only manufacturers were easy to do business with.

IN A RECENT qopinion piece in *Roll Call,* IPC president and CEOJohn Mitchell – addressing the Biden administration's willingness to invest mightily in the global chip output – points out it will take this and much more to maintain the US electronics manufacturing industry's competitiveness.

"The issue," Mitchell notes, "is that America's supply chains keep generating problems that frustrate consumers, threaten companies and undermine American competitiveness."

He hits the nail on the head by calling for a more "holistic" approach and points out that while chips are important, they are just one piece of the puzzle. The printed circuit board, on the other hand, ties together all the components of electronics manufacturing, and that seems to be the greater domestic challenge.

In my opinion, it's not so much the chip shortage causing the US to fall behind in the technology race. Instead, it's poor sales management and customer service.

In my long career as a PCB broker, I have been both salesman and buyer; to sell the boards, I had to buy them first. My biggest challenge during that time has been successfully procuring PCBs from our domestic manufacturing industry.

What I'm talking about has nothing to do with technology, quality or pricing. Instead, it's about customer service from today's PCB industry.

To put it bluntly, that service is often subpar. I can't tell you how many times I have tried to bring business to US manufacturers, only to be disappointed with quality and delivery. It's rarely been about pricing.

For the most part, I get better customer service from manufacturers halfway around the world than I do in the United States. And that is nothing new.

The rise of the PCB broker over the past 20 years is testament to that lack of domestic service. Customers are willing to pay more to use US-based manufacturers, even while knowing they could go direct and pay less.

But domestic manufacturers have not made it easy to do business. And they still don't. Today, I teach companies how to buy PCBs better, including how to work directly with domestic and offshore manufacturers. In that role, I visit several domestic manufacturers each year. In fact, my company supports a number of them, as we provide an economical solution by supplementing their production with boards manufactured in Asia.

But I am frequently astonished at the condition of some of these domestic facilities. Outside, I see overgrown landscaping. If it weren't for the cars parked in front, I'd assume the business was closed.

Inside, it's even worse: dirty floors and walls, worn carpets, mismatched furniture. Lobbies look shabby, with awards displayed that are years old and often reflect previous ownership. Rarely is anyone at the front door to greet customers or prospects.

On the PCB manufacturing floor, I've seen dust covering tops of machinery and garbage collecting under plating equipment. I understand it's tough to keep a wet process or drill room looking presentable. But really?

How these PCB manufacturers expect to impress OEM or EMS companies is beyond me.

I am not just talking about the small shops. Some of the larger, well-known manufacturers are just as guilty.

A manufacturing facility's curb appeal, along with a clean and orderly interior, will help attract and retain customers. It will also soften the blow when, inevitably, a quality concern rears its ugly head, and a presentable and pleasant workspace will help attract and retain good employees.

PCB buyers regularly complain to me that, because of specific technology requirements or customer demands, they are forced to buy from domestic shops that think they are too big to bother providing decent customer service.

Just as bad, the inside sales teams at many of these companies appear untrained and overworked, with no real authority to resolve issues. The quoting process usually takes too long. And pricing is inconsistent.

Sure, the cost of PCB raw materials has increased, shipment delays occur, and quality issues arise, but that does not excuse the other failures I've described.

In addition, these firms fail miserably in getting the word out about their capabilities. Just encouraging people to "Buy American" is not a viable marketing strategy.

Don't get me wrong. Not all domestic PCB manufacturers are like this, but a significant number are. And the blame rests squarely with their ownership and management.

Maybe they don't know any better, or they accept things as they are because that's the way it's always been. But change to any organization starts at the top. Investing in your facility, along with ensuring proper training in sales and customer service, will provide an even greater return than buying a new piece of equipment.

Yes, investing in the chip industry is a good start, but a chip needs a PCB. And the truth is China doesn't bear the responsibility for the condition of our domestic PCB industry or the electronics industry in general.

Instead, we should be looking in the mirror. □

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

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2 Approaches to Ensuring Even Copper Distribution

The best designs use the least amount of material possible.

WHY EVENLY DISTRIBUTE copper on a PCB? Look at the material stackup as it alternates between conductor and dielectric material. The goal is to build a mirror image of copper weights as you work outward from the centerline.

Going beyond specifying alternating shape and route layers, the "greenest" PCB involves a minimum of etching. It's intuitive that removing less material requires less time in the solvent tanks. Time is money, so that should be reason enough to have all layers biased toward copper fill.

Besides being easier on the equipment, copper-biased design will help maintain an even thickness across the entire board. While fabricators generally offer a +/-10% thickness tolerance, we often want a tighter distribution when it comes to the actual PCB thickness.

Basically, we must permit the 10% thickness tolerance, while aiming for a 5% variance by providing artwork that makes the most of the raw materials. The more evenly we design the board, the more consistent the outcome.

This applies to warpage (bow and twist) as a percentage of the overall length of the board. (As an aside, 0.75% is the new 1%, as we continue to push fabricators to deliver flatter boards that support high pin-count surface-mount devices.) The objective is printed circuit boards that are all the same thickness and flat as a pancake. (Mmm, pancakes!) The result we're looking for is a high yield through assembly and a low defect rate down the road while saving resources during fabrication. OK, let's do it.

HDI strategy. HDI offers quite a bit more latitude over traditional through-hole technology. My recommendation is to add a ground fill around the traces once the signal layers are fully connected. Once the copper flood is in place, it will be more obvious where a session of trace shoving will benefit the routing layers **(FIGURE 1)**.

We're looking to isolate differential pairs in their own Faraday cages. Clock nets and sense nets are also routed in their own channels for different reasons. Clocks are aggressors, while many sense lines are, you know, sensitive to outside influence, particularly from clocks and high-speed connections.

Once the traces are grouped to maximize copper flood while maintaining ideal inter-trace spacing, it will be relatively easy to stake out ground vias around the perimeter of the shapes on a layer-by-layer basis. The microvias used in HDI construction will fit into small spaces and will span only the layers necessary to stitch the local ground planes to the general ground planes on their dedicated layers.

HDI technology is always used for a reason. Invariably, one or more components is a technology driver, while other circuits on the board are overserved by such fine-pitch geometry. The microvias can still be useful as a via-in-pad solution for the larger power and ground pins on the typical voltage regulators, even though they were meant for more mainstream solutions.

Once microvias are in play, make the most of them. It is always much faster to make a microvia than a through-hole via. Yes, there are more of them as they sequence through the board one layer at a time, but the process is well understood and known to be fairly reliable.

Board with plated through-hole vias strategy. Budgetary constraints often compel us to keep the PCB construction low-tech. There are times when the old-school fabrication is all that is required, of course.

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

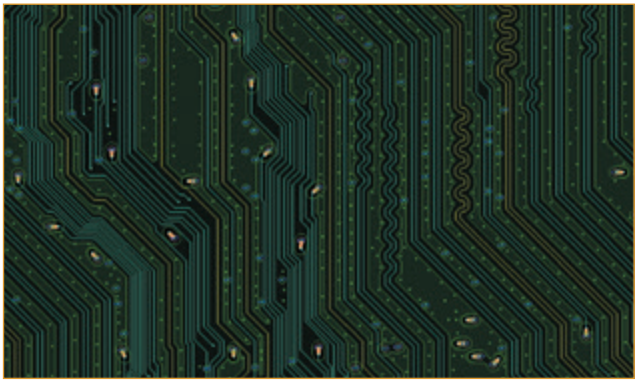

FIGURE 1. Isolating differential pairs and clocks (tinted yellow) is a good way to use copper flood on routing layers.

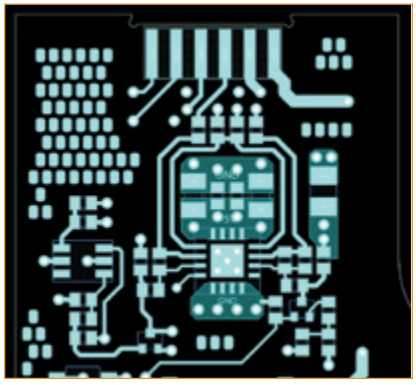

FIGURE 2. Metal loading in locations of too many vias would be disruptive.

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Evening Reception (Wed. Oct. 6)	✓	✓	✓
Exhibits (Wed. Oct. 6)	✓	✓	✓

The plated through-hole (PTH) process is the most reliable technique in use. We often find it under the hood of vehicles or onboard space rockets. No matter which end of the cost scale we consider, PTH boards have a long runway.

The thing is every via crosses every layer, so it's easy to wind up with too much of a good thing when we attempt to use vias to create thermal paths or Faraday cages. The density of the stitching vias can create barriers on power and routing layers that diminish the flow.

In general, HDI boards are used to manage current density and high-speed transmission lines to a greater extent than their PTH cousins. In low-to-medium-density designs, the space between pins is more relaxed; thus, the routing solutions may be simpler.

We'll still see a wide variance in metal loading between power, ground and signal layers **(FIGURE 2)**. To prevent the PCB from resembling a potato chip, we want to even out the copper distribution. All the layers, no matter their function, should have a similar percentage of metallization coverage.

You may be able to get there by flooding copper ground planes on all unused areas. The issue then becomes staking down the perimeter of each shape with vias. If they are left "floating," then the shape is more likely to become a conduit for transferring noise from one place to another.

Ground bounce, ripple and other signal integrity effects are more common when the ground planes are not well connected wherever they go. Components, routing busses and power planes may make it difficult to add as many vias as necessary for each layer of copper pour.

For this reason, I tend to go for adding nonfunctional copper in places where ground pour is inadvisable. There can be a fabrication note that spells out the size, shape and spacing of the nonfunctional copper. Taping out an unbalanced board without a note on the subject will trigger the fab shop into asking permission to add "thieving."

Fabricators are volunteering to do so to meet IPC requirements for flatness and thickness, but I'm sure they would be happier if you lead the way. I don't want to leave it to them, so I create the thieving as part of the artwork, rather than relying on a fab note.

A final thought on implementing copper thieving. Ever heard of the golden ratio **(FIGURE 3)**? It's something found in

continued on pg. 26

Taking Charge of Professional Development

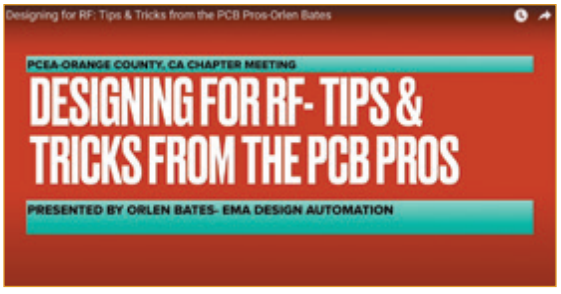
Invest in yourself: You are your own best asset!

IN THIS MONTH'S column, I give kudos to our PCEA chapter liaison, who has been capturing the efforts of the PCEA to educate our members and our industry as a whole, then pass the mic to PCEA chairman Steph Chavez to provide some thoughts on taking charge of your career.

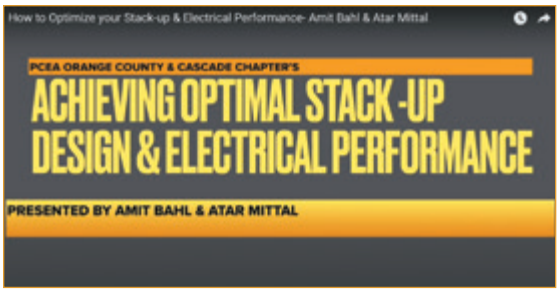
PCEA Updates

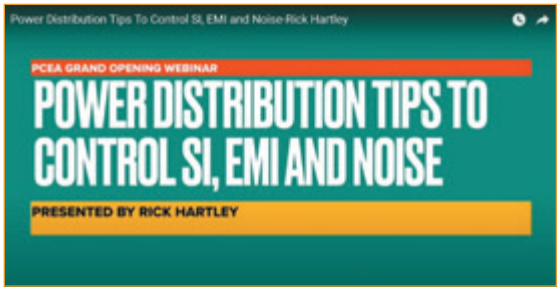
This month we highlight the work of PCEA's Scott McCurdy, a tireless force for collaboration within the printed circuit engineering industry. Not only has McCurdy worked hard in the industry as director of sales & marketing for Freedom CAD Services in Orange County, CA, but for years he has worked as a leader in trade organizations specializing in educating their members.

Presently serving as PCEA's chapter liaison and PCEA-Orange County chapter president, McCurdy coordinates all chapter leadership and inspires them to move in a consistent and helpful direction. Local PCEA chapters are actively planning their yearly itineraries to serve our industry. From the founding of PCEA throughout the pandemic of 2020, McCurdy has worked with chapter members and industry educators to create a PCEA YouTube channel to spread educational presentations: https://www.youtube.com/channel/UCTJc-ksUtG-vUPvu1hBe3hA.



KELLY DACK, CIT, CID+, is the communication officer for the Printed Circuit Engineering Association (PCEA). Read past columns or contact Dack at kelly.dack.pcea@gmail.com.





Message from the Chairman

by Stephen Chavez, MIT, CID+

This month's topic on education is a good one. It is important to many of us, especially anyone involved in printed circuit engineering, fabrication, assembly and test of printed circuit boards (PCBs). For me, continuing education/professional development is a must to stay relevant and competitive. When I think of this topic, a few things immediately come to mind. First, who is responsible for your continuing education and professional development? Is it your employer? Is it you as an individual? These are questions I hear debated often.

Overall, I get mixed responses to those questions. Some say it's their employer's responsibility to provide continuing education and professional development, while others say it is ultimately up to the individual to take charge.

I feel strongly it's up to each of us to ensure we stay on track, not our employers. Yet I also feel a good company in today's industry views their employees as their best internal assets and best long-term investments to be successful. Such companies provide opportunities and look for creative ways to provide continuing education and professional development to get the best return on investment (ROI) from their employees. It's a win-win. It also helps cultivate a positive culture and working environment so long-term success is most likely to be achieved.

Sadly, not every company takes this approach. The downside to abstaining from these opportunities is slow or lack of evolution, longer-than-normal project schedules and excessive budgets, and, in the worst cases, a high employee turnover rate, leading to lack of long-term company success. (For some data on the percentage of design engineers who receive company reimbursement for outside professional development, see the annual PCD&F salary survey in this month's issue.)

Those who feel it's their employer's responsibility to provide for this are at the mercy of their company for their personal development, which may happen at a slower pace or, worse, not at all. This too will clearly have a negative impact on the company. It becomes a lose-lose. No one gains if neither the company nor employee feels responsible for continuing education and professional development.

My advice is take ownership of your own continuing education and professional development, whether your company provides the opportunity or not. Invest in yourself because you are your own best asset! In today's industry, especially with how we have adapted during this pandemic, there are so many opportunities to take advantage of. Between all the available industry online webinars and online courses, to the many industry conferences now returning to face-to-face engagements, many more opportunities are available today than a decade ago.

The Printed Circuit Engineering Association (PCEA) is one of many industry associations where you can find such awesome continuing educational and professional development opportunities. A great example is the recent event held by our Orange County chapter. This successful event had valuable work-related content that was well-received by the large contingent that attended. PCEA will continue to do our part by collaborating, educating and inspiring within the industry by providing such opportunities. Make sure you stay tuned into PCEA and up to date with opportunities and industry events listed on the events page of our website.

