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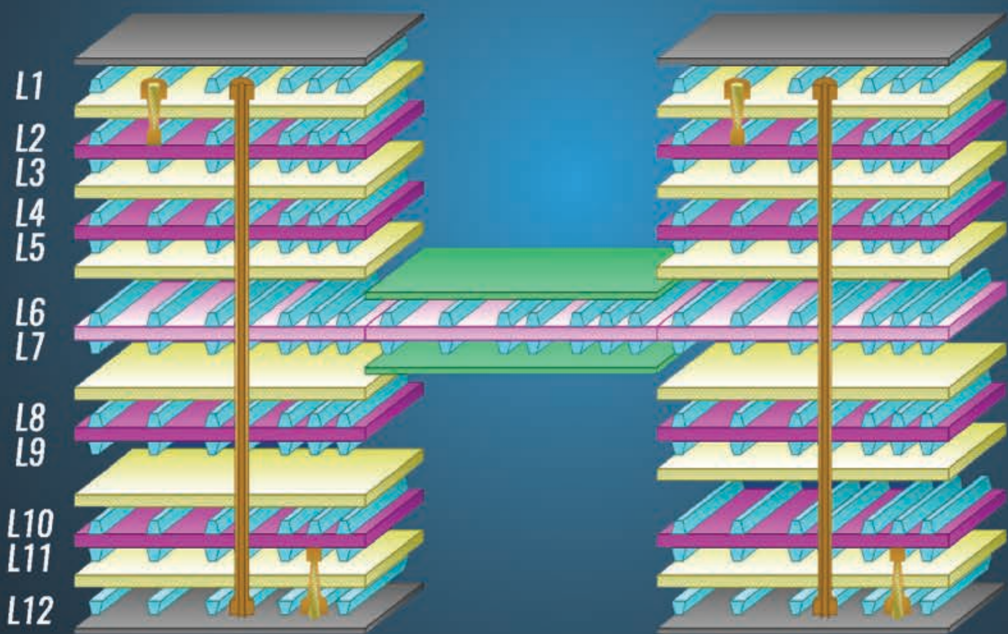

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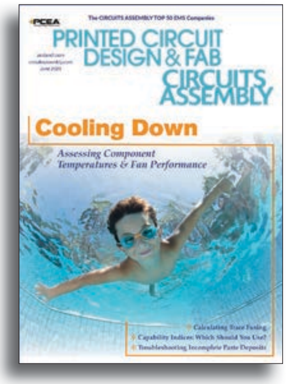

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Summary statistics can be misleading, but in different ways. Always graph your data.
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CIRCUITS ASSEMBLY TOP 50
The West is Rediscovering India
Putting aside the obvious supply chain disruptions, the two big stories out of the EMS industry in 2022 were the emergence of India, led in particular by Apple's pivoting from China, and the number of IPOs.
by MIKE BUETOW

ON PCB CHAT (PCBCHAT.COM)

QUANTUM MECHANICS
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THE LATEST ECAD MARKET DATA
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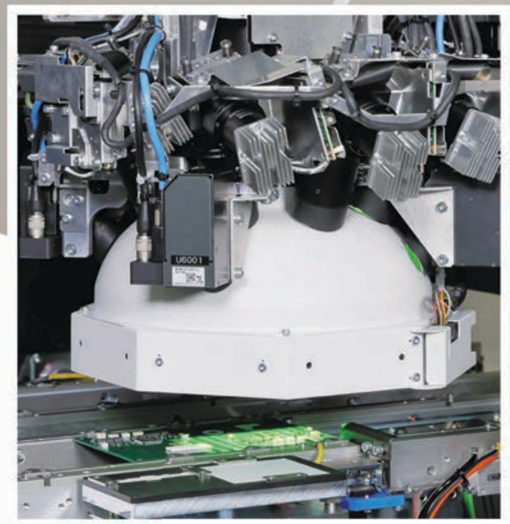

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STAFF

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

VICE PRESIDENT, SALES & MARKETING
Frances Stewart 678-817-1286 | frances@pcea.net

SENIOR SALES EXECUTIVE
Brooke Anglin 404-316-9018 | brooke@pcea.net

MANAGING EDITOR
Tyler Hanes 205-258-0067 | tyler@pcea.nett

PCD&F/CIRCUITS ASSEMBLY EDITORIAL

MANAGING EDITOR
Tyler Hanes 205-258-0067 | tyler@pcea.net

COLUMNISTS AND ADVISORS

Clive Ashmore, Peter Bigelow, Robert Boguski, John D. Borneman, John Burkhert, Jr., Stephen Chavez, Joseph Fama, Geoffrey Hazelett, Mark Finstad, Nick Koop, Alun Morgan, Susan Mucha, Greg Papandrew, Chrys Shea, Jan Vardaman, Gene Weiner

PRODUCTION

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

SALES

VICE PRESIDENT, SALES & MARKETING
Frances Stewart 678-817-1286 | frances@pcea.net

SENIOR SALES EXECUTIVE
Brooke Anglin 404-316-9018 | brooke@pcea.net

REPRINTS

brooke@pcea.net

EVENTS/TRADE SHOWS

EXHIBIT SALES
Frances Stewart 678-817-1286 | frances@pcea.net

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

SUBSCRIPTIONS

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As the Temperature Warms, is the Competition Heating Up Too?

WHEN IT COMES to the monthly editorial content in PCD&F/CIRCUITS ASSEMBLY, we typically don't do "themes."

So it's a matter of randomness and luck that we have not one, not two, but three pieces this month related to electronics thermal management and cooling. Fitting, too, being the month of June is, for the Western Hemisphere at least, on average the warmest of the year to date.

But June is also the month of the most significant trade show in the bare board fabrication industry: The JPCA Show in Tokyo. Regrettably, few Westerners will attend. It's too bad.

We are seeing significant interest at all levels – technical, management, and even political – at beefing up domestic printed circuit board capabilities. In particular, the West is attempting to make up for decades of failed progress with new investments in IC substrate production.

The IC substrate industry is worth an estimated $10 billion annually, but practically none of it is in North America or Europe. (AT&S in Austria is the only major exception.) Yet look at the annual list of the largest PCB fabricators as compiled by Dr. Hayao Nakahara at N.T. Information, and no fewer than eight of the top 15 companies – whose annual revenues exceed $1.5 billion, or slightly more than half the total size of the North American PCB output – are building IC substrates. (Indeed, almost all the growth has been from IC substrates or flex circuits.)

The West's investments, however, pale in comparison to what's taking place in Asia. Part of that is economics. Capital has flowed into acquisitions, but not necessarily into new technologies. And one reason, perhaps, is the West doesn't yet understand what needs to be done to make the technology leap into IC substrates and interposers.

Western governments are, at long last, awakening to the realization that domestic semiconductor production is critical to defense readiness and industrial competitiveness. It's one thing to pontificate about technology deficits; action is another.

There is no time for working groups and task groups and special ad hoc groups and all that … stuff.

Want to see the latest in substrate development methods and materials? Go to the JPCA Show.

Want to see the best PCB fabrication technology? Go to the TPCA Show.

Want to get up to speed on lights-out assembly and smart factories? Go to Productronica.

It's not just about the equipment and materials you'll find in the booths. It's the people walking the floor who are in the know. Those are the connections that will help cut time and costs from your technology curve.

And it might not just be the biggest shows, either. The person responsible for the three most recent greenfield PCB factories in North America was at PCB East in May.

It's summer. But if you think you feel the heat now, just wait until another year passes while you stand in place.

mike@pcea.net

@mikebuetow

P.S. This month we welcome Geoffrey Hazelett to our columnists. Geoffrey is an EE with 10 years' experience in software quality engineering and SI tools.

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

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US Congress Introduces Legislation to Support America's PCB Industry

WASHINGTON, DC – New bipartisan legislation introduced by US Representatives Blake Moore (R-UT) and Anna Eshoo (D-CA) encourages investment in a trusted, reliable domestic source of PCBs and substrates, and is generating plaudits from an industry association dedicated to building the domestic printed circuit board industry.

The Protecting Circuit Boards and Substrates Act of 2023 "finishes the job the Chips Act began by incentivizing investment in the domestic printed circuit board (PCB) industry," said the Printed Circuit Board Association of America in a press release. The Chips Act passed by Congress last year allocates tens of billions of dollars in direct funding and tax incentives to promote US technological superiority in semiconductor manufacturing.

US PCB market share has shrunk over the past 20 years, falling from 30% in revenue terms to barely 4% of the world's supply. Ninety percent of the world's supply now comes from Asia, 56% from China.

Among the major provisions of the bill:

- $3 billion to fund factory construction, workforce development and R&D
- A 25% tax credit for purchasers of American-made PCBs and substrates

"Now is the moment for Congress to take decisive action by furthering robust legislation to reshore our manufacturing, strengthen our supply chains, and prioritize national security," said Rep. Moore.

“The Protecting Circuit Boards and Substrates Act provides a tried-and-true approach to incentivizing American companies to produce printed circuit boards here at home, which will maintain the integrity of military and national security commercial materials, boost our economy and workforce, and usher in a new era of American manufacturing. The progress we have made on semiconductors is a significant step in the right direction, but congressional support for the entire microelectronics ecosystem is needed to reduce reliance on China. I am grateful to reintroduce this bill with Congresswoman Eshoo and am hopeful this bipartisan effort will successfully move through the legislative process.”

“Printed circuit boards are critical components of almost every piece of electronics used today,” said Rep. Eshoo. “However, over the past two decades, a vast majority of PCB manufacturing has moved offshore, making PCBs vulnerable to tampering by foreign adversaries, and only 4% of PCBs are manufactured in the United States. If we want to ensure technological superiority across the global stage and strengthen national security, we need to bring PCB production back to America, which is exactly what my bipartisan bill does.”

“Remember, chips don’t float. They need PCBs to connect to any electronic device. With production of American-made semiconductors ramping up, PCBs are a key ingredient in revitalizing the nation’s microelectronics ecosystem. Without a robust domestic supply chain, we have become almost entirely reliant on foreign suppliers for the PCBs we need,” said Travis Kelly, chairman of the Printed Circuit Board Association of America.

Added PCBAA president Will Marsh, “Our industry is grateful for this bipartisan support for American-made microelectronics. This is the right response to years of offshoring and a dangerous dependence on foreign sourcing.”

PCBAA executive director David Schild said, “From F-35s to F-150s, the modern world is built on printed circuit boards, and we need to make more of them in America. This bill will lead to new factories, high paying jobs and an ecosystem to support the work being done by our colleagues in the semiconductor industry.”

ASKPCB Building New Thai Facility

YIYANG, CHINA – Chinese PCB fabricator ASKPCB is building a factory in Thailand that is expected to have a production capacity of 120,000 sq. m. and be capable of providing volume production of 28-layer PCBs in all fields, including data centers and next-generation switches.

The factory is being built in Thailand's Rojana Ayutthaya Industrial Park, which is near Wus Group's Thai factory and near the city center of Bangkok. With a land area of around 26.67 hectares, the Thailand factory is expected to commence trial production by the second quarter of 2024.

In an online investor briefing, the company said the primary goal of the Thailand factory is to address supply-chain security concerns of core customers, providing them with matched services across various domains, including servers, cars, communications, and consumer products. The factory is positioned to meet the rapidly expanding PCB demand in Thailand and surrounding Southeast Asian countries. In recent years, these countries have experienced rapid GDP growth and are following the path of China with a strong demand for PCBs and favorable order prices, ASKPCB said.

ASKPCB currently has two factories in China and has the capability to mass-produce various large-size and small-size boards related to servers with 18 or fewer layers, with capability to produce customizeorders of up to 28 layers in small batches. The testing boards can achieve more than 36 layers. The company's total production capacity is approximately 760,000 sq. m. per month, with the monthly production capacity of its Hunan site 320,000 sq. m., and its Guangdong campus being 440,000 sq. m.

TPCA: Taiwan's PCB Industry Creating New Cluster in Thailand

TAOYUAN CITY, TAIWAN – The Taiwanese PCB industry is increasingly investing in Southeast Asian countries – particularly Thailand – as customers look to secure their manufacturing bases against global uncertainties and move out of mainland China, according to the Taiwan Printed Circuit Association.

Currently, Taiwanese PCB manufacturers have more than 60% of their capacities in Mainland China and 37% in Taiwan, and for many years, Taiwanese companies have not valued the Southeast Asian countries because of their planning and management in Taiwan and mainland China. Since last year, however, international political instability and end-customers' concern about supply-chain disruption have driven a worldwide trend to relocate the supply chain.

Thailand has the highest PCB output among Southeast Asian countries, and its open business environment with a high level of internationalization have made it the best choice for Taiwanese companies to base production factories at this time, TPCA said.

In the past two years, Taiwanese PCB companies such as Unimicron, Compeq, Wus Printed Circuit, Dynamic Electronics and Complex Micro Interconnections, along with suppliers of raw materials, such as Taiflex, TUC and ITEQ, have established factories in and around Bangkok. Several Chinese counterparts have also relocated factories to Southeast Asia, including Aoshikang Technology, Chian Eagle Electronic Technology, Jove PCB and FSQuality.

TPCA has organized two investment tours to Thailand, one investment tour to Vietnam and one to Malaysia, and on July 21, it will hold the Thailand PCB Industry Link Summit where the Thai government, Thai and Taiwanese PCB companies, and industry park representatives will be invited. This communication platform is meant to help those who want to invest in Thailand, and TPCA will work with the Thailand Printed Circuit Association to discuss the major issues relevant to how the PCB industry chain moves to Thailand.

AT&S Building New Research Center in Austria

LEOBEN, AUSTRIA – AT&S has received a €250 million loan ($271 million) from European Investment Bank to fund research and development activities and help finance the construction of a new research center at its headquarters here.

The new center in Leoben will help the European Union to achieve digital autonomy, a priority under the European Chips Act, and the goal is to create a chip ecosystem to ensure Europe's security of supply in microchips and to strengthen its digital technology production capabilities, EIB said in a release.

“We are proud to support AT&S, a highly innovative company that is key to achieving digital autonomy in Europe,” said EIB vice president Thomas Östros, who oversees financing in Austria. “The Leoben research center, in collaboration with universities and research institutions, will serve to develop knowledge within the industry.”

“AT&S’s new R&D center will make a significant contribution to Europe’s competitiveness in the field of microelectronics, in line with the European Chips Act,” said AT&S CEO Andreas Gerstenmayer. “This center of expertise for IC substrates and microelectronics packaging being built in Austria is the only one of its kind in Europe. This investment will serve AT&S customers in the high-end semiconductor sector as well as international research institutions. It will be a major regional development project and create many appealing jobs.”

HDP Announces Launch of 3 New Projects

ROUND ROCK, TX – Following the successful completion of its spring member meeting, held in Santa Rosa, CA, in February, the High Density Packaging User Group has launched three new projects:

- Large Footprint BGA Warpage. PCB warpage is a common phenomenon due to material CTE mismatch, copper distribution, PCB processes, etc. For large BGA footprints (e.g., >75mm square), extra warpage on the PCB surface and package warpage have been creating significant challenges to SMT (solder joint issues) due to the flatness mismatch between the PCB surface and package. This project focuses on flatness within the BGA footprint that is impacting assembly with the aim of defining a sustainable and achievable BGA flatness guideline.
- Permittivity of Cooling Liquids. It is well known that immersion cooling liquids are used to cool infrastructure equipment to improve thermal reliability and energy efficiency. What is not well understood is the permittivity properties of these liquids. What needs to be addressed is accurate modeling to predict the electrical performance of high-speed busses

when these are immersed in a cooling liquid as opposed to air, and is the focus of this project.

- Sequential Lamination. In thicker PCBs and higher layer counts built with sequential lamination, some issues have been associated with this technology, such as resin cracks, delamination, resin voids, and failed microvia connections. The possible goals suggested so far includes: determining how best to test for the ability of the materials to withstand multiple laminations; testing specific laminates for the ability to withstand multiple laminations cycles; defining the critical material factors for a material to be compatible with multiple laminations; develop a standard test board and test methods to evaluate materials in multiple laminations; determine the limit as to how many laminations are possible for a given material; and, define the criteria of what "good" performance is versus "bad" performance relative to the material is when used in multiple laminations.

HDP is a global research and development organization based in Round Rock dedicated to reducing the costs and risks for the electronics manufacturing industry when using advanced electronic packaging and assembly.

FTG Completes Acquisitions of IMI, Holaday Circuits

TORONTO – Firan Technology Group has completed its previously announced acquisitions of Holaday Circuits and IMI Inc. Completion of the deals, both of which were announced last year, was slowed by mandatory US regulatory reviews.

Further to the previous announcements made by FTG regarding these acquisitions, FTG has now attained the approval from the Committee on Foreign Investment in the United States (CFIUS) and all closing conditions have been met and both acquisitions are now closed.

Combined, the acquisitions had sales of about $45 million pre-pandemic. The combined purchase price is approximately $19.3 million and the Holaday agreement also has an earnout of up to approximately $6 million depending on financial performance over the next 18 months. The acquisitions will be funded primarily from existing cash and bank facilities will be used for remaining balance.

The IMI acquisition bolsters FTG's presence in RF circuit boards for the aerospace and defense market. The RF market is growing, and IMI's specialized capabilities will enable FTG to better address this market segment.

The Holaday Circuits acquisition gives FTG a large, US-based facility that can address the market for high technology circuit boards, particularly for defense applications.

"FTG had identified a desire to add US manufacturing capacity for RF and high technology product for aerospace and defense applications. These acquisitions accomplish this and will complement FTG's existing capabilities and locations," stated Brad Bourne, president and CEO, FTG. "Having met the teams at IMI and Holaday Circuits, I am truly thrilled by their skills, dedication and commitment to excellence and I welcome them all to FTG."

CHIPS for America Outlines Vision for the National Semiconductor Technology Center

WASHINGTON, DC – The National Institute of Standards and Technology (NIST) released a paper outlining its vision and strategy for a National Semiconductor Technology Center (NSTC), a key component of the research and development program established by President Biden's CHIPS and Science Act.

Congress appropriated funds for the creation of a national center to support and extend US leadership in semiconductor research, design, engineering, and advanced manufacturing and strengthen US competitiveness.

The paper, "A Vision and Strategy for the National Semiconductor Technology Center," lays out how the NSTC will accelerate America's ability to develop the chips and technologies of the future to safeguard America's global innovation leadership. The vision and strategy paper describes the center's mission, core programs, and other features. In addition to creating and sponsoring research programs, the NSTC will work with academic and industry partners to create affiliated technical centers around the country, fostering a network of research and innovation that is unprecedented in scale, breadth, and focus. The NSTC will lay the groundwork for good jobs that will grow a domestic semiconductor workforce.

"The NSTC will be an ambitious public-private consortium where government, industry, customers, suppliers, educational institutions, entrepreneurs, and investors will come together to innovate, connect and solve problems," said Secretary of Commerce Gina Raimondo. "Most importantly, the NSTC will ensure that the US leads the way in the next generation of semiconductor technologies which can enable major new advances in areas that will advance our economic and national security. While the manufacturing incentives of the CHIPS Act will bring semiconductor manufacturing back to the US, a robust R&D ecosystem led by the NSTC will keep it here."

The NSTC's programs are intended for the entire ecosystem: fabless companies, research institutions, community colleges, state and local governments, national labs, foundries, integrated device manufacturers, equipment vendors, materials suppliers, labor unions, and investors. The NSTC aims to fulfill the unmet needs of the sector with member services such as access to emerging materials and process technologies, digital assets and design tools, a chiplet stockpile, and incubation support for startups. It also will offer the opportunity for participation in industry grand challenges, road mapping and standards activities, and workforce training and technical exchange programs.

As outlined in the strategy paper, the NSTC has three high-level goals:

- **Extend America's leadership in semiconductor technology.** Designing, prototyping, and piloting the latest semiconductor technology in America will provide the foundation for future applications and industries and strengthen the domestic semiconductor manufacturing ecosystem.
- **Reduce the time and cost of moving from design idea to commercialization.** The NSTC will leverage shared facilities and expertise for designing, prototyping, manufacturing, packaging, and scaling of semiconductors and related products that provide innovators in the US with critical capabilities to advance economic and national security.
- **Build and sustain a semiconductor workforce development ecosystem.** The NSTC will serve as a coordinating body and center of excellence to scale the technical workforce,

including scientists, engineers, and technicians. The NSTC workforce programs will support expanding recruiting, training, and retraining for the semiconductor ecosystem, including reaching groups that are traditionally under-represented in the industry.

"The National Semiconductor Technology Center is designed to drive innovation and speed the transfer of new technologies to market," said Under Secretary of Commerce for Standards and Technology and NIST Director Laurie E. Locascio. "This center will give the US semiconductor industry an enduring technological lead and help develop a skilled workforce capable of manufacturing the world's most advanced devices."

In addition to establishing a center for research, administration, and operations, the NSTC will establish technical centers by expanding and improving research facilities across the country or by building new, advanced facilities. Inventors and entrepreneurs, start ups and established businesses, chipmakers, materials and equipment suppliers, educators and trainees can all collaborate on NSTC programs. The NSTC is designed to address the real-world technical challenges of the semiconductor industry and provide immediate and hands-on knowledge transfer and training to participants.

Extensive feedback from stakeholders made clear that the NSTC must address a wide variety of issues for a great diversity of stakeholders. The Secretary of Commerce, in collaboration with the Secretary of Defense, will establish the NSTC through the creation of a public-private consortium as required by the Act.

Quanta Betting Big on Mexico

NUEVO LEÓN, MEXICO – Quanta Computer will invest a reported $1 billion in the northern state of Nuevo León, Mexican government officials announced in late May.

Governor Samuel García cited the nearshoring trend for the investment, saying the area expects an almost-ninefold increase in foreign investment in 2023.

"There's a geopolitical issue, a conflict between the U.S. and China," García said. "The U has said everyone has to leave China and come to North America, and the big winner is Nuevo León, which is receiving 72% of nearshoring. For Nuevo León, a good year in foreign investment was $2 billion dollars. This year, we're aiming for $17 billion at the minimum."

Quanta already has invested nearly $500 million and hired 2,500 employees in Nuevo León, Pedro Campa, vice president of manufacturing operations in Mexico, told Reuters.

Éolane Launches Malaysian Subsidiary

PENANG, MALAYSIA – Éolane is launching a new subsidiary here, which will include a new factory to better serve its customers as closely as possible to their markets, especially those of the Asia-Pacific Economic Cooperation (APEC).

Éolane Malaysia's new factory is planned to open at the end of the year, and will join Intel, Hewlett Packard (now Keysight Technologies and Agilent Technologies), Robert Bosch, AMD, Litronix (now Osram Opto Semiconductors), Hitachi (now Renesas), Clarion and National Semiconductor at Kulim Hi-tech Park.

The company said the new facility in Penang will benefit customers by offering optimized sourcing of electronic components thanks to its geographical proximity to OEMs manufacturing in Southeast Asia.

Several customers have already confirmed their orders at this new site, with production starting in January 2024, Éolane said.

APG Makes 'Significant' Investment in XLR8

SAN CLEMENTE, CA – XLR8 EMS in May announced a significant equity investment from American Pacific Group, a $1.2 billion private equity fund. The small-tier electronics manufacturing services provider said the investment, the terms of which were not disclosed, would be used to expand its facilities and capabilities.

Founded in 2013, XLR8 is a rapidly growing contract manufacturer of printed circuit assemblies with a core focus on speed and technology for commercial, AS:9100, ISO:13485, and ITAR customers. For the past five years, XLR8 has been recognized by the CIRCUITS ASSEMBLY Service Excellence Awards as a leader in its category for quality and dependability, as voted by its own customers, and for the past three years won the top honor of overall leader in its category.

"We could not be more pleased to announce our new partnership with American Pacific Group and Concisys," said Jason Powell, president and founder, XLR8. "This investment is a reflection of our intention to continue to meet and exceed the needs of our customers, and to remain at the forefront of technical solutions and high-quality, high reliability service. I look forward to continuing to lead the business with APG's support, and to expanding our capabilities and footprint."

Fraser Preston, managing partner at APG, said, "Jason and the XLR8 team are partners to some of the world's leading and emerging aerospace and defense, medical, consumer and industrial companies for a reason. The team has a proven track-record for executing a differentiated business model, and we see a compelling opportunity to bring XLR8 and Concisys together, and to leverage our value creation framework, the "Q Process," to further catalyze XLR8's trajectory."

XLR8 marks American Pacific Group's second investment within the EMS market, following an investment in Concisys, a San Diego-based quickturn and prototype contract manufacturer, in August 2022. XLR8 and Concisys will partner going forward to best serve growing demand for highly technical onshore manufacturing solutions, and APG will continue to invest as both businesses further pursue organic and inorganic growth.

SigmaTron Sells Majority Position of Wagz

ELK GROVE VILLAGE, IL – SigmaTron announced that it reached an agreement in late April to sell a majority position of its wholly owned subsidiary, Wagz, to Vynetic.

During SigmaTron's preparations for its third quarter financial statements, it was determined that updated projections resulted in a triggering event for the company's goodwill and long-lived asset groups, which would incur non-cash impairment charges of approximately $23.1 million. These impairment charges coupled with Wagz' operating losses triggered a default with SigmaTron's credit agreements with J.P. Morgan Chase Bank and TCW Asset Management Company. The company also received a delinquency notification letter from Nasdaq indicating that it was not in compliance with the continued listing requirements of Nasdaq for failing to timely file the Company's Form 10-Q for the fiscal quarter ended January 31, 2023. That notification also constituted a default.

SigmaTron said Wagz was in the process of developing three new products that were scheduled to be released during the middle of calendar year 2023. Sales of existing products during this development period did not materialize to expectations and resulted in a significantly higher level of losses and cash consumption than anticipated. Sales were negatively impacted by a shortage of parts for production for several months, resulting in missing the holiday season for sales, a slowing economy relating to inflation and a slower than anticipated acceptance of the product by the market. When projections were updated, the company determined that there was an impairment.

After negotiating the default with lenders, SigmaTron agreed to the sale of 81% of Wagz to Vynetic, which will become the majority shareholder of Wagz. Sigmatron will retain a 19% ownership position in Wagz as a passive investor at closing, and will provide a $900,000 working capital loan to Wagz during the month of April, during which time Vynetic would raise capital to support Wagz going forward.

SigmaTron has agreed to work with Wagz as an EMS provider pursuant to a manufacturing agreement but did not commit to further financial support. The company said it expects that the transaction will allow it to potentially recover some of the assets that it will write off as of April 30, 2023.

"During this period, the company's EMS business has remained robust. We have seen some modest signs of a slowing economy and continue to experience supply chain shortages," said Gary R. Fairhead, chairman and CEO. "However, at this time, we are cautiously optimistic that the revenue volume will continue, and we expect to add additional business based on the opportunities we are working on at this time. Regarding Wagz, we believe that the opportunities they are pursuing in the Pet Tech market remain attractive and we are hopeful that our continuing minority ownership interest in the company will yield benefits to the company in the future.

ISC Acquires MX Electronics' Santa Ana Facility

SANTA ANA, CA – Interconnect Solutions Company, a provider of electromechanical and interconnect solutions, announced that it has acquired the Santa Ana-based assets of MX Electronics Manufacturing.

In a statement announcing the acquisition, ISC said the addition of MX Electronics' assets adds capacity in many existing business lines, plus capability in printed circuit board assembly (PCBA) to better serve both existing and future customers. ISC is part of Tide Rock's manufacturing portfolio.

"We are thrilled to be able to continue serving customers of MX Electronics just up the road from where they're used to," said Mark Papp, Tide Rock YieldCo president. "This acquisition is a natural fit for our company. It will add important capabilities to our shop and allow us to provide our customers with even greater value."

PCD&F

Accurate Circuit Engineering purchased an **Excellon** COBRA-II hybrid laser system.

Gold Circuit Electronics announced plans to set up a new plant in Thailand.

