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November 2022

Embrace the COLD

Low-Heat Soldering Gets Its Time in the Sun

The 'Universal' **Footprint**

SPC for Process Engineers

Standards Get Off 'Target'

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PRINTED CIRCUIT DESIGN & FAB CIRCUITS ASSEMBLY

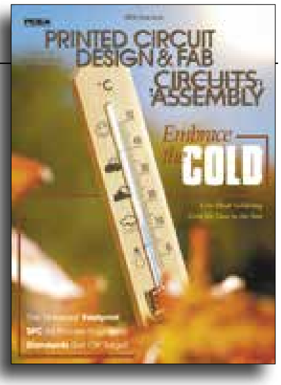
FIRST PERSON

MONEY MATTERS

TECH TALK

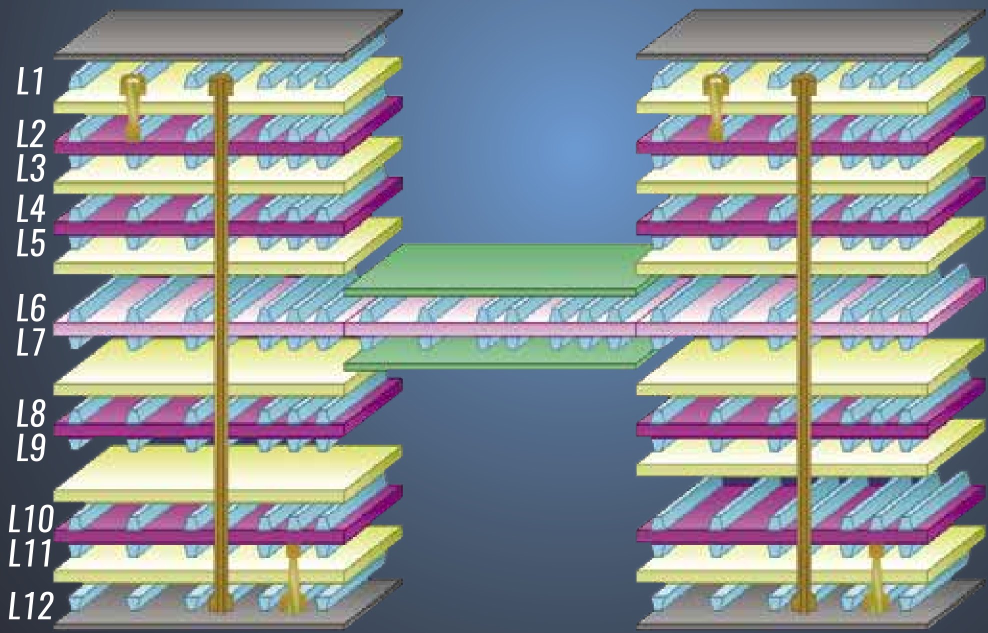
DEPARTMENTS

FEATURES



ON PCB CHAT (pcbchat.com)

PCB Chat



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MIKE
BUETOW
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Bank Shots

THE WORLD'S LARGEST tech companies are masters of their domains: Apple in phones; Google in search; Facebook in social media.

Why stop there? All three are going into financial services, and if past is prelude, they intend to dominate the space.

To date, Apple appears to have a leg up on the others, by virtue of its omnipresent hardware. It has also, according to some sources, been the most aggressive. If you use an iPhone, you must use Apple Pay, for instance (even though legally you shouldn't have to).

The company launched a credit card backed by Goldman Sachs in 2019, and in mid-October announced it will allow users to park rebates earned from use of said credit card – named, not surprisingly, Apple Card – in a savings account, also from Goldman Sachs.

Apple is massive, of course, with a market capitalization of roughly $2.29 trillion. At $1.26 trillion, Alphabet, Google's parent, is worth slightly more than half that. By contrast, Meta, the company formerly known as Facebook, is worth a paltry $360 billion.

By comparison, JPMorgan is the largest bank in the United States and fifth largest in the world in terms of total assets. For a sense of scale, the total assets of JPMorgan are $3.95 trillion, which is slightly *more* than the annual budget of the US government.

US banks alone had about $28 trillion in assets as of 2020, with the top four banks holding about $12 trillion of that.

What if the banking sector turned the tables?

US federal law prohibits the merger of, say, JPMorgan and Apple. But, if the book value of the acquired assets does not exceed 10% – the Federal Reserve threshold for bank risk (I'll spare you the jargon) – or $10 billion in value, there is the possibility of a financial holding company (under which a bank can operate) buying a smaller entity, then leveraging it.

US banks hold nearly $900 billion in credit card debt. With the average credit card assessed interest rate north of 16%, those interest payments add up to tremendous monthly recurring revenue.

And it doesn't take much to imagine that the financial services industry will push back – hard – on regulators, should Apple (or Alphabet or Meta) take much of a bite out of that debt pie.

So consider what the printed circuit manufacturing world would look like if the top 10 customer list included Bank of America, Citigroup and Wells Fargo. How quickly would those financial services firms be able to ramp procurement and quality operations? Where would they be located, and how large would they be? What (additional) pressure would be brought to bear on employee sourcing? Would design be performed in-house or out? Would they team only with top-tier manufacturers, or would they partner with regional specialists?

Uber upset the personal logistics space by blasting holes in municipal codes covering licensing of hackneys (taxis). Likewise, we already see some banks and credit unions implementing mobile technology solutions that enable faster access to personal or company assets using third-party platforms like smartphones. This could happen.

If you think it's farfetched, remember this: Once "just" a contract assembler, Foxconn now owns huge standalone operations in semiconductors, telecom and electric vehicles, among others.