I continue to wish everyone and their families health and safety. Best of success to all as 2021 unfolds.

Warmest regards,

Steph

Next Month

A lot of items on the PCEA roadmap were presented in our meeting Jul. 9. As we evaluate our important list of "to-dos," I'm not sure which will be moving forward first. Next month's PCEA column topics will be a potpourri of subject matter coverage as the PCEA moves into trade show season.

Upcoming Events

Below is our list of upcoming events. Hope to see you at any of these!

- **PCB West**
  Oct. 5-8, 2021
  Santa Clara Convention Center
  Santa Clara, CA
  www.pcbwest.com

- **SMTA International**
  Nov. 1-4, 2021
  Minneapolis, MN

- **Productronica**
  Nov. 16-19, 2021
  Munich, Germany

Spread the Word

If you have a significant electronics industry event that you would like to announce, send me the details at kelly.dack.pcea@gmail.com, and we will consider adding it to the list.

Conclusion

Educating the industry is one of the key goals of the PCEA. PCEA leadership is delighted to find so many educators in our industry willing to provide their knowledge and allow us to capture it and present it in the spirit of altruism. As we continue to collaborate, inspire and educate as a nonprofit, please take time to watch, comment and thank the many presenters we bring to you as a service.

See you next month or sooner! ▫

PDN Effectiveness: The Devil's in the Decap Details

Understanding cap differences and modeling will help identify loop inductance issues early.

WE'VE WRITTEN FOR months about how to control power delivery. While we have learned the effects of layout on the PDN, we haven't yet focused on the other major influencing factor: the decoupling capacitor.

These simple, 2-pin devices perform two main tasks: resist a change in voltage across their pins and accumulate and store "charge" that can be delivered from those pins to maintain that voltage. In the world of digital design, this "decoupling" function is huge and is arguably why we do power integrity (PI) simulation in the first place. The power demands of a product's components are largely defined by its features and performance requirements, which determine supply sizes. Between those lies the power delivery network (PDN), a subject we've intensely studied. Composed almost entirely from capacitors and the copper that connects it all together, the success or failure of a PDN is often determined in layout. In previous articles, we've written about "loop inductance" and how it impacts the capacitors' ability to do their job. A solid understanding of cap differences and modeling will help identify loop inductance issues early to ensure a successful PDN.

We are limiting this discussion to decoupling capacitors, also known as multilayer ceramic chip capacitors (MLCC), as these are the type seen in volume for most PCB tasks. While not minimizing the value of component engineering and other factors, we can generally determine the capacitor we need by considering the following parameters:

- Size (0402, 0603)
- Capacitance (10pF, 1pF)
- Voltage (3V, 25V)
- Tolerance (1%, 5%)
- Temperature coefficient (TEMPCO: C0G, X5R).

For each parameter it is important to understand how your choices impact PDN, manufacturability, reliability, and sometimes overall design cost.

Size matters. The size of a capacitor is often the primary influence when selecting a component and can be varied to optimize the PDN. Smaller packages, such as 0201s, are desirable due to their low inductance but can be challenging to assemble. Larger packages, such as 0603s, take up valuable room on the PCB but may provide a lower mounting inductance by aligning with the breakout vias for a BGA. For a successful design, a balance needs to be achieved between inductance, capacity, manufacturability and cost.

Determining capacitance and voltage. Not a single reader will be surprised that capacitance and voltage are key considerations when choosing capacitors, as these values are based on the design requirements. While decoupling capacitance values can be calculated through complex design calculations, simulations or measurement results, many designers take a different approach. To produce a design that is both effective and responsive, select a capacitance value that provides the greatest amount of localized supplemental charge and replace some of the capacitors to obtain an acceptable frequency response (foreshadowing: the subject of next month's article). Like most of the parts on a PCB, decoupling capacitors come with recommended operating conditions, including the acceptable input voltage. When deciding on the appropriate voltage, it's not uncommon for designers to select a device based on a "derated" voltage. This is a reduction from the specified maximum voltage based on operating temperature and capacitor aging and will ensure functionality over the product lifespan.

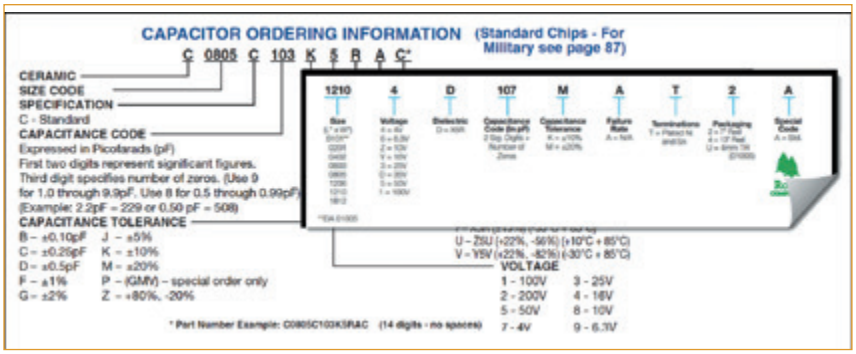


FIGURE 1. Typical part number "decoder."

Understanding tolerance across all operating conditions. Like any value in engineering, capacitance has tolerance. This is a range deemed close enough to the advertised value to be unnoticeable for the intended purpose. What's often overlooked is tolerance only holds true for a specified temperature range. TEMPCO

TERRY JERNBERG is an applications engineer with EMA Design Automation (ema-eda.com), with a focus on PCB design and simulation. He spent his early career on signal integrity simulation for the defense industry and was fundamental in the adoption of these tools at EMC and Bose. A vocal advocate for simulation, his enthusiasm for physical modeling has expanded to include power and thermal capabilities.

(aka "dielectric") refers to the capacitor's ability to remain within the tolerated capacitance value over the specified temperature range. Outside that range, the effective capacitance can drop off well beyond the specified tolerance. This is a vital parameter for decoupling capacitors, as the entire PDN's ability to respond can be dramatically reduced to 50% when a board heats up or is exposed to wide environmental changes. TEMPCO is defined by a three-character sequence (letter, digit, letter) that refers to international standards that characterize temperature stability and are influenced by the insulating, or dielectric, material used to construct the capacitor (hence the misnomer). The capacitor cost significantly increases with stricter tolerances and wider operating temperature ranges; however, ignoring these aspects in your component selection can lead to field failure, especially in military and aerospace applications that experience extreme environmental conditions.

These five properties are so useful in differentiating capacitors, they often find their way into the vendor's part numbering **(FIGURE 1)**. For example, by looking at Kemet's C0603C508K8GAC (0603 package) or AVX's 08054W226MAT2A (4V) we can gather vital component information from just the part number. Many vendors value this inherent ease of use and provide guides to assist in the effort. These properties are only part of the equation, however.

Enter the capacitor model.

While it is common for these properties to be used as the criteria to determine alternative components, they are not the only attributes to be considered. As demands on the PDN increase, and its margins and tolerances decrease, many designs are more sensitive to variability in the capacitor devices not captured by these properties alone. Understanding this, capacitor vendors have responded, providing Spice models and S-parameter models that include electrical aspects which can't be characterized with simple attributes. Information beyond what a supplier could convey with properties alone can be contained in the model, including package inductance, internal resistance, and operating conditions such as temperature and bias voltage **(FIGURE 2)**.

The Spice model for a capacitor is intended to provide an electrical view of the inner workings of the device, as seen from its external pins. It does this with a circuit approximation, composed of the basic RLC elements like how a circuit simulator would approximate a PCB wire as a transmission line. While this "inner view" of the capacitor can be useful to

understand device behavior, when dealing with capacitors, we are most concerned with its behavior at the pins (as opposed to what's going on inside). This is significant, particularly as an introduction to the other common modeling format, the network parameter, specifically an S-parameter.

The S-parameter opts to describe the capacitor behavior in terms of voltage and current from the outside at the device edge, treating the contents as a "black box." While this makes the model useful, without any knowledge of its contents, it is necessary to know if the data within represent the device connected in series or in parallel. The capacitor separates the AC (or switching) parts of a signal from the DC (or level sensitive) part. During our board design, we may want to keep the DC and remove the AC, as in the case of a sensitive voltage source (i.e., filtering ripple noise from a voltage island). This requires a shunt configuration. Likewise, we may want to maintain the AC portion, removing the DC that requires a series configuration. This is common in a high-speed serial link where the DC part isn't relative to the transmission but can cause a DC shift between driver and receiver.

Spice models and S-parameter models **(FIGURE 3)** can be incorporated into your simulations, are interchangeable and work in mixed combinations. Neither method is inherently more accurate, and vendors are free to choose one or both.

FIGURE 2. Beyond the ideal capacitor, Spice model syntax can include the package parasitic.

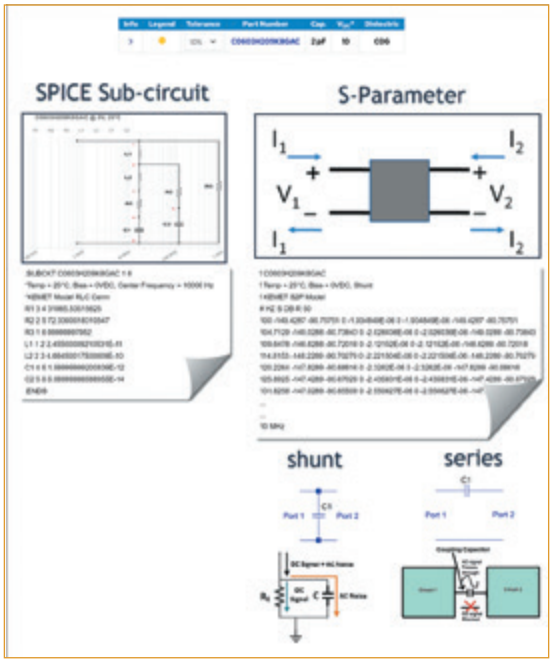


FIGURE 3. Spice and S-parameter models.

Building a complete model of your PDN. With the progression of solvers, simulators, and the readily available capacitor models, PDN creation and analysis are evolving. A basic understanding of capacitors is required to determine the necessary parameters for your design and incorporate realistic models into your simulation. By producing a complete and realistic picture of your power delivery network, analysis can be taken a step further, identifying loop inductance issues, optimizing capacitors, and ensuring target impedance. □

Designer's Notebook, continued from pg. 23

nature, like the chambers of a nautilus shell or a hurricane. It is also favored by architects and graphic designers. That is the geometry I like to use when creating an area of thieving. My favorite method is making rows of rectangles offset to resemble a brick wall, but a bunch of little dots will do as well for metal loading. I like to think the board gets a little more stiffness from the brick wall approach, although there is no proof of that.

Spacing rules will drive the air gaps, and the size of the area to be filled will inform the size of the bricks. This filler method can be used on any layer but is most common on component and routing layers. Bottom line: Don't wait to be asked to even the metal loading. Just go for it either by a design note or getting a little satisfaction with the layout tool. □

FIGURE 3. The geometry of the golden ratio is seen in the small rectangle. Numerically, it is close to 1:1.6. (Source: Deposit Photos)

As Today's PCBs Become Increasingly Advanced, the Original Principles Remain So Right

Could optical interconnects and graphene change the view?

MANY THINGS, INCLUDING the electronics industry, have changed beyond recognition over the past 40 years or so. It's all the more incredible how little the PCB has changed in its makeup since its inception, and thus fitting that PCD&F named its Hall of Fame after the printed circuit inventor, Paul Eisler. His radio, the first commercial product to contain a PCB, is on display at the Science Museum in London. It was made in 1945, containing a simple and straightforward PCB designed to implement point-to-point connections. Things have become more sophisticated, of course, as human nature provides both the push from engineers' curiosity and the pull of market demands.

The main goal of early PCBs was to replace traditional soldered wire connections. This helped streamline assembly, reduce wiring errors, and increase reliability. The PCB's arrival also facilitated automation of electronics product assembly. In early PCBs, the role of the substrate was barely considered, except to separate the conductors. Now, the substrate properties are the most important aspect where high signal frequencies are present. In other ways, it's surprising how little has changed, as the constituent parts remain the same: a composite core, comprising a reinforcement and a resin binder, and copper conductors.

Of course, much has been done to boost and optimize the properties of the entire assembly. With efficient thermal transfer a key demand in high-power circuits, unreinforced materials have come to the fore that remove the effects of glass as a thermal insulator.

As far as conductive layers are concerned, alternatives to copper could offer improvements such as greater signal integrity and reduced attenuation, especially when handling high data rates. Graphene offers interesting properties, including excellent electrical conductivity, as well as high strength and flexibility in very thin films down to one atom thick. Of course, graphene is being positioned for many applications, including supercapacitors for energy storage, high-efficiency lighting, and even in higher-performing replacements for silicon-based ICs. On the other hand, board-level optical interconnects using miniature photonic modules can deliver freedom from the loss mechanisms of copper, while also increasing the bandwidth per interconnect. These gains could deliver greater performance, with a significant reduction in PCB size and thickness, driving miniaturization, as well as reducing material consumption.

While adapting to capture the benefits of alternative technologies such as graphene and photonics, the PCB will almost certainly remain the primary substrate and interconnect medium for electronics for many years. It is very difficult to improve the underlying concept. PCBs produced today deliver tremendous performance and functionality, with only a few dollars' impact on the BoM for a device like a smartphone.

Predictability and repeatability are further strong points. Material suppliers can provide ECAD vendors with accurate data about material properties that let product designers know exactly how the choice of PCB material will affect the operation of the circuit and engineer the composition and dimensions to achieve the performance needed. This is as true for specialty high-performance products as for general-purpose materials such as traditional FR-4 variants.

It's been said the PCB is the last aspect of a project to be designed and the first to be needed. Its importance is often overlooked. But as we push performance limits, the PCB is a key component and an important factor in determining whether the end-product will meet those requirements. Right now, supply and costing challenges must also be considered.

We can expect the global supply problems to become less severe as producers return to normal work patterns. This is of little comfort to OEMs and EMS businesses seeking materials and assemblies to meet immediate demands. It's one of the factors driving calls for more PCB production to be done in the US or Europe. This is not a short-term fix but rather a vision to protect industries against trade and shipping problems in the future.