Mitsubishi Electric's ME Innovation Fund invested in startup PCB maker **Elephantech** as part of a 900 million yen ($6.67 million) funding round.

Tianjin Pulin announced that the company plans to purchase 20% of the equity of **Taihe Circuit Technology** (Huizhou) held by **TCL Digital Technology** (Shenzhen).

Trackwise Designs has launched the sale process for its subsidiary, **Stevenage Circuits,** to focus on its harness technology business.

Yaohua announced plans to establish a subsidiary in Thailand, with a total investment of 1 billion baht ($29.6 million).

CA

Aculon named **Ellsworth Adhesives** global distributor of its NanoProof 3 series coating.

ASML will build a new research center including a clean room together with **Eindhoven's**

Technical University.

BPC purchased a **Kulicke & Soffa** wire bonder to support its expansion into sectors where battery packs are required, particularly EV OEMs.

Cetec ERP was recognized as a top cloud ERP provider for aerospace/defense distributors by Aerospace Export.

CommScope Tijuana purchased a **ViTrox** V810i x-ray inspection unit.

Creation Technologies has doubled the production capacity at its St. Peter, MN, facility to total 88,000 sq. ft.

Ersa installed its 2,000th Versaflow 3/45 selective soldering machine in Hungary.

Forge announced the expansion of its relationship with connector manufacturer **Samtec.**

Foxconn opened a new global business headquarters in Zhengzhou, China, to cover its electric vehicles and robotics segments, and acquired a 300-acre land parcel on the outskirts of India's tech capital Bengaluru as it looks to ramp up the production of iPhones in the country.

Gizmore announced a strategic partnership with **Staunch Electronics India** to expand its presence in wearable devices.

Green Circuits purchased a **Takaya** double-sided flying probe.

Ilfa purchased a **Schmoll** A-RMXY2-60S-CCD drilling and milling machine.

Integrated Micro-Electronics and **Zero Motorcycles** have agreed to build the first electronic vehicle motorcycle manufacturing site in the Philippines.

Kitron signed a production agreement with **Maven Wireless.**

Lacroix suffered a cyberattack resulting in the temporary closure of three of its EMS sites worldwide.

Micross Components has acquired **Technograph Microcircuits,** a provider of hybrid integrated circuits, RF and microwave products, optoelectronics, and PCB assembly.

NeoTech opened a new training center in Juarez, Mexico.

Pegatron announced plans to purchase land and a building in Taoyuan, northern Taiwan, for a total of NT$755 million ($25 million)

PDR appointed **Process Automation & Tool** as manufacturers' representative in the southeastern US.

Rohde & Schwarz provided a complete EMC test system to **Emitech's** new vehicle test center in Montigny-le-Bretonneux, France.

Ross Video is adding a fourth SMT line at its Iroquois, Ontario, site.

RØDE Microphones purchased surface-mount assembly equipment, including a YSM20R modular mounter, from **Yamaha Robotics SMT Section.**

Scanfil has been chosen by **Grandcentrix** to manufacture and further develop its Modbus Cloud Connect IoT solution.

Silicon Mountain purchased four **Pillarhouse** selective solder systems and a **Universal Instruments** Radial 88HTi radial insertion machine.

Surf-Tech purchased an **Austin American Technology** Aqua ROSE 4.0 batch cleaner.

Versalogic has launched an in-house production line for its embedded computer products in the US.

Wistron ceased production at its Taizhou plant in China, joining other Taiwanese ODMs who are accelerating the downsizing of production capacity in China. Wistron also exited its iPhone business in India, selling its remaining factories to **Tata Group.**

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PCD&F

Confidee appointed **Andrea Queirolo** sales manager Italy.

Millennium Circuits named **Mike Tucker** director of engineering and technology.

The U.S. Partnership for Assured Electronics named **Nathan Edwards** executive director.

CA

Alert Tech SMT named **Troy Schlegel** director of production operations.

Altus appointed **Charles Lower** sales manager for the southwest region.

ASMPT SMT Solutions named **Josef Ernst** CEO, succeeding **Guenter Lauber.**

Hentec Industries/RPS Automation hired **Stacey Jones** as purchasing agent.

Jabil named **Kenny Wilson** its new CEO, succeeding **Mark Mondello,** and appointed **Corinne Baker** director of supply chain management.

StenTech appointed **Sean Park** western regional sales manager.

VivaQuant named **Alex Zeitler** director of manufacturing.

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

BluePrint-PCB

CAM350

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

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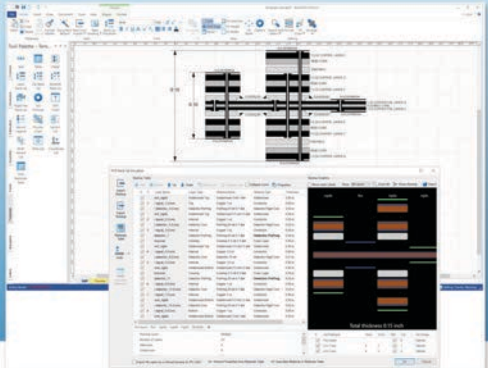
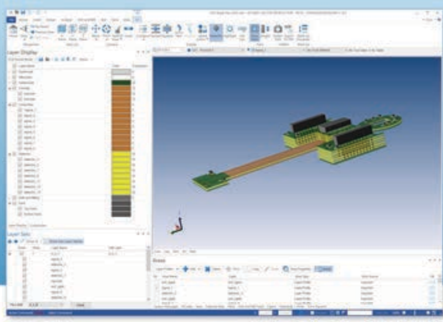
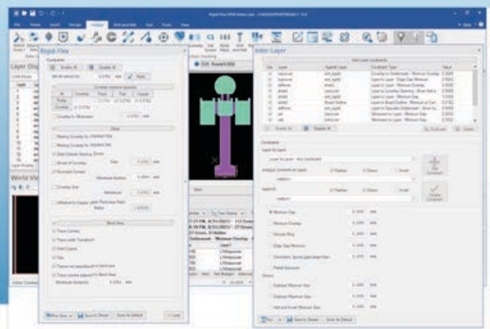
- **Use DFM analysis to analyze a flex or rigid-flex design for potential fabrication or bend related defects**



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



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



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

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PCB East 2023 Registration Up 59% Year-over-Year

PEACHTREE CITY, GA – Registration for the PCB East 2023 conference and exhibits rose 59% overall from last year, the Printed Circuit Engineering Association announced.

Conference registration more than doubled, rising 110% from last year, while the expo-only trade show registration rose 63% over the same period.

The annual trade show was held May 9-12 at the Boxboro Regency Hotel and Conference Center in Boxborough, MA. In all, more than 60 leading suppliers of electronics design tools, manufacturers of bare boards and assemblies, and suppliers of fabrication and assembly equipment and materials exhibited at the show.

Figure 1. Susy Webb addresses a full house during PCB East. (Photo: Tomas Chester)

"We couldn't be more pleased with the turnout for PCB East 2023," said Mike Buetow, conference director and president, PCEA. "Attendees spoke highly of the quality and breadth of the presentations, and noted that they often had to make tough choices on which classes to attend."

Exhibitors agreed the show is filling a need for the vibrant New England market.

"Great show!" said Bob Burns, VP sales and marketing, All Flex Solutions, Inc. "Well attended and we found some really good prospective customers, and uncovered two new materials as a bonus!"

"Great show!" echoed Claire Jamieson, marketing manager, NCAB Group. "This is our first exhibition since prior to the pandemic and it was an excellent opportunity to catch up with some familiar and new faces."

Figure 2. Registration for the exhibits was up 63% over last year.

"The PCB East experience was truly enjoyable, and I had an amazing time throughout," said Syed Ubaid Ali Warsi, engineering manager of Wavetroniks.

"PCB East this year did not disappoint!" added Stephen Chavez, senior product marketing manager of Siemens. "Exceeding all expectations, from us industry veterans, to the new generation engineers starting their careers off in our industry. There were 'golden nuggets' of knowledge for everyone in attendance."

PCEA said plans for PCB East 2024 will be announced shortly.

Figure 3. Jeff De Serrano of PCB Technologies USA speaks during the Lunch-and-Learn.

PCB Fab Database Now Available

PEACHTREE CITY, CA – The Printed Circuit Engineering Association now offers FabFile Online, a list of active North American printed circuit board fabricators, free as an industry service.

This database was initially compiled and provided to the industry by Harvey Miller. For over seven decades, Miller was a leading source of data on market and technology trends for the printed circuit board industry. Using the FabFile database, Dr. Hayao Nakahara of N.T. Information performed extensive editing to clean up and add commentary to the list.

The database is available for download in the free section of Printed Circuit University (printedcircuituniversity.com).

National News

Conferences Task Group. The PCB West 2023 technical conference schedule is now available at pcbwest.com. This year's conference features more than 120 hours of top-rank training from the leading names in electronics design and manufacturing. We will also have a special "Ask the Experts" session all day on Sept. 20, where you can get advice or just commiserate with gurus like Rick Hartley, Keven Coates, Mark Finstad and Nick Koop. Visit pcbwest.com for details.

EMI seminar. Rick Hartley will present a special live two-day workshop on "Control of EMI, Noise and Signal Integrity in High-Speed Circuits and PCBs," coming June 20-21 to the Atlanta suburb of Alpharetta. As Hartley notes, EMI is a leading concern for electronics designers and a major cause of failures. The seminar has been updated to contain a fair amount of new information that was not taught in years past. Each attendee will receive a color PDF copy of the full slide deck. For details, visit pcb2day.com.

Chapter News

San Diego. Palomar Community College is offering a comprehensive online PCB design course, taught by John Watson. The classes include a 16-week beginner course and a 16-week advanced course, with the beginner classes starting on Aug. 22, 2023, and the advanced courses starting on Jan. 30, 2024.

The chapter has elected John Watson vice chair and Nick Maldonado communications director.

Register by August 18 and save $200!

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MARKET **WATCH**

Electronics Supply Chain Coming into Balance in H2, Says Supplyframe

PASADENA, CA – Lead times and prices are expected to drop toward historical norms in the second quarter, while inventory reductions and corrections will continue into the second half of the year, according to the latest analysis from Supplyframe.

Consumer markets remain lethargic, but automotive and industrial segments are relatively robust. And macroeconomic shifts will have massive repercussions for the global electronics supply chain – with a demand rebound for PCs, smartphones, and data centers required to drive new growth.

"Despite global economic challenges and uncertainties, [our data] show that commodity supply-demand rebalancing is well underway," said Supplyframe CEO and founder Steve Flagg. "Some electronics commodities and end markets have shown initial signs of recovery through Q1."

Global electronic component sourcing activity rose 3.6% quarter-on-quarter, led by fiber optic component demand, which increased 22.1% and offered signals for potential demand rebounds, according to Supplyframe.

In the second half of 2023, just 4% of all semiconductor lead time dimensions (excluding memory) will expand, while 35% will decline. However, to a lesser degree, lead times for certain devices – including power MOSFETs and some automotive-grade ICs – will remain extended. At-volume passive components under 12-week lead times for the second quarter more than doubled, the latest data from Supplyframe reveals. The number of quoted lead times beyond 52 weeks was halved.

Just 1% of pricing dimensions are projected to increase, and over half will be stable across all electronic commodities in the second half of 2023. But average selling prices for global DRAM are eroding and will continue to slide into the third quarter. Yet spot prices for DDR4 are stabilizing, reinforcing Supplyframe's forecast that DRAM recovery is set for the fourth quarter. Additional flexibility in price and availability exists across many materials commodities and sub-commodities, including resins and metals, Supplyframe added.

"Supplyframe forecasts a markedly more balanced electronics supply chain in the second half and expects component inventories to be largely digested into the third quarter," said Richard Barnett, chief marketing officer and SaaS sales leader at Supplyframe. "However, industries sharply cut factory utilization to adjust to weakened demand. Some manufacturers and distributors need to rebalance inventory positions, and macroeconomic uncertainty still lingers."

Interest rate increases across the globe, the spreading banking crisis, and a new report from the World Economic Forum predicting that the global labor market will lose 14 million jobs over the next five years could send the US and other world economies into sharp downturns.

Conversely, news from the US Census Bureau revealed that new orders for nondefense durable goods outgrew previous estimates. New orders for US electronics surged year-over-year through March by 8.4%, and global job numbers have been solid to date, indicating that the US and other economies may be poised for a soft landing – or avoid a downturn entirely.

"Economic conditions are at a tipping point, with ongoing debate regarding the timing, severity, and certainty of a global recession in 2023," said Flagg. "If conditions and sentiment improve, demand will rebound. And rebounds could possibly lead to the return of constraints for certain electronics commodities as manufacturers ramp capacity."

KEY COMPONENTS

	DEC.	JAN.	FEB.	MAR.	APR.
EMS book-to-bill[1,3]	1.36	1.36	1.30	1.28	1.21
Semiconductors[2,3]	4.4%	-18.5%	-4%[r]	0.3%[p]	TBA
PCB book-to-bill[1,3]	0.87	0.94	0.99	0.91	0.89
Component sales sentiment[4]	65.8	82.2	90.6	88.7	86.8

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

MARCH MADNESS

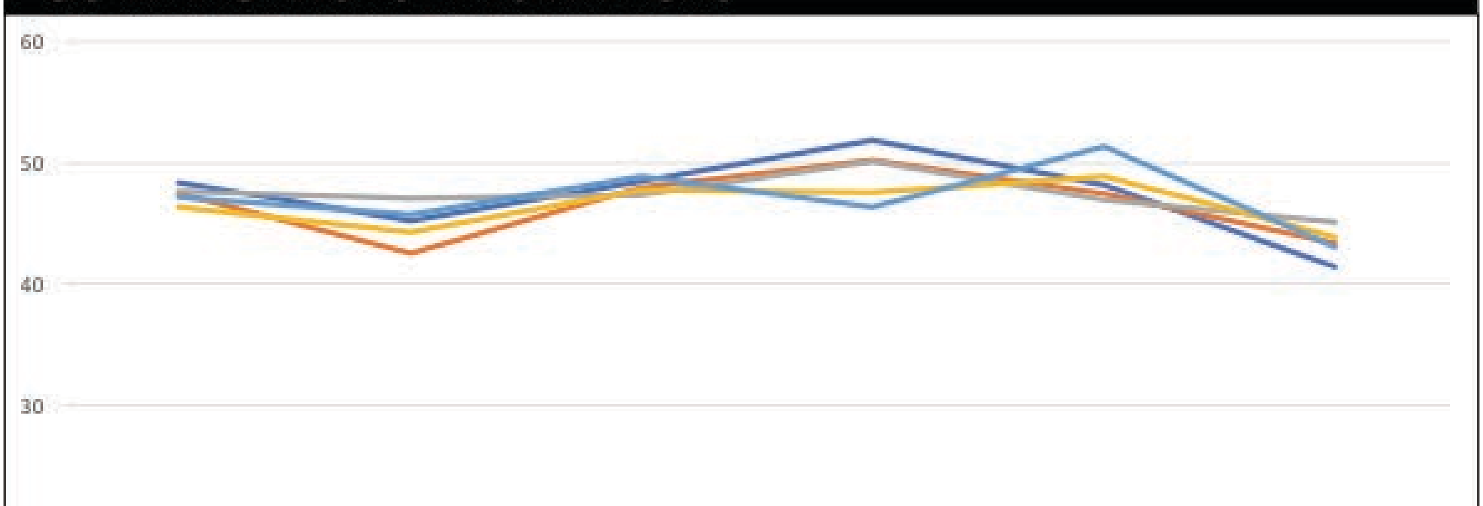
Trends in the US electronics equipment market (shipments only)

	% CHANGE			
	JAN.	FEB.[r]	MAR.[p]	YTD
Computers and electronics products	0.1	-0.4	-0.3	4.1
Computers	8.5	-1.1	-2.8	8.4
Storage devices	4.4	-1.2	4.3	10.9
Other peripheral equipment	2.9	-4.0	6.1	89.5
Nondefense communications equipment	-0.7	1.1	-1.8	-3.6
Defense communications equipment	0.9	0.9	-0.9	5.2
A/V equipment	8.4	-12.5	0.6	-17.7
Components[1]	1.2	1.9	-2.0	4.6
Nondefense search and navigation equipment	-0.2	-0.7	-1.8	1.3
Defense search and navigation equipment	-1.3	-0.2	-0.3	1.2
Electromedical, measurement and control	-1.1	0.3	1.0	2.1

[r]Revised. [p]Preliminary. [1]Includes semiconductors. Seasonally adjusted.

Source: US Department of Commerce Census Bureau, May 2, 2023

US MANUFACTURING INDICES



Source: Institute for Supply Management, May 1, 2023

Hot Takes

EMS M&A activity saw a slight year-over-year increase in the first quarter, with 10 transactions recorded, versus nine a year ago. Six involved consolidations. (Lincoln International)

China's AI market will exceed $26 billion by 2026, with hardware making up 56% of the market. (IDC)

Technology supply chains show an average increase of about 27% in total inventory levels from 2019 to 2022. (Kearney)

The **ABF substrate market segment** is expected to rebound in 2024, buoyed by rising demand for AI servers. (DigiTimes)

Production cuts to **DRAM and NAND flash** have not kept pace with weakening demand, and DRAM average selling prices are projected to fall 13 to 18% this quarter, while NAND flash is expected to fall 8 to 13%. (TrendForce)

Global notebook shipments performed better than originally expected in the first quarter of 2023, and the volumes will grow back 9% sequentially in the second quarter. (DigiTimes Research)

Some 54% of respondents in an April survey said **labor and material costs are rising,** but the number of companies experiencing rising costs continues to decline. (IPC)

Electric vehicles, charging stations, renewable energy, fast charging for mobile devices, and power suppliers are driving demand for **legacy packages** such as TOs and power modules for SiC and DFNs and QFNs for GaN. (TechSearch International)

North American EMS company shipments rose 14.3% in April from a year ago, and 5.5% sequentially. Bookings decreased 6.1% year-over-year and fell 1.2% from March. (IPC)

North American PCB shipments rose 12.1% year-over-year in April and fell 18.4% sequentially. (IPC)

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The Real Cost of Production

Manufacturing costs include more than just material, labor and overhead.

POSSIBLY IT'S BECAUSE inflation has ticked up over the past year or so, or possibly it's because despite a long career in manufacturing, and I am still not sure all stakeholders from production, sales, customers, suppliers – and especially accounting – really understand or agree, but I find myself now more than ever trying to identify and come to grips with the "real cost" of what I produce.

I am hardly the first to ponder this question. Truth be told, I spent too many years early in my career performing standards engineering and being responsible for product costing. All that experience, I fear, has left me more a skeptic than an expert on product costing. Too many companies in our industry have ended up foundering, in no small part because of their leadership not understanding the real cost of their product.

Cost accounting 101 will teach you to consider material cost, labor and overhead. Yet it is the "other" costs that, in my experience, are far more significant and usually either not considered or undervalued as part of the costing equation. Supplies, required services, benefits and most of all, risk, all seem to get rolled into one of the basic three (materials, labor, overhead) rather than being understood and properly valued. So, let's quickly run through all seven of them.

Materials. To fabricate a circuit board, laminate is needed, as is surface finish, processing films, etc., and these usually make it onto the bill of materials because they are relatively easy to quantitate and are needed to produce product.

Supplies. Now the slope begins to get a bit slippery. Yes, everything from chemicals to drill bits to rags and filters and other "stuff" is consumed while producing the product. And yes, most people in manufacturing understand that these items are needed. What is almost always missed, however, is that there are typically lax controls on managing these often low-cost items and, therefore, the actual cost of these supplies is almost always higher than costed into a product. My experience tells me they are too often woefully underestimated in product costing. However, as they are collectively supposed to be a relatively small percentage of total cost, managers typically just look the other way when costing supplies.

Services. Another slippery slope. Services mean everything from an outside service used when in-house capability is not available, to the support services, such as calibration, that are "assumed" to be minor. With the ever more complex capital equipment and demand for more detailed verification and validation of processes, they are an ever-increasing component of cost in manufacturing.

Labor. One of the basic three costs. Despite automation and thanks to a combination of decreasing interest in manufacturing careers and rising inflation, labor represents both a talent sourcing concern and a more expensive piece of the costing equation.

Benefits. Typically lumped with labor or thrown into the overhead cost, benefits are becoming a cost category of their own. Offering better benefits can often mitigate some of the problems in attracting new hires, but it comes with a cost. Some states also have requirements for benefits that add costs. And finally, some benefits are "soft" costs that sound inexpensive when initially offered, but when employees take advantage of them, the true cost becomes apparent.

Overhead. Whether the company's facility appears more like the Taj Mahal or that of a slum, they will most likely end up costing the same. The Taj Mahal will hit the depreciation account while the slum will hit the repair and maintenance account. Regardless, they are both real costs, regardless of where in the budget they are listed. And more often than not, the real cost of each is more than what is accounted for.

Risk. This cost is never adequately considered and includes the trifecta of expenses that can do real damage to a company's financial picture. When a company takes on a job that is risky, they will consider the yield and add cost (read: price) to compensate for it. So in a simplistic world, if yield "risk" is 50% then they expect to produce two for every one they ship and get paid for. That's great until the trifecta is taken into consideration. The trifecta is 1. loss of capacity; 2. cost of reputation; and 3. collateral damage including impact on on-time delivery. Two of the three costs are soft costs while one is real, very real.

If a facility has unlimited capacity, which is never the case, then costing out the risky low-yield job will work fine. If too many risky low-yield jobs are taken, however, the capacity is consumed by scrap at the expense of building good (and profitable) product. This impacts on-time delivery, which suffers as staff tries to get the low-yield job through now capacity-stressed processes at the expense of other jobs in the queue. Low on-time delivery in turn impacts the manufacturer's reputation as customers lose confidence in a supplier with poor delivery and quality.

What is the "real cost" at your company? How well are each of the cost drivers really being managed? Are any cost areas putting your business at financial, operational or reputational risk? After all these years, I continue to grapple with balancing all these and staying hyper-focused on improving in every cost-driving area.

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

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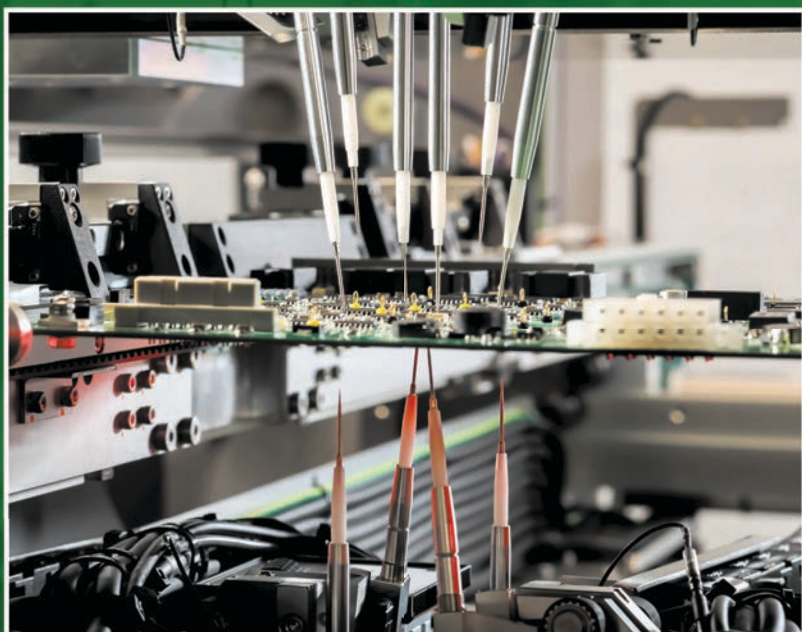

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Pride in the Workforce

Are you tapping all the opportunities in your labor market?

FOR US ELECTRONICS manufacturing services (EMS) providers, the only thing in shorter supply than long lead-time components is labor. Decades of manufacturing job losses translate to a generation of workers who don't consider manufacturing jobs because they don't know anyone in manufacturing. EMS companies are addressing this in multiple ways including job enlargement for existing workers, greater use of automation and closer ties with community colleges. Flexible work schedules better aligned with college student or single-parent schedule preferences have also been successful tactics. In areas with large retired populations, flexible work schedules may also appeal to retirees who are feeling inflationary pressures to re-enter the workforce and want better compensation than found in retail.

Recently, I had a discussion with Andrew Williams, engineering manager at Pride Industries' EMS operation in Roseville, CA. Pride Industries' mission is to create employment for people with disabilities. Pride Industries was founded in 1966 in the basement of a church in Auburn, CA, by a group of parents of young adults with developmental disabilities who wanted their grown children to have purpose and experience the dignity of a paycheck. Today, Pride Industries operates across 15 states plus Washington, DC, and is the leading employer of people with disabilities in the nation.

The EMS division was started in the 1990s as a job shop performing through-hole assembly with a slide line for a customer that had a product that represented a perfect production flow for adding inexperienced production workers with disabilities. Today, the division has grown to a full-service EMS company with two SMT lines producing a variety of products including Class II medical devices. It employs more than 100 people in production and recruits from a labor pool referred by state and regional agencies. Most of those workers have some form of a disability that has limited their job opportunities.

People with disabilities are one of the most underrepresented groups in the labor force. One in five Americans has a disability, and two-thirds of working-age Americans with disabilities are unemployed. Pride Industries' EMS division is successfully creating jobs for people in this labor market and has services to help other companies that wish to hire more people with disabilities. This choice is not without tradeoffs, however, Williams points out.

In Pride Industries' EMS model, some job descriptions have been narrowed to better align with employees whose disabilities limit their range of skill sets. That said, employees with narrow skill sets often perform their assigned tasks with a level of focus and repeatability not found in the workforce at large. From a manufacturing engineering standpoint, there is strong focus on Lean manufacturing principles including developing fixtures, tooling and jigs to support integrating employees with disabilities into production jobs. That focus also increases quality and efficiency in the production line. Employees with disabilities work at all levels of the company, including production supervision. Turnover is typically lower because the company tailors its policies to the needs of employees with disabilities. However, employees may need greater accommodations in work scheduling due to medical appointments, flexibility with breaks, or technical assistance.

Pride Industries' model also aligns closely with state agencies that place people with disabilities. It provides services to employees with disabilities that can include counseling and job coaching, coordinating benefits and work, and providing monthly reports on work performance, etc. This activity is funded through a state program.

Will hiring people with disabilities solve every EMS company's labor shortage? No. Focusing on this underrepresented segment of the labor market does two things, however. First, it changes lives. Many people with disabilities simply need the right opportunity to become productive members of society. Second, it helps reduce unemployment. Just as Lean manufacturing sees underutilization of production resources as one of the seven wastes, chronic unemployment of people who would work if an opportunity were available is the worst kind of societal waste.

Pride Industries also provides services to companies looking to structure employment programs that help them successfully employ people with disabilities. Its EMS division is proving that this model can work in a full-service EMS model. For more information on these services, contact Pride Industries.

Properly structured, employing people with disabilities is a win for the employees, the company and the surrounding community that changes lives, reduces community safety net costs, and provides a measurable social program to a company's ESG framework.

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

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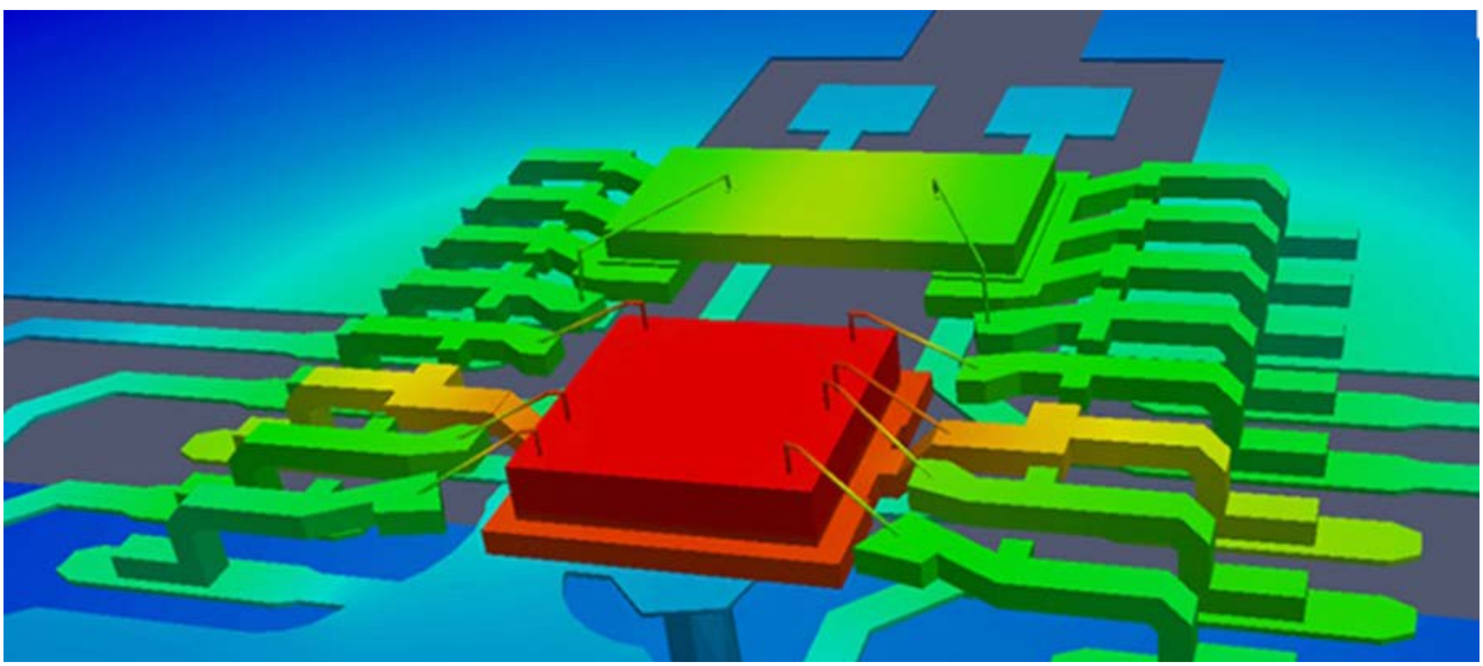
Thermal Considerations for Printed Circuit Board Designers

Leave more metal behind.

BEING COOL USED to be easy. Modern times call for a more comprehensive approach to keeping the lights on when it comes to our PCB layouts. The early days of electronics saw through-hole components bearing a single transistor that sat well above the board much like a water tower commands the skyline in a pastoral setting.

The device was free to blow off as much steam as required without scorching the stuff we call FR-4. Fun fact: Did you know that the FR in FR-4 stands for "fire retardant" and that 4 is the number of iterations that lead to the resin/glass combo that undergirds our industry's history to this day? The material is rated by its ability to withstand high temperatures without breaking down.



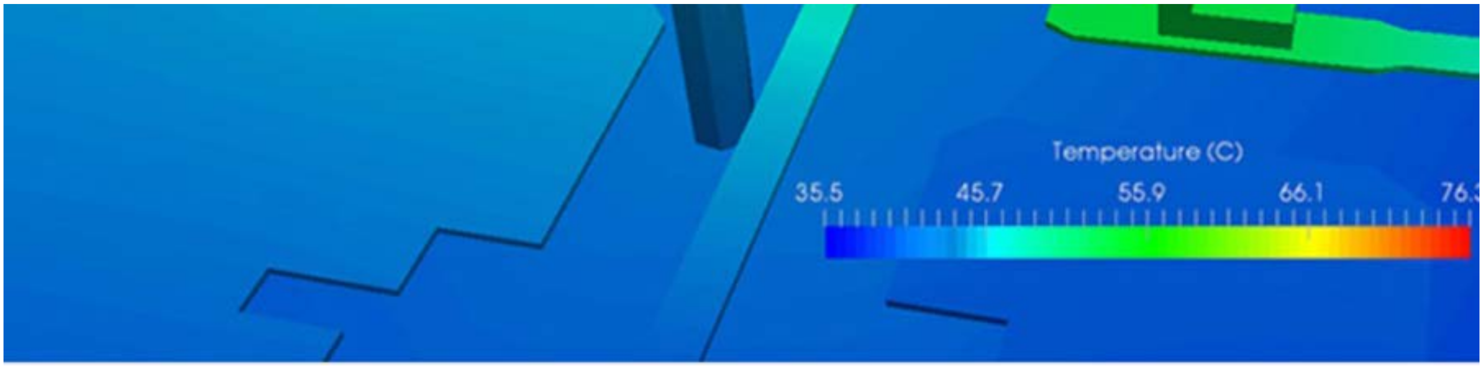


Figure 1. Thermal simulation can save an iteration, saving time and money in the long run. (Source: Cadence)

One of the most important characteristics of FR-4 is the glass transition temperature, or T_g, where the material simply melts down and fails. It is measured in centigrade, and a working number is between 140° and 170°. That will not be sufficient for extreme environments and hard-working chips. There may be exceptions but you're nominally looking at exotic dielectric materials that are meant to cater primarily to data centers and broadcast scenarios. The ancient art of ceramics plays a part in withstanding higher temperatures for devices and PCB laminates.

When reliability really matters, a class of PCBs is for just that purpose. As you would figure, the extra degree of reliability is also a cornerstone of the military industrial complex. A designer can spin up an IPC Class 3 board even if no defense contract is involved. Taking a piecemeal approach, you can design for more robust performance without buying in to all the baggage that comes with Class 3. In other words, you can employ the high-reliability geometry but skip over some of the test coupon requirements or component derating. You also are not restricted to ITAR-compliant fab shops unless you really are on a Mil-spec program.

Legislation is afoot in the US to address the decline in the size of the onshore PCB market. Hot take: The need for legislation only underscores the existing gap. Investing in HDI fabrication is mostly a matter of how many presses one has. The bulk of the fabrication timeline is spent under the heat and pressure of the lamination cycle. Then you factor in the local supply chain. Can you procure and process those thin dielectrics required for the microvia ecosystem?

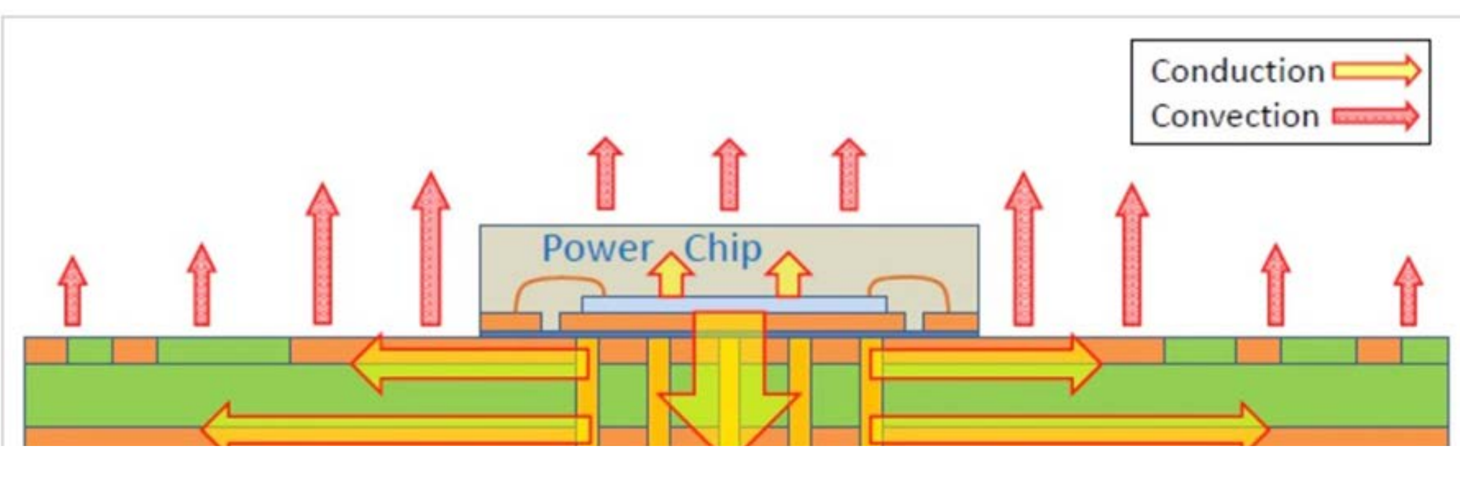
On a global basis, the number of vendors seems to be expanding. It's not only in Shenzhen anymore, although that remains the nexus of worldwide fabrication by volume. Going to a different near-shore or offshore, a cottage industry shadows the major players with local knockoff materials. End-result: The actual material used depends on where the boards get fabricated. You must connect your supply chain with your end market, working around tariffs where possible.

We get a lot of heat on the job but it's mostly about the schedules. Meanwhile the printed circuit board spends its service life generating some amount of heat. The journey from the die to the outside world is seen as a series of thermal pathways. The output pin of the device will be the source of the thermal energy. This temperature rise (above ambient) at this first node is called transistor junction temperature, or simply "junction temp," which shortens further to T_j.

The case temperature is a measure of the next part of the escape route. The original burst of energy works its way from the die through the substrate to the pins as well as through the device cap. In surface mount packages, the majority of heat is carried into the board by way of the pins rather than out through the lid of the device. Either way, the eventual heat sink is the world outside of the product.

For this reason, the PCB plays a key role in evacuating excess energy, especially when the thermal path flows almost entirely downward out of the package. This is another area where the 80/20 rule can be applied. A common example is the square pad in the middle of a QFN/QFP package. That will be the red zone on the thermal image.

Minimizing the temperature excursions will keep the product in service. According to the design for thermal app notes from Texas Instruments, "Every 10°C rise in temperature reduces the average life by 50%." Poor thermal management will end up with the device failing on a regular basis. Adequate coverage of the thermal path will yield something that works but is being throttled in certain circumstances. Depending on what we're doing, that may be the best we can expect. Size, cost, operating environment and the specific role of the product are factors in expected outcomes.



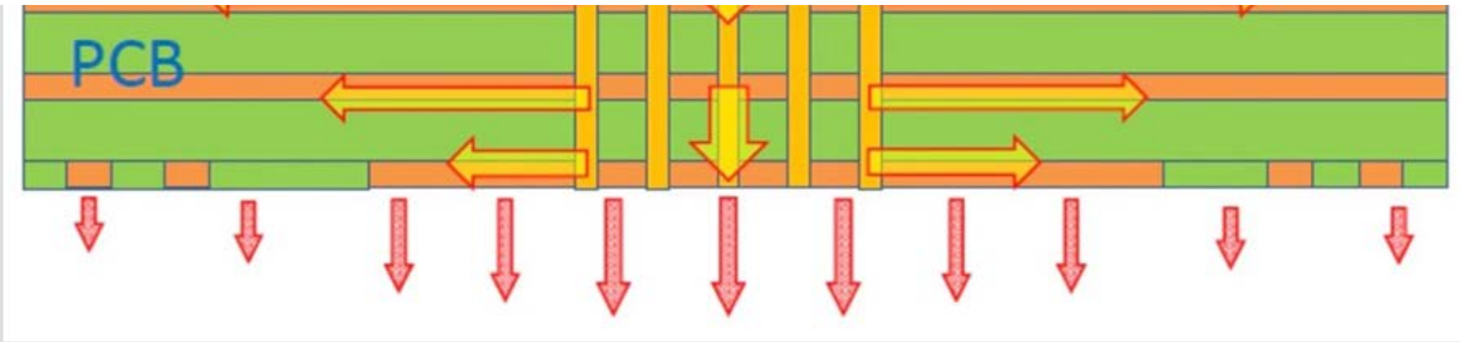


Figure 2. Conduction and convection are two thermal pathways. In outer space, you could substitute radiation for convection. (Source: On Semiconductor)

Power to the PCB (and then it gets interesting). Heat generation is proportional to the work being done. It isn't always the largest chip in the fleet that causes the biggest temperature rise but that's a good place to start. The most power-hungry devices I find are SoCs; short for system-on-a-chip. The power requirements of a huge SoC are broken into different voltage domains, which are further subdivided by filters into a power tree that addresses all individual functions expected of the system. Meeting all the current carrying requirements of this collection of power feeds is an important starting point. Narrow choke points create hot spots.

On a board with less integration, the issue is the same, just spread across different functional devices rather than being hosted in a central system. Microcontrollers, sensors, radios and all the accessories that support the product are distributed across the board. You can usually find a way to satisfy the splintered voltage feeds on a single layer plus the top and bottom to fan-out/decongest the power distribution network. Other times, the power density requires multiple layers of the same shape to carry the load.

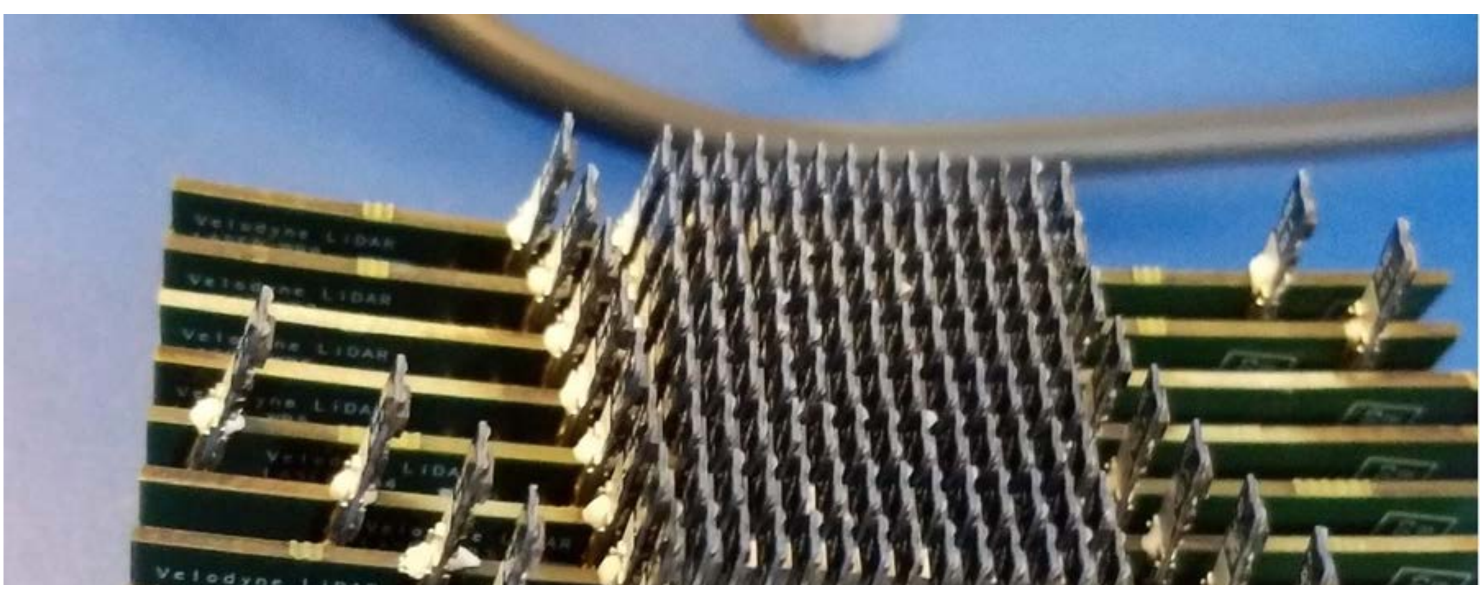


Figure 3. When a collection of eight PCBs has 16 lasers attached to each, the temperature inside the Lidar sensor is bound to rise.

There is always temptation to overdesign the power grid for resilience. A little excess copper is OK, but there are times when a large surface area of power is a hindrance. Circling back to the radios mentioned above, it is often the case where the least amount of copper that gets the job done is the ultimate approach.

For RF purposes, a power plane is replaced by a trace no thicker than it must be. You end up with something called star-routing where a power trace runs around shooting off narrow spurs as it goes past the decoupling cap ahead of the voltage pin. The minimalist power footprint reduces the noise floor which is worth the effort. That is but one of the many quirks of mobile systems.

Having power is good, being well grounded is better. Of course, the ground net is the vital piece of the puzzle as we consider thermal options. The chip app notes encourage lots of ground flood to be poured in the vicinity of the device. This seems almost ironic given the number of components that also want to be right up against the processor. Fold that into the kind of spacing requirements the market demands and walk that tightrope. Boards cost money and you get more of them out of a panel if each piece is smaller. Mobile applications cite more room for batteries as the usual justification for shrinking the board. The pressure is on.

If your envelope isn't shrinking, a well-known method of increasing reliability is to use larger geometry for the solder joints. This has two effects: one is the extra toe fillet acts as a bit of a radiator for each pin. The knock-on effect is the extra pad area pushes each component that much farther from the other. That alone alleviates some of the buildup of thermal energy.

Adjusting the footprint library from Class 2 to Class 3 may not be workable for every part but it takes only a few common parts to change the landscape. Larger air gaps are a worthy goal as they allow us to specify thicker copper. Fabricators differ in their abilities to produce boards with copper thicker than 1 oz. (35µm), so it is wise to check with the approved vendors to see what rules apply. When it comes to HDI stack-ups, the nominal copper is usually 0.5 oz., around 18µm. Read on for methods to employ when you're bound to the thinner copper layers.

Stifling local thermal loads with heatsinks. Passive cooling can also be applied locally in the form of a copper coin. Imagine a thermal pad under a quad flatpack style component. The pad is pierced with vias that land on a copper zone on the opposite side of the board. Attaching a metal slug below the thermal pad increases the dissipation factor. Note that you want to plug the vias with solder mask so solder does not leak away during reflow. In tighter enclosures, there may not be room for the heat slug, so the vias could be filled with a conductive paste.

Bus bars and stiffeners can act as heat spreaders. Unlike copper coin, these are not necessarily soldered down but are held in place with hardware while a thermal compound fills the gap between board and stiffener.

Aluminum is also a popular heatsink material since it is very good at thermal transfer and is lighter than copper. It can be extruded into specific geometries for your applications. Going way back to the time when I was assembling telecom hardware, we had one component, a TO-5 transistor, that was failing from overheating. It had to be removed from the board but not from the system.

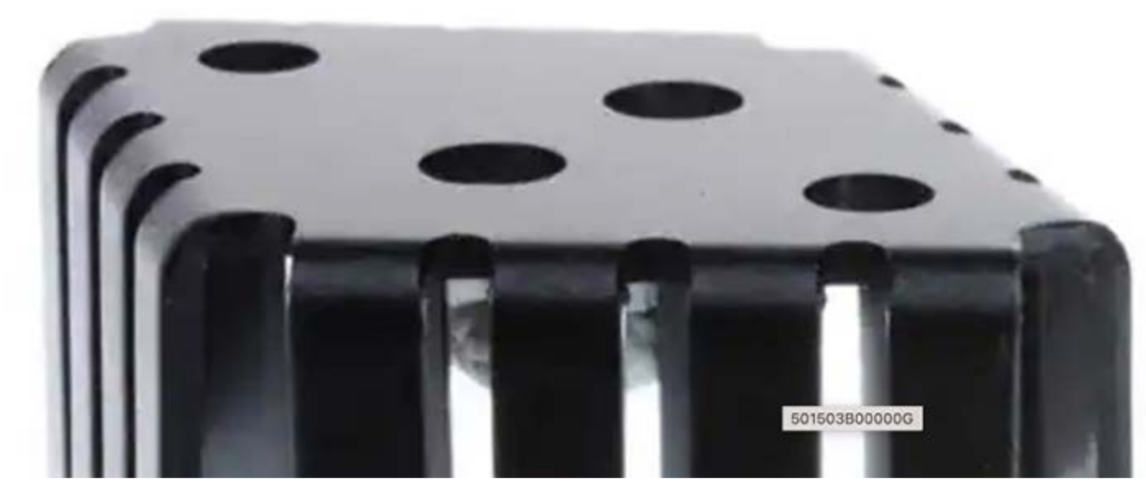


Figure 4. A single transistor heatsink mount can isolate and dissipate, saving the other components from being affected. (Source: Aavid Boyd)

The solution came about with a finned heatsink that had the proper holes for the transistor to be mounted to it while the heatsink was suspended above the board on four standoffs. A trio of 18-gauge stranded wires connected the transistor to turret terminals on the PCB. That was the end of our problems with that device. It cost more, but cutting down on field service calls more than made up for it.

There are more technologies to bring forward these days in the pursuit of higher performance. I finally replaced my old touch bar MacBook with a newer one that purports to have some kind of recirculating liquid cooling, sort of like what is used in a traditional gas-powered car. We have static solutions using materials like AL/SiC, graphene, beryllium copper, maybe even carbon nanotubes.

Keeping heat under control will prolong the life and retain the performance of the system. Solid board design will contribute to longevity and will increase the value of the product to the end-user. Parts age while dust accumulates. These and other factors challenge the resilience of the PCB. Use as much of the copper as possible, etching away only metal as required to define the circuit. Leaving more metal behind is a leg up on reliability and takes less energy to produce. Stay cool, my friends.

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.

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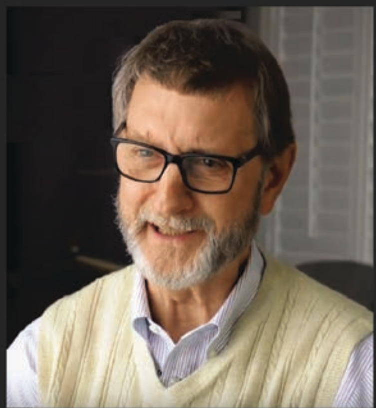

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MCAD-ECAD Co-design

A common component library aids engineering integration.

AS I MENTIONED in my column last month, PCB design best practices have five pillars. The first pillar, digitally integrated and optimized, is the foundation. It specifically addresses interactions within the design process and how multidiscipline and multidomain integration and collaboration should take place.

This leads me to pose a simple question: Is your engineering team digitally integrated and optimized when it comes to MCAD-ECAD co-design, or is it functioning with a legacy approach that contains many manual efforts/tasks while team members are working in silos?

Every PCB design starts with the design of the physical package/box (the system) where the PCB will reside. As this occurs, the physical features of the PCB are defined. These features include items such as the dimensions of the PCB outline; board thickness; mounting holes; tooling holes; restricted areas/rooms such as specific components' height ceilings; component keep-ins and keep-outs; critical components such as connectors, heatsinks and sub-assemblies; plus any other pertinent critical features and or details.

While the mechanical engineer is addressing the mechanical/physical aspects of the system, the electrical engineer is doing their part addressing the electrical requirements of this system. This includes the creation of the required circuits that ultimately define the electrical schematic.

Historically, several issues hampered cross-domain collaboration. The different domains had completely different tools, different user specialties, different languages/terms for communication, and different databases. This made it difficult to communicate changes while both domains proceeded in parallel and worked in silos – the best that could be expected was email, drawings on post-it notes, or in-person verbal direction. The struggle with the handoff between electrical and mechanical disciplines within the legacy methodologies lies in this manual approach and can be error-prone. There is inefficiency and a lack of instant bidirectional communication when addressing these legacy data exchange formats.

The industry has evolved, providing a digital thread in the form of industry standard data exchange formats. Decades ago, DxFs became a common way to pass graphical data, but the information was very limited (often 2-D, with no intelligence about objects, thus requiring interpretation) so they were typically only used in a one-way path from MCAD to ECAD. STEP enabled more 3-D intelligence, including enclosures. IDF was constructed for bidirectional collaboration, but transferred the entire database without any tracking to identify changes. Incremental Design Exchange (IDX) brought the ability to send incremental changes and traceability.

The IDX format is the latest and greatest format for MCAD-ECAD co-design. This format enables a more efficient, unified collaboration workflow. It allows designers to accept or reject any proposed items sent from the other domain. To keep data synchronized, every proposal comes with a response from the other domain. This helps users to understand the current status of the board within both mechanical and electrical domains to ensure they stay in sync with each other. This also makes it much easier to address problems as they are encountered, rather than undertaking a long review at the end of the design process and updating or correcting the project after it is complete.

It must be noted that even tighter integrations are possible. A model-driven approach, with both MCAD and ECAD sharing the same component library, has the potential to save significant library creation time and ensure that all of engineering is on the same page. Today's 3-D ECAD design tools enable layout designers to view what the mechanical engineer is working on without leaving their native environment and verify their design in that context. Likewise, PCB data down to the trace and via level helps the mechanical engineer accurately model and simulate the board in their environment.

A number of analysis tools available validate the digital twin before prototype. Ideally, these tools work directly off the ECAD or MCAD authoring database (a high-fidelity digital twin) to minimize rework. While adopting these tools sounds like extra work, it's been proven that "virtual prototyping" (analysis and verification during design) saves significant time and cost through re-spin reduction.

When we look at the complexity of today's electronic system design, legacy processes created decades ago and still being deployed don't fully meet today's needs nor do they fully address the challenges and problems engineering teams face. The industry addressed this with the evolution of the IDX standard.

The value we get from a digitally integrated and optimized MCAD-ECAD co-design process is a streamlined approach that contains multidiscipline and multidomain integration and collaboration, which minimizes risks during the ECAD-MCAD data exchange throughout the PCB design process.

STEPHEN CHAVEZ is a senior printed circuit engineer with three decades' experience. In his current role as a senior product marketing manager with Siemens EDA, his focus is on developing methodologies that assist customers in adopting a strategy for resilience and integrating the design-to-source Intelligence insights from Supplyframe into design for resilience. He is an IPC Certified Master Instructor Trainer (MIT) for PCB design, IPC CID+, and a Certified Printed Circuit Designer (CPCD). He is chairman of the Printed Circuit Engineering Association (PCEA); stephen.chavez@siemens.com.

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Reshoring or Resurrection?

The road to resilience for Western manufacturing must begin with small steps.

FOR MORE THAN three decades, leading electronics brands in the West have enshrined leanness, maximum efficiency and lowest cost. The drive to outsource manufacturing to areas where labor costs are lowest has enabled the industry to deliver more advanced electronic products at relatively affordable prices.

It has made perfect sense for the world's OEMs, relieving demand for capital investment and helping to cut costs while giving access to cutting-edge processes and providing rapid, low-risk scalability. The trend to outsource began in the late 1970s and became the dominant model in the '80s and '90s. Throughout the 21st century, this has been the way to operate a competitive supply chain. Now, the largest EMS operations are based in China and Southeast Asia and the sector is currently worth about $800 billion. It's still growing at more than 7% compounded annually.

But something else happened during this transformation. As production migrated geographically, the essential skills associated with designing and making advanced electronics products also moved away from the OEMs and became concentrated in Asia. Many associated industries also moved out. In the 1980s there were 23 full-scale manufacturers of substrate base materials in Europe. Currently, there are two. Similarly, the number of manufacturers of glass and copper foil has fallen from 12 to just one.

The global pandemic has now sounded a wake-up call, highlighting the weaknesses in such a stripped and lean machine. We now see a critical need for resilience in our supply chains. Not to mention, in the current political climate, the importance of maintaining independent local skills in cutting-edge technologies and state-of-the-art production capabilities.

Both the US and Europe have become concerned about losing ground in the race to continue acquiring high-tech knowledge. The balance of technical power has shifted decisively toward China. This is evident in the current moves within both regions to increase their power in semiconductor development and production. The US and EU each now has its own Chips Act with the specific goal of growing the indigenous semiconductor sector. Although this grabs attention and may boost national economic morale, I have said before that focusing solely on this one attractive high-value aspect has only limited value. Chip production is merely one aspect of the globally distributed machine that puts smart tech in our homes and factories, on our roads and railways, and in the hands of our emergency and homeland security services. These acts, bullish as they sound, will make little difference without due consideration of other essential elements including manufacturing, PCB fabrication and substrate materials.