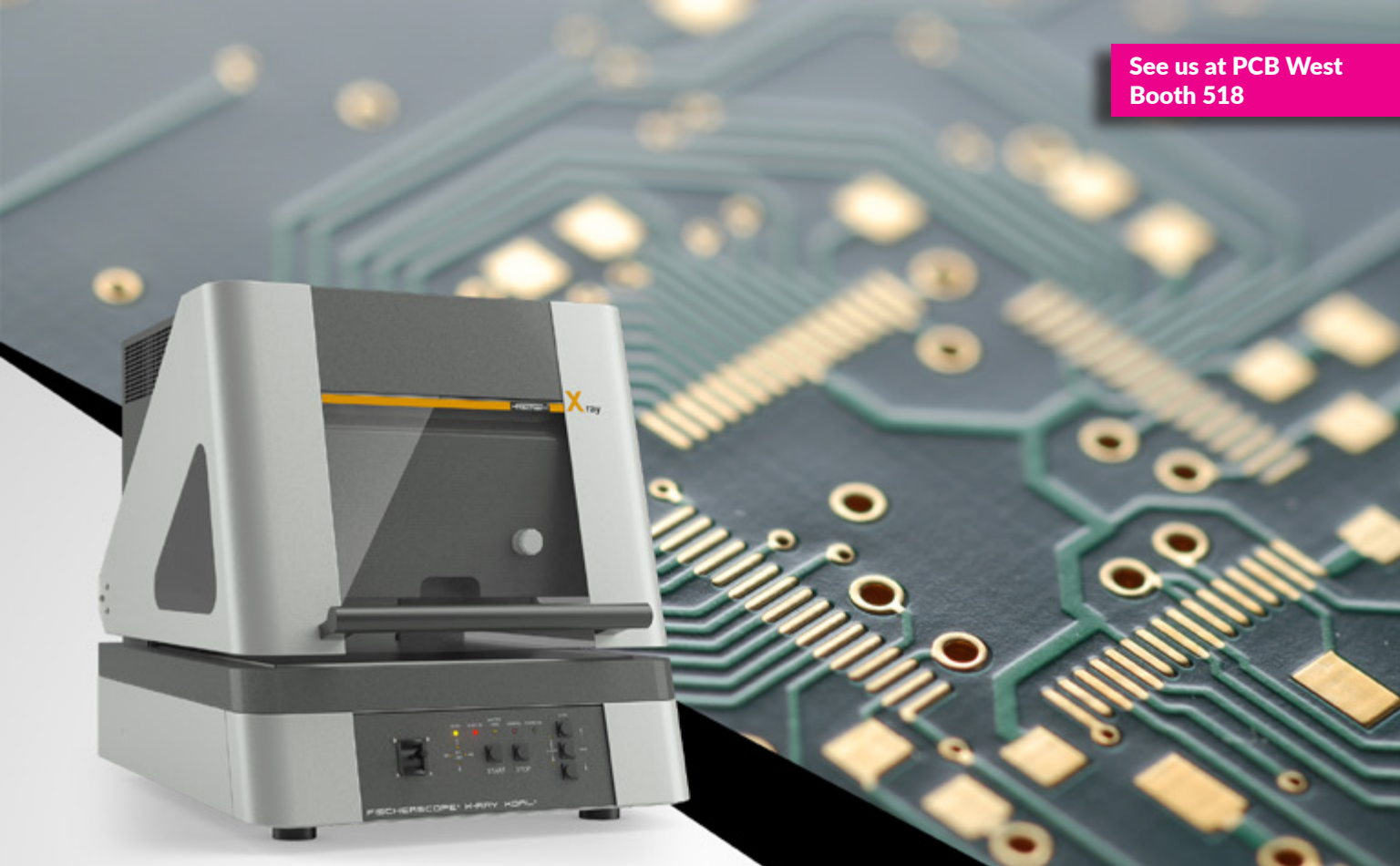
Currently, Asia is by far the dominant region in PCB manufacturing. It produces over 90% of the world's PCBs, while manufacturing in the US and Europe accounts for a little over 6%. I've already drawn attention to the value of the supply infrastructure and subject expertise in areas such as materials technologies needed to sustain PCB manufacturing, wherever it is done. Driving any significant shift in volume demands these types of facilities also be present in the new location. It will not happen quickly, or easily.

There are some successful examples. Clusters of low-loss and medical-focused PCB manufacturing in Switzerland, for instance, show local manufacturing can be highly effective for specialty items in small volumes. However, supply and pricing issues also would affect local manufacturing, so it's difficult to make a case for moving production of high-volume, price-sensitive boards to the West when they are being made so economically to the high standards we have come to expect.

Ongoing improvements are certain to happen, but it's hard to see how the PCB that we know and recognize will ever be superseded in its role. ▫

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

See us at PCB West
Booth 518



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In an Unpredictable World, PCB DESIGN ENGINEERING Stays Steady

PCD&F's annual salary survey reflects the consistency and stability of the PCB design industry. **by CHELSEY DRYSDALE**

To say much has transpired in the past year and a half is the understatement of all understatements. When we published the findings of our last designers' salary survey in May 2020, we were still in the early months of the Covid-19 pandemic, many of us in the initial stages of a lengthy quarantine we thought was temporary. We were unsure how the virus would affect the world in the short-term, let alone the long-term – with regard to the health of loved ones and the economy as a whole, to name two of countless concerns. It will be many years before we fully comprehend the enduring global impact of this unmitigated health crisis, but if this year's survey is any indication, one thing that has remained consistent is the PCB design engineering profession.

The US unemployment rate in July 2020 was 10.2%, and as of July 2021, it was 5.4%, according to the US Department of Labor.[1] More specifically, for engineering occupations, the unemployment rate as of Jun. 30, 2020, was 6.1%, and at Jun. 30 this year, it was only 3.4%, BLS says, and the computer systems design and related services sector added 100,000 jobs in June alone.[1]

The figures are consistent with the ESD Alliance trade group's findings, which showed companies tracked in its quarterly statistical report employed 49,024 workers in the first quarter 2021 (the most recent data available), up 6.7% from 2020.[2]

According to PCD&F's 2021 salary survey, PCB design engineers are retaining their jobs – if they choose to keep them; bringing in a substantial paycheck; and feeling satisfied with their chosen profession. Plus, the workload isn't abating and shows no signs it ever will. So, if you have an engineering degree, here's a virtual high-five because you made a solid choice.

PCD&F conducted its annual design engineers' salary survey from mid-May through July, receiving 202 qualified responses from bare board designers, managers and design engineers. Data compiled included job titles and functions, ages, years of experience, education, location, types of projects, annual salaries and sales, job satisfaction and challenges, ECAD tools used, and years left in the field. The survey had a new question concerning board revisions (re-spins) produced each year and revised the list of job titles to reflect where the field is headed. While year-over-year changes are shown, they are for comparison only, and should not be assumed to be definitive.

Job titles and functions. Nearly half of all respondents in 2021 consider themselves senior PCB designers or senior PCB design engineers. Some 19% said they are PCB designers or PCB design engineers, without the senior designation. The slight change in job titles in this year's survey is reflected in **TABLE 1.** Hardware engineers made up over 17% of responses, and all other job titles received fewer than 7% of responses each.

Most respondents report PCB design as their principal job

TABLE 1. Respondents by Job Title

	2021	2020	2018	2017	2016	2015	2014
Senior PCB designer	26%	39%	59%	56%	52%	52%	54%
PCB designer	7%	17%	13%	14%	15%	16%	20%
Senior PCB design engineer *(New!)*	22%						
Senior engineer (See above title change)	N/A	8%	2%	5%	3%	3%	2%
PCB design engineer *(New!)*	11%						
Design engineer (See above title change)	N/A	13%	7%	8%	8%	8%	7%
Hardware engineer	17%	12%	9%	3%	7%	4%	3%
PCB design manager	6%	4%	6%	9%	9%	9%	8%
Principal engineer	6%	2%	2%	3%	2%	3%	2%
Electronics technician	1%	1%	1%	1%	1%	1%	1%
Technical director	2%	1%	1%	0%	1%	1%	1%
CAD librarian	0%	2%	2%	1%	2%	2%	1%

Numbers might not total 100% due to rounding. n = 202

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

For Information or Registration:
info@pce-edu.com

Upcoming Class Openings:
Sep 20-24, 2021 & Oct 18-22, 2021

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Printed Circuit Engineering Professional

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function (TABLE 2), followed by PCB engineering (14%) and engineering management (6%). Design/layout management was 6%.

A modest number of respondents (7%) spend 100% of their professional time on board design, including schematic, layout and placement, versus 17% in 2020 (FIGURE 1). In this year's survey, a third of respondents indicated they spend 50% or less of their time performing board design, comparable to 2020.

The depth and breadth of responsibilities are growing, our survey found. More respondents than in the past are charged with evaluating, recommending, specifying and approving ECAD software (80%) and CAM software (32%). Likewise, more design engineers are being asked to recommend prototype fabrication services and assembly providers (TABLE 3), among other product and service purchases.

When asked their highest level of purchase power, more than a quarter of designers said they can recommend products, while 24% can specify products. Almost 23% can evaluate products, and 13% can approve product purchases. Fewer than 15% are uninvolved in the procurement decision process.

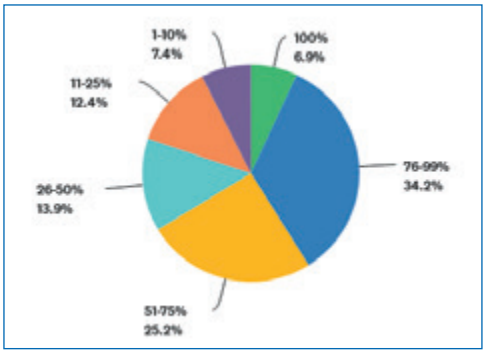

FIGURE 1. Weekly time spent on board design.

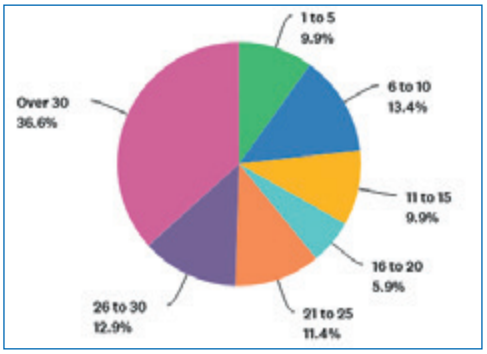

FIGURE 3. Years of experience.

Age, experience and satisfaction. A higher percentage of respondents are over 50 years of age in 2021 than those who took the survey in 2020: 61% compared to 53% (FIGURE 2, online). Respondents who are 35 years old or younger accounted for 23% of responses this year. This could reflect the changing nature of the industry, including differences in how willing various demographics are to respond to surveys.

The picture looks similar to last year in terms of years of experience in printed circuit design (FIGURE 3). Those with more than 20 years of experience accounted for 61% of responses, nearly flat with 2020, while respondents with more than 30 years of experience made up 37%, compared to 34% last year. A third of designers have 15 years or fewer of experience, slightly less than in 2020 (35%).

Within the next 10 years, 55% of designers plan to leave the profession, according to survey results, versus 61% last year. Of those, more than a quarter will retire within the next five years. Within the next 15 years, 78% of designers said they will no longer work in the field, most likely because they will have aged out. Nearly 22% of designers say they'll continue to work for 16 or more years, versus 26% in 2020.

On a scale of 1 (completely dissatisfied) to 7 (highly satisfied), designers are still happy with their

TABLE 2. Principal Job Functions

	2021	2020	2018	2017	2016	2015
PCB design	64%	64%	74%	75%	70%	73%
PCB engineering	14%	13%	10%	9%	10%	9%
Systems design	7%	8%	4%	2%		
Design/layout management	6%	6%	5%	8%	11%	10%
Engineering management	6%	2%	0%	2%	4%	3%
Engineering consulting	1%	2%	1%	<1%	1%	2%
Applications engineer	1%	2%	1%	1%	2%	
General/corporate management	1%	<1%				
ECAD librarian	<1%	2%	3%	2%	2%	2%
Design support (drafting)	<1%	1%	<1%	<1%	<1%	<1%

Numbers might not total 100% due to rounding. n = 202

TABLE 3. Procurement Participation

	2021	2020	2018
ECAD software	80%	75%	74%
CAM software	32%	26%	24%
CAE software	16%	15%	16%
MCAD software	16%	14%	12%
Prototype PCB services	56%	56%	44%
Volume PCB fabrication services	33%	33%	26%
Design services	39%	38%	35%
Connectors and cables	33%	37%	24%
Active/passive components	37%	35%	24%
FPGAs/PLDs	14%	16%	14%
Assembly services	32%	32%	23%
Solder mask	21%	21%	12%
Substrate materials	21%	21%	19%
Computers and peripherals	16%	18%	17%
Solder materials	20%	18%	10%
Epoxies and finishes	14%	15%	6%
Consulting services	14%	15%	13%
Test/measurement services	18%	22%	13%
None of the above	10%	10%	15%

Respondents could choose more than one answer.

jobs. More than 87% indicated some level of satisfaction, up from 79% in 2020. Some 18% rated their job satisfaction a perfect 7, versus 22% last year. Roughly 13% are mildly or totally dissatisfied with their profession, nearly flat with last year.

Salaries. Over half of respondents are at or above the top of their company's salary range for their current job position (51%), compared to 47% in the prior survey. Being a PCB design professional has its perks, with the most obvious being compensation. Nearly 73% make $70,000 or more, up from 65% in 2020, with over a quarter of respondents earning in excess of $110,000 **(TABLE 4)**. Only 18% of respondents make $50,000 or less, compared to more than 21% in 2020, and over 10% make more than $150,000 annually, compared to nearly 7% last year and just over 4% five years ago.

More respondents will receive a bonus this year than in 2020, according to survey results (over 57%, compared to 51%). Of those who will, nearly 44% say their bonus is 1 to 3% of their annual salaries, compared to 38% last year; 29% of bonuses are 4 to 7% of annual salaries, compared to 30% last year; and 28% of respondents will receive a bonus that's greater than 7% of their annual salaries, down from 31% in 2020.

When asked how respondents' salaries have changed in the past year, 47% say their salary rose 1 to 3%, up from 45% last year. About 21% say their salary didn't change, nearly flat with 2020. Nearly 4% said their salary fell 7 to 10%, a slight jump from 1% in 2020. Overall, 72% of respondents' salaries grew in the past year, compared to 75% in the prior year.

Over 93% of those who took the survey said they have the same job as they did in 2020, compared to over 95% last year. Some 6% were laid off in the past year, fewer than in the prior year (8%).

Most respondents aren't in managerial positions, and 92% are male. No one who took the survey identifies as nonbinary; one respondent chose not to specify a gender.

Educational opportunities and benefits. In terms of educational opportunities supported by employees' companies, they were asked to check all that apply, with on-the-job training garnering the most responses (56%), compared to 58% in 2020. About half receive tuition reimbursement, and 43% can attend classes at conferences, compared to 47% in the prior survey. For the first time, the annual survey included industry certifica-

tion, with 37% indicating it's an option. Roughly a third of companies offer in-house classes, and the same percentage offer on-the-job mentoring. Twenty-two percent of designers said their company doesn't provide educational opportunities, versus 26% in 2020.

Company benefits include the following. Respondents checked all that apply. Given the challenges of the past year, the telecommuting figure seemed low:

- Health insurance: 2021: 85%
- Dental insurance: 67%
- Life insurance: 67%
- 401(k) plan: 61%
- Telecommuting: 35%
- Company pension or retirement plan: 25%
- Stock purchasing plan: 25%
- Profit sharing: 19%
- Sabbatical: 6%
- Daycare facilities: 5%

Asked, "How have your benefits changed in the past year?" 12% of respondents said more benefits are offered, or the same benefits at a lower cost, nearly flat with 2020. Another 15% said fewer benefits are offered, or the same benefits but at a higher cost, versus 22% in 2020. Nearly 73% said their benefits haven't changed, versus 66% in the prior survey.