Implementing any of these activities to a meaningful extent in the West could be problematic. Currently, the leading EMS businesses in Asia are operating at placement efficiency of about $0.01 per placement. This contrasts with the typical cost in the US and Europe of about $0.05 per placement. The efficiency gap is even greater for board manufacturing and component packaging. This is a huge gulf that appears right now to be unbridgeable. The West is also five to 10 years behind technical capabilities in China. Catching up will take time.

The West must begin to act, however. It is possible to contemplate a decoupling from China, moving toward destinations such as Thailand, Vietnam and the Philippines to mitigate geopolitical risks. Currently, China's words and actions in relation to Taiwan are particularly concerning. Taiwan, of course, is hugely important to the world's high-tech businesses as the home of the largest semiconductor wafer fabrication plants as well as IC and power supply design expertise. It is also a center of excellence for advanced substrate materials including glass and resins.

Large OEMs often now ask about their suppliers' plans to mitigate the risks of sourcing parts of the supply chain to China. Many found that the blanket closure of Chinese ports during the pandemic severely crippled their activities. It exposed a serious weakness in those leaned-out supply chains, which must now be strengthened to prevent the same thing happening again.

So, we expect to see some reshaping of supply chains, which will involve investment outside of China. It's believed that about 35% of manufacturing currently performed in China could feasibly be moved to other countries in the region.

The EIPC has highlighted the fact that Europe's PCB manufacturers are facing energy costs several times higher than in Asia. The world market for PCBs in 2022 was estimated at $82 billion. While the European and US share is 2% and 4% respectively, more than 54% of production happens in China. The EIPC sees a real risk that Europe's share will reduce further. UK aerospace and defense OEMs are concerned that the local PCB industry's technical capabilities and production capacity could become insufficient to supply its needs.

A white paper by ASD Eurospace suggests that the European Chips Act is too narrow in scope and that industrial policies effectively marginalize electronics manufacturing. While the corresponding US act has similar limitations, the ASD Eurospace paper acknowledges various US support initiatives for electronics assembly, PCB fabrication, and chemicals production. Some specific frameworks such as the American Printed Circuit Boards Act have not yet successfully passed into legislation. Efforts to reshore PCB manufacturing in the US face additional barriers such as environmental restrictions that block the production of certain necessary chemicals.

The reality today is that the ability to build advanced electronic products independently in the West has become seriously depleted. Moreover, it is impractical and uneconomical to bring it all back as urgently as appears necessary. However, that quest needs to begin. With the ultimate objective being to establish independence and self-reliance for political reasons, it is realistic first to focus on establishing resilience for practical purposes.

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

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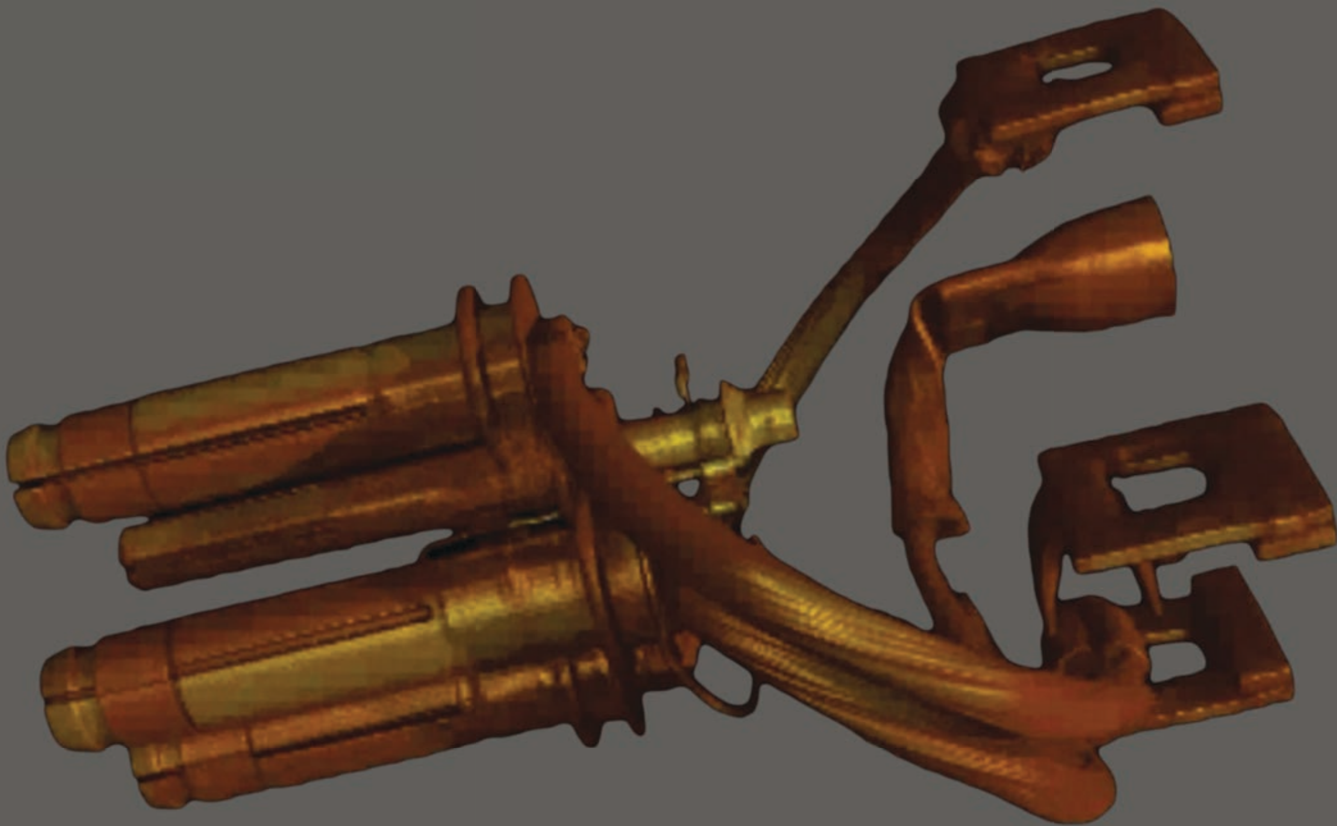

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When it comes to high speed, rigid-flex is very capable of meeting the challenge. It all comes down to good design and material selections.

For the high-speed signals, think in all three dimensions. Map out which layers carry these signals. Rigid and flex layers will have different dielectrics and copper types. If all the high-speed signals reside within the rigid layers only and do not span the flex region, concentrate just on those rigid layers and associated materials. For this discussion, however, let's assume that one or more of the flex layers will be involved.

On the rigid layers, you may select from a wide range of rigid copper clad laminates as well as various copper profiles just as you would for a rigid PCB. Manage loss by selecting low-profile coppers and low-loss tangent laminate.

On the flex layers, we get to enjoy a couple of advantages right out of the gate. The polyimide film substrate is very low-loss, with a Df in the 0.002-0.003 range. That is coupled with a rolled annealed copper (if 0.5oz. or thicker), the lowest profile copper available.

Two areas require careful material selections in order to meet loss budgets. These are the prepreg and any flexible coverlay or bondply.

For the prepreg, board fabricators will typically use a no-flow prepreg throughout the stack-up, especially if the board is a single lamination construction. This is because not all prepreg materials have the same lamination profile. The good news is that a few material suppliers have developed low-loss no-flow prepreg materials over the past few years, which has helped tremendously.

In some cases, when a construction requires multiple laminations, it opens options after the first lamination to use standard-flow prepreg. That means you could once again choose most anything for those outer layers to satisfy signal integrity. Just keep in mind that your fabricator will not have qualified every material from every supplier, so consider generic callouts to allow a selection of materials they have experience with.

In the flex region, standard flex coverlay and bondply do not have good loss tangent values. To combat this, we can select alternate flexible materials developed specifically for low-loss. These will have Dk values in the 0.002-0.004 range.

Coupling these various material sets together permits a design that is fully capable of carrying high-speed signals throughout the system with minimal insertion loss. Now you can concentrate on the circuit design. All the standard design practices for circuit layout still apply. You will still want smooth flowing conductors without sharp corners or turns and you will need to model trace pairs for the optimal line width and spacing.

If backdrilling is needed for stub-length reduction, that can be accomplished as well. The one caveat here is that if the critical signal is on a flex layer, it will be difficult to cut the adjacent copper layer using backdrilling. This is because the flex laminates run thinner than rigid laminates, so the adjacent layer is much closer. Total stub length will remain the same, but not all layers you want to disconnect may get cut.

Another consideration when it comes to rigid-flex is whether to incorporate cross-hatch patterns on the reference planes. As we have discussed in past columns, cross-hatch planes are sometimes employed to achieve impedance values while keeping the flex as thin as possible. This has proven to work very well in many applications. However, modeling and testing tells us that as frequency rises, insertion and return losses rise rapidly when cross-hatch planes are used. It appears that at frequencies of 1GHz and above, the losses will be too excessive to use cross-hatch planes.

Hopefully you see it is very possible to use rigid-flex in high-clock-speed applications. Also, an intrinsic advantage of rigid-flex is that it eliminates signal disruptions due to the use of connector and solder joints when comparing a rigid PCB and wire harness to a rigid-flex. In the end, signal integrity, speed and skew are improved in a rigid-flex design. All that in a lighter weight, more compact and more reliable package solution. Your boss should give you a raise for all the money you are going to save the program!

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

ROUGHLY **SPEAKING**

Datasheets, Unveiled

Smooth copper isn't always what it is purported to be.

I ALWAYS TRUSTED datasheets. Why shouldn't I? Every time I picked one up, I understood they were harbingers of truth about what something did and how to interact with it. From chips to components to widgets, manufacturers have a vested interest in ensuring users know what and how to use their products.

My trust in datasheets was eviscerated the very week I entered the printed circuit board industry. I was attending a weeklong training session on signal integrity taught by Eric Bogatin when he surveyed the attendees about datasheets and their accuracy. While my memory of the day and exact content isn't perfect, I do recall that as the very moment I learned the harsh reality: Datasheets are sometimes not as accurate as one would hope! (As an aside, Eric Bogatin's books on signal integrity are excellent resources because he has that special gift of teaching and explaining complex topics in approachable and understandable ways. The concept of "being the signal" and walking down a transmission line is just fantastic.)

With that established, I will backtrack a bit and say datasheets indeed can be trusted, but it is important to understand the capabilities of the test method being used, the reason why it is used, and the terminology involved.

For the PCB designer and fabricator, laminate datasheets are a good starting point for understanding how material will behave before, during and after fabrication and assembly. While the fabricator is primarily concerned with the mechanical properties, such as glass transition temperature, peel strength, etc., a designer is likely concerned with signal integrity and as such will be focused on a few key parameters:

- Roughness profile of the copper
- Dielectric constant/permittivity (Dk) of the resin/filler/glass combination
- Dissipation factor/loss tangent (Df) of the resin/filler/glass combination
- Glass weave for skew effects.

For the moment, we are going to focus on the copper roughness. As a designer, if you start with a material datasheet, you might see a side column section describing the available copper roughness types. There are no standardized industry terms, unfortunately; only marketing terminology to describe roughness types. There are some common ones, though, but how can one hope to comprehend the roughness profiles when the variety of marketing terminology gets extreme: reverse treat foil (RTF), very smooth profile (VSP), very low profile (VLP), hyper very low profile (HVLP), almost no profile (ANP), etc. These can get confusing fast!

Following Bogatin's approach, let us "walk the path" with a sheet of copper foil, freshly manufactured, to help understand what happens when we read about a 5-mil copper-clad core (CCL) with HVLP (or choose your preferred roughness term). Keep in mind, this journey is meant to convey the concepts, not necessarily the exact processes and order at each step along the way.

We start our journey as a copper sheet just after being created. After all, we wouldn't have been awake yet for being pressed through giant rollers or chemically built up through electrodeposition. As this copper, fresh from the fabrication process, we will be tested for quality control and be assigned to certain lots. The methods for measuring the profile are either mechanically or optically performed, and the results presented as averages for the lots of copper foil types with the methods used on datasheets.

Boom, shuffle, shuffle, screech.

Next, we are arriving at a laminate supplier, which takes our nice "perfect" sides and processes them. Via a process conceptually similar to what the PCB fabricator will do for the entire board, the copper is bonded to the resin, glass and filler that make up the laminate, resulting in the copper-clad laminate (CCL). Now our sides aren't exactly what they were when we left the copper factory, and the inner portions of our sheets of foil attached to the outer sides of the resin, glass and filler are no longer accessible for measuring. But at least they won't change anymore!

Boom, shuffle, shuffle, screech.

Now we are arriving at a printed circuit board manufacturer which is going to take the CCL that we are part of and process us further. We will be subjected to harsh etching chemicals to tear away sections of unwanted copper, leaving behind only the desired traces and planes. A plating process may add more copper for our vias or increase us to the desired thickness. Along the way, we will be processed with some form of oxide, oxide alternative or micro-etch treatments to 1) improve adhesion to the resin, filler and glass combination that is the b-stage laminate (prepreg) and 2) prevent corrosion. Unusual, to be sure, but a horror story I once heard involved a fabricator taking sandpaper to a sheet of copper to "improve" its roughness profile for mechanical adhesion.

Together with other CCLs and prepregs, we are put in a press and heated. The prepregs get gooey and stick to us, cool and harden. At this stage, quality control tests will be performed to verify the mechanical and electrical properties of the board are in compliance with the customer's specification. Once passing, we are done and ready to be sent to assembly where components will be soldered on to us.

So, to review the journey, the copper has been through multiple steps altering the surface at different locations and has resulted in a unique surface profile that we no longer have full access to measure. The only options now are to take cross-section cuts of the board and make side profile measurements of that slice or to make electrical signal integrity measurements of the impedance and scattering parameters.

A lot of thought has gone into correlating mechanical surface profiles to electrical characteristics over the past 70 years, from the Morgan model in 1949 to newer methods like the Huray surface roughness model. But these simulation methods require good data to match with the final board electrical measurements. Since passing from the copper supplier, we have had two different manufacturers make modifications to the surface profile. Do those coppers still have the same roughness profile as our initial datasheet? Hint: Not likely!

If you are a designer who cares about the surface roughness of the copper on your boards, talking with your PCB fabricator to get an idea of what kind of surface roughness you can expect for your final board is important. You may request and pay for some of the smoothest coppers to be put into your board, but if you aren't paying attention to what your fabricator is doing with it, you might just be throwing money away.

GEOFFREY HAZELETT is a contributing editor to PCD&F/CIRCUITS ASSEMBLY. He is a technical sales specialist with more than 10 years' experience in software quality engineering and sales of signal integrity software. He has a bachelor's degree in electrical engineering; geoffrey@pcea.net.

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THERMAL MANAGEMENT

Onderdonk's and Preece's Equations: How Do They Compare?

Two unique equations can be used when fusing a trace – each offering its own strengths and weaknesses.

by DOUGLAS BROOKS, PH.D.

Up until about 10 years ago, when PCB designers searched for information about the current needed to melt a trace on their boards, only two names popped up in the literature, W. H. (Sir William Henry) Preece and I. M. Onderdonk. Each is credited with developing a unique equation, bearing their respective name, and those equations became the basis for many PCB calculations.

Preece's background is considerably well known. In the 1880s, he was a consulting engineer for the British General Post Office and became engineer-in-chief in 1892. At that time, the Post Office was responsible for the telegraph (and later wireless telegraph) system in England. He published three papers in the Proceedings of the Royal Society of London in the 1880s that formed the basis for his famous equation[1]:

$$I = a * d^{3/2}$$

EQ. 1

where d is the diameter of the wire in inches

a is a constant (10244 for copper), and
I is the fusing current in amps.

Interestingly, in the 1890s, Preece became an ardent supporter, both politically and financially, of Guglielmo Marconi and his work on trans-oceanic wireless telegraph.[2]

On the other hand, almost nothing is known about Onderdonk. I have found no earlier reference than a small article in a 1928 issue of the *General Electric Review* by E. R. Stauffacher.[3] Onderdonk's equation is referenced a few places in the literature, and it is always quoted as a "given" (much like we take Ohm's law as a given.) I have found no original work by Onderdonk.

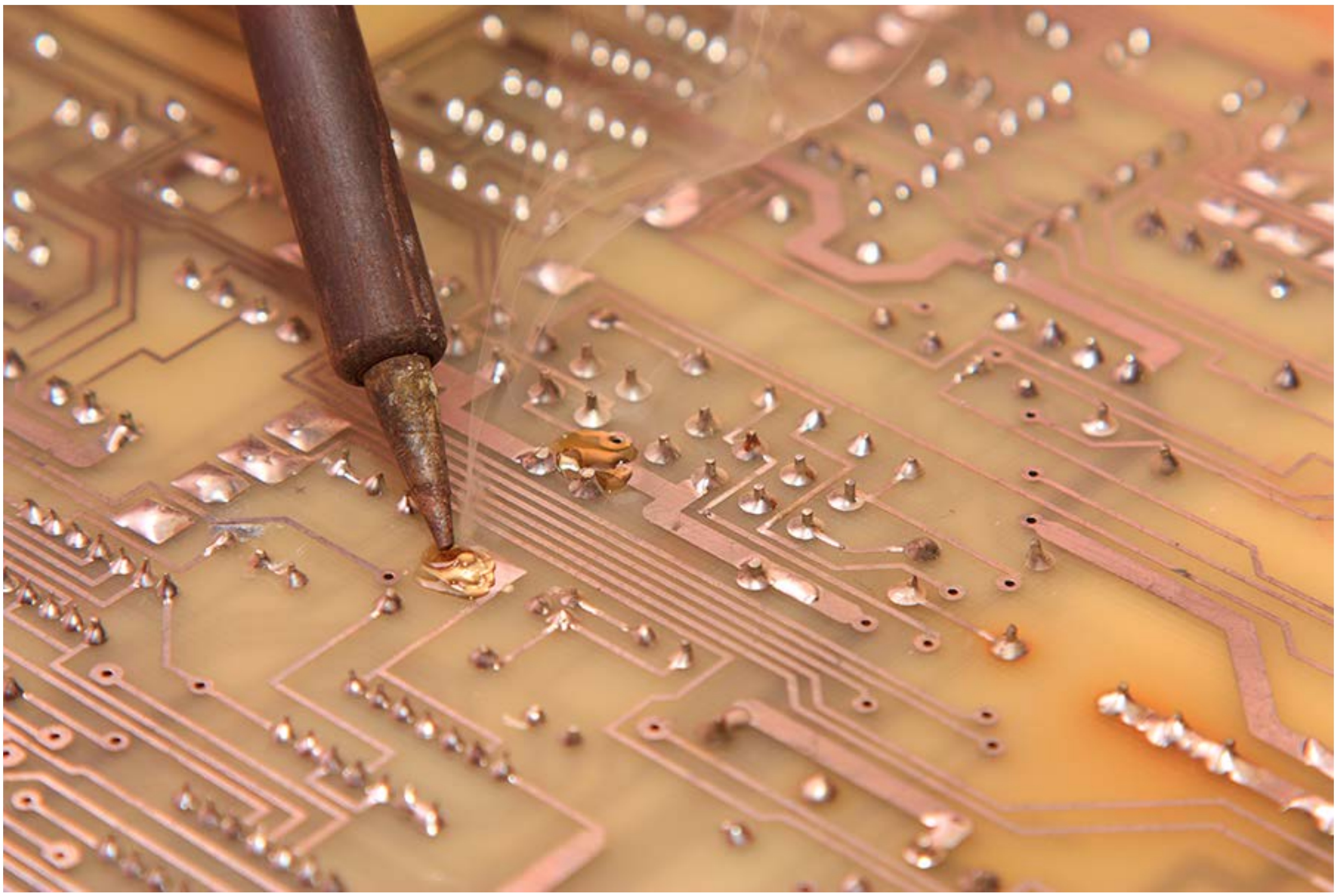

Figure 1. Reaching the point of fusing on the printed circuit board.

Objectives

Preece's objective in developing his equation is clear. He was concerned about how the electrical energy from lightning strikes may travel along the telegraph wires and injure an operator. He was looking for the best conductor material that would a) carry sufficient current under ordinary conditions for the telegraph system to operate yet b) fuse (melt) if a lightning strike caused a current surge. He tested a large number of potential candidates and developed the constant, a, (Eq. 1) for each.

Since we have no original work by Onderdonk, and since Stauffacher's article is the earliest we can find, we infer from Stauffacher that Onderdonk was motivated by a similar problem. The supporting towers for long-distance electrical transmission lines were themselves supported by steel cables anchored into the ground. These cables got covered with dust through time. During periods of rain, the damp wires could conduct large electrical spikes, shorting the transmission line to ground. The question was how large did the transmission line wires need to be to "not melt" long enough for the safety equipment to safely shut down the transmission line?

Interestingly, at this time, Stauffacher worked for Southern California Edison, and the power company was building a long transmission between Southern California and Henderson, Nevada, to support the construction of Hoover Dam. It is possible that Onderdonk created his (her) equation to support that work.

Procedures and Limitations

Fusing (melting) a conductor involves two stages, each taking a certain amount of time and energy. The first is to bring the temperature of the conductor *to* the fusing (melting) temperature. The second is the time and energy required for the sample to actually melt while at the fusing temperature. This second stage is called the Heat of Fusion.

Preece appears to have been a lab rat. His papers disclose that his procedure was to pass a current through a test sample. He increased the current until the sample glowed a bright red. Just before the sample melted, he recorded the current and called it the "fusing current." Clearly, this was the current needed to bring the sample *to* the fusing temperature (in his judgment), but not high enough to actually melt the sample. The *time* to reach the fusing temperature was never a consideration.

Onderdonk, on the other hand, developed his equation rigorously through mathematical derivation.

No original derivation by Onderdonk exists that I have found. But Dr. Johannes Adam has independently derived Onderdonk's equation and it has been published in two places.[4] This derivation explicitly excludes the heat of fusion, and it explicitly assumes Joule heating through I^2R dissipation but no cooling whatsoever.

Equations

Preece's equation is straightforward (Eq. 1). He developed constants for many different materials, but the one of interest to us is the constant for copper. That results in Eq. 2:

$$I = 10244 * d^{3/2}$$

EQ. 2

where, again, d is the diameter of the wire in inches and I is the current in amps. A little algebra transforms this equation into:

$$I = 12277 * A^{3/4}$$

EQ. 3

Where A is the conductor cross-sectional area in sq. in.

For example, let's assume a 1.0oz, 100-mil wide copper trace and see what Preece's equation gives us for the fusing current.

I = 12277*A3/4 = 12277 (.0013*.10)3/4 15 Amps

Onderdonk's equation is much more complicated.

$$33\left(\frac{I}{A}\right)^2 t = \log_{10}\left(\frac{\Delta T}{274}+1\right)$$

EQ. 4

for T = 40°C, but occasionally in the more general form:

$$33\left(\frac{I}{A}\right)^2 t = \log_{10}\left(\frac{\Delta T}{234+Ta}+1\right)$$

EQ. 5

Where:

I = the current in amps

A = the cross-sectional area in circular mils[5]

t = the time in seconds the current is applied

ΔT = the rise in temperature from the ambient or initial state

Ta = the reference temperature in °C

We are interested in knowing the fusing current for copper and the time it takes to reach the fusing current at any given current level. Thus, we can do some significant simplifying. Let the ambient temperature be 20°C and the melting point of copper be 1083°C. Then convert A from circular mils to square mils. When we do that, we derive Eq. 6[6]:

$$t = .0346*(A/I)^2$$

EQ. 6

As an example, assume an application of a 15A current to a 1.0oz. thick, 100-mil wide copper trace. Onderdonk's equation would predict a fusing time for that trace to be:

$$t = .0346*((1.3 * 100)/15)^2 = 2.6 \text{ seconds}$$

Relationship between the Equations

Preece's equation gives a relationship between fusing current and conductor area. Onderdonk's equation gives a relationship between fusing current and conductor area, and adds information in the form of fusing time. It is instructive to see that these two (completely independent) equations result in reasonably consistent results. In the examples above, Preece's equation calculated a 15A fusing current for our trace. Onderdonk's equation calculates that that current will fuse the trace in 2.6 sec. Given the nature of the assumptions made in the Onderdonk derivation and the testing apparatus Preece had available to him in the 1880s, these are very reasonable results.

Relevance of the Results

A significant weakness in Onderdonk's derivation is the implicit assumption that no cooling is taking place. Almost everywhere we see this equation published, there is an admonishment that the time estimate is only accurate up to about 10 sec. That is because it applies to a wire suspended in the air. After that time, the "zero cooling effect" assumption breaks down. We have simulated a bare wire in the air with zero cooling and the results fit Onderdonk's equation perfectly.[7]

Preece's notes don't provide much of a clue about how he applied the current to his samples or how long he spent with each sample. Nevertheless, his results are reasonably compatible with Onderdonk's.

Dr. Adam and I have run many fusing simulations and experiments on PCBs and have found that in this environment (printed circuit board substrate) the cooling effect kicks in very quickly, less than 1.5 sec. Nevertheless, we feel we can estimate fusing times on PCB out to four or five seconds within a reasonable tolerance.

It is interesting to note that if we calculate a trace temperature for a 1.0oz., 100-mil wide copper trace with 15A current using equations derived from IPC-2152[8] results, we get about 180°C, not the melting temperature of copper. The difference is that the calculations using the IPC-based equations *do* assume cooling is taking place.

NOTES

1. These references are very hard to find. I have collected them for download at www.ultracad.com/articles/reprints/preece.zip.
2. A very interesting book covers this time in Marconi's life and his support from Preece, as well as a parallel murder story and how these two stories intersected in 1910. See Eric Larson, "Thunderstruck," Crown Publishers, 2007.
3. E. R. Stauffacher, "Short-time Current Carrying Capacity of Copper Wire," *General Electric Review,* vol. 31, no. 6, June 1928 (www.ultracad.com/articles/reprints/stauffacher.pdf).
4. See Douglas Brooks and Johannes Adam, *PCB Design Guide to Via and Trace Currents and Temperatures,* Artech House, 2021, Appendix G, and also Johannes Adam white paper No. 10, www.adam-research.de/pdfs/TRM_WhitePaper10_AdiabaticWire.pdf.
5. A circular mil is the area of a circle with a diameter of one mil. The formula is $A = d^2$. The conversion from circular mils to square mils is π/4.
6. For details and derivation steps, see references in Note 4.
7. See Brooks and Adam, Note 4, Chapter 12 for more in-depth information.
8. IPC-2152, "Standard for Determining Current Carrying Capacity in Printed Board Design," August 2009. Calculations were made with UltraCAD's UCADPCB4.3 Calculator, available for free download from ultracad.com.

DOUGLAS BROOKS, PH.D., has bachelor's and master's degrees in electrical engineering from Stanford and a Ph.D. from the University of Washington. He owned an engineering service firm and has published multiple books, including *Physics of Electronics for PCB Designers* and *PCB Design Guide to Via and Trace Currents and Temperatures;* doug@ultracad.com.

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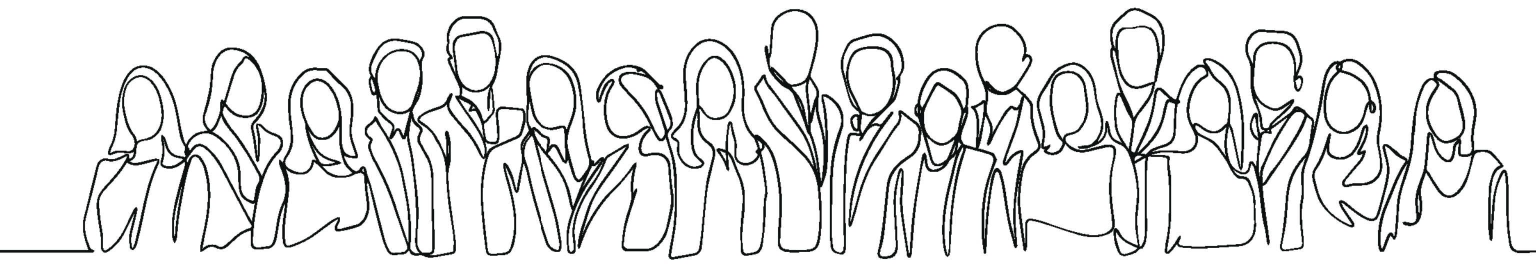

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HEAT TRANSFER

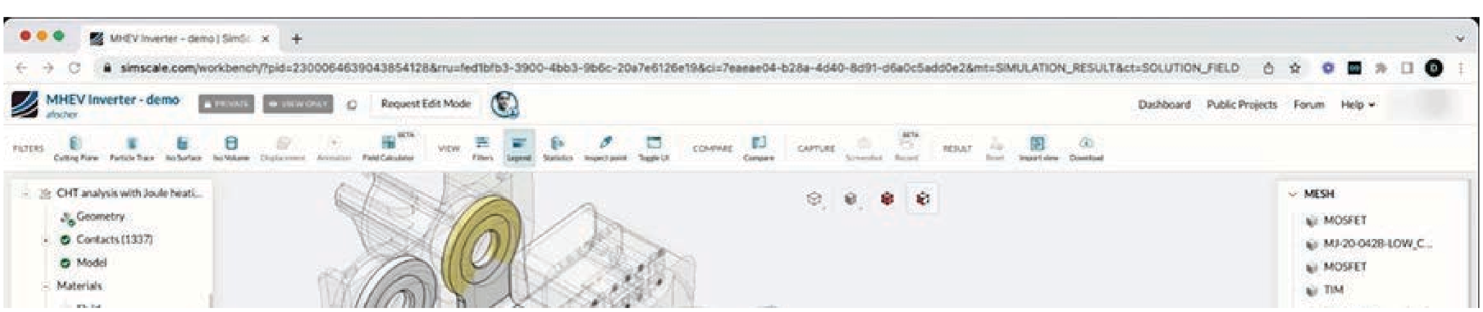
Simulating Electronics Components in the Cloud

Methods for assessing component temperatures and fan performance.

by ALEX FISCHER

Cloud technology has become increasingly prevalent, allowing use of 3-D models and numerical methods to analyze CAD models of electronic devices and components. Numerical computations of conduction, convection and radiation are essential for understanding how these heat transfer mechanisms can be utilized for effective cooling techniques.

Advantages of cloud-native simulation include fast and easy access in a web browser, the ability to explore a complete design space and eliminate poor design choices earlier in the development process, and the ability to import geometry without tedious CAD cleanup constraints. The mesh for Immersed Boundary Method (IBM) solvers, for example, is founded on a cartesian grid, making it resilient to geometrical features and obviating CAD simplification. The sheer limitless computing power and scalability of the cloud means sharing simulation capabilities across a full organization of geographically dispersed engineers is simple and easy. Engineers can perform cooling, heat and fluid flow analysis of electronic devices, PCBs, electronics systems and enclosures along with structural and mechanical assessment using a single CAD model, all in one simulation platform.



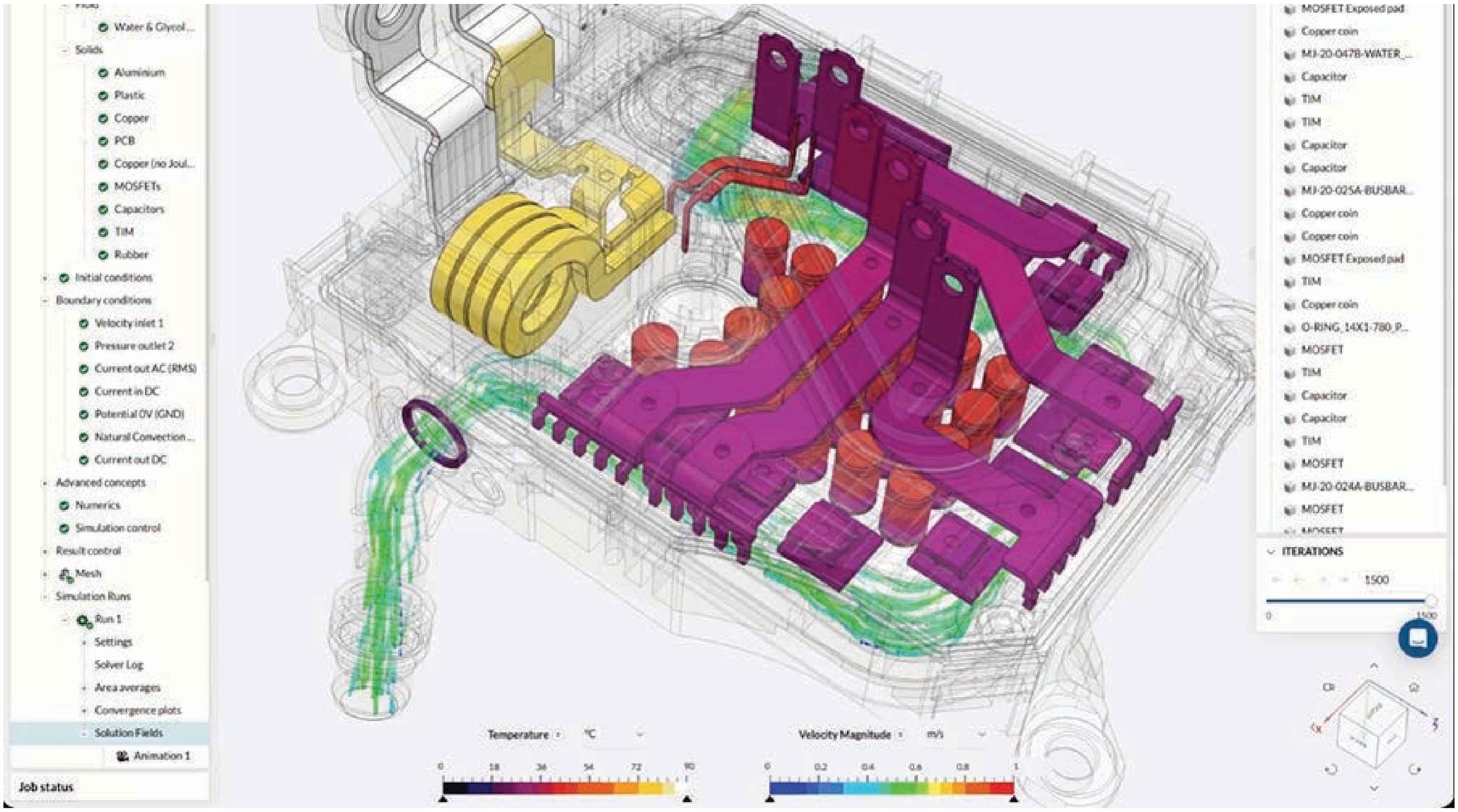


Figure 1. Joule heating simulation of an electric vehicle inverter showing temperature increase on the bus bars and electric components such as MOSFETs and capacitors.

Thermal Performance of a Raspberry Pi

A Raspberry Pi is simulated using a publicly available 3-D model of the device taken from GrabCAD. A conjugate heat transfer simulation with forced convection (fan) was used to model the computer using standard 30mm fans for cooling. Manufacturer data were used for the fan performance, with four different model types providing data on volumetric flow rate and pressure drop. Simulation tools can determine fan operating points and generate system resistance curves by performing a thermal flow analysis of a Raspberry Pi. Such tools can then be used to determine the system resistance curve and generate a flow rate study to derive the fan operating point, which is done simultaneously.

This approach is instrumental to assess *in-situ* fan performance in the system or device and optimally cool the heat generation from circuits and components. For the simulation setup, fan inlet and pressure outlet boundary conditions are used, the air is used for the flow region, and several materials are specified for the chips and electronic components, including copper, PCBs, silicon for chips and aluminum for heat sinks **(FIGURE 2)**. Power values represent the CPU (3W) and more minor chips (0.25W). The air inlet is ambient at 19.85°C, and a CSV file is used to upload the fan curve.

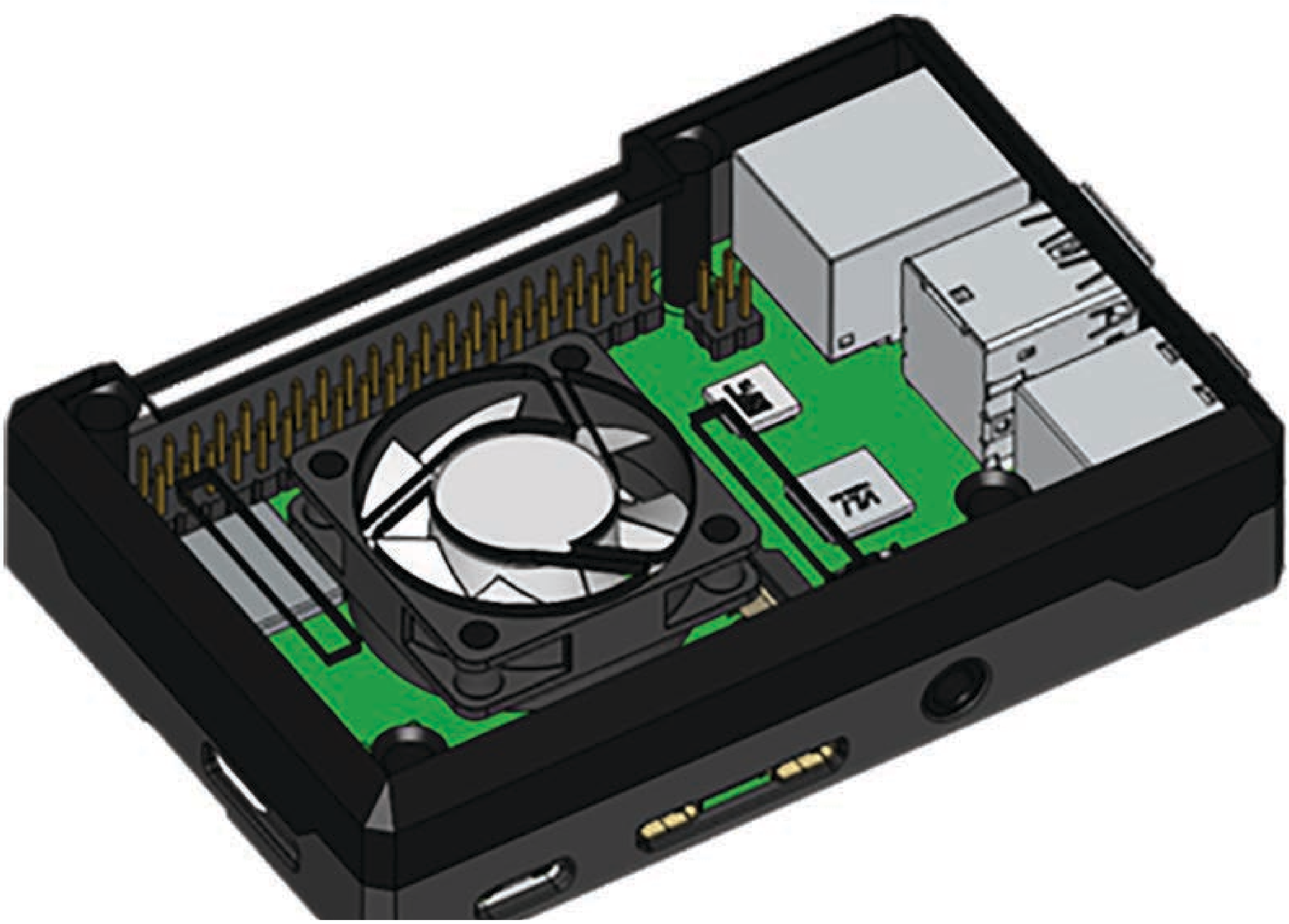


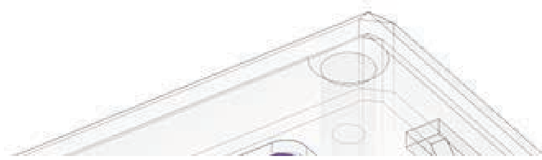
Figure 2. Raspberry Pi and a simplified version of the product CAD model for simulation. Images courtesy Michael H. (Laserlicht) / Wikimedia Commons (top) and Ankit Jangid (bottom)

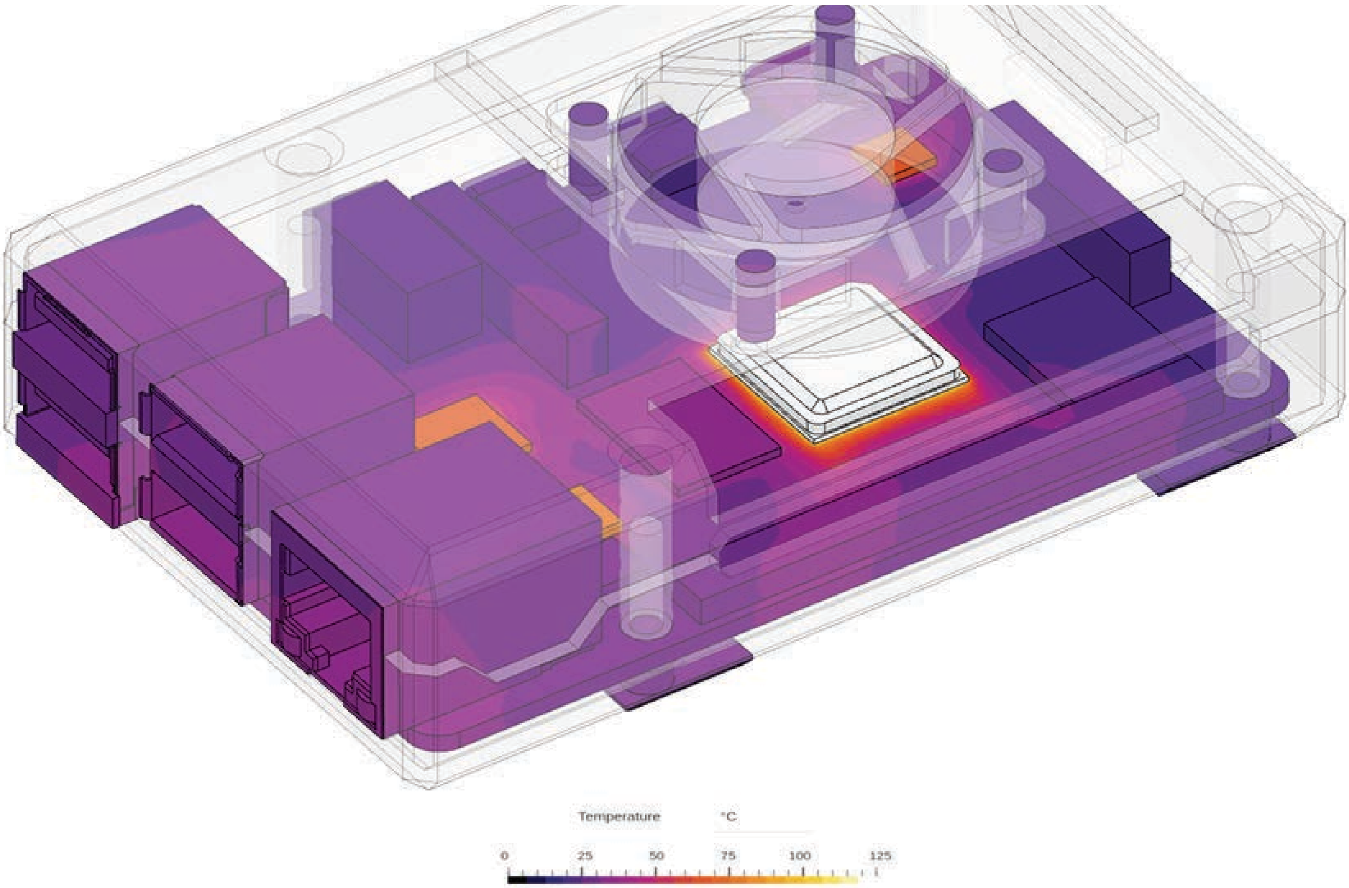
There are several ways (boundary conditions) to specify chip/component temperature or power values:

- Fixed or variable component temperature – a prescribed constant or variable temperature value can be applied to the assigned entities (faces or volumes). This is useful to model constant temperature heat sources or sinks, or to apply a known spatial distribution of temperature.
- Surface heat flux – a prescribed constant or variable heat flux per unit area can be applied to the assigned boundary faces on the geometry model. This is useful to model heat sources or heat sinks, where the power per unit area is known.
- Volumetric heat flux – a power per unit volume is applied to a component, useful when not able to model the component/chip physically.

Likewise, fan performance can be modeled several ways. A boundary condition where the fan inlet is placed can have a direct mass flow applied to it as a velocity inlet with appropriate fluid material properties and ambient temperature. Alternatively, a momentum source can be defined to represent the flow from a fan, and, most recently, engineers can upload fan-curve data in a tabular format directly and use it as a boundary condition. In the case of the Raspberry Pi, we have modeled two fan options (L and H) by taking manufacturer data.

We can visualize heat removal on the chips by looking at surface area average temperatures. **FIGURES 3** and **4** show up to 120°C on the CPU (max.). Users can extract point-specific data and pressure drop across air inlets and outlets and assess the chip cooling performance based on comparing multiple fans.




Temperature
°C
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25
50
75
100
125

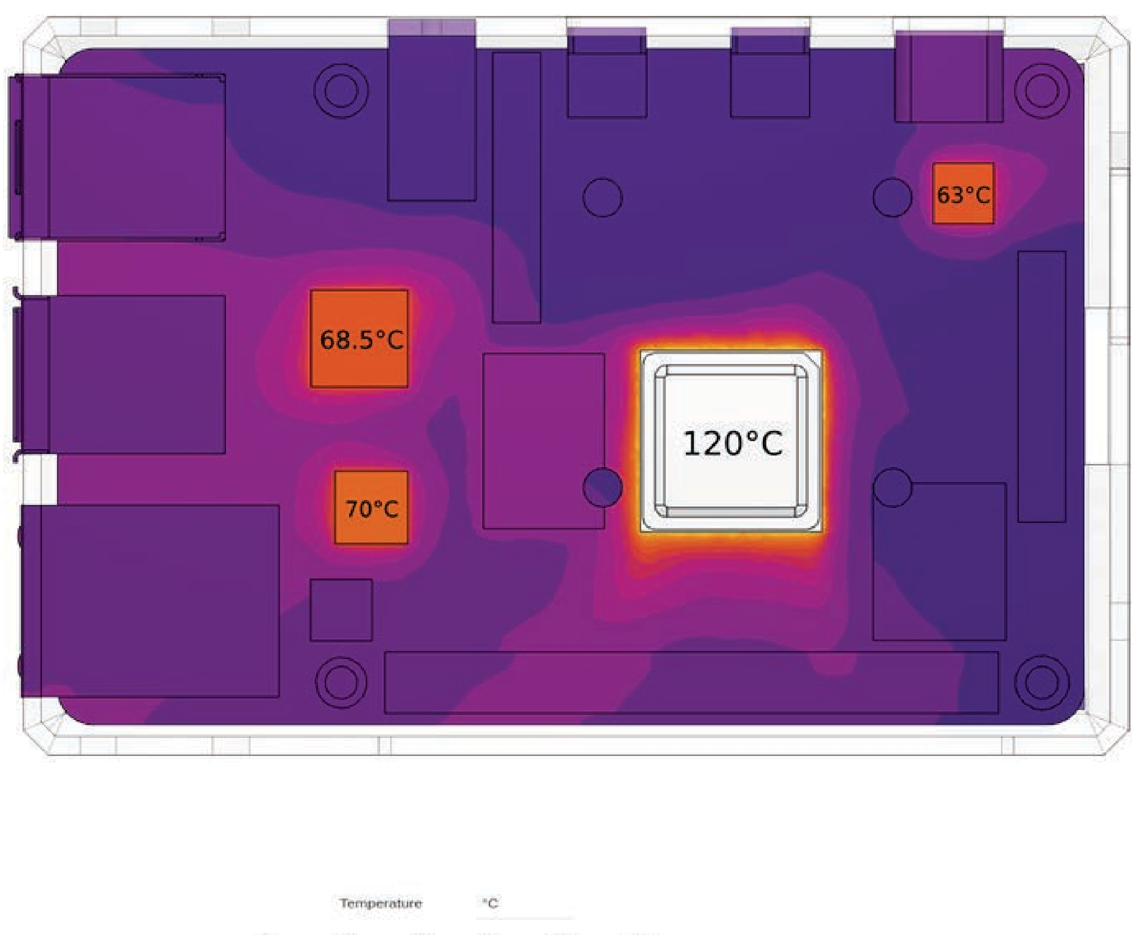

63°C
68.5°C
120°C
70°C
Temperature
°C
0
25
50
75
100
125

Figure 3. Visualization of temperature on solid domain, showing CPU chip at highest temperature (white/yellow).

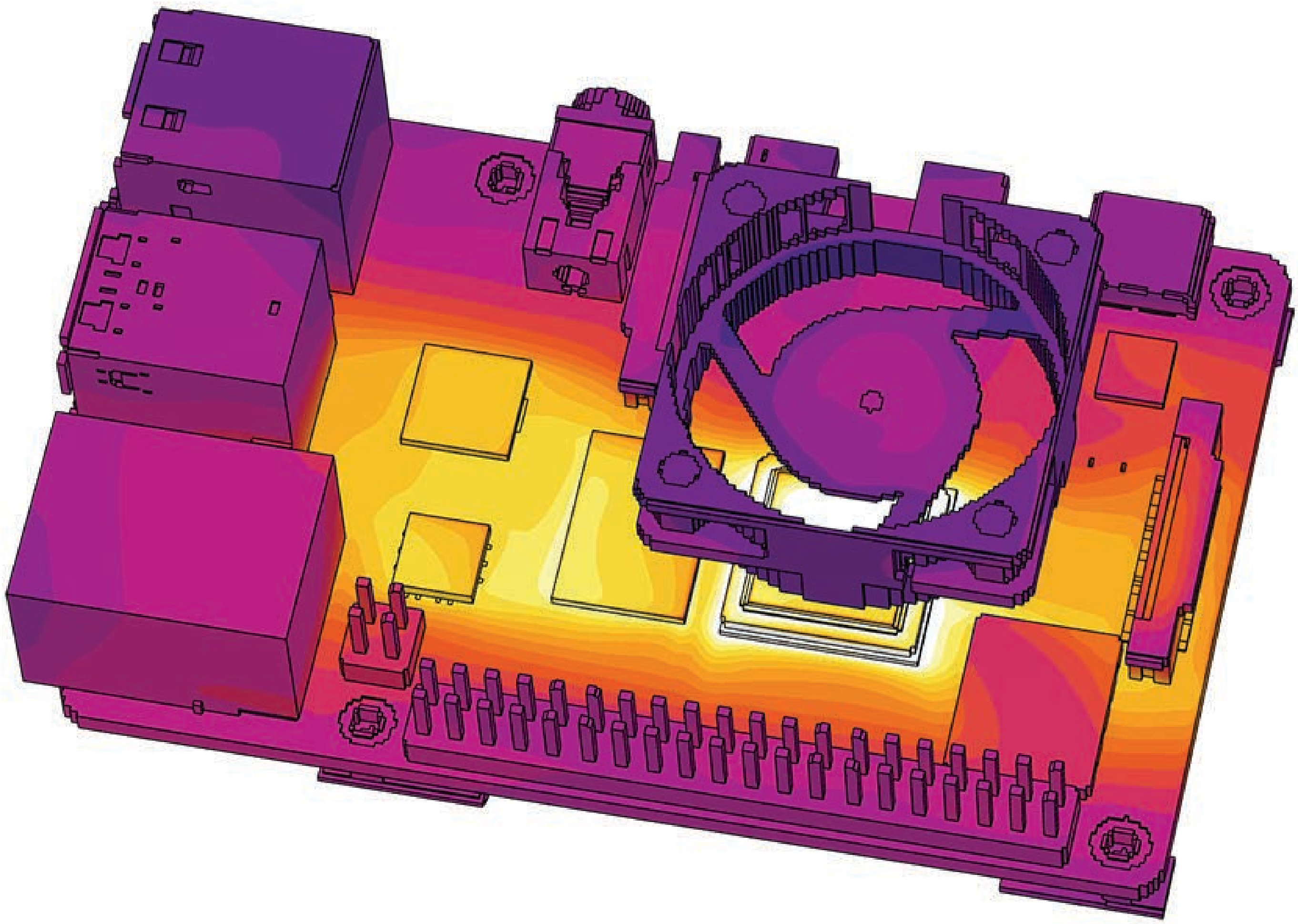


Figure 4. Visualization of temperature on solid domain, showing CPU chip at highest temperature (white/yellow).

Fan inlets show a 4.78 pascal (0.5mmAq) pressure difference at a flow rate of 7.55e-4m^3/s, and this matches the fan curve data sheet for the baseline model (L). The fan outlets are at 0 gauge pressure as intended. We can easily switch the fan curve data to simulate a more powerful fan (H) for comparison. Doing this shows a 10 pascal (1mmAq) pressure drop, but also a higher achieved flow rate cooling the components. The two are compared in **FIGURE 5.** Through this analysis, we can start generating a system curve for the enclosure (Raspberry Pi) derived from simulating various fan operating points (orange line in Figure 5). Running 10 simulations of different flow rates in parallel, we generated the entire system curve for the Raspberry Pi in 2 hr. Chip cooling performance based on comparing the two fans is also shown, with the more substantial model H fan better at removing heat **(FIGURE 6)**.

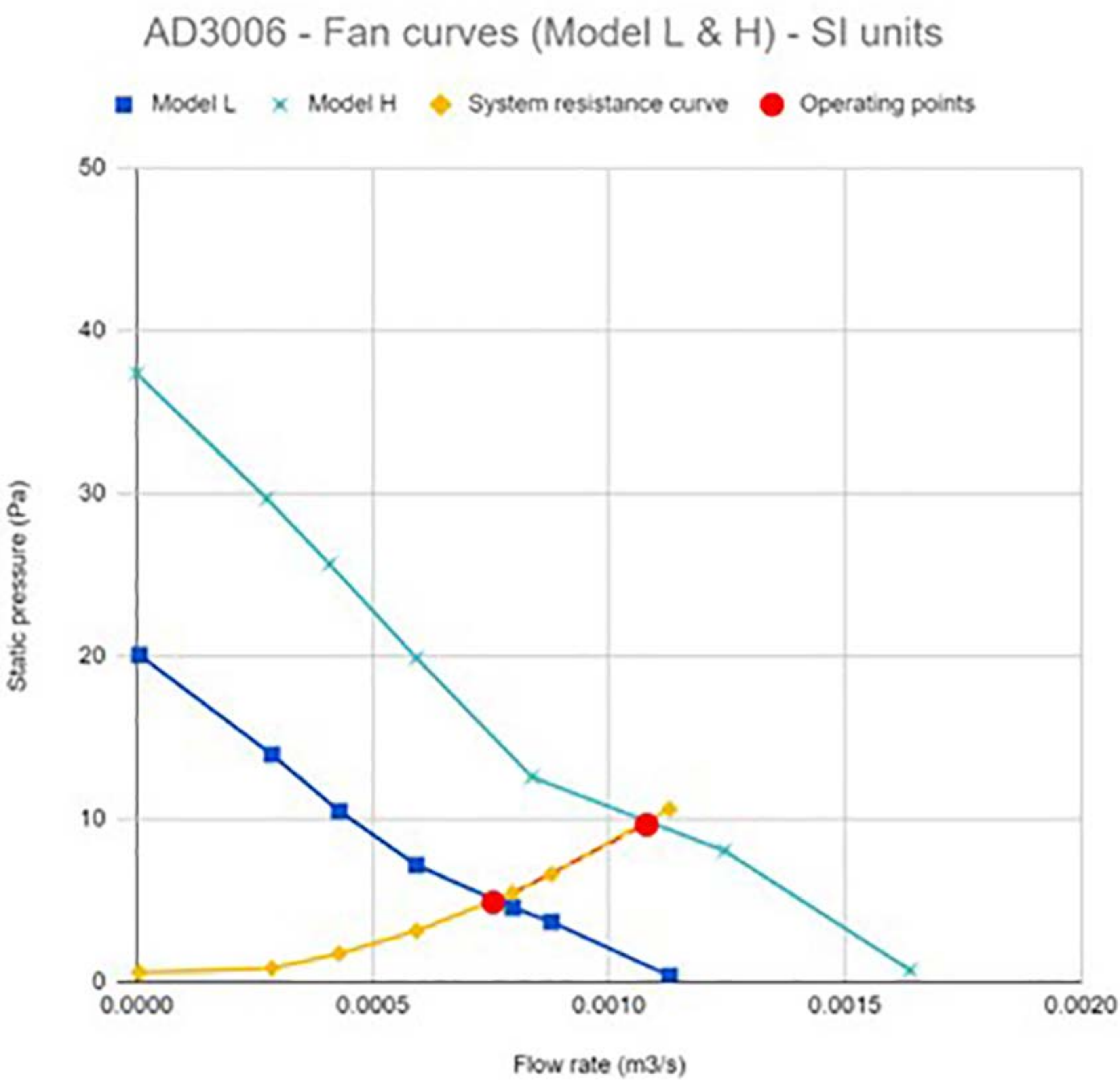


Figure 5. Fan performance curves and Raspberry Pi system resistance curve for different fan models for comparison purposes.