Education. Engineering bachelor's degrees are more common among respondents this year than last, with 39% indicating they have one, up from 37% in 2020 **(TABLE 5)**. Of those with a four-year degree, 77% have an electrical engineering degree, up from 70% last year, and 4% have a degree in mechanical engineering. Those who have an associate's degree or have attended college but have no degree accounted for 42% of responses. Thirteen percent

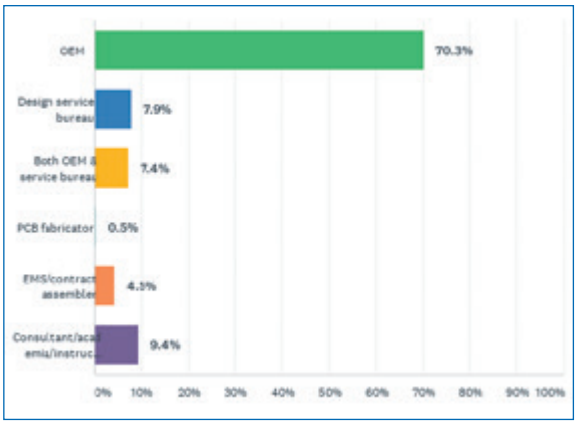

FIGURE 4. Company type.

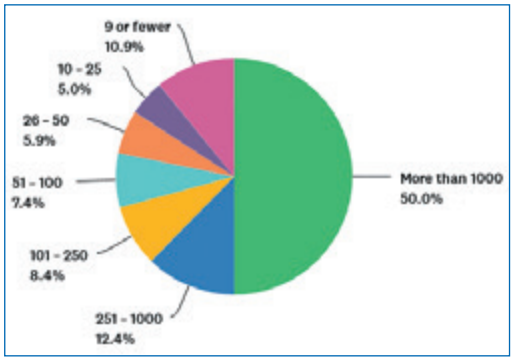

FIGURE 5. Company's number of employees worldwide.

TABLE 4. Average Annual Salary by Segment

	Total	4-Yr. Degree	2-Yr. or Less	AGE =/<40	AGE 41+	Male	Female	Manager?	N. America	Europe	SE Asia/China
<$10,000	3%	4%	1%	8%	1%	2%	13%	3%	0%	2%	40%
$10,000 to $15,000	3%	5%	0%	8%	1%	3%	7%	3%	0%	5%	40%
$15,001 to $20,000	3%	3%	2%	4%		3%	0%	3%	1%	7%	0%
$20,001 to $25,000	2%	3%	1%	6%	1%	2%	0%	2%	0%	2%	0%
$25,001 to $30,000	1%	2%	0%	4%	0%	1%	0%	2%	0%	2%	0%
$30,001 to $40,000	3%	5%	0%	9%	0%	3%	0%	7%	0%	10%	0%
$40,001 to $50,000	4%	5%	2%	6%	3%	4%	0%	5%	2%	12%	0%
$50,001 to $60,000	6%	5%	6%	9%	4%	6%	0%	13%	2%	10%	0%
$60,001 to $70,000	5%	4%	7%	8%	4%	4%	7%	2%	5%	7%	0%
$70,001 to $80,000	9%	7%	11%	13%	7%	9%	7%	7%	9%	14%	0%
$80,001 to $90,000	14%	13%	16%	17%	13%	15%	7%	5%	19%	0%	20%
$90,001 to $100,000	11%	8%	14%	2%	14%	11%	13%	10%	14%	7%	0%
$100,001 to $110,000	12%	11%	13%	2%	15%	12%	13%	10%	14%	12%	0%
$110,001 to $120,000	6%	6%	4%	2%	7%	5%	13%	2%	7%	2%	0%
$120,001 to $130,000	5%	4%	7%	0%	7%	5%	0%	8%	7%	0%	0%
$130,001 to $140,000	4%	1%	7%	0%	5%	3%	7%	3%	5%	0%	0%
$140,001 to $150,000	2%	3%	1%	0%	3%	2%	0%	2%	3%	0%	0%
>$150,000	10%	13%	8%	4%	13%	10%	13%	16%	13%	7%	0%

Numbers might not total 100% due to rounding. n = 202

of respondents have a master's. Similar to last year, nearly 3% specified high school as their highest level of education.

Certification. The majority (62%) of respondents are not IPC-certified designers. However, of those who are, nearly 53% are CID+. We did not ask about PCE-EDU certification, the new design engineering curriculum, as the program was just launched this year.

Employers. If survey results are indicative of the big picture, OEMs are employing design professionals more than ever. Over 70% of respondents work for OEMs, up from 67% in 2020 **(FIGURE 4)**. The second most prevalent response was consulting or academia (9%), while those who work for a design service bureau made up 8%. (This may explain the seemingly low telecommuting response.) Half of all respondents work for firms with more than 1,000 staff members **(FIGURE 5)**.

Many respondents either work at large firms with estimated annual sales of $5 billion or more (17%), or small firms with less than $5 million in sales each year (16%). Over a quarter of designers are unsure of their company's annual sales figures, and another 13% said their company makes $5 million to $49.9 million annually. Nearly 10% of respondents said their employer brings in $1 billion to $4.9 billion each year.

Location. Nearly 63% of respondents reside in the United States, with 21% on the West Coast, including Arizona, flat with 2020 **(FIGURE 6,** online**)**. Another 18% are in Central/Western Europe, and 6% live in Canada.

Projects and technology trends. Over half of respondents said they still engineer, design, and/or lay out single-sided PCBs **(TABLE 6)**, up from 44% in 2020. Double-sided PCBs and 4- to 6-layer PCBs continue to be the most common technology, with more than 83% of responses. Nearly two-thirds indicated they work on boards of 7 to 10 layers.

An addition to the list in the 2021 survey is high-speed design: 66% of respondents do high-speed work.

On average, half the respondents produce 10 or fewer designs, or part numbers, per year **(FIGURE 7,** online**)**. Over 12% said they produce more than 20 designs per year.

For the first time, PCD&F asked respondents to share how many board revisions (re-spins) they produce annually, on average. The most common response was 1 to 5 re-spins

(50%) (FIGURE 8, online). Another 24% said they produce 6 to 10, while 11% produce 11 to 15.

Respondents primarily design for these end-markets:

- Government/military/aerospace/avionics/marine/space: 2021: 24%
- Industrial controls/equipment/robotics: 15%
- Automotive/other ground vehicles: 12%
- Consumer electronics (including wearables and white goods): 11%
- Medical/optical electronics and equipment: 11%
- Communications/related systems equipment (including all phone types): 10%
- Electronic instruments/ATE design and test: 6%
- Computers/peripherals: 3%
- Semiconductors and related packaging or test equipment: 3%
- Other: 5%

Challenges. PCB design professionals are most concerned about their workload and keeping up with technology changes, more so than whether they'll keep their jobs. Sixty-four percent indicated the biggest challenge of 2021 is workload, versus 59% last year. More than 39% are concerned about keeping up with technology changes, and 27% said their biggest challenge is getting funding to continue professional development – a new option on the survey. Only 18% indicated they worry about being laid off, versus 24% last year, and even fewer are concerned about outsourcing (15%).

ECAD tools. In terms of ECAD tools used on a weekly basis, Altium Designer is making headway, with 55% of responses (FIGURE 9, online). Some 44% of designers use Cadence software (Allegro or OrCAD), and 39% use Mentor – now Siemens (Xpedition, BoardStation or Pads).

The weekly numbers were generally consistent with the annual figures. At least once a year, 53% of respondents use Altium Designer (FIGURE 10, online), while nearly half use one of the Cadence tools, and 38% use Mentor.

With the future uncertain and the pandemic not over yet, the job of the PCB designer remains sound, with well-educated respondents to this year's survey at the higher end of their salary range, receiving ample benefits, and working as hard as ever, while continuing to absorb and use new technologies.

We would be fortunate to be on the other side of the worst of Covid-19 when it's time for the 2022 design engineers' salary survey, and hopefully by then many of us who haven't seen colleagues since early 2020 will have had the ability for in-person visits because, in addition to the data PCD&F recently collected, the importance of connections made in the industry can't be underestimated. □

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See online.

Ed.: A special thank you to Stephen Chavez, chairman, PCEA, for reviewing the 2021 designers' salary survey questions and providing his expert input.

For additional figures and tables, see the online version. For a look at past surveys, click here. [https://www.pcdandf.com/pcdesign/index.php/menu-research/menu-market-data/8452-pcb-designer-salary-surveys].

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TABLE 5. Highest Level of Education

	2021	2020	2018	2017	2016	2015
High school	3%	2%	4%	3%	6%	4%
Some college - no degree	15%	15%	25%	24%	23%	23%
1- to 2-year associate's degree	27%	22%	30%	38%	31%	33%
BA/BS degree in non-engineering field	3%	6%	6%	5%	4%	5%
BS degree in engineering or related field	39%	37%	27%	24%	28%	26%
Master's degree (any field)	13%	16%	7%	5%	7%	9%
Ph.D. (any field)	1%	2%	1%	<1%	1%	<1%

Numbers might not total 100% due to rounding. n = 202

TABLE 6. Projects and Technology Trends

	2021	2020	2018	2017	2016	2015	2014	2013	2012
Single-sided PCBs	51%	44%	53%	50%	53%	55%	57%	57%	47%
Double-sided PCBs	83%	83%	82%	84%	83%	83%	84%	82%	81%
4 to 6 layers	84%	79%	82%	86%	83%	85%	83%	83%	84%
7 to 10 layers	61%	58%	70%	75%	65%	68%	69%	66%	61%
12+ layer PCBs	53%	45%	66%	63%	60%	59%	61%	56%	53%
Flex/rigid-flex PCBs	48%	45%	53%	58%	53%	55%	53%	50%	44%
FPGAs/PLDs	38%	41%	38%	40%	37%	36%	43%	40%	36%
Microvias/HDI	47%	47%	63%	55%	49%	52%	51%	45%	38%
RF/microwave circuitry	41%	37%	48%	42%	42%	42%	40%	42%	36%
High-speed design *(New!)*	66%								
BGAs	58%	60%	65%	65%	65%	65%	67%	68%	58%
ASICs/ICs	30%	35%	31%	38%	30%	32%	33%	29%	28%
Embedded systems	30%	30%	19%	16%	21%	20%	18%	22%	15%
CSPs	14%	23%	16%	19%	16%	19%	13%	13%	11%
SoCs	26%	28%	18%	16%	15%	16%	14%	13%	9%
SiPs	12%	16%	11%	10%	11%	10%	10%	11%	10%
Enclosures	25%	26%	18%	19%					
Optoelectronics	25%	31%							
PoP	9%	11%							

Respondents could choose more than one answer.

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BLOCKCHAIN TECHNOLOGY and Electronics Manufacturing: Getting Started

From secure data exchange to managing EoL parts, the applications are numerous. by **QUENTIN B. SAMELSON**

In last month's discussion of how electronics companies first began to use Blockchain technology to automate and simplify "high-friction" multiparty processes, we noted many of the earliest projects tended to focus on the relationship between a single "sponsor" company and its partners. In other cases, companies worked together as a consortium to solve a common problem. Quickly, however, electronics companies began to leverage applications originally developed for other industries, especially to leverage the "track and trace" capability originally developed for the food industry.

Basing a new blockchain network on functionality that has been developed and implemented for another network[1], even in a completely different industry, lowers the cost of entry and simplifies the process of setting up that new network. That has turned out to be very important, since it also makes it easier to create a valid business case for the application.

Of course, the benefit to your own company will be your biggest concern in building a business case, but be aware of the value proposition for the other trading partners in the network. Blockchain requires a team effort. The business case is likely to proceed from one or a combination of the following:

1. Labor savings and efficiency. These often are the result of *not* having to do redundant work, such as filling out a series of different forms at different steps of a process, all of which repeat most of the same data. Avoiding unnecessary effort generally comes from improving the different partners' trust in the process, which comes from the fact that they can all view at least part of the same transaction.
2. Quality improvements. These may be related to component or product quality, where early detection, enabled by sharing quality data via a blockchain network, eliminates a quality problem before it reaches customers. In addition, frequently there are also improvements in the quality of data, as blockchain creates a single source of verified truth.
3. Cycle-time reductions. These often are associated with the labor savings and the data quality improvements mentioned above. Much of the cycle time of multiparty processes is caused by waiting for information from the previous party, checking and verifying the previous party's data, or reentering that data for the next party in the process. Blockchain eliminates nearly all this work and the associated cycle time.
4. Improved access to data and other network parties. In many companies' reverse supply chains, extensive, manual (and therefore expensive) visual inspection is needed to verify the product received back from customers is actually a product that the company *sold* to the customer. Blockchain can provide the mechanism for secure, controlled access to data that permits automated verification. This improves the process, again reducing time and labor costs.
5. Some companies have also found that blockchain enables improved access to potential business partners. Once a blockchain network has been established for a specific purpose, engaging with the network provides access to every member of that network.

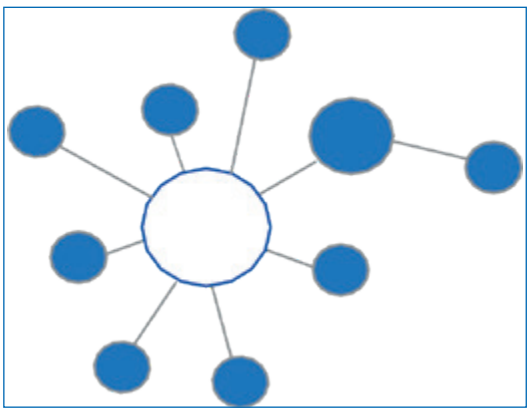

FIGURE 1. A blockchain network set up to support companies in one industry can be adapted to provide the same functionality in a completely different industry.

If you primarily need a way to track and trace items between parties in a network – whether in the forward or the reverse supply chain – leveraging and adapting existing functionality can provide the needed functionality in a cost-effective manner. Not only does this take advantage of existing functionality, but it also provides

all the other mechanisms necessary for an effective network: onboarding services, user authorization and assignment, data services, and other support.

Of course, another way to leverage blockchain technology is to join an existing network, as long as other companies have already joined to solve a problem that you also need to address. They can join a network already set up to solve an industry-wide problem. As mentioned last month,[2] networks already exist to assist with logistics, responsible sourcing of minerals, local contractor qualification, and other industry issues.

Where Blockchain is Going

As blockchain networks and capabilities mature, it has also become possible to integrate blockchain capabilities into other systems. For instance, IBM has demonstrated an end-to-end process that uses blockchain to securely and privately provide the results of artificial intelligence-powered visual inspection at a supplier to the quality system at a customer. This integration permits the customer to accept or reject a production lot before the supplier ships it and ensures the two parties maintain a common understanding of what constitutes a "good" part.