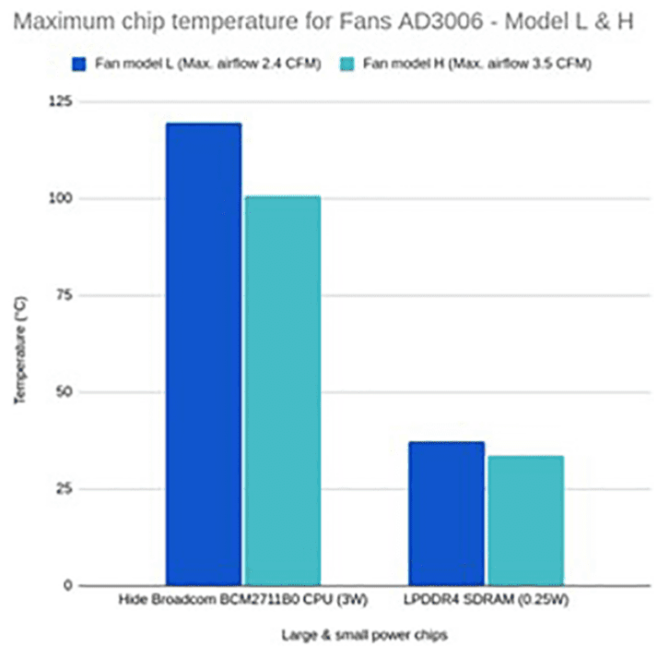
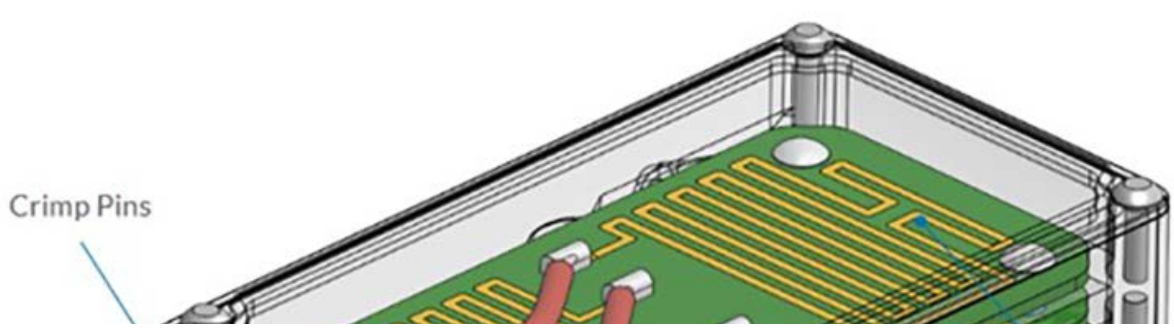


Figure 6. Chip temperature model L vs. model H; H gives lower temp with higher flow rates (CPU).

Heat Flux Across a Resistor

Resistors are used to protect other components in an electric circuit with high voltages or current pulses using highly resistive materials, ideally in a compact structure. The power resistor model in **FIGURE 7** has four separate resistive conductor circuits and is used in vehicles to ensure the electronic control unit (ECU) for fuel injection does not overload from high current spikes. The full 12V potential is connected and provides the required high opening current of 22.6A, but the components cannot withstand the high current load for long. The ~6! resistor circuits are added to the circuit with a switch and reduce the current below 2A. The component is mounted at a sheet metal component next to the engine and must only rely on natural convection cooling.



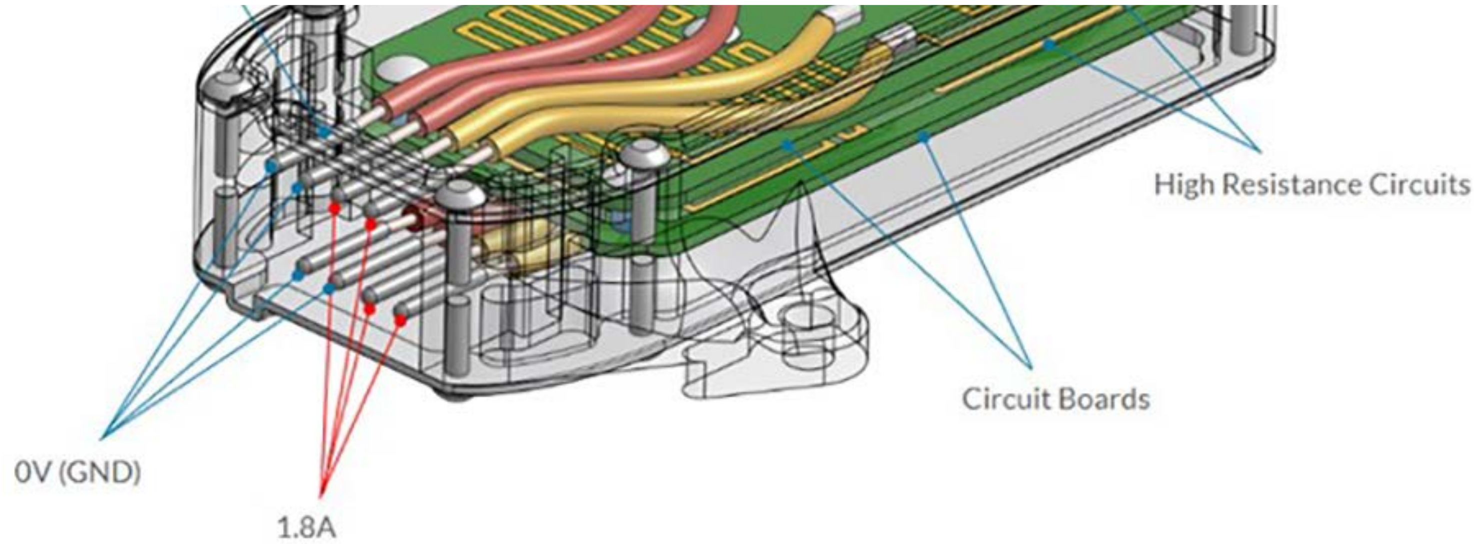
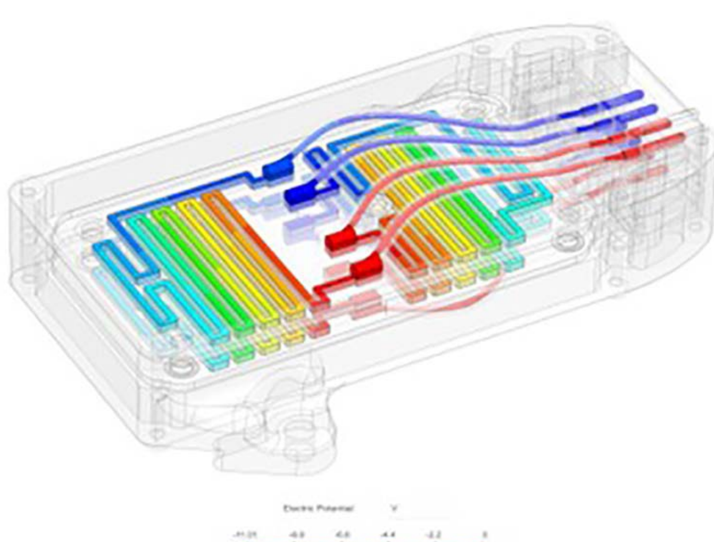


Figure 7. Power resistor device used in the fuel injection circuit in automotive applications.

The electric potential (voltage) gives insights into the voltage drop across electronic components and wires within the electric circuit and the expected voltage drop overall in case of a current drain-driven simulation. The electric current density (A/m^2) provides essential information about the electric current flow in the whole circuit and if current density spikes occur. The Joule heat generation (W/m^3) result field is used to judge the heat flux that needs to be considered when designing the thermal management solution for the system. Using internal statistical tools, the distributed heat load as well as the integrated total power loss on a part of the model can be extracted.



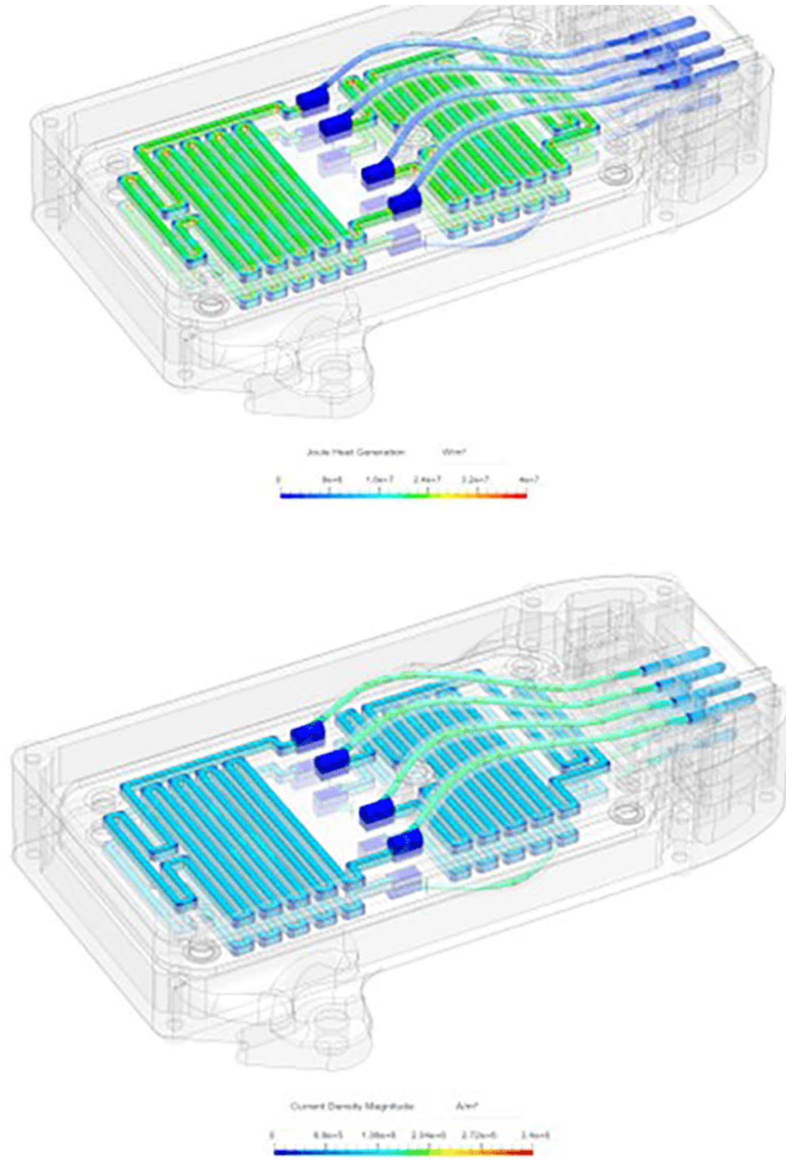


Figure 8. Joule heating simulation in SimScale, showing a) the electric potential, b) generated heat, and c) current density magnitude on the resistor (red indicates a higher value).

ALEX FISCHER is cofounder and product manager at SimScale (simscale.com) and leads the company's thermal management and electronics solutions; afischer@simscale.com. He has a background in computational mechanics and control technology, and has worked for 10 years in a range of product and engineering roles, building a fully cloud and web-based simulation platform.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PROCESS CONTROL

C_{pk} or P_{pk}? A Look at Using Both Capability Indices

Summary statistics can be misleading, but in different ways.

by Patrick Valentine, Ph.D.

C_{pk} and P_{pk} are numeric capability summaries of process or product characteristics based on common cause variation (due to chance) and assignable cause variation (special cause). Understanding these capability indices and their limitations is critical in pursuing world-class quality, “on target with minimal variation.” C_{pk} and P_{pk} indices are reviewed, and details on how to use them synergistically are provided.

Capability indices are numeric summaries that compare the behavior of a process or a product characteristic to customer specifications. Capability indices relate the customer specification limits (voice of the customer) to the natural process limits (voice of the process). Large index values imply that the process can produce parts that meet the customer’s specification limits. Small index values imply the process will likely produce some parts that will not meet the customer’s specification limits.

Process capability is a statistical measure of the inherent process variability of a given characteristic.[1] Capability indices are convenient numeric summaries. These indices reduce complex process information to a single number. Capability indices are unitless values, and can be used to compare the capability of different processes. Most process engineers and quality managers believe capability indices less than 1.00 are unacceptable, and many process engineers and quality managers consider 1.33 a minimum acceptable value for capability indices. Capability indices Ó1.50 are generally considered world-class quality, “on target with minimal variation.”

The most common capability indices are C_p | C_{pk} and P_p | P_{pk}. C_p measures short-term potential capability, while P_p measures long-term potential performance. C_{pk} measures short-term actual capability, while P_{pk} measures long-term actual performance. Potential and actual capability indices are related through k, which measures process centering (the process average).

C_{pk} and P_{pk} Indices

C_{pk} provides an index of the short-term actual capability. Actual capability is based on the process average and standard deviation (common cause variation only). C_{pk} is calculated as the distance to the nearest specification (voice of the customer) divided by three times the natural process limits (voice of the process; i.e., the standard deviation).

Common cause variation is based only on the variation within the subgroups. This common cause variation standard deviation is known as the within dispersion statistic and is denoted as $^{e}{}_{\text{Within}}$. The C_{pk} index seriously underestimates the total variation if the between subgroup variation is substantial.[1] Most end-users are concerned with all the variation in the process, regardless of its source. P_{pk} does not have this inherent underestimation flaw.

P_{pk} provides an index of the long-term actual performance. Actual performance is based on the process average and standard deviation (common cause and assignable cause variation). P_{pk} is calculated as the distance to the nearest specification (voice of the customer) divided by three times the natural process limits (voice of the process; i.e., the standard deviation).

Overall variation is comprised of both common cause and assignable cause variation. This common cause and assignable cause variation standard deviation is known as the overall dispersion statistic and is denoted as $^{e}{}_{\text{Overall}}$. The P_{pk} index estimates the total variation. P_{pk} accurately tells us “what the customer feels.”

Common and Assignable Cause Variations

Common cause. Causes of variation (due to chance) inherent in a process over time. They affect every outcome of the process and everyone working in the process.[2] An example of common cause variation is the minor temperature fluctuations of a heated electroless nickel bath due to normal cycling of the heater.

Assignable cause. A name for the source of variation in a process that is not due to chance and, therefore, can be identified and eliminated; also called "special cause."[2] An example of assignable cause variation is the major temperature fluctuation of a heated electroless nickel bath due to an operator bringing the tank level to volume by adding cold water.

With variation, the goal then is twofold: 1) continuously strive to reduce common cause variation, and 2) identify and eliminate assignable cause variation. All this effort is put out in pursuit of world-class quality, "on target with minimal variation."

Visualizing Capability Indices

Consider a car and a garage. The garage represents the specification limits (voice of the customer). The car represents the natural process limits (voice of the process). If the car is wider than the garage, it does not matter if the car is centered; the entire car will not fit in the garage (C_{pk} | P_{pk} < 1.0). If the car is the same size as the garage, the car must be centered and remain centered over time to get all of the car in the garage (C_{pk} | P_{pk} = 1.0). If the car is narrower than the garage, the car has some wiggle room and can be slightly off-center (C_{pk} | P_{pk} > 1.0). With a process that is in control and with little variation, the car can easily park within the garage. **FIGURE 1** is a visual image of these capability indices, with a C_{pk} of ~1.33 depicted.

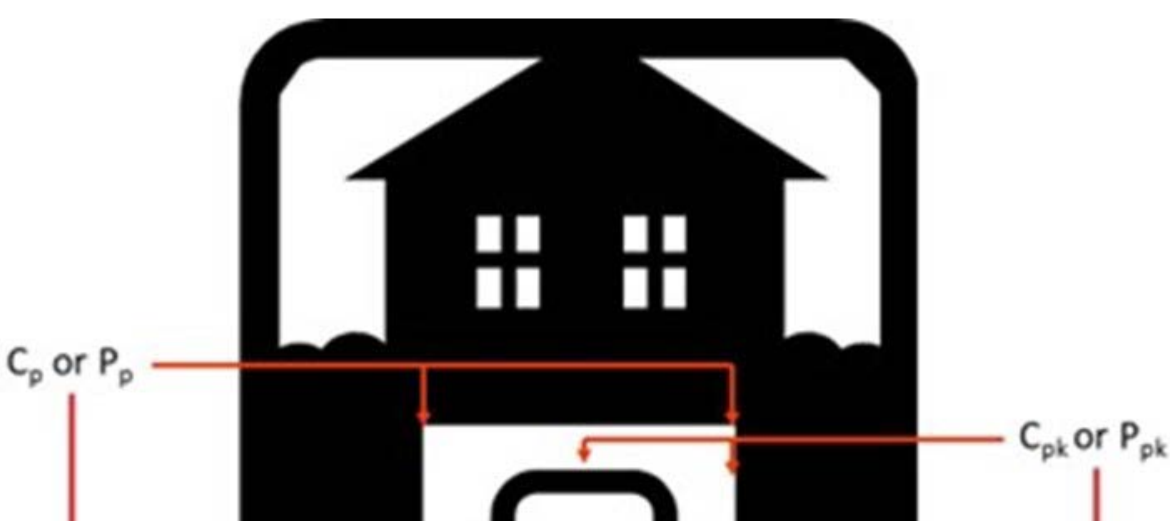
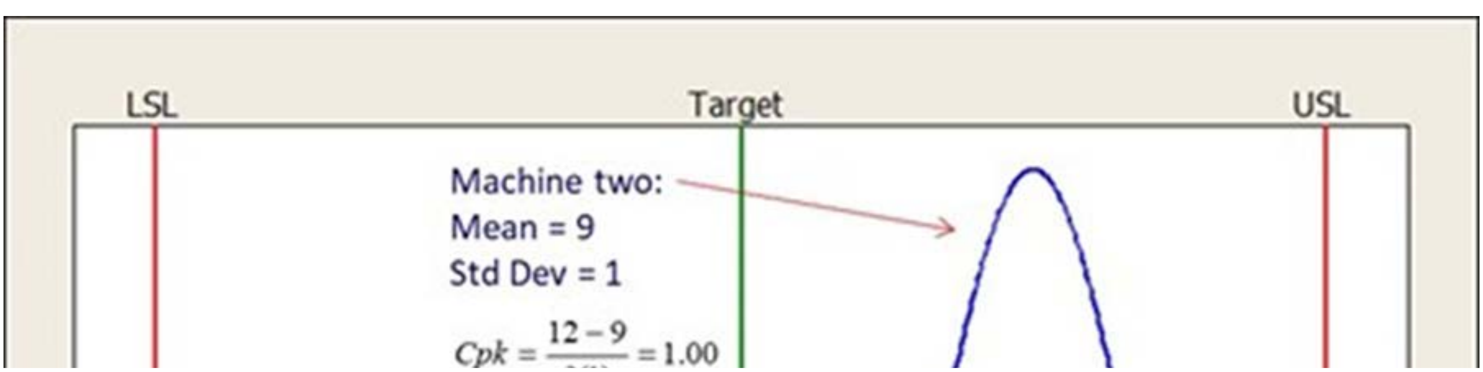


Figure 1. Visual depiction of capability indices.

In the car and garage analogy, C_{pk} | P_{pk} summarizes the relationship between the size of the car (process), the size of the garage (specification limit), and how far away from the middle of the garage the car is parked. The capability indices values can be considered as the amount the car can drift before hitting the nearest garage wall. Motorola postulated that every process, over many manufacturing cycles, could drift as much as 1.5^{e} .[3] Hence the need for C_{pk} | P_{pk} > 1.0. A C_{pk} | P_{pk} of 1.33 means there is approximately one-third of the car width between the side of the car and the nearest garage wall. And a C_{pk} | P_{pk} of 1.50 means there is approximately half the car width between the side of the car and the nearest garage wall.

Using C_{pk} and P_{pk}

Capability indices are convenient numeric summaries, but summary statistics can be misleading. For example, consider a factory with two machines (one and two) producing the same part. Both machines produce parts that have a C_{pk} of 1.0. This implies both machine outputs are equal, which may or may not be valid. In this example, it's not true. Machine one is centered but has a much larger voice of the process (standard deviation). Machine two is not centered but has a much smaller voice of the process (standard deviation); see **FIGURE 2.** The crucial point is don't be fooled; always graph your data.



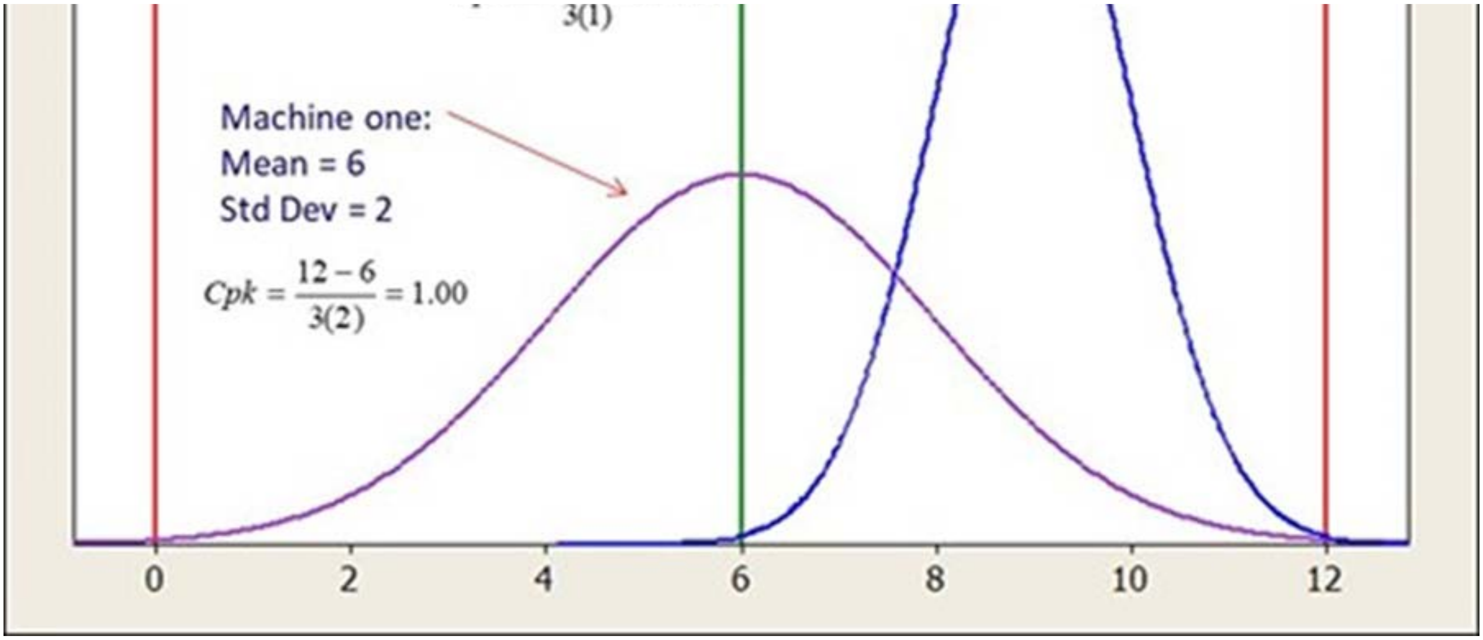


Figure 2. Machine outputs with identical C_{pk} indices.

C_{pk} and P_{pk} can be used together synergistically. C_{pk} provides an index of the short-term actual capability based on common cause variation only. P_{pk} provides an index of the long-term actual performance based on common cause and assignable cause variation. When C_{pk}' P_{pk}, the process contains only common cause variation. For example, a process output has a C_{pk} of 2.30. At face value, one could conclude world-class quality, "on target with minimal variation." The same process output has a P_{pk} of 0.31. In this example, C_{pk}˜ P_{pk}, the process contains common cause and assignable cause variation. C_{pk} seriously underestimates the total variation; see **FIGURE 3.** In this example, the process engineering team must first identify and eliminate the assignable cause variation, then strive to reduce the common cause variation.

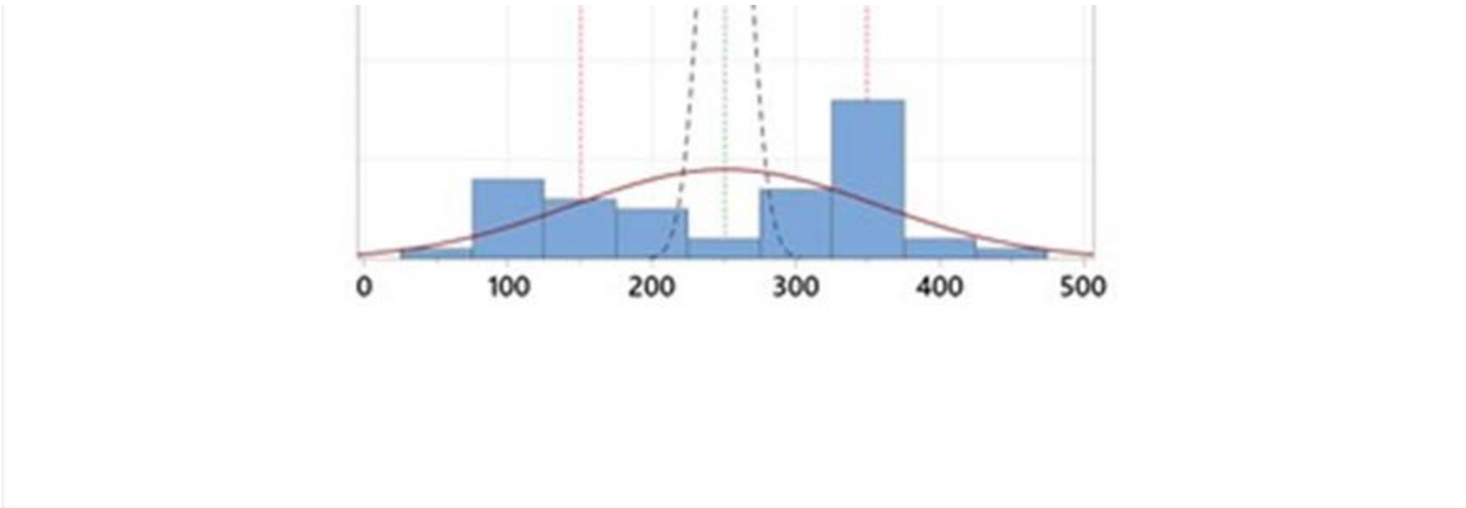


Figure 3. Process output with both common cause and assignable cause variation.

Conclusions

Capability indices are numeric summaries that compare the behavior of a process or a product characteristic to customer specifications. C_{pk} provides an index of the short-term actual capability but can seriously underestimate the total variation. P_{pk} provides an index of the long-term actual performance and does not have this inherent underestimation flaw. These summary statistics can be misleading, so always graph your data. In pursuing world-class quality, “on target with minimal variation,” one must identify and eliminate assignable cause variation and continuously strive to reduce common cause variation. The goal is to have C_{pk}’ P_{pk}, each with a value of 1.50 or greater.

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PATRICK VALENTINE, PH.D., is technical and Lean Six Sigma manager at Uyemura USA (uyemura.com); pvalentine@uyemura.com. He holds a doctorate in Quality Systems Management from New England College of Business and ASQ certifications as a Six Sigma Black Belt and

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CIRCUITS ASSEMBLY **TOP 50**

The West is Rediscovering India

The subcontinent explodes with new EMS work, prompting a spate of IPOs.

by MIKE BUETOW

Putting aside the obvious supply chain disruptions, the two big stories out of the EMS industry in 2022 were the emergence of India, led in particular by Apple's pivoting from China, and the number of IPOs.

While the Indian government is aggressively recruiting foreign electronics investment, there's no question India's appearance as a viable competitor to – dare we say it? – China is being driven by Apple. The world's most valuable company tripled its production to more than $7 billion of iPhones in what is now the world's most populous country during the past fiscal year,[1] mostly at the expense of China. Some reports hold Apple will raise India's share of its production to 25% in two years.

One of the winners was Pegatron, which beat out Foxconn for the India orders, and is reportedly investing $150 million in a second iPhone manufacturing facility in Chennai.[2] Luxshare, called little Foxconn by some, has also barged in, buying two of Wistron's plans in India, and projecting unit sales to more than double to nearly 50 million units this year.

Not to be outdone, Foxconn will invest a reported $700 million on a plant in southern India to make telecom components and possibly iPhones.[3]

The EMS operations of Salcomp, the Finnish maker of mobile chargers, currently are just under $500 million in India alone, and the company expects to surpass $2 billion in the country by 2025.[4]

It plans to double its workforce there to 25,000 in that time.

Contrarily, Wistron is bailing on India, with plans to sell its remaining plants to domestic giant Tata Group.[5] Tata is India's largest company, with revenues of $128 billion last year. Drawing a range of end-markets – aerospace, industrials, finance, IT, and telecom, among them – Tata is perhaps best known outside India for its auto unit, which brought in $44 billion in revenue in 2022. While its market cap is roughly one-tenth that of Apple, it appears to be taking advantage of Wistron's inability to generate profits from the iPhone business, which, coupled with well-publicized worker riots, pushed the Taiwanese ODM back to less challenging locales.

Not everyone is focusing on smartphones, or even going it alone. Reliance Industries, an Indian conglomerate, plans to invest 16.7 billion rupees ($221 million) to form a joint venture with Sanmina.[6] The new entity would make hardware for 5G communications, cloud infrastructure, healthcare systems, clean technology, and defense and aerospace, Reliance said.

Another ODM that is aggressively expanding is VVDN Technologies. The privately held company was founded by ex-Silicon Valley engineers in 2007, and now claims to be India's largest ODM.[7] In February it announced plans to invest $100 million over the next five years in a new 100-acre factory in Tamil Nadu. That plant will add PCB fabrication capability, rounding out the firm's vertical integration strategy.

Besides India, perhaps no other country has benefitted from the China migration more than Mexico. Foxconn, Pegatron, Wistron, Kimball, and NeoTech are among those adding capacity south of the US border.

Other Southeast Asian nations are also reaping the spoils. Foxconn (again), Pegatron (again), Luxshare, Key Tronic, Spartronics and others either added or plan to add capacity in Vietnam. GPV's largest plant is in Thailand, and it plans to expand the production area by some 75,000 sq. ft. in 2023, bringing it to 237,000 sq. ft. Not to be outdone, Plexus just opened a 400,000 sq. ft. site in Bangkok. And Fabrinet, which has the largest footprint of any EMS in Thailand, opened a 1 million sq. ft. building on its Chonburi campus.

Long an electronics power in its own right, Malaysia has set its sights on capturing a 15% market share of the global semiconductor and electronics sector by 2030, according to government officials.[8] Éolane is launching a new subsidiary in Penang.

Some perspective on how this may play out, however. As of the end of 2021, Thailand had fewer electronics enterprises than the Silicon Valley. Malaysia has a population of about 33 million. Thailand's is twice that, and Vietnam's is about 100 million. Based on that, plus its longstanding warm ties with the US, Vietnam is better positioned than most other Southeast Asian countries to attract Western electronics companies. And India is poised to trump them all.

If we look at the countries represented on the CIRCUITS ASSEMBLY Top 50, it's plain to see how the landscape is shifting. Europe and the US have fewer entries than ever **(TABLE 1)**, even with Creation Technologies' relocation from Canada. Meanwhile, India and China continue to emerge.

Table 1. Top 50 Entrants by Nation

Country	No.
Canada	1
China	6
Denmark	1
Finland	2
Germany	2
Hong Kong	1
Hungary	1
India	2
Japan	5
Malaysia	1
the Netherlands	1
Norway	1
Philippines	1
Singapore	1
Taiwan	12
Thailand	2
US	10

Defining the Data

Before we go further, some explanations are in order. The industry classifies companies by size, called tiers. Definitions vary. Investment bank Lincoln International, for example, calls EMS companies with revenues greater than $3 billion Tier 1, $300 million to $3 billion is Tier II, and below $300 million is Tier III. We feel revenue is only one measure of classification. A private company with a single site and specializations in prototypes and small runs has little in common with a publicly traded firm with operations in multiple countries or regions – which the all-encompassing Tier III definition could entail. As such, we add a Tier IV, which covers entities up to $50 million.

Next, for every EMS company in the world, there are almost as many business models. Standalone; vertical; NPI; volume; design; regional; multinational; plastics; sheet metal; components; subsidiary to an OEM; parent to an OEM: You could almost say, if you've met one EMS company, you've met one EMS company. One look at the Top 50 list **(TABLE 2)** and the variations become apparent.

Table 2. The CIRCUITS ASSEMBLY Top 50 EMS Companies, 2022

Rank	Company	Nationality	2022 Revenues	2021 Revenues	URL	Notes
1	Foxconn Electronics[1,2]	Taiwan	215165	194619	foxconn.com	
2	Pegatron[1]	Taiwan	42776	41028	pegatroncorp.com	Building $150M iPhone factory in Chennai
3	Quanta[1]	Taiwan	41585	36682	quantatw.com	Notebook decline
4	Compal[1]	Taiwan	34846	40120	compal.com	Notebook decline
5	Jabil Circuit[1]	US	34546	30020	jabil.com	Auto up 40%+ 2 years in a row
6	Wistron[1]	Taiwan	31946	27970	wistron.com	Sold India iPhone biz to Luxshare, Tata
7	Flex[1,3]	US	30346	26041	flextronics.com	Spun off NEXTracker; automotive revenue +40% in 2 years
8	Luxshare[1]	China	25704	18486	luxshare-ict.com	Beating out Foxconn for iPhone 16 in India
9	BYD Electronic[1]	China	20565	10482	electronics.byd.com	Riding the EV wave
10	Inventec[1]	Taiwan	17598	16883	inventec.com	Slowed by Covid. Growth seen in notebooks and servers
11	Goertek[1]	China	12152	11050	goertek.com	ODM of smart audio and smart hardware
12	Universal Scientific Industrial Co. (USI)[1]	Taiwan	9681	7813	usiglobal.com	Industry leader in SiP modules for smart wearables
13	TPV[1]	China	8745	9980	tpv-tech.com	Public once more, and partially owned by China gov't
14	Celestica[1]	Canada	7250	5635	celestica.com	Never bet against them
15	Sanmina[1,4]	US	6921	5452	sanmina.com	Excludes PCBs and PIM; Nokia, Motorola both 10%+ customers
16	Kinpo Electronics[1,5]	Taiwan	5901	4547	newkinpogroup.com	Excludes Cal-Comp
17	Plexus[1]	US	4088	3304	plexus.com	400,000 sf expansion in Bangkok
18	Cal-Comp Electronics[1]	Thailand	3463	2492	calcomp.co.th	Unclear whether Philippines spinoff will happen
19	Benchmark Electronics[1]	US	2886	2255	bench.com	Board fab operation didn't last long
20	Venture Corp.[1,6]	Singapore	2853	2294	venture.com.sg	Net profit margin ~10%
21	Fabrinet[1]	US	2473	2208	fabrinet.com	Still Thailand's largest EMS
22	Shenzhen Kaifa[1]	China	2278	2334	kaifa.cn	Smartphones and storage modules
23	Zhen Ding[1]	Taiwan	2226	2015	zdtco.com	Flex circuit maker has major SMT ops
24	Taiwan Surface Mounting Technology Corp.[1]	Taiwan	2222	2133	tsmt.com	235 SMT lines in China, Taiwan, India
25	SIIX[1]	Japan	1976	1617	siix.co.jp	Automotive now 60% of revenue
26	DSBJ (MFlex)[1]	China	1743	1735	dsbj.com	Is Mexico expansion on its horizon?
27	Kimball Electronics[1]	US	1584	1248	kimball.com	CEO retired; expansions in Thailand and Mexico
28	Zollner Elektronik	Germany	1582	1465	zollner.de	Still family owned
29	Integrated Microelectronics Inc. (IMI)[1,7]	Philippines	1409	1311	global-imi.com	Includes $298M from VIA Optronics and STI
30	Sumitronics[1e]	Japan	1350	1242	sumitronics.co.jp	Total guess. Electronics business stable
31	Nippon Mektron[1]	Japan	1159	1134	nok.co.jp	Phones (70%+), automotive (24%)
32	GPV	Denmark	1222	1034	gpv-group.com	Includes Enics (merger closed November 2022)
33	UMC Electronics[1]	Japan	1138	958	umc.co.jp	Office equip. sales up 62%; auto flat
34	Kaga Electronics	Japan	1066	838	taxan.co.jp/en/	Also does $2.8B in component sales
35	Creation Technologies[e]	US	1055	1001	creationtech.com	What will they buy next?
36	V.S. Industry[1]	Malaysia	1051	910	vs-i.com	Expanding in Johor as China ops slow
37	VTech Communications[1,8]	Hong Kong	972	938	vtechems.com	European sales down 12%
38	Scanfil[1]	Finland	909	750	scanfil.fi	Cleaning up on green tech
39	Pan-International[1]	Taiwan	853	787	panintl.com	Big in flex assembly
40	Neways[e]	the Netherlands	837	775	neways.nl	Acquired by Infestos, June 2022; delisted
41	Katek	Germany	833	579	katek-group.de	Includes $100M for SigmaPoint in Canada, Nextek in US
42	Salcomp	Finland	800	720	salcomp.com	Expects to hit $2B in India in 3 years
43	VVDN Technologies[e]	India	800	760	vvdntech.com	India's largest ODM. Revenue total is a guess.

48	Dixon Elecronics	India	618	258	dixoninfo.com	Constant expansion in India
49	Kitron[1]	Norway	592	339	kitron.com	2023 forecast: EUR 700-800M
50	KeyTronic EMS[1]	US	552	538	keytronic.com	Counting on Vietnam

Numbers rounded: e = Estimated, 1. Publicly held, 2. Excludes sales from PWB, connectors, Sharp, Innolux, etc., 3. Excludes Nextracker plus Sheldahl ($575M), 4. EMS only, 5. Includes distribution, Qbit Semi, 6. Includes Univac Precision, 7. Excludes Via Optronics, 8. Based on four quarters ended Mar. 31

Some lists attempt to split the baby by differentiating between pure-play EMS companies (electronics assembly and tightly related services) and those that have a wider variety of offerings (such as manufacturers that build the entirety of white goods for name brands). Where the effort falls down, of course, is that while not every list includes, say Taiwanese mega-ODMs Compal or Quanta, no one dares omit Foxconn. Yet Foxconn's side businesses, such as FIH Mobile (a $1 billion+ cellphone subsidiary), Foxconn Interconnect Technology (connectors) and Foxconn Industrial Internet Co. (networking equipment ODM), are themselves larger than most other EMS companies, and are publicly traded besides. We don't attempt such maneuverings, if only because they obfuscate the true picture. The would-be no. 51 company on our list won't like it, but Compal performs more contract electronics assembly in a day than 96% of the world's EMS companies do in a year, and it deserves recognition.

Same goes for New Kinpo Group. The 46% owner of Cal-Comp (Thailand), Kinpo has vast other holdings including AcBel Polytech, Qbit Semiconductor and XYZprinting. It also has EMS operations separate of Cal-Comp (Thailand). We split the two for the purposes of this list. Combined, Kinpo would have revenues of $9.36 billion, including its branded (non-EMS) companies.

For years we have included the major fabricators that also offer EMS on our list. Our argument in favor of inclusion boils down to this: If Sanmina, which derives most of its revenue from EMS work but is also a significant bare board fabricator is eligible, then Zhen Ding, DSBJ (MFlex) and Nippon Mektron, three of the world's largest flex circuit makers which also happen to have hundreds of SMT lines, should be included as well.

The trick, then, is to determine a formula for reporting the EMS side of their respective businesses. For years, we calculated by estimating that the assembly portion of a populated flex circuit was approximately 40% of the entire unit. (This is less, of course, than the value of a typical rigid board assembly, wherein the bare board cost might be 4% of the total unit cost.)

However, according to Dr. Hayao Nakahara of N.T. Information, the world's foremost market researcher for PCBs, there's no one-size-fits-all equation. For a camera module, for instance, the unpopulated flex circuit value might be 15% of the total unit cost. But for a cellphone board, perhaps 40% would be attributable to the flex circuit, 40% to components, and 20% to labor and equipment amortization. Thus, knowing the product mix is important to understanding the "true" EMS portion of a flex circuit manufacturer, and even they might not know for certain.

That said, we do our best to exclude non-ODM/EMS revenue from the data. Luxshare, for instance, generates about 15% of its sales from connectors, so we deduct that much from its revenue on the CIRCUITS ASSEMBLY Top 50. Likewise, we cut $575 million from Flex to account for its Nextracker (solar products) and Sheldahl (flex circuits and materials) subsidiaries. Goertek, a major Chinese ODM of smart electronics wearables and home devices, generates about 18% of its sales from components. Dixon Technologies shows EMS only, not white goods, LEDs, etc. BYD includes just the electronics unit, not the auto group. DSBJ's (M-Flex) figures are based on the 65% of its revenue that comes from PCBs, then weighted for (estimated) EMS value. There will be mistakes.

Jabil includes Green Point (plastics) and Nypro/Johnson & Johnson (health care devices). If we include just the EMS unit, calendar 2022 revenues were $17.38 million, about half the overall sales. But, its diversified manufacturing services do include some sales that would be otherwise "EMS" had Jabil chosen a different reporting configuration.

Going Public

Even with GPV's acquisition of Enics and Neways going private, there are now about 130 publicly traded companies offering electronics manufacturing services either primarily or through a subsidiary. At least nine companies have gone public or announced plans to do so since January 2022 **(TABLE 3)**. Continuing the theme, many of them are India-based. Most fall in the Tier III range, with annual revenues of $50 million to $300 million.

Table 3. EMS IPOs Since January 2022

Company	Nationality	Exchange
Aurelius Technologies (ATech)	Malaysia	Bursa Malaysia

In-Tech Holdings*	Hong Kong	HKE
Kaynes Technology	India	BSE
Syrma SGS Technology	India	BSE

*Submitted but not yet realized

Notably, no North American-based EMS/ODMs have gone public in that time, nor has any firm listed on the primary US exchanges. We expect that to change over the next five years as private equity groups begin to wind down their investments.

TPV Technology went private in 2019, then was "acquired" in a reverse IPO by Nanjing Huadong Electronics in 2021 and is public once more. Another of the hybrid ODMs, TPV designs and manufactures products for numerous branded TV and PC makers, distributes its self-owned brands (which include AOC, AGON and Envision), and manufactures and sells Philips' monitors, TVs and AV products. It is 25% owned by Nanjing CEC Panda Information Industry Group, which is part of China Electronics Corp. (see below for more on that).

Gaining Currency

Most major currencies fell against the US dollar in 2022 **(TABLE 4)**. For those companies reporting revenues in non-US currencies, we converted the numbers using the averages set forth on May 23, 2023. Currency fluctuation will account for why some companies appear on some industry lists and not others. Likewise, CIRCUITS ASSEMBLY attempts in all cases to use the calendar year, not company financial years. Again, differing methodologies explain variances with other rankings.

Table 4. Currency Conversions

1 USD =	%Δ YoY
0.93 euros	0.46
7.06 Chinese RMB	-5.5
7.84 Hong Kong dollars	0.22
348.4 Hungarian forint	5.8
138.6 Japanese yen	-9.1
4.58 Malaysian ringgit	-5.1
1.35 Singaporean dollars	1.6
10.62 Swedish krona	-8.9
30.77 Taiwanese dollars	-4.1
34.57 Thai baht	-1.2
82.9 Indian rupees	-6.3

The Future

Predicting the EMS industry is more complex than it seems. Who among us, for instance, anticipated the meteoric rise of Luxshare? But much like Apple is the must-watch (no pun intended) entity on the hardware side, the EMS/ODM to stay locked on to is also the largest in its class: Foxconn. Last year, the company established the Hon Hai Research Institute to focus on key technologies in the next three to seven years. After R&D results are mature, they will be transferred to the business department for commercialization. Few of Foxconn's competitors are willing to underwrite this type of R&D (Jabil is one). Such forward-looking strategy coupled with ample capital reserves (and little to no pressure from shareholders) suggest that barring a geopolitical disaster, Foxconn will remain in the driver's seat for years to come.

Omissions

Every year there will be omissions, some intentional, some not. Some examples:

China Electronics Corp. The third-largest assembly operation in China, behind Foxconn and BYD. CEC, which owns Great Wall Computers and a moderate stake in TPV, among others, is also a thinly veiled subsidiary of the Chinese army.

Lens Technology. One of China's largest suppliers to the phone, computing and TFT markets, Lens is a highly vertically integrated $6.5 billion behemoth. It has electronics ODM capacity, but it is unclear how much of its revenue comes from that segment versus its glass materials and optical modules.

Diehl Controls. We have seen this German OEM of white goods and industrial electronics listed elsewhere. It says it produces around 50 million electronic units per year on a contract basis, and some lists indicate its revenues fall between those of Kitron and Neways, but we have no such insight.

iHPS. The EMS arm of Hytera Communications, it is likely over $500 million.

BOE Technology. Yet another Chinese company, with revenues over $30 billion, BOE both OEMs and private labels IoT devices, semiconductor displays, and various other components like sensors. Dissecting the integrated design and manufacturing services from the rest of the mix is not possible based on the information the company makes public.

ATA IMS Berhard. This Malaysian EMS lost its largest customer, Dyson, which made up 81% of its business. Revenue dropped by more than 50% from the first half to the second.

Lacroix Electronics. At $522 million in 2022, it misses the list. Add in the non-electronics revenue and it's a different story.

Katolec. Distribution revenue is 27% of its sales. EMS portion is $520 million.

TT Electronics. The conglomerate has OEM products, components, distribution and EMS. The latter was just under $400 million in 2022.

Computime, another OEM-EMS blend, generates about 70% of its revenue from contract assembly, putting its EMS sales at just under $400 million as well.

The author apologies for any oversights.

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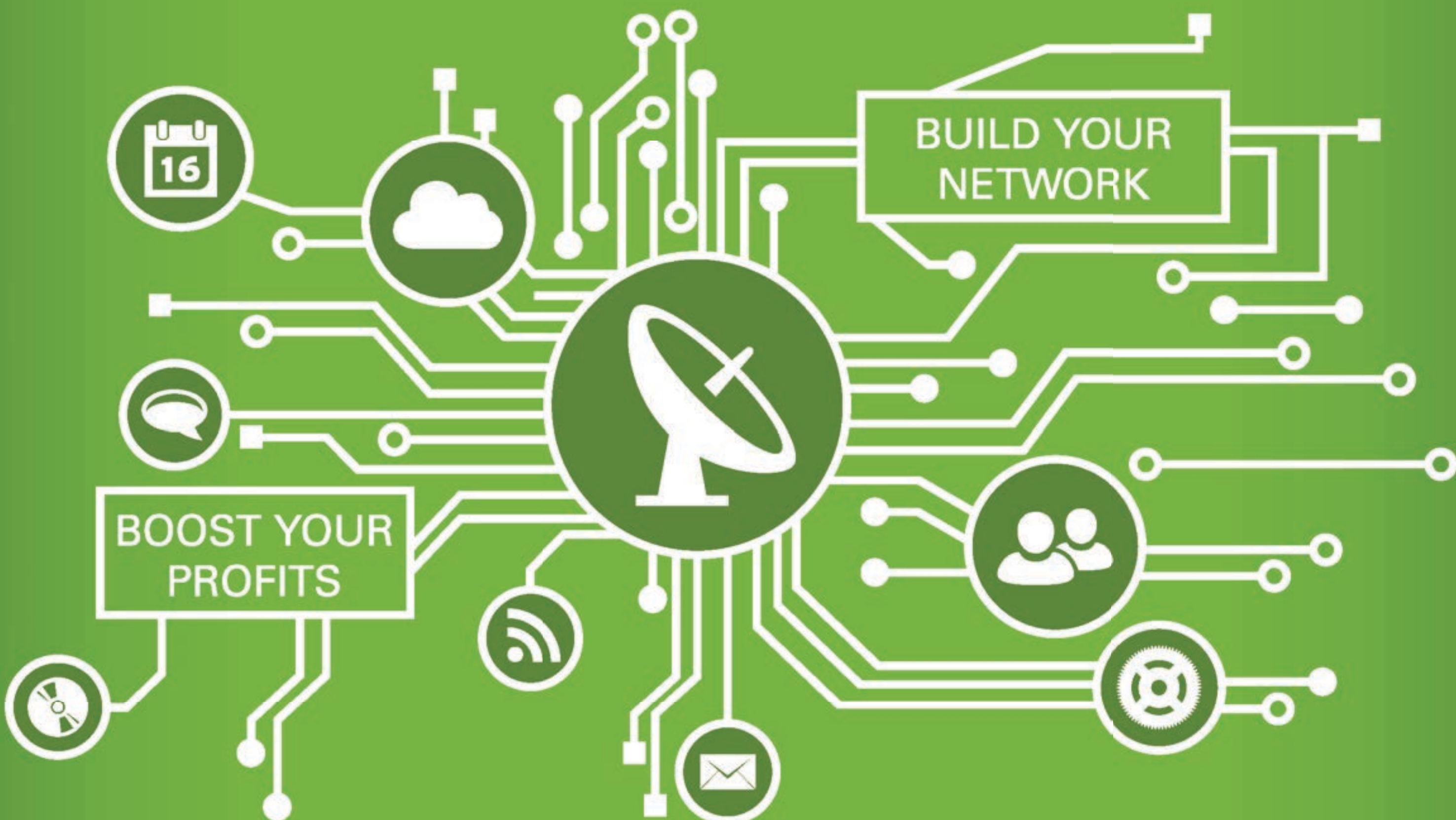
MIKE BUETOW is president of PCEA (pcea.net); mike@pcea.net.

The *Circuits Assembly* Directory of EMS Companies



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CIRCUITS ASSEMBLY

circuitsassembly.com/dems

The Printer and the Pea

Seemingly small issues can have big print implications.

MOST READING THIS column are probably familiar with "The Princess and the Pea" fairy tale by Hans Christian Andersen, wherein a tiny pea under 20 mattresses keeps a true princess from a good night's sleep. Similarly, in the stencil printing process, seemingly small settings or interferences can prevent a good print outcome – particularly as assemblies continue to move toward higher densities and miniaturization. Our team had such a scenario recently while troubleshooting the cause for incomplete deposits on a complex board assembly.

This project involved printing on ultra-thin substrates – approximately 400µm thick. That's about the thickness of a playing card, so very, very thin, which makes for challenging print stability. Moreover, the panel was on the larger side, about 400mm x 400mm made up of multiple PCBs with no routing, making it more difficult to ensure coplanarity during printing. Tooling stability is always critical and even more challenging with very thin substrates. Today's tooling support solutions number a handful of options: Equipment standard tooling pins, reconfigurable pin systems like Grid-Lok, smart automatic pin placement, and dedicated tooling blocks with and without vacuum. Given the size and thickness of this substrate, our team used dedicated tooling blocks with vacuum to offer the most robust support for the process analysis.

We were printing only one side of the substrate, which contained apertures ranging from 01005s with dimensions of 200µm x 150µm to larger apertures measuring approximately 1.5mm x 2mm, and were using an 80µm thick stencil. The smaller apertures put the area ratio below the generally acceptable 0.6 rule, which also added to the challenge of this print. Finally, underneath the live print area for each PCB – on the opposite side of the substrate – there could be no contact, so any tooling support had to sit between the live print areas. Envision multiple 20mm x 20mm pockets, each surrounded by metal webbing in a grid configuration. Around the perimeter, vacuum channels secured the substrate into the tooling block.

The team honed in on the 01005 apertures due to the area ratio challenges, and the initial prints of the smaller dimensions were excellent. The pressure and speed balance were good and met the print quality criteria. The larger apertures did not fare as well, however. Upon inspection, we discovered that the larger apertures were missing material on the front edge in the direction of the print – or where the blade first passes over the aperture. When the squeegee traversed in the opposite direction, the back side of the aperture experienced the same phenomenon. Our engineers had observed this under other conditions – when using rubber squeegees or when printing too quickly with certain materials, for example. But this was unexpected with a metal blade positioned at the proper angle and with recommended pressures. Beginning with speeds and pressures, adjustments were made that only slightly modified the amount of material missing on the front edge of the larger apertures. Next, the team moved to the squeegee blade angle, going from a 60° angle to a 45° blade, but the problem persisted. Changing the solder paste material to a formula preferred in our lab also had little effect.

Going back to the basics, and as I always recommend in these columns, our team dissected the process parameters from the beginning, from the bottom up. The culprit was revealed by taking out the stencil, leaving the tooling setup in, bringing the board under control, and then using a dial test indicator (DTI) clock to measure the flatness of the substrate in the tooling block with the vacuum on. Because the panel was very thin and the vacuum was set to hold it tight, the vacuum pull was sucking the board into the pockets in the tooling plate. When analyzed, it was clear the substrate was slightly scalloped and wasn't being presented flat to the stencil; a gap was interfering with the filling process. A simple adjustment to the vacuum flow eliminated the filling issue, and the substrates printed perfectly with the original squeegee angle, speeds, pressures and specified solder paste. Problem solved! Little things can, indeed, have a big impact on the result.

CLIVE ASHMORE is global applied process engineering manager at ASMPT (asmpt.com); clive.ashmore@asmpt.com. His column appears bimonthly.

semi

Connecting Semiconductors and Electronics

About SEMI:
SEMI connects more than 2,500 member companies and 1.3 million professionals worldwide to advance the technology and business of electronics design and manufacturing. The breadth and depth of our events, programs and services help members accelerate innovation and collaboration on the toughest challenges to growth.

Electronic System Design Alliance
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MIT MARKET INTELLIGENCE TEAM
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THOUGHT LEADERSHIP
SEMICON
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Cyber Security

PCD&F

ALTAIR SIMSOLID CLOUD SIM TOOL

SimSolid Cloud structural simulation software allows access to simulation technology from any web browser anywhere, anytime. Eliminates geometry simplification and meshing, the two most time-consuming and expertise-intensive tasks done in traditional finite element analysis, and is said to deliver results in seconds to minutes while handling complex assemblies. Requires no software installation or extensive computing resources, and offers structural linear and nonlinear static, modal vibration, and thermal stress analyses in user's preferred web browser. Features include mesh-free technology and full-fidelity CAD simulation, comprehensive physics support, adaptive solver technology, automated model connections, results in seconds, intuitive, user-friendly interface, and extensive material library.