Some of the most innovative ideas use blockchain to address security and privacy issues with applications based on IoT (Internet of Things) devices. An early example of this idea that uses blockchain to help manage loads on an electricity grid managed by TenneT in the Netherlands has now grown into a European energy consortium called Equigy[3] that uses blockchain, consumer batteries and electric vehicles to balance the supply of energy to electricity grids. Blockchain may also be of interest to assist in managing warranty and service calls for IoT-enabled devices on consumer appliances like washers and dryers or on sensitive medical equipment, especially equipment assigned to a specific person.

New use cases for blockchain most often arise either from recognizing that a particular multiparty process is time-consuming and inefficient or by identifying a desirable new process that will function best if it is transparent but secure and immutable. As the electronics industry implements and enables new capabilities leveraging IoT devices and platforms, cloud and edge computing, machine learning and artificial intelligence, it's helpful to understand that blockchain doesn't usually replace capabilities but rather complements and improves those processes.

Just as it would have been difficult to predict ride-sharing and food-delivery applications when the world was introduced to the internet, it's hard to know new blockchain applications the electronics industry may be using five years from now. However, as several people[4] have said, "the best way to predict the future is to create it." It isn't hard to identify several use cases in the electronics industry that would benefit from a way to securely and privately share data between parties. Blockchain could even permit competitors to do business with each other in a mutually beneficial way. Here are a few examples:

- Manage end-of-life (EoL) parts inventories. Companies often purchase more than they need and hold EoL parts longer than they should. If a company needs a quantity of parts that have already gone EoL, they often must engage in a long, frustrating search. If they are lucky, they may find some of the parts at a steep markup and questionable quality. Blockchain could provide a secure and private mechanism for a shared "pool" of EoL parts.
- Provide verified data for rebates or ship-and-debit transactions between manufacturers and distributors. Even with automation, this process can require a good deal of extra verification. With blockchain, the process could be extended to make it essentially self-verified.
- Exchange of quality data between manufacturer and customer. Most of the time, electronics companies can trust the quality of the parts they buy, but nearly every company has at least one supplier that causes issues. It isn't necessarily because the supplier is incompetent. Sometimes problems are the result of miscommunication of expectations, design changes, tolerance stack-ups, or other issues. Provided a supplier's parts don't consistently work in the application, however, there is value in advance information on the conformance levels of each lot as it is shipped. Blockchain can provide the means to securely and privately transmit quality data direct from a manufacturer to a customer. Because the structure and

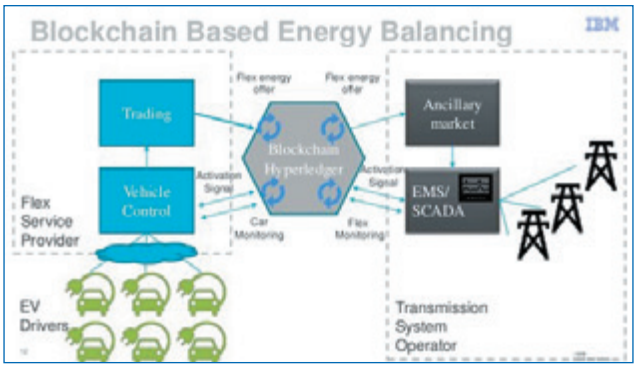

FIGURE 2. Blockchain-based energy balancing. (Source: IBM)

format of quality data depend on the item (different for a lot of chip capacitors than for a lot of transistors or ICs), this sort of data exchange has always been difficult to automate. But blockchain, perhaps combined with XML "tags," would make this possible.

We don't know all the ways in which the electronics industry will use Blockchain technology in the coming years, but we do know it has the potential to make any number of dysfunctional multi-party processes work more efficiently and effectively. The companies that identify and implement use cases for this exciting new technology now will have the opportunity to steer the direction of those use cases, gaining cost and performance advantages ahead of the rest of their industry. ▫

Ed.: See the previous two articles in this series in the June 2021 and July 2021 issues, respectively.

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TIN WHISKERS Eliminated by Slight Alloying with Indium

The indium additive relieves stresses that drive whisker growth. **by INDRANATH DUTTA, PH.D.**

Copper components in electronic packages (e.g., lead-frames, interconnects, integrated circuit leads and press-fit connector pins, to name a few) are often electroplated with tin (Sn) to prevent tarnishing and to facilitate subsequent soldering. With passage of time during storage or service, long whiskers grow from these tin coatings, causing electrical shorts between neighboring circuitry, posing serious reliability risks.[1-3] This problem is particularly problematic in long-life applications, and failures have been reported in many arenas, including aerospace, nuclear power plants, automotive electronics, and military electronics systems, causing damages worth millions of dollars.

A number of approaches to mitigate whisker growth have been pursued during the past 30 years, including additions of Pb, Bi, Au, Sb or Ge, or post-plating thermal treatments.[4-8] These approaches mitigate whisker growth to varying degrees; however, none eliminates it. Over time, and under thermal-mechanical excursions, whiskers continue to grow.

Over the past five years, researchers at Washington State University have developed a robust method to eliminate, rather than reduce, whisker growth. The team showed the addition of 4 to 10 weight percent indium to Sn films produces no whiskers whatsoever under both isothermal aging and cyclic thermal shock loading.

The findings are detailed in a series of publications,[9-16] culminating in the award of a US patent in December 2020 on the elimination of Sn whiskers by indium addition.[17] The principal claim of the patent is pure Sn or Sn-based lead-free solder coatings containing 3 to 20 weight percent In are immune to whisker growth, either directly after deposition, or following a short post-deposition thermal treatment. Key results from the associated studies are summarized below.

The addition of eight to 10% indium eliminates whisker growth outright (i.e., without any post-plating treatment), regardless of the method by which In is incorporated in Sn.[9-17] In contrast, in control samples of pure Sn coated on Cu, numerous long (~25µm) whiskers grow under identical conditions. When only 4% In is added, a very small number of short (~2µm) whiskers grows from the untreated coating. But whisker growth is completely eliminated if the coating is subjected to a 30-minute heat treatment at 160°C following electroplating.[15]

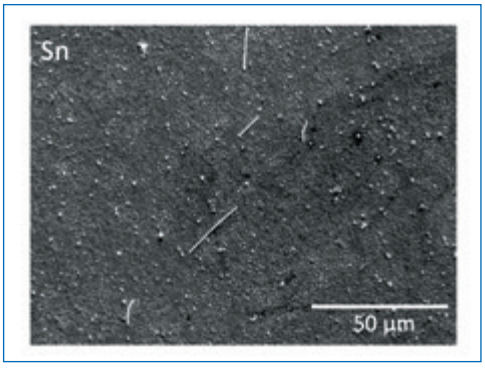

FIGURE 1. Surface of a copper substrate with a 3µm-thick electroplated coating, after ambient temperature aging for 1.5 months. The Sn version shows multiple whiskers.

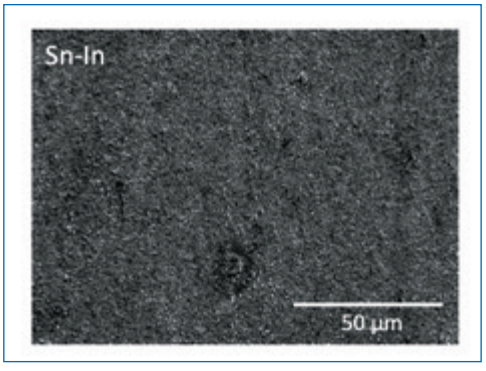

FIGURE 2. An otherwise identical substrate with Sn-10%In, aged under the same conditions, shows a complete absence of whiskers.

The root cause of whisker elimination due to In addition was investigated.[10-13] Indium gets incorporated in the surface-oxide film on Sn, introducing discontinuities in the oxide, thereby enabling relaxation of the compressive stresses in the film that drive whisker growth. In addition, In gets incorporated in the intermetallic compound (IMC) layer at the interface between the Sn coating and the Cu sub-

strate, forming ternary Cu-Sn-In IMCs, and these may further reduce the stresses in the film.

A method to co-electroplate tin with indium from a methanesulfonic acid (MSA) electrolyte, which is the most widely used bath for electroplating of Sn, was developed.[15] This method enables co-electroplating of Sn and In with only a small modification of the commonly used industrial practice for electroplating Sn.

The major advantage of In addition is it completely prevents the growth of whiskers, whereas all other currently available approaches slow whisker growth. As such, this technology proffers a way to completely solve the Sn-whisker growth problem in electronics using a lead-free approach.

Industry professionals interested in prevention of tin whisker growth from components may contact the author for more information.

Acknowledgements

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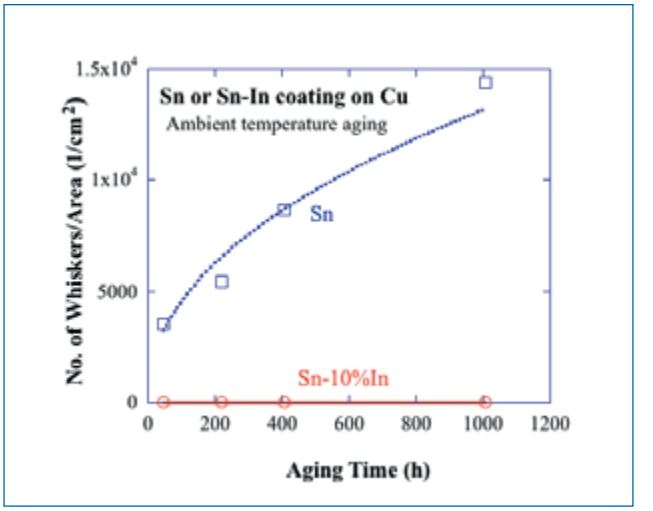

FIGURE 3. Numerous tin whiskers grow from a 1µm-thick electroplated tin coating on copper, but a Sn-10%In coating is immune to whisker growth.

Lean Six Sigma and Agility

How to identify opportunities for improvement and enable corrections before the product is at risk.

THE ELECTRONICS MANUFACTURING community is facing unprecedented challenges in 2021. Component supply and product demand are completely out of sync in many industries. Material constraints and transportation shortages are stretching lead-times even on committed orders. An economy flush with stimulus money and pent-up demand for products not available during much of 2020 has eliminated the ability of original equipment manufacturers (OEMs) to plan based on historical trends. In the middle is the EMS provider that sees material arriving later than planned, while at the same time experiencing unplanned increases in order volumes on many programs. Lean Six Sigma provides production teams the tools they need to identify issues, analyze potential improvements and implement changes that help keep production flowing on time even with changing production inputs.

SigmaTron International's Tijuana, Mexico, facility utilizes teams of Lean Six Sigma Green and Yellow Belts in its continuous improvement activities. They use a variety of core tools in that process.

One tool is the Gemba Walk. The term Gemba comes from the Japanese word for "the real place." Taichi Ohno, a Toyota engineer and leader, is often credited with developing the concept of the Gemba Walk or the idea that leaders should regularly and frequently be present to observe the work of their organization when and where it takes place.

In a Gemba Walk, leaders visit the work area to glean first-hand knowledge regarding:

- How products are built
- How services are provided
- Current challenges
- Opportunities for improvement.

One of the benefits of Gemba is its role in identifying opportunities for improvement, enabling corrections of any potential issue before they represent a risk for the product. This interaction also enables leaders to learn more about each operator's experiences and knowledge over the process. Gemba and a 5S work environment are fundamental to sustain any Lean Six Sigma project.

At SigmaTron, weekly Gemba Walks involve a multidisciplinary group. Findings and opportunities are posted on a central key performance indicator (KPI) board. A Gemba Walk earlier this year identified the potential for improvement in a project experiencing significant volume increases.

A Lean Six Sigma team utilized the DMAIC (define, measure, analyze, improve, control) methodology to analyze the project and set improvement goals. In the define phase the key goals identified included improving throughput and operator productivity.

The team utilized the SIPOC (suppliers, inputs, process, outputs, customers) diagram during the define phase to create a high-level process map of all inputs and outputs, similar to mapping done in value stream analysis. They mapped the process and then created a current state production layout. This exercise did two things: First, it ensured a high-level understanding of the scope of the production process they were evaluating; second, it helped them identify process elements that could be improved. Time studies were performed on specific production steps to determine areas of line imbalance. A steady-state production layout was created that reflected an improved, better balanced production layout. In the current state layout, printed circuit board assembly (PCBA) arrays were separated into individual pieces prior to conformal coating inspection. In the steady-state layout, arrays were inspected prior to depaneling. As part of the DMAIC control phase, electronic pacemakers were added to track units completed by hour to ensure production operators were aware of output vs. goal on an hour-by-hour basis.

Takt time, or the average time interval between the start of production of one unit and the start of production of the next unit, was cut by more than half in the steady-state process, improving throughput and operator productivity. The entire project took less than a week.

Examples such as this illustrate the combined benefits of the Gemba process when coupled with well-trained teams and core tools. To further enhance this process, a Lean Six Sigma database has been created that enables teams to review past projects and results in a dashboard format. Lean Six Sigma tools are beneficial in their ability to drive continuing operational improvement even in times when supply and demand are well aligned. In the current environment, where material constraints and transportation issues can lengthen the cycle time associated with material arrival and product shipment, they offer a way to shorten the actual time it takes to manufacture the product, helping manufacturing teams stay agile in the one variable they can control. ▫

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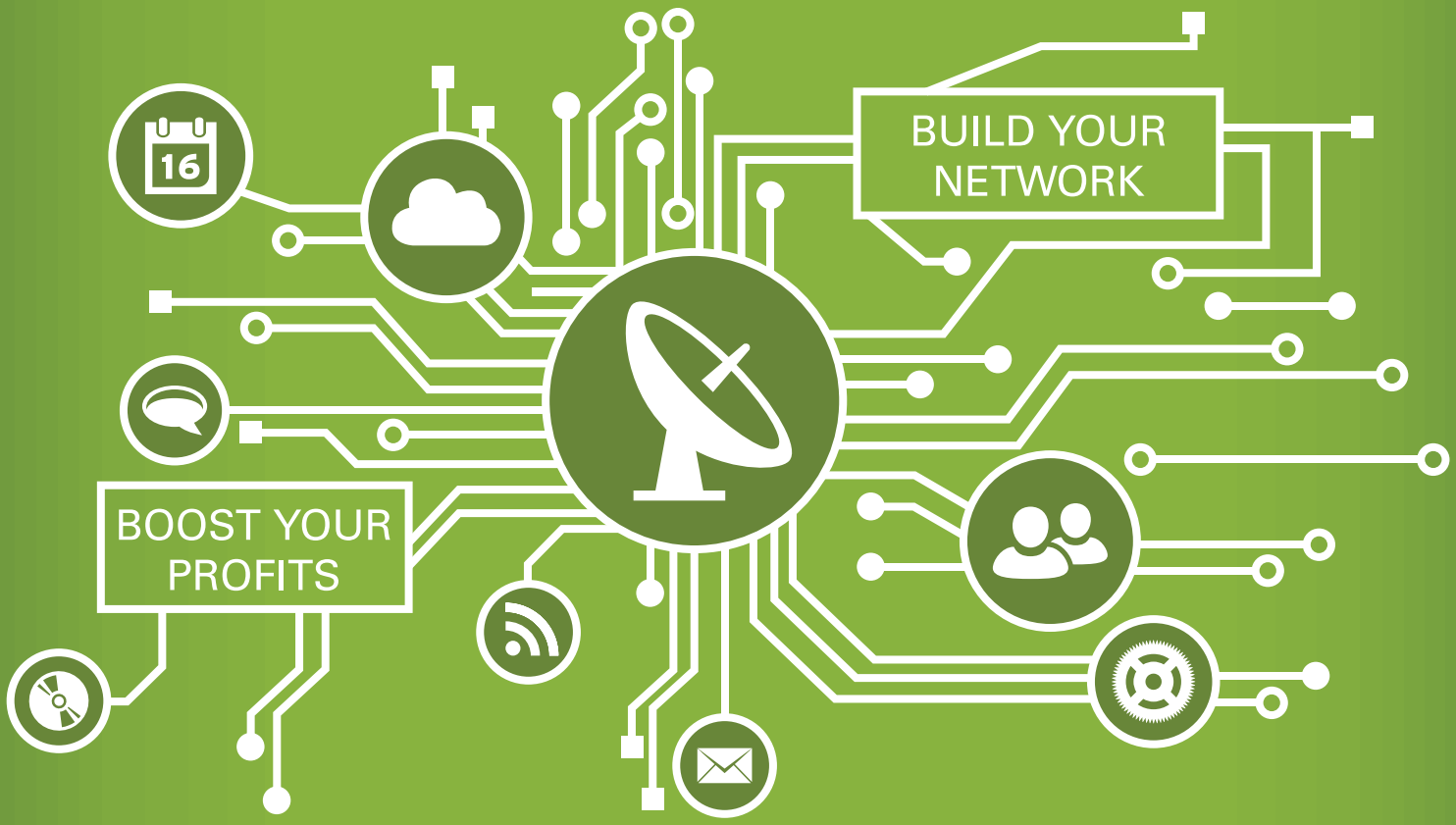

- Build your EMS database
- 3,000+ facilities worldwide
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State-of-the-Art Technology Flashes

Updates in silicon and electronics technology.

Ed.: This is a special feature courtesy of Binghamton University.

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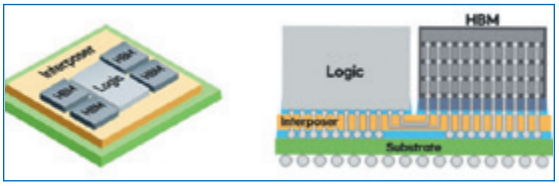
The **INTEGRATED ELECTRONICS ENGINEERING CENTER (IEEC)** at Binghamton University is a New York Center of Advanced Technology (CAT) responsible for the advancement of electronics packaging. Its mission is to provide research into electronics packaging to enhance our partners' products, improve reliability and understand why parts fail. Research thrusts are in 2.5/3-D packaging, automotive and harsh environments, bioelectronics, flexible and additive electronics, materials for packaging and energy storage, MEMS, photonics, power electronics, sensors, embedded electronics, and thermal challenges in electronic packaging. More information is available at binghamton.edu/ieec.

Integrated photonic circuits demonstrate ultralow loss. EPFL researchers have developed a technology that produces silicon nitride integrated photonic circuits with low optical losses and small footprints. Silicon nitride has been a material of choice for applications where low loss is critical, such as narrow-linewidth lasers, photonic delay lines, and those in nonlinear photonics. The team combined nanofabrication and material science based on the photonic Damascene process developed at EPFL. With this process, the team made integrated circuits of optical losses of 1dB/m, a record value for any nonlinear integrated photonic material. That low loss considerably reduces the power budget for building chip-scale optical frequency combs used in applications that include coherent optical transceivers, low-noise microwave synthesizers, lidar, neuromorphic computing and optical atomic clocks. *(IEEC file #12282, Photonics Media, 5/6/21)*

Samsung develops advanced chip packaging tech. Samsung Electronics has developed an advanced chip packaging technology for high-performance applications. Its next-generation 2.5D packaging technology, Interposer-Cube4 (I-Cube4), is expected to be widely used in areas like high-performance computing, artificial intelligence, 5G, cloud and data centers with enhanced communication and power efficiency between logic and memory chips. I-Cube is heterogeneous integration technology that horizontally places one or more logic dies, such as CPU and GPU, and several high bandwidth memory dies on a paper-thin silicon interposer. *(IEEC file #12285, Science Daily, 5/6/21)*



Reconfigurable optical networks will move supercomputer data 100X faster. Supercomputer processors can handle large amounts of data per second, but the flow of data between the processor and computer subsystems is not as efficient, creating a data transfer bottleneck. Peraton Labs researchers have devised a system design involving reconfigurable networks called FLEET, which could potentially speed up the transfer of data 100-fold. The team's solution was the development of optical network interface cards (O-NICs) that plug into existing computer hardware. Whereas traditional NICs typically have one port, the newly designed O-NICs have two ports and can support data transfer among many kinds of computer subcomponents. The O-NICs are connected to optical switches, which allow reconfiguring the data flow. *(IEEC file #12288, IEEE Spectrum, 5/7/21)*

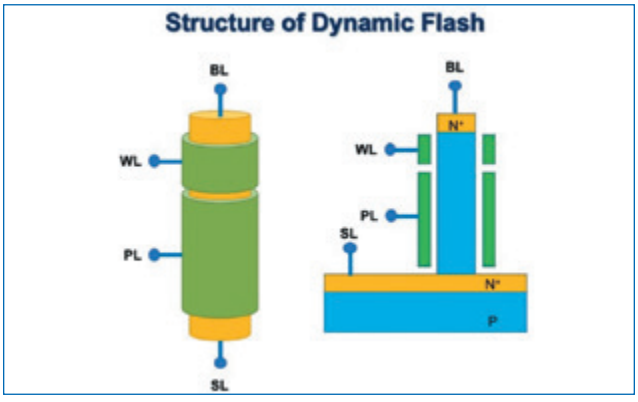
Silicon chips combine light and ultrasound for better signal processing. High-end wireless and cellular networks rely on light for signal distribution. The selective processing of such signals requires long delays, too long to support on a chip using light alone. Hebrew University of Jerusalem researchers brought together light and ultrasonic waves to develop ultranarrow filters of microwave signals in silicon integrated circuits. The information-carrying surface acoustic waves is imprinted upon the output light wave multiple times. The concept permits large freedom for filter design. *(IEEC file #12307, Science Daily, 5/20/21)*

Self-healing gels could power future electronics. For flexible ion gels to become critical components in wearable and stretchable electronic devices, they must be able to withstand repeated mechanical deformation, such as bending or stretching. Ion gels are made of a polymer matrix containing ionic liquids: room temperature molten salts containing positively and negatively charged ions. Ionic liquids are being considered for use in a variety of electronic devices, including supercapacitors, rechargeable lithium batteries, fuel cells and soft robotics. The repairable ion gels are made by adding the compound azobenzene. Exposing the damaged gel to ultraviolet light changes it into a liquid that fills the damaged region. Then exposing it to visible light restores the gel damaged section to its original state. *(IEEC file #12287, Nanowerk, 5/12/21)*

Aluminum batteries take a step closer. Cornell University researchers have taken a step closer to aluminum batteries that can be used in grid-scale storage. Aluminum is more plentiful and cheaper that lithium, making it potentially attractive for large-scale energy storage. Aluminum also has the advantage over lithium that it can be used in metallic form without the safety concerns that metallic lithium arouses. The team also studied why aluminum batteries develop short-circuits and die after only a few charge-discharge cycles. They found that tall, sparsely spaced aluminum peaks grew on the stainless steel in a few charge-discharge cycles, pushing through the glass fiber and shorting the opposite aluminum electrode. *(IEEC file #12224, Electronics Weekly, 4/9/21)*

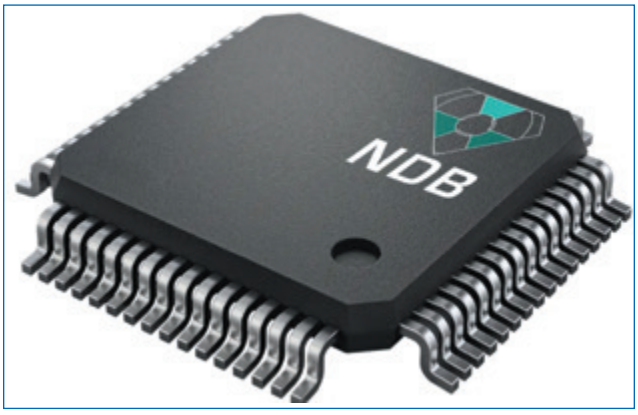
Engineers harvest Wi-Fi signals to power small electronics. National University of Singapore researchers have developed a technology that uses tiny smart devices known as spin-torque oscillators (STOs) to harvest and convert wireless radio frequencies into energy to power small electronics. They successfully harvested energy using Wi-Fi 33-band signals to power a LED wirelessly, and without a battery. This is a step toward turning readily available 2.4GHz radio waves into a green source of energy, reducing the need for batteries to power electronics. In this way, small electric gadgets and sensors can be powered wirelessly using radio frequency waves as part of the Internet of Things. *(IEEC file #12302, Science Daily, 5/14/21)*

DRAM replacement unveiled. Unisantis Electronics has developed dynamic flash memory (DFM), a faster and denser technology than DRAM (or other types of volatile memory). DFM takes a revolutionary approach to overcome limitations of conventional volatile memory with its inherent short refresh cycles and destructive read processes. DFM is also a type of volatile memory, but since it does not rely on capacitors, it has fewer leak paths and no connection between switching transistors and a capacitor. The result is a cell design with the potential for significant increases in transistor density, and it offers block erase. *(IEEC file #12303, Science Daily, 5/14/21)*



Research breakthrough in 5-nanometer transistors. IBM and its partners GlobalFoundries and Samsung have developed a first-of-a-kind process to build silicon nanosheet transistors that will enable 5nm chips. The breakthrough involved stacking so-called nanosheets to build the 5nm transistors instead of the current FinFET process used to make 7nm transistors. Such an increased transistor density gives the 5nm chip a 40% performance boost and enables 75% power efficiency at the same performance level. The resulting increase in performance will help accelerate cognitive computing, IoT and other data-intensive applications delivered in the cloud. The power savings could mean batteries in smartphones and other mobile products could last two to three times longer than today's devices before needing to be charged. *(IEEC file #12305, Electronic Design, 5/24/21)*

Nano diamond battery provides universal applicability. The nano diamond battery (NDB) is a high-power, diamond-based alpha, beta, and neutron voltaic battery that can provide lifelong and green energy for numerous applications and overcome limitations of existing chemical batteries. The NDB acts like a tiny nuclear generator. The power source for the NDB is intermediate- and high-level radio isotopes shielded for safety by multiple levels of synthetic diamond. Energy is absorbed in the diamond through a process called inelastic scattering, which is used to generate electricity. The self-charging process will provide a charge for the full lifetime of any device or machine, with up to 28,000 years of battery life. *(IEEC file #12228, NASA Tech Briefs, 4/1/21)*



Market Trends

Printed electronics automotive market $12.7 billion by 2031. Opportunities for printed and flexible electronics are increasing from the transition to electric and autonomous vehicles. The printed electronics automotive market is predicted to be $12.7 billion by 2031. Technologies include sensors within EV batteries, interior HMI components, displays, and new manufacturing methods such as in-mold electronics. Hence, it is an exciting time for the automotive industry, with technological transitions toward electric vehicles and increased autonomy occurring simultaneously. *(IEEC file #12291, Printed Electronics World, 5/5/21)*

Compact, multifunctional device uses infrared light to deliver images. University of California researchers have developed a thin, large-scale device that converts infrared light into images. The imager can be used to see through smog and smoke, to see through silicon wafers to inspect the quality and composition of electronic boards, and to map a person's blood vessels while monitoring heart rate. The imager detects the shortwave IR part of the spectrum and falls just outside the visible spectrum. In applications, it shines shortwave IR light on an object and then converts the low-energy IR light that is reflected to the device into shorter, higher-energy wavelengths that are visible. Three of the layers are made of a different organic polymer: a photodetector layer, an OLED display layer, and a layer located between that blocks electrons. *(IEEC file #12299, Photonics Media, 5/7/21)*

Wind-powered streetlight only turns on when you pass it. Berlin University of the Arts researchers have created a streetlight called "Papilio" that combats energy pollution on two fronts: It's wind-powered, which reduces its dependence on electricity, and the light itself has a motion sensor that's only activated when someone passes underneath it. Some 60% of the electricity used is produced from fossil fuels. Roughly 83% of the world's population lives under artificial lights that brighten the sky 10% more than its normal level, which can negatively impact biodiversity. *(IEEC file #12315, Electronics Weekly, 5/21/21)*

Smart finger ring with integrated RFID. The smart finger ring multifunctional ring was developed by Fraunhofer IGCV researchers. Produced by a 3-D printing process using "powder bed-based additive manufacturing," the ring has an integrated RFID chip, and is tamperproof, sealed, and invisible. This precisely controllable production technology is opening the door to a host of possibilities for realizing individualized ring designs. The technology of integrating electronics via 3-D printing can be used for many other applications. The RFID tag can pay at checkout, open a smart front door, act as a health insurance card when attending a medical appointment, or replace the key card in a hotel. *(IEEC file #12295, Printed Electronics World, 5/7/21)*

Memory market to reach $155 billion in 2021; $180 billion in 2022. A stronger DRAM pricing is expected to lift total memory revenue 23% this year to $155.2 billion. The DRAM ASP rose 8% in Q1 2021, and nearly all the leading memory suppliers expected stronger demand in Q2. The memory upturn is forecast to continue into 2022 when total memory sales are expected to rise 16% to $180.4 billion. The memory market is forecast to reach its next cyclical peak in 2023, when revenue grows to nearly $220 billion. In 2021, DRAM is expected to account for 56% of the memory market, with flash memory accounting for 43% share. *(IEEC file #12312, Electronics Weekly, 5/21/21)*

Photovoltaic roof for highways. Fraunhofer Institute researchers have developed a photovoltaic (PV) system for motorways and are testing how roofs may be deployed along highways. The demonstrator consists of a PV system with a 10 x 17m roof area installed on a steel structure about 5.5m above the road. Construction on the pilot project is expected to begin next autumn, and its operations then will be monitored for about a year. The roofing of a motorway is a particular technical challenge because of the fast-moving traffic underneath. *(IEEC file #12318, PV Magazine, 5/26/21)*

Scientists develop transparent electrode that boosts solar cell efficiency. Penn State University researchers are developing an ultrathin metal electrode that permits creation of semitransparent perovskite solar cells that are highly efficient and can be coupled with traditional silicon cells to greatly boost the performance of both devices. The research is a major step toward developing completely transparent solar cells. Transparent solar cells could find a place on windows in homes and office buildings, generating electricity from sunlight. Perovskite cells offer a promising alternative, and stacking them on top of the traditional cells can create more efficient tandem devices. The perovskite solar cell the team developed achieved 19.8% efficiency. Combined with a traditional silicon solar cell, the tandem device achieved 28.3% efficiency, up from 23.3% from the silicon cell alone. *(IEEC file #12307, Science Daily, 5/28/21)*

Recent Patents

Additively manufactured flexible interposer (assignee: Boeing Corp.) patent. no. 16/390,256. The method includes providing a flexible interposer, providing a first redistribution layer on the flexible interposer, and providing a second redistribution layer on a portion of the first redistribution layer.