Altair
altair.com

AMPHENOL RF INTERNAL ANTENNAS

Flexible and PCB patch antennas are for use inside connected devices and feature either a flexible pad or rigid PCB which can be mounted inside the device. Come in dual-band, multi-band and wide-band configurations with Wi-Fi 6E supported options with reliable frequency range up to 7.2GHz. Dipole design has a relatively low profile and can be mounted in various locations and supports standard cellular protocols, which makes them suited for IoT, Wi-Fi and LTE technology. Use center-fed micro-coax cables that terminate to an ultraminiature AMC connector and feature an adhesive mounting tape on one side for secure placement inside the device.

Amphenol RF

amphenolrf.com

FLUX COPILOT DESIGN ASSISTANT/PCB DESIGN TOOL

Copilot AI-powered hardware design assistant is integrated into a PCB design tool. Understands schematic designs, component lists, connections, and part information from datasheets. Flux-trained large language model (LLM) resides within a project, providing an array of functionalities to assist engineers in the design process. Can be queried through comments or chat, offering a convenient and intuitive way to interact with the AI-powered assistant. Aids part selection, evaluates compatibility, offers schematic feedback, and performs design analysis. Can suggest alternative components with similar specifications, validate calculations for accuracy, and provide insights on component limits to ensure a robust design. Can generate new ideas and explore design options based on project goals, constraints, and specifications. Can generate a bill of materials (BoM) for a target project, providing a comprehensive list of components and their quantities required for the design. Can be used to brainstorm new concepts, evaluate alternative approaches, and optimize designs for performance, cost and manufacturability. Integration into the PCB design tool allows seamless collaboration between engineers and the AI assistant.

Flux

flux.ai

IDENTCO TT413 PCB LABELS

TT413 series of labels is designed to withstand prolonged, repeated exposure to the chemicals and high temperatures typical to post-production washing processes. Features a 2.4mil gloss white polyimide that provides ultra-durable resistance against smudges, solvent, heat, and abrasion, and serves as a receptive surface for a variety of thermal transfer ribbons. Also features a 2.0mil ultra-aggressive permanent acrylic adhesive that offers excellent resistance to harsh chemicals and high temperatures. Peel adhesion strength is 40oz./in. or higher for both stainless steel and PCB, and at 24 hrs. boasts dwell strengths of 43oz./in. for epoxy and 55oz./in. for stainless steel. Is said to be suited to a wide array of electronics components manufacturing environments, including box builds, internal and external vehicle parts (such as in-cabin infotainment systems and outside sensors), and various other computer unit and PCB assembly settings.

Identco

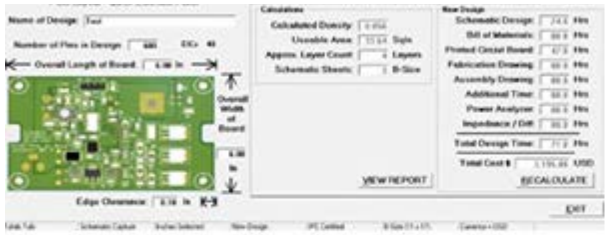
identco.com

LOGICSWAP ECADSTAR MIGRATION SOFTWARE

Free data conversion package to transfer third-party PCB design data to Zuken's eCADStar format. Enables eCADStar users to utilize Altium Designer library, schematic, and PCB design data for design, analysis, and manufacturing within the eCADStar toolset.

LogicSwap Solutions

logicswap.com



OZTRONICS 53000 PCB LAYOUT ESTIMATOR

53000 layout tool is designed to estimate the time required for creating PCB layouts. Can estimate the number of hours to create the PCB after an initial input consisting of number of the pins, x dimension, y dimension, and edge clearance. Other time variables can also be estimated and accounted for in the design such as bill of materials, schematic capture, fabrication drawing, assembly drawing and additional time. Results can be written to a report that can be sent to the client or manager for approval prior to starting the work.

Oztronics
oztronics-tech.com

PANASONIC ZTU SERIES CAPACITORS

ZTU series of hybrid aluminum capacitors is AEC-Q200 qualified, and offers exceptional reliability and ruggedness for any demanding application. Available with a rated voltage 25V~35VDC/220 560μF and an increase of 80% in ripple current capability in comparison to the ZC series, and has been proven for 4000 hrs. at 125°C and 135°C, making it ideal for applications needing high temperature tolerance and high current capability. Vibration tolerance of 10G, but also comes in vibration-proof version able to handle shocks of up to 30G in 8mm and 10mm diameter versions.

Panasonic

panasonic.com

ROHM 650V GAN HEMTS

GNP1070TC-Z and GNP1150TCA-Z are 650V GaN (gallium nitride) HEMTs optimized for a range of power supply systems applications. Are said to deliver industry-leading performance in terms of RDS(ON) × Ciss / RDS(ON) × Coss, a figure of merit for GaN HEMTs, translating to higher efficiency in power supply systems. Built-in ESD protection element improves electrostatic breakdown resistance up to 3.5kV, leading to higher application reliability, and high-speed switching characteristics also contribute to greater miniaturization of peripheral components.

Rohm Semiconductor

rohm.com

TIMES MICROWAVE SYSTEMS TF-047 MICRO-COAXIAL CABLE

TF-047 is compact and flexible for easy routing in space-constrained areas, with an overall diameter of 0.055in/1.40mm, and can support bends as tight as 0.20in/5.08mm. Is optimized to perform from DC to 50GHz, and is available with a variety of push-on and threaded connectors. Is for board-to-board, backplane and crossover box-box/inside-the-box connectivity, as well as for bench/production tests, troubleshooting setup, signal fanout and ATE in semiconductor manufacturing.

Times Microwave Systems

timesmicrowave.com

WITHWAVE VERTICAL LAUNCH CONNECTORS

Vertical Launch Connectors are designed for solderless vertical PCB launch on test and measurement boards. Feature DC to 26.5GHz (SMA), 40GHz (2.92mm), 50GHz (2.4mm), 67GHz (1.85mm) and 110GHz (1.0mm). Also feature excellent vertical transition performance (VSWR <1.3, 1.85 and 1.0mm type : VSWR <1.6), and easy and solderless installation on designed substrate.

Withwave

with-wave.com

ZUKEN HARNESS BUILDER 2023

Harness Builder 2023 for E3.series features a complete graphical overhaul, giving the tool a modern feel and making it easier to understand and use. Includes an improved window configuration with an added structure to the window tabs, making navigating detailed sections such as reports, exports, analysis, and utility tools easier. User interface also groups core settings in one location under the main Harness Builder window, making finding and keeping consistent report data more manageable. Interface now allows choice of the export options for the plug-in.

Also includes ability to apply automatic watermarks for shareable harness drawings, with option to refine controls such as the number of watermarks to add, rotation, placement, and other text properties. Features a refresh for the method of adding documentation for splices, allowing ability to quickly place the on-sheet splice documentation for multiple splices using the new splice context menu options. Selecting several splices and then running the command through the Harness Builder context menu will have the tables appear individually, ready to insert into the documentation. Adds ability to define how to identify a wire harness based on attributes, a drawing sheet, the complete project, or bringing together an entire assembly through structure nodes, and reports and exports can then apply and use the wire harness name and version for release tracking. Also features improved handling of twisted wire length calculations for detailed reports, and considers factors relating to the number of twists and material composition to ensure that length calculations are accurate, preventing short wires during wire cutting that can lead to rework and waste. Adds a harness braiding cost and weight estimator that provides a precise estimate of the cost and weight of material for the braiding machines, and has a new export option to nVent PWA6000 for wire processing.

Zuken

zuken.com

CA

ACCU-ASSEMBLY ACCULIFT REEL STORAGE

AccuLiFT SMT component reel vertical modular storage and retrieval system features a flexible reel configuration that enables small and large reels to be interchanged at any position on the pallet. Can store up to 3,900 7" reels, with the ability to store up to 8,400 reels with two additional vertical storage units. Stores component reels on pallets constructed of a steel frame with ESD plastic trays. Vertical lift stores and retrieves parts, and expands vertically to conserve floor space. Uses Direct Drive Technology with auto correction requiring no calibration. Features a robotic, automated, dual-level operator reel loading/unloading station, allowing reel loading and unloading to take place simultaneously to reduce cycle time. Also includes automatic barcode scanning of all reels on the pallet, automatic reel thickness detection, and multiple job sorting capability. Optional features include the ability to print and place UID label on component reels and interface to x-ray component counters.

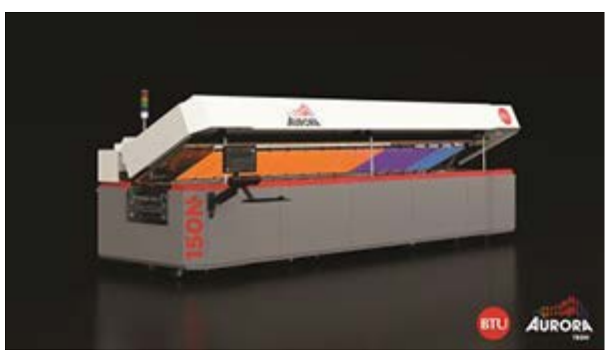
Accu-Assembly

accuassembly.com

AVEN MICROVUE 360 VIEWER ATTACHMENT

MicroVue 360 Viewer Attachment is designed for use with the line of MicroVue Digital Microscopes and offers a range of benefits for users who require enhanced precision and comfort during their work. Features a 35° angled mirror for looking around multilayered parts such as circuit boards, medical tools, industrial parts, and more. Also includes 360° rotation capability, for easy adjustment of viewing angle to achieve perfect line of sight.

Aven
aventools.com



BTU AURORA REFLOW OVEN

Aurora reflow oven platform features a modern, fully updated user interface, integrated Aqua Scrub flux management technology, Smart Power energy savings software, and advanced process control technologies. Features the industry’s first factory configurable heating and cooling architecture providing the flexibility to customize oven for specific product/process characteristics including very heavy boards, slow cooling requirements, or increased throughput. Also features closed-loop convection control technology that has been shown to maintain thermal performance even at significantly increased belt speeds, providing greater productivity, efficiency and throughput.

BTU

btu.com

EMIL OTTO ESD CLEANING PRODUCTS

EO-RA-ESD/01 and EO-RA-ESD/02 are for cleaning conductive surfaces and floors, especially for the ESD area. EO-RA-ESD/01 removes grease and lubricant films or other stubborn contaminations that occur in production. Is compatible with common plastics and is gentle on sensitive plastic surfaces while also for use on coated or painted surfaces. EO-RA-ESD/02 is a concentrate developed for daily use on damp mopping floors. For manual cleaning and mechanical use on conductive floors. Is compatible with common floor coverings such as PVC, linoleum, artificial and natural stone.

Emil Otto

emilotto.de

ERSA I-CON MARK 2 SOLDERING STATIONS

i-Con Mark 2 soldering station series features soldering tip technology from the IoT soldering station i- Con Trace with fast heat-up and reheat characteristics and a precise temperature control of +/-2°C. Also offers up to 20% more soldering power and is 30g and 150mm long, fitting easily in the hand. Features bayonet lock, which keeps heating element intact and in place when tip is changed. Handle remains comfortably cool during continuous operation and recovers in time for all solder joints to be made with virtually the same temperature. Sensor measures actual tip temperature very close to tip extremity and signals operator if temperature leaves preset process window.

Ersa

kurtzersa.com

EXPRESS ASSEMBLY BT-001 SCREW FEEDER

BT-001 semiautomatic benchtop machine automates screw feeder systems. Holds screwdriver and automatically lines up with the part, eliminating need for an operator to hold the driver. Automates screw fastening process, works with all Sumake electrical screwdrivers and transducer screwdrivers and is adjustable to any torque application. Also integrates with screw feeder systems for even more automation and is adaptable for multiple screwdrivers on a common benchtop.

Express Assembly

expressassembly.com

HENKEL LOCTITE ABLESTIK ABP 8068TI ADHESIVE

Loctite Ablestik ABP 8068TI is an ultra-high thermal conductivity pressure-less sintering die attach adhesive that meets automotive grade reliability standards. Features 165 W/m-K thermal conductivity, meeting performance requirements for high-reliability automotive and industrial power discrete semiconductor devices. Meets multiple metrics for power semiconductors like MOSFETs, and is compatible with traditional Si and newer wide-bandgap semiconductors, among other power discrete devices. Is said to demonstrate excellent sintering properties with good adhesion on copper, pre-plated (PPF), silver, and gold lead frames, robust electrical conductivity and stable RDS(on) after 1,000 hrs. of thermal cycling, and MSL 3 reliability. Is recommended for dies measuring 3mm x 3mm or smaller, and fully cures at 175° C or above to form a rigid sintered Ag network in the bulk epoxy and at the interface. Does not require high pressure to achieve structure, and features workability at three hours of void-free open time and 24 hrs. of stage time with no degradation in shear strength.

Henkel

henkel-adhesives.com

INDIUM INDALLOY 303 REFLOW ALLOY

Indalloy 303 is a bismuth-based alloy developed for low-temperature reflow processes. Features reflow temperature as low as 170 , excellent thermal cycling performance, resistance to hot tearing, compatibility with SAC in hybrid BGA joints, and low voiding. Its flux vehicle, Indium5.7LT-1, delivers superior print transfer efficiency; clear post-reflow flux residue; solder bead and solder ball minimization; exceptional wetting on OSP, immersion Ag, immersion Sn, and ENIG; excellent coalescence of small deposits; and outstanding SIR performance under challenging low-temperature reflow conditions.

Indium Corp.

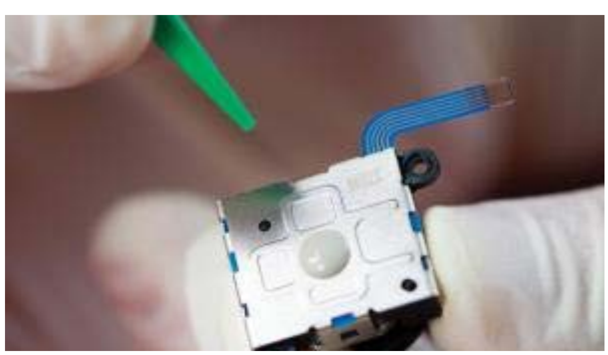
indium.com

INDIUM 8.9HFRV SOLDER PASTE

Indium8.9HFRV air reflow, no-clean solder improves voiding performance of next-generation Pb-free high reliability alloys. Offers low voiding when used with high-reliability alloys, high transfer efficiency through small apertures (Ò0.66AR), excellent wetting, superior response-to-pause performance, and compatibility with air and N_2 reflow environments. Can be used for high-reliability alloys, and is also fully compatible with standard SAC alloy systems.

Indium Corp.

indium.com



MASTER BOND EP17HTDA-2 EPOXY

EP17HTDA-2 is a one-component epoxy for bonding, sealing and die attachment. Is not premixed and frozen, and cures with heat. Features excellent mechanical properties with both a high modulus and die shear strength, and transfers heat and resists thermomechanical stresses effectively. Has exceptional temperature resistance, with a service temperature range of -80°F to +600°F [-62°C to +316°C] and Tg of 185°-190°C. Features thermal conductivity of 9-10BTU•in/ft^2•hr•°F [1.30-1.44W/(m·K)], a low CTE, and is also electrically insulative with a volume resistivity greater than 10^{15}ohm-cm. Withstands a variety of chemicals including acids, bases, salts, fuels, oils, water and many solvents. Does not require any mixing and is curable in the temperature range of 300°-350°F for around 4-5 hrs. To optimize properties, a post cure of 2-3 hrs. at 400°F is recommended. Bonds to a variety of substrates, such as metals, ceramics, plastics and composites. Upon curing, delivers a tensile modulus exceeding 1,100,000psi and a die shear strength of 20-23kg-f at room temperature (2 x 2mm [80 x 80mil]). Minimal shrinkage upon curing.

Master Bond
masterbond.com

MASTER BOND EP5LTE-100 EPOXY

EP5LTE-100 is a one part, non-premixed and frozen epoxy with a very low CTE, high Tg, and extremely high modulus. Features a thixotropic paste consistency making it ideal for bonding, sealing and gap filling applications, and is ideal for optoelectronics or applications needing high dimensional stability and good heat resistance. Passes NASA low outgassing specifications and provides a tensile modulus that exceeds 1 million psi at room temperature. Minimal shrinkage upon cure combined with a low CTE of 8^{-12} x 10^{-6} in/in/°C enables precise alignment for bonding dissimilar substrates with low coefficients of thermal expansion. With a Tg between 120°-125°C, and a service temperature range from -60° to +175°C, is effective in high temperature environments. Is a reliable electrical insulator featuring a volume resistivity of more than 10^{14} ohm-cm. Bonds well to a variety of substrates including metals, glass, composites, ceramics and many plastics, and has good resistance to water and damp heat. Unlimited working life at room temperature and requires heat cure at 100°C for 90-120 min. Optimum properties are obtained by post curing for 2-3 hrs. at 100°-125°C. Comes in syringes, jars and cans.

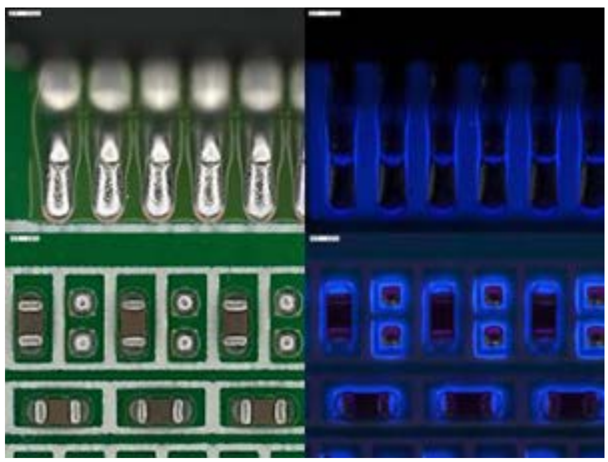
Master Bond

masterbond.com

MEK ISPECTOR AOI

iSpector inline AOI is an entry-level system for low-volume, high-mix production. Utilizes DOAL, main and side LED light sources from three different angles, creating a meniscus profiling light pattern that allows for the inspection of component bodies and solder joints. Is equipped with Mek Colour Histogram analysis, which provides accurate and reliable inspection results with low false calls. Easy to install, and novel online training program is said to make it exceptionally easy to program. Clean and simple UI with powerful features, including full programming capabilities for solder inspection, component presence/absence, polarity, and value. Z-axis allows inspection of taller components and hybrid PCBs, and users can import NC data from pick-and-place or most popular CAD/CAM software while also taking advantage of Mek's custom libraries. Fully compatible with Mek's Catch System, which offers full traceability and I-4.0 readiness, and is fully scalable from single AOI stations to multiple machines.

Marantz Electronics
marantz-electronics.com



SHENMAO PF629-P214UV SOLDER PASTE

PF629-P214UV UV-visible lead-free no-clean solder paste is for a range of applications, from consumer electronics to automotive and aerospace components. UV-visible feature allows easy and accurate quality control inspection during production and ensures product is used correctly and reliably. Flux residue after reflow process can be easily identified by UV light. Is said to offer superior solderability and printability performance, has excellent wetting ability and forms strong, smooth and shiny solder joints.

Shenmao
shenmao.com

TITAN TOOL SUPPLY ZMM-1 MICROSCOPE

ZMM-1 industrial inspection monocular zoom microscope provides reliable, accurate, real-time quality control and remote visual inspection capabilities across a full production cycle. Features a 1:4 zoom ratio and offers constant focal length, highly favorable depth of field, a large field of view at 15X magnification, plus a higher magnification with smaller field of view at 60X as standard. Optional extra 20X eyepiece performs reliable and accurate remote visual inspections of a workpiece over an expanded magnification of up to 120X – without need for a change of lens. Operable in either vertical or horizontal position and comes mounted on desktop pillar stand, with further optional extended rod lengths.

Titan Tool Supply
titantoolsupply.com

TRI TR7700 SIII ULTRA CI AOI

TR7700 SIII Ultra CI detects coating issues, measures coating thickness, and inspects dispensed flux and glue. Precisely measures coating thickness from critical areas on the PCB, detecting unwanted coating spills near PCB connectors, sensitive components, and designated mounting holes. Can identify common coating issues, including cracks, bubbles/voids, insufficient/excess coating, and loss of adhesion, with algorithms calculating maximum/minimum coating coverage length and measuring coating length, splash or insufficient coating. Coating thickness measurement range is from 35μm to 750μm.

Test Research, Inc.

tri.com.tw

VITROX SMART REEL CHANGER 2.0

Smart Reel Changer 2.0 for TR3000i Inspection Handler is designed to improve throughput and reduce operator dependency. Automates loading and unloading output of up to 10 reels without presence of operators, eliminating need for manual transfer and intervention. Designed to take up less space on the production line and is easy to integrate into TR3000i.

ViTrox

vitrox.com

WELLER WXSMART TWEEZERS

WXsmart Tweezers meet all state-of-the-art soldering and desoldering requirements, from miniaturization to heavy duty applications, as well as traceability and connectivity needs. Feature color lighting for fast tool identification and offers fast and precise toolless tip change. Also feature fast heat-up and reaction times, integrated chip to control the workflow and make adjustments possible, and optimized handle ergonomics to provide support for repetitive, identical work processes.

Weller Tools

weller-tools.com

YAMAHA YRM20DL SMT MOUNTER

YRM20DL surface mounter is a dual-lane version of the YRM20. Accommodates various dual-lane production methods. In a wide range of SMT production lines, from high-volume production to high-mix production, it significantly reduces transfer loss and other losses, and improves productivity. By revising the layout in the machine and further optimizing the motion control of the x-y axis, it achieves 120,000cph. In addition, high-accuracy mounting of +/-15µm (Cpk>=1.0) is achieved by improving the rigidity of the newly developed conveyor and the mount position compensation function. In dual-lane production mode, the maximum board width is 12.9" (330mm) when boards of the same width are conveyed in two lanes. In single-lane production mode, where only one lane is used, can transfer boards up to 31.8" (810mm) in length, 24.0" (610mm) in width, 6.6lb (3kg) in transportable weight, and 0.25" (6.5mm) in maximum board thickness. The laser unit's board height measurement and low static load nozzle reduce stress on tiny components during mounting.

Yamaha Motor IM

yamaha-motor-im.com

In Case You Missed It

Additive Manufacturing

"Creating 3-D Objects with Integrated Electronics via Multiphoton Fabrication In Vitro and In Vivo"

Authors: Sara J. Baldock, *et. al.*

Abstract: 3-D objects with integrated electronics are produced using an additive manufacturing approach relying on multiphoton fabrication (direct laser writing). Conducting polymer-based structures (with micrometer-millimeter scale features) are printed within exemplar matrices, including an elastomer (polydimethylsiloxane, or PDMS) have been widely investigated for biomedical applications. Printing process fidelity in PDMS is assessed by optical coherence tomography, and the conducting polymer structures are demonstrated to be capable of stimulating mouse brain tissue in vitro. Furthermore, the applicability of the approach to printing structures in vivo is demonstrated in live nematodes (Caenorhabditis elegans). These results highlight the potential for such additive manufacturing approaches to produce next-generation advanced material technologies, notably integrated electronics for technical and medical applications (e.g., human-computer interfaces). *(Advanced Materials Technologies*, March 2023, https://doi.org/10.1002/admt.202201274)

Flexible Electronics

"Colloidal Approaches to Zinc Oxide Nanocrystals"

Authors: Joel van Embden, *et. al.*

Abstract: Zinc oxide is an extensively studied semiconductor with a wide band gap in the near-UV. Its many interesting properties have found use in optics, electronics, catalysis, sensing, as well as biomedicine and microbiology. In the nanoscale regime the functional properties of ZnO can be precisely tuned by manipulating its size, shape, chemical composition (doping), and surface states. In this review, the authors focus on the colloidal synthesis of ZnO nanocrystals (NCs) and provide a critical analysis of the synthetic methods currently available for preparing ZnO colloids. First, the authors outline key thermodynamic considerations for the nucleation and growth of colloidal nanoparticles, including an analysis of different reaction methodologies and of the role of dopant ions on nanoparticle formation. They then comprehensively review and discuss the literature on ZnO NC systems, including reactions in polar solvents that traditionally occur at low temperatures upon addition of a base, and high temperature reactions in organic, nonpolar solvents. A specific section is dedicated to doped NCs, highlighting both synthetic aspects and structure–property relationships. The versatility of these methods to achieve morphological and compositional control in ZnO is explicated. The authors then showcase some of the key applications of ZnO NCs, both as suspended colloids and as deposited coatings on supporting substrates. Finally, a critical analysis of the current state of the art for ZnO colloidal NCs is presented along with existing challenges and future directions for the field. *(Chemical Reviews,* December 2022, https://doi.org/10.1021/acs.chemrev.2c00456)

Printed Electronics

"All-Carbon Thin-Film Transistors Using Water-Only Printing"

Authors: Shiheng Lu, *et. al.*

Abstract: Printing thin-film transistors (TFTs) using nanomaterials is a promising approach for future electronics. Yet, most inks rely on environmentally harmful solvents for solubilizing and postprint processing the nanomaterials. In this work, the authors demonstrate water-only TFTs printed from all-carbon inks of semiconducting carbon nanotubes (CNTs), conducting graphene, and insulating crystalline nanocellulose (CNC). While suspending these nanomaterials into aqueous inks is readily achieved, printing the inks into thin films of sufficient surface coverage and in multilayer stacks to form TFTs has proven elusive without high temperatures, hazardous chemicals, and/or lengthy postprocessing. Using aerosol jet printing, the approach involves a maximum

temperature of 70°C and no hazardous chemicals – all inks are aqueous and only water is used for processing. An intermittent rinsing technique was used to address the surface adhesion challenges that limit film density of printed aqueous CNTs. These findings provide promising steps toward an environmentally friendly realization of thin-film electronics. *(Nano Letters,* February 2023, https://doi.org/10.1021/acs.nanolett.2c04196)

Solder Materials

"Characterizing Solder Materials from Random Vibration Response of Their Interconnects in BGA Packaging"

Authors: Joshua A. Depiver, Sabuj Mallik and Emeka H. Amalu

Abstract: Solder interconnection in electronic packaging is the weakest link, thus driving the reliability of electronic modules and systems. Improving interconnection integrity in safety-critical applications is vital in enhancing application reliability. This investigation qualifies the random vibration response of five essential solder compositions in ball grid array (BGA) solder joints used in safety-critical applications. The solder compositions are eutectic Sn63Pb37 and SnAgCu (SAC) 305, 387, 396, and 405. Computer-aided engineering (CAE) employing Ansys finite element analysis and SolidWorks software is implemented in this investigation. The Sn63Pb37 solder deformed least at 0.43μm, followed by SAC 396 at 0.58μm, while SAC 405 deformed highest at 0.88μm. Further analysis demonstrates that the possession of a higher elastic modulus and mass density culminates in lower solder joint deformation. Stress is concentrated at the periphery of the solder joints in contact with a printed circuit board (PCB). The SAC 396 solder accumulates the lowest stress of 14.1MPa, followed by SAC 405 at 17.9MPa, while eutectic SnPb accrues the highest at 34.6MPa. Similarly, strain concentration is found at the interface between the solder joint and copper pad on a PCB. SAC 405 acquires the lowest elastic strain magnitude of 0.0011mm/mm, while SAC 305 records the highest strain of 0.002mm/mm. These results demonstrate that SAC 405 solder has maximum and SAC 387 solder has minimum fatigue lives. *(Journal of Electronic Materials,* March 2023, https://doi.org/10.1007/s11664-023-10394-x)

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