The second redistribution layer is provided by additive manufacturing. The first redistribution layer may be deposited in a clean room environment. The first redistribution layer may be deposited via chemical or physical deposition. A semiconductor device is attached to the first redistribution layer. The flexible interposer may be attached to a board with the semiconductor device electrically connected to the board via the first redistribution layer, the flexible interposer, and the second redistribution layer. The flexible interposer may be attached to a flexible hybrid electronic (FHE) board. The flexible nature of the flexible interposer and/or the FHE board may redistribute stress on the semiconductor device assembly.

Optical coupling of optical signals for a photonic integrated circuit (assignee: Mellanox Technologies) patent no. 16/313,503. An optical coupler and method of assembly are described that provide efficient coupling from the photonic IC (PIC) waveguide layer to external components, such as optical fibers, VCSELs, photodetectors, and gain blocks, among others. The optical coupler includes a PIC that can be supported by a printed circuit board, an optoelectronic transducer supported by the PIC that can convert between optical signals and corresponding electrical signals, and a coupled waveguide assembly. The coupled waveguide assembly includes a low-index waveguide, a high-index waveguide, and a reflective surface that changes a pathway of the optical signals to direct the optical signals from the optoelectronic transducer into the low-index waveguide or from the low-index waveguide into the optoelectronic transducer.

PCB assembly comprising chemical vapor CVDD wires for thermal transport (assignee: Microchip Technology) pub. no. WO / 2021089974. A method and apparatus for conducting heat away from a semiconductor die are disclosed. A board assembly is disclosed that includes a circuit board, a semiconductor die electrically coupled to the circuit board and a chemical vapor deposition diamond (CVDD) coated wire. A portion of the CVDD-coated wire extends between a hot-spot on the semiconductor die and the circuit board. The board assembly includes a layer of thermally conductive paste that is disposed between the hot spot on the die and circuit board. The layer of thermally conductive paste is in direct contact with a portion of the CVDD-coated wire.

Wafer-level derived flip-chip package (assignee: Texas Instruments) patent. no. 11,018,111. A leadless IC package includes a spaced apart plurality of lead terminals on at least two sides of the leadless IC package, and a die including a substrate having at least a semiconductor surface including circuitry coupled to bond pads with the bond pads having bonding features thereon. The bonding features are flip-chip bonded to the plurality of lead terminals. Mold compound is above the IC die and between adjacent lead terminals. The lead terminals and the substrate both extend out to have exposed surfaces at edges of the leadless IC package, and the terminals also provide a backside bondable contact.

Optical device including buried optical waveguides and output couplers (assignee: Intel Corp.) pub. no. US10996408. Embodiments of the present disclosure are directed toward techniques and configurations for an optical coupler, including an optical waveguide to guide light to an optical fiber. In embodiments, the optical waveguide includes a tapered segment to propagate the received light to the optical fiber. In embodiments, the tapered segment is buried below the surface of a semiconductor substrate to transition the received light within the semiconductor substrate from a first optical mode to a second optical mode to reduce light loss during propagation of the received light from the optical waveguide to the optical fiber. In embodiments, the surface of the semiconductor substrate comprises a bottom planar surface of a silicon photonic chip that includes at least one or more of passive or active photonic components.

Hermetically sealed printed circuit boards (Assignee: Covidien LP) patent no. 10,973,142. A method of assembling a hermetically sealed printed circuit board includes securing a flange of a cap against an electrical contact region on the first side of a substrate, the flange extending across a first end portion of a wall of the cap, the wall extending around the electrical contact region and including a second end portion disposed in an open configuration, and closing the second end portion of the wall to form a hermetically sealed chamber around the electrical contact region. □

Ratholes, Or You Will Never Recover This Time

If time is money, getting to The Point is invaluable.

ADD "SPACE" TO the growing list of vandalized spoken English words.

As in, "We work in the AI space."

Reminds one of workers beavering away in a corrugated shipping container with the letters "AI" stamped on the outside.

Or, "My career trajectory has symbiotic granularity with the ERP or IT or CRM space."

What?

Are people who speak like this born this way or did they acquire this skill in school? For what purpose? Contrary evidence above notwithstanding, one must nevertheless cultivate the space between the ears.

Famously there is NASA, which spends its days laboring in the Space space. Or used to. Now commercial interests dare to boldly go where no one went before, spatially. NASA just writes the rules. Billionaires get the accolades.

It's a strange world. We just live in it. Submitted herewith in evidence thereof is the latest dispatch from the cognitive vacuum that is the Common-Sense-Free Zone of the customer-centric universe:

We would like a quote from you for functional test development and testing of production boards in this project. It's urgent. We emailed you the specification for this ITAR job free and clear over the weekend to expedite the process.

Everything's urgent. Try telling that to the ITAR investigators, whose working coat of arms might as well include molasses, January, an upward slope and a downward wind. You know the type: the unsmiling ones wearing dark glasses in the dark SUVs with tinted windows; the same ones wearing dark suits with wires protruding from their lapels. The government agency with the incomprehensible, arduous website that takes your money every year in penance, if for no better reason than a kind of premonition of hell.

Meanwhile, more manufactured crises from the invertebrates at our customer's sales department.

We need your quote by tomorrow to submit as part of our turnkey bid for this project. We are one of three competitors in the running. Despite the fact that our companies have not done any business in four years, we'd like you to assign priority status to this quote.

We'd like you to get a life. Meanwhile, take a number. Can you spell F.I.F.O.?

Seriously, this project is extremely urgent. The test quote may tip the balance in deciding the award of this contract. We sent it to you on Sunday rather than wait until Monday so you could get a jump on it.

Very considerate of you. Block diagrams beat church on Sunday. When did you receive this spec from your customer?

Not sure. Maybe a month or two ago, when we first received the quote package.

What were you doing, letting it ferment? It's 285 pages long.

We didn't think it would be any big deal to review. Can you read and respond to it today? It's urgent.

We heard a rumor it was urgent. We can read. We rate literacy as one of our core competencies.

Can we get a quote today?

You clearly aced the class in repetitiveness in grade school, not so much the listening class. It will take us many days, possibly several weeks, to read this spec and fully digest its contents. That's D.I.G.E.S.T. Then we'll have to provide you with a quote, which will take engineering time to accomplish. Time away from other (revenue-generating) projects.

At first glance, the spec lists several pages of equipment needed to perform the required tests. Will you or your customer provide that equipment, or will we be expected to do so? That will make a big difference in cost.

The OEM has its own in-house setup to do this, but the expected production quantities would overwhelm their staff and equipment. They want to outsource the testing as part of the complete turnkey requirement.

At least until they get our quote.

What?

They'll be gung-ho to do this until three nanoseconds after seeing the price. Then thoughts will reorganize in patterns like iron filings adjusting to magnetic north. Their schedule will spontaneously reprioritize itself in an instant.

We have another urgent requirement to go along with this requirement. We need to CT scan part of a solar panel that is integral to the system. We need to be onsite when we do it.

To do what? Watch a CT scanning system? That's like watching paint dry. Depending on the application, it could last an entire day. Tell us what to do, and we'll do it and send you the images when we're done.

Can't do that. The part can't leave our possession.

Then you have a decision to make. With Covid restrictions, we aren't allowing visitors on our production floor.

But I'm vaccinated and have the card to prove it.

Asymptomatic transmission can still happen even among those who are vaccinated. Look around and

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watch the news. We can't allow that risk to our people. You need to adapt. This is nonnegotiable.

We also want to do an onsite quality survey, under contract from our customer, of your company's quality management system. Never mind that you just passed an AS9100 audit; we want to do our own survey, using our own proven methods.

Begs the question: What do your methods prove that AS9100 audits don't?

We want to verify you have a Six Sigma process.

Your order is for 10 boards, with 225 parts on each board. Not even close to a million defects. What's the point? Anyway, we're just the test guys pointing out the mistakes your EMS company made.

Corporate edict.

LEAVE YOUR
PITCHES AND SPIN
AT HOME.
WHAT EXACTLY DO YOU WANT:
SPEED, SECURITY OR PRICE?
CHOOSE TWO.

Just like Jack Welch and GE. How's that working out for them? Did you short their stock on the way down in between checking boxes on your clipboard?

As noted, we've just sent you a 285-page test specification. Can you do everything it specifies, and at what cost? Are you prepared to pay us $5,000 for an engineering review to answer that question? We also sent you a quality management survey to complete. Do not skip any sections. There are no exemptions for vendors with ISO9001 or AS9100 certification.

Additionally, we need you to share information with our conformal coating supplier. They will be coating our boards after you finish testing them. They need to program their machines and will be asking you for board-specific information to do so. Please give them free reign among our boards you are working on to gather that information, and coordinate your test cycle with their coating cycle.

Do they have an NDA with you?

Yes, they have an NDA with us. Please hurry. This project is late.

There is much talk now of inflation. There is much evidence of renewed inflation. (See the prices of used cars compared to those same prices a year ago.) Memo to economists: Why doesn't "core inflation" include food and fuel? Ever tried living without food? Ever tried driving sans fuel? It seems to me that those elements make up some of the core of living. And yes, I know it's a convention you've set up with a long tradition. Don't evade the question: Why did you set it up? Traditions can change. Costs remain costs, no matter which bucket one dumps them into.

Stupidity seems to be on the rise as well. Witness the daily ratholes we waste time in. Pity you can't quantify stupidity. Perhaps some lonely graduate student is working on it as a possible thesis topic. Time and knowledge march on.

I'm 62 years old. Leave your pitches and your spin at home. Get to the point. The rest is worthless. What exactly do you want: speed, security or price? Choose two. And for God's sake, show some backbone to your customer. They might find the truth refreshing.

Your hesitancy suggests you can't do this. We need to chat.

Okay, I'm available. Personally, I need to barf.

We also need you to certify compliance to the Giant Squid HAL9000 Specification, especially section 8, Clause B, Subparagraph IV, Line 228, requiring all employees touching our boards submit to an eye examination.

Save the expense. I can attest, here and now, that each and every one of our dedicated staff have eyes. In the majority of cases two per person, for redundancy's sake and disaster preparedness. It pays to have backups. Anyway, I'll happily sign something to that effect that you can notarize.

Random thought: What makes someone sophisticated?

> *Sophisticated (Merriam Webster):* having a refined knowledge of the ways of the world cultivated especially through wide experience. Ex: *a sophisticated lady.*
>
> Finely experienced and aware, as in a *sophisticated* columnist
> Intellectually appealing, as in a *sophisticated* novel
>
> **SYNONYMS**
> Baroque, byzantine, complex, complicate, complicated, convoluted, daedal, elaborate, intricate, involute, involved, knotty, labyrinthian, labyrinthine, tangled
>
> **ANTONYMS**
> Guileless, ingenuous, innocent, naïve, unsophisticated, untutored, unworldly, wide-eyed

In plain English and personalized: eminently more qualified and, therefore, better than you.

You want our business? Give us what we want. Skip the scruples and the tired old ethics.

Not that badly. We thought you just wanted us to quote. You sound like consultants. Arrogant ones, too. Who the hell do you think you are?

Arrogant consultants.

That's a relief. To think we originally guessed you were naïve jerks. In reality you are sophisticated jerks.

Thanks for the compliment. We have the certifications to prove it. What was the cost of this project?

It will probably begin at $350,000. Plus the $5,000 we need up front to endure your begging and review your 285-page spec. And our standard 100% PITA (Pain In The A--) premium for the likes of you. Micromanaging is unbecoming of sophisticated end-users like you.

We'll get back to you.

Sure, you will. ❑

Lifted Solder Mask: Don't Blame the Resist

When separation occurs, check the oven settings.

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

THIS MONTH WE look at printed circuit board delamination. As **FIGURE 1** shows, delamination is barely visible on the surface of the board and confined to the area around through-holes and where the solder mask is cracking.

Most examples of delamination are visible and generated by high soldering temperatures or excess time for soldering. Although during soldering there are differences in the expansion rate of materials used in PCB manufacture, the board content can have a dramatic impact.

We have presented live process defect clinics at exhibitions all over the world. Many of our Defect of the Month videos are available online at youtube.com/user/mrbobwillis. Find out how you can share our new series of Defect of the Month videos to explain some of the dos and don'ts with your customers via CIRCUITS ASSEMBLY: https://bit.ly/3mfunlF. □

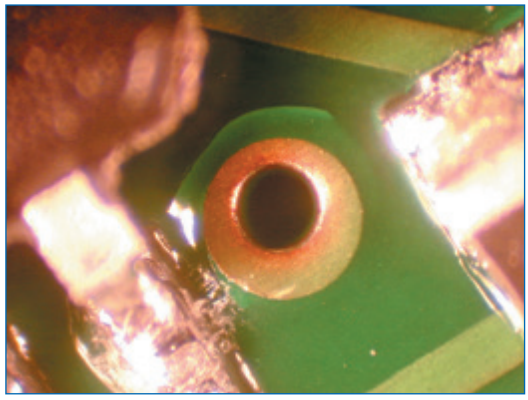

FIGURE 1. PCB delamination, likely caused by excessive soldering temperatures.

Dragos Maciuca
Executive Technical Director
Ford Motor Company

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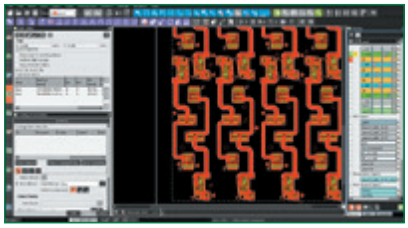
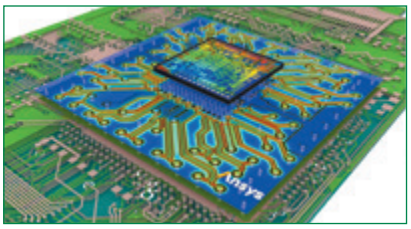
Rohde & Schwarz
rohde-schwarz.com



FRONTLINE INCAM PRO FLEX

InCAM Pro Flex CAM system optimizes wet processes to maximize yield using etch compensation tools. Delivers dedicated flex CAM tools from realistic FPC multi-zone models and automatic FPC panel creation to flex editing tools, analyses and DfMs. Automatic flex and rigid-flex board panelization with any angle rotation and PCB alignment for strip creation.

Frontline
frontline-pcb.com



ANSYS 2021 R2

Ansys 2021 R2 increases data visibility and reuse for materials, digital twin components, electronic components and compliance initiatives. Productivity enhancements perform optical simulation meshing up to 20X faster and local meshing up to 100X faster. New chip-package-system (CPS) and PCB enhanced workflows with automation for IC-on-package and multi-zone PCBs with rigid-flex cables.

Ansys
ansys.com

OTHERS OF NOTE

EASYLOGIX PCB-INVESTIGATOR V. 12.3

PCB-Investigator v. 12.3 CAD/CAM software has improved dynamic text handling; better handling of wrong drill definitions (start/end exchange); extended interface of Panel Optimizer v. 2.3 (counts, attributes, layer thickness, etc.); improved polygon handling; improved step export (self-intersecting check); IPC-2581B import panel bug fix; and more. PCB-Investigator v. 12.3 CAD/CAM software has improved dynamic text handling; better handling of wrong drill definitions (start/end exchange); extended interface of Panel Optimizer v. 2.3 (counts, attributes, layer thickness, etc.); improved polygon handling; improved step export (self-intersecting check); IPC-2581B import panel bug fix; and more.

EasyLogix
pcb-investigator.com

ROGERS VLP ED

Very low profile (VLP) ED copper cladding for CLTE-MW laminates reportedly reduces insertion loss of transmission lines operating at 77GHz by about 20% compared to standard ED copper foil. Comes in 9µm, 18µm and 35µm thicknesses. Reinforced with spread glass. Low z-axis CTE (30ppm/°C) for PTH and component board level reliability. For mmWave.

Rogers Corp.
rogers.com

AVX UBC 550 SERIES

UBC 550 series ultra-broadband capacitors deliver performance from 16KHz to 70+GHz in ultra-broadband microwave and mmWave RF applications. Come in rugged and compact single-piece, surface-mount, multilayer ceramic construction made of RoHS-compliant materials and exhibit ultra-low insertion loss, excellent return loss, flat frequency response, and high unit-to-unit repeatability.

AVX
avx.com

RS COMPONENTS DESIGNSPARK PCB PRO V. 10.0

DesignSpark PCB Pro v. 10.0 features new disconnect from signal nets option; component-to-component SMT check; output drill data to Gerber; library item time stamps; improvements to new component wizard; intelligent backups; new design rule checks; nets bar; manufacturability enhancements; plotting enhancements. Pro v. 9 customers can upgrade to v. 10 using RS stock number 220-5327.

RS Components
rs-online.com/designspark/pcb-pro-software

VITECH GENESYS 2021

Genesys 2021 model-based systems engineering development platform can model objects specifying attributes, parameters, and properties once, and then inherit, specialize, and extend these entities based on need. Models general and specialized ideas, avoiding duplication of work and streamlining updates and reuse. Exposes values for enhanced management and analysis, while maintaining natural language statements. Extends fields associated with each parameter.

Vitech
vitechinc.com

BAY AREA CIRCUITS INSTANTDFM

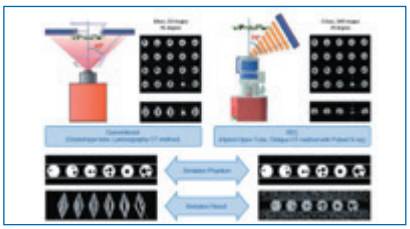
InstantDFM online DfM software has improved interface and greater accessibility to analysis functions. Allows customized manufacturing specifications with options not otherwise contained in design data such as material, surface finish, via fill, and other special processes. Helps verify process-critical parameters and general manufacturing readiness, providing automated, intelligent design feedback and recommendations.

Bay Area Circuits
bayareacircuits.com

YAMAHA I-CUBE10

i-Cube10 (YRH10) hybrid placer performs surface mount and die bonds (for wafer components). Bare chip mounting speed 10,800cph with mounting accuracy of ±15µm. Component recognition via head-mounted scan camera. 10-unit multi-nozzle mounting head. Feeder unit capacity twice that of previous models.

Yamaha Robotics SMT Section
yamaha-motor-im.eu



SEC X-EYE 6300NTI

X-eye 6300NTI inline 3-D CT AXI features pulsed x-ray with hybrid open tube. Reportedly acquires high-res images at high speed without image dragging. Performs oblique CT at 70° tilt; minimizes image distortion. Has 3.5sec/FOV and 9.6Mp detector with large FOV. Hybrid open tube enables high magnification and defect detection in 50[U]m. For double-sided and multilayer PCBs and chip packages.

SEC
seceng.co.kr

EUTECT E-CELL

E-cell scalable standard cell customizes soldering automation. Combines new design with higher precision and greater cell modularity. Has higher rigidity than predecessors and enables higher precision in soldering process and automation. Machine frame, including doors and discs, is ESD-compatible. Control cabinet allows quick replacement of all electronics, including wiring. E-cells can be customized in width and length by grid dimension of 300mm.

Eutect
eutect.de

OTHERS OF NOTE

AMKOR DSMBGA

Double-sided, molded ball grid array is for 5G RF module design, characterization and packaging. Increases level of integration for RF frontend modules used in smartphones and other mobile devices. SiP design rules and DSMBGA enable integration of antenna tuners and passive components. Improves signal integrity and reduces losses, resulting in improved Rx/Tx amplification.

Amkor
amkor.com

KOLB FR60

FR60 flux remover is spray detergent for quick manual cleaning of assemblies. Short application time. Is for typical PCBA contamination. Apply from spray bottle to surface to be cleaned. Is ESD-safe; evaporates residue-free. Dissolved flux residue can be removed using bottle's brush head, which is gentle on components.

Kolb
kolb-ct.com

DELO DELOLUX 203

Delolux 203 UV area curing lamp can be used in clean rooms where there can be no influence on continuous laminar airflow. Features modular design and can be adapted to customer-specific requirements. Based on Delolux 20 but works with water cooling instead of air cooling. Intensity of more than 600 mW/cm². Plug-and-play connectivity.

Delo
delo-adhesives.com/us

HUMISEAL UV500-2

UV500-2 high solids UV dual-cure elastomeric acrylate conformal coating is for automotive applications. Is tack-free after exposure to UV light. Secondary moisture cure mechanism fully cures unexposed areas of coating within seven days at ambient conditions. Properties include improved flexibility, improved thermal cycling and thermal shock performance, and excellent humidity and chemical resistance. Developed to address higher temp. cycling demands. Reportedly demonstrates defect-free performance, while achieving cycle counts in the thousands.

Humiseal
chasecorp.com/humiseal

HENKEL LOCTITE STYCAST OS 5101

Loctite Stycast OS 5101 dual-cure adhesive is for optical lens and component alignment during inline assembly. Maintains dimensional stability to ensure lens position while in operation. CTE below Tg of 20 PPM/°C; volume shrinkage <1%; moisture absorption of 0.8%; adheres to various substrates; high UPH capability with energy savings; first-phase UV cure achievable in 40 sec. using 1W UV.

Henkel Adhesives
henkel-adhesives.com

KOLB FR100

FR100 flux remover is intensive spray detergent for manual cleaning of assemblies. Is applied from spray bottle to surface to be cleaned. Is ESD-safe; evaporates residue-free. Dissolved flux residues can be removed using bottle's brush head, which is gentle on components.

Kolb
kolb-ct.com

In Case You Missed It

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

Circuit Fabrication

"Fabricating Functional Circuits on 3D Freeform Surfaces Via Intense Pulsed Light-Induced Zinc Mass Transfer"

Authors: Ning Yi, *et al.*

Abstract: 3-D freeform surface is of significant interest to wear-able devices on curvilinear skin/tissue surfaces or smart Internet of Things with sensors on 3-D objects. Here the authors present a new fabrication strategy that can directly print functional circuits either transient or long-lasting onto freeform surfaces by intense pulsed light-induced mass transfer of zinc nanoparticles (Zn NPs). The intense pulsed light can locally raise the tem-perature of Zn NPs to cause evaporation. Lamination of a kirigami-patterned soft semi-transparent polymer film with Zn NPs conforming to a 3-D surface results in condensation of Zn NPs to form conductive yet degradable Zn patterns onto a 3-D freeform surface for constructing transient electronics. Immersing the Zn patterns into a copper sulfate or silver nitrate solu-tion can further convert the transient device to a long-lasting device with copper or silver. Functional circuits with integrated sensors and a wireless communication component on 3-D glass beakers and seashells with complex surface geometries demonstrate the viability of this manufacturing strategy. (*Materials Today,* Aug. 5, 2021, www.sciencedirect.com/science/article/abs/pii/S136970212100225X)

Quality Assurance

"Printed Circuit Board Defect Detection Based on MobileNet-Yolo-Fast"

Authors: Guohua Liu and Haitao Wen Guohua

Abstract: Automatic detection of defects is an essential part of the PCB production process. In recent years, while great progress has been made in PCB defect detection, various problems remain in traditional defect detection methods: for example, overreliance on the perfect template, difficulty in achieving precise image registration, and high vulnerability to environmental factors such as light, noise and reflectivity. The authors propose a fast defect detection network. On one hand, this algorithm solved the problems of traditional methods. On the other hand, this algorithm solved the problems of large model size and poor real-time of existing deep learning methods. First, the k-means clustering algorithm is used to obtain more reasonable anchor boxes. Second, an improved MobileNetV2 is used as the backbone network. After the feature extraction network, the spatial pyramid pooling (SPP) structure is introduced to increase the receptive field of the image. Then, the authors use complete intersection over union to optimize the loss function. Finally, the authors build an enhanced feature extraction network based on the feature pyramid network for multi-scale feature fusion. The experimental results show this method has small model size, good real-time, and good portability, suitable for practical production. (*Journal of Electronic Imaging,* July 2021, www.spiedigitallibrary.org/journals/journal-of-electronic-imaging/volume-30/issue-4/043004/Printed-circuit-board-defect-detection-based-on-MobileNet-Yolo-Fast/10.1117/1.JEI.30.4.043004.short)

Solder Reliability

"Microstructure and Damage Evolution During Thermal Cycling of Sn-Ag-Cu Solders Containing Antimony"

Authors: Tae-Kyu Lee, Weidong Xie, *et al.*

Abstract: The interaction between the continuous microstructure evolution during thermal cycling and the long-term reliability of wafer-level chip-scale packages (WLCSPs) with Sn-1.0Ag-0.5Cu (wt%) (SAC 105), Sn-3.0Ag-0.5Cu (wt%) (SAC 305), and Sn-3.9Ag-0.6Cu (wt%) (SAC 396) solder ball interconnects were investigated. Three different body-sized WLCSP with three different solder alloys on three different board thicknesses were thermally cycled from 0° to 100°C with 10 min. of dwell time, and the microstructure evolution and their impact to the lifecycle numbers were identified. Based on both experimental and calculated data, higher Ag-containing solder alloys perform better in thermal cycling. However, the comparison between the calculated lifecycle and the experimental results revealed mismatch, due to the localized recrystallization areal fraction differences. Smaller die WLCSP with 4 x 4mm^2 and 3.2 x 3.2mm^2 exhibited a large difference in expected lifecycle numbers. The calculated lifecycles expected a lower cycle number with thicker boards for SAC 105 and SAC 396 WLCSPs, but the experimental data revealed an increase with SAC 105, and a similar level of lifecycle time with SAC 396 for thicker boards. A widely distributed areal fraction of damage accumulation through the solder rows was observed in SAC 105 compared with higher Ag solder alloy joints, which show localized damage accumulation at corner joints. The difference of areal recrystallization distribution explains the difference between SAC 105 and SAC 305/396 thermal cycling behavior between the calculated and experimental thermal cycling results. (*IEEE Transactions on Components, Packaging and Manufacturing Technology,* vol. 10, no. 10, October 2020. https://ieeexplore. ieee.org/document/9167251)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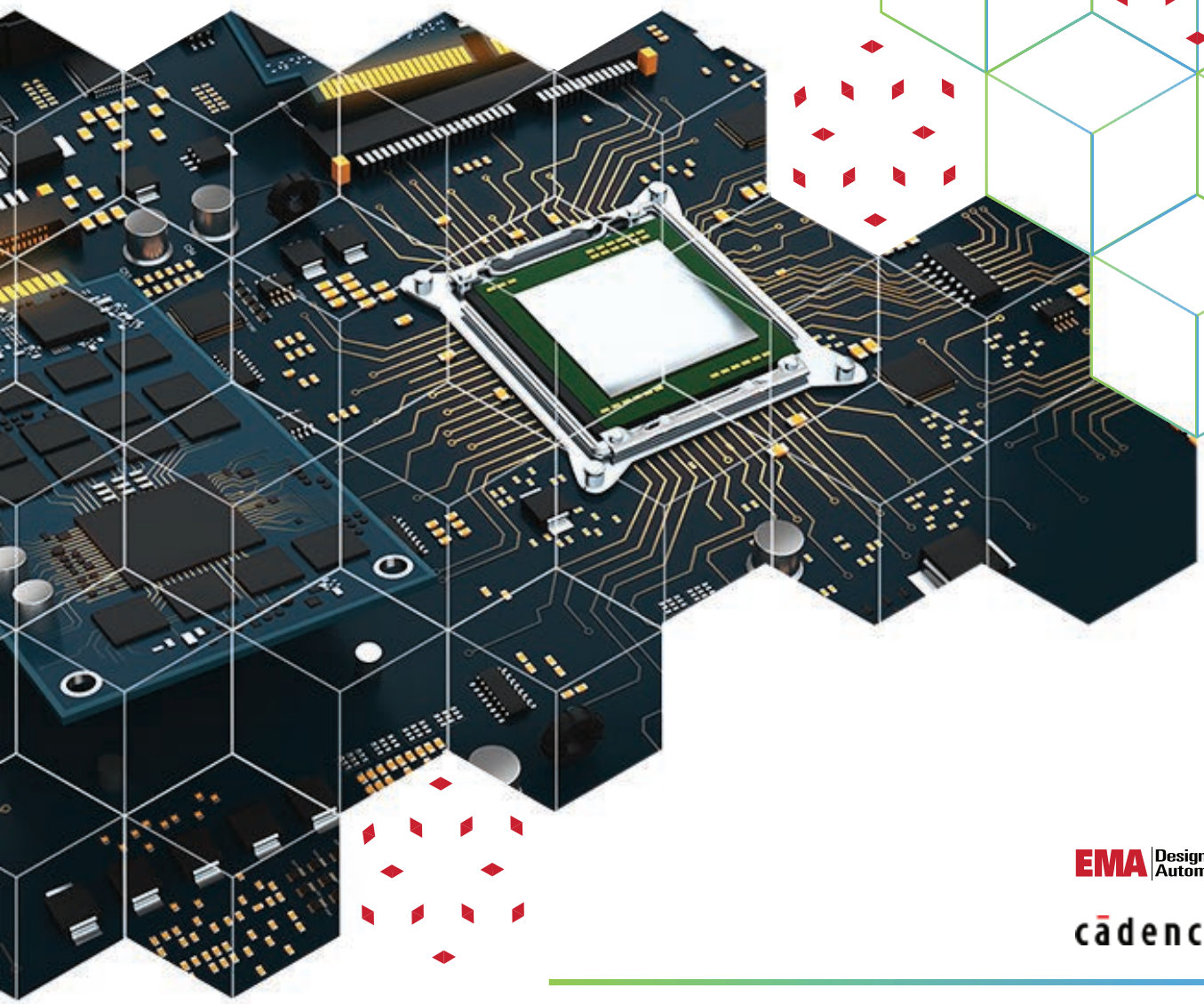

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