Mountains can move in many directions.

PCB West a success. Thanks to all who attended and exhibited PCB West in October. Nearly 2,000 industry professionals, representing some 35 countries, registered for the conference and exhibition. Of particular note was conference registration, which reached its highest point in more than 10 years. We are already looking forward to PCB East next May in the Boston suburbs.

Staff updates. Finally, I'd like to welcome our new managing editor, Tyler Hanes. A graduate of the University of Alabama with a degree in journalism, he comes to us after nearly six years in regional newspapers followed by a year in communications with a trade association. Tyler will attend at the PCEA booth at PCB Carolina in November; please be sure to say hello.

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PCDF People

Winonics named **Connie Herring** vice president of sales.

Isola named **Mike McMaster** director of high-speed digital materials.

NCAB promoted **Howard Goff** to vice president sales and named **Benjamin Klingenberg** to head Segment Europe.

Summit Interconnect named **Ramsin Davoodi** general manager and **Jordan Wines** engineering manager.

Marshall Lewis, owner of Holaday Circuits, and **Meyer Averbuch,** founder of ZOT, have passed away.

Ventec named **Chad Wood** director OEM Sales and business development, focused on the Western US. He is an experienced technical sales leader who has worked in the electronics and semiconductor industries for more than 28 years.

PCDF Briefs

AGC Chemicals Americas opened an office in Cupertino, CA, to support electronics manufacturers located on the northern West Coast.

Altair has completed the acquisition of **RapidMiner,** a developer of advanced data analytics and machine learning software.

A California environmental group is suing **Cirexx International,** alleging the PCB manufacturer and assembler is polluting the local waterways.

The **Electronic Components Industry Association** released new guidance for noncancellable, nonreturnable components. The intent is to help clarify the use of the NCNR process in the electronic component authorized channel by publishing updated industry guidelines and communicating these best practices to the industry, the trade group said in September. The document includes an explanation of the need for the guidelines, as well as a sample form for transactions. The guidelines can be downloaded at www.ecianow.org/issues-practices.

Escatec will establish a dedicated Innovation Hub in Heerbrugg, Switzerland, to boost its design and development (D&D) services. The new workspace will house 22 D&D professionals.

Green Arrow Capital has sold **Somacis Graphic Group** to **Chequers Capital.** Financial terms were not disclosed, but Somacis expects business as usual at its operations.

Printed Circuits, All Flex Merge

NORTHFIELD, MN, AND CHASKA MN – Flex circuit fabricators Printed Circuits and All Flex have merged and have begun operations under the name All Flex Solutions. The merger closed Aug. 31, following two years of collaboration and integration. Financial terms were not disclosed.

Chaska-based Printed Circuits primarily offers rigid-flex PCBs, while and Northfield-based All Flex produces flexible circuitry and assemblies.

"With marquee customers in medical, aerospace, and defense end-markets, the combined company will provide both life- and mission-critical solutions," the firms said.

Dale Nordquist, chairman, All Flex, becomes chair of the merged company. Kevin Jackson, who joined the company in early July, has been named chief executive.

Customers' and suppliers' points of contact at All Flex Solutions will remain the same, and all products will continue to be manufactured on the same equipment in the same locations, which include three facilities and more than 160,000 sq. ft. to support increased capabilities and growing capacity.

All the more than 340 All Flex Solutions team members have been retained.

In a statement, Ken Tannehill, founder, Printed Circuits, said, "Our companies are natural and better together, sharing common values, geography, processes, and customers after having collaborated informally for many years."

The executive team includes John Fallon as president of the Flexible Circuit Center of Excellence, Matt Tannehill as president of the Rigid Flex Center of Excellence, Joy Fries as chief development officer, and Stacy Colbert as chief financial officer.

Granite Partners led the investment in the merged company.

EC Expected to Add TBBPA to RoHS Directive

BRUSSELS – The European Commission is currently reviewing recommendations to restrict tetrabromobisphenol A (TBBPA) under the EU RoHS Directive. A decision on the recommendations from Oeko-Institut is expected by year-end.

TBBPA is found in brominated epoxy resins used as flame retardants in printed circuit board laminate, among other uses. The restriction would be adopted as an amendment to the RoHS Directive.

Foxconn Acquires Majority Stake in Juarez EMS Firm

TAIPEI – A Foxconn subsidiary is purchasing a majority share in PCE Technology de Juarez, an electronics manufacturing services company focused on consumer electronics, for $361 million.

ECMMS Precision Singapore has obtained an 84.5% stake in PCE Technology, Foxconn said.

PCE was founded in April 2008 and is located minutes south from the US border and El Paso, TX.

Just minutes east of PCE, Foxconn also operates a massive campus in Juarez and its FIH Co. subsidiary is expanding in Mexico this fall.

Pegatron Opens $135M India Assembly Plant

CHENNAI, INDIA – Pegatron has inaugurated an electronics assembly facility here that could employ up to 14,000 workers at full capacity. The ODM will invest about Rs

1,100 crore ($135 million) in the unit, which will build products for Apple.

Apple is expected to move at least a quarter of its manufacturing facilities to India by 2025, according to published reports.

"The fact that Pegatron has started production within 18 months of signing the MoU highlights the investor-friendly climate in Tamil Nadu," said M K Stalin, chief minister, Tamil Nadu. "China is where new cellphone models are manufactured in bulk. We are working to change that and make Tamil Nadu such a manufacturing hub."

Electronics Companies Take 'Split Manufacturing' Approach to Combat Counterfeit Components

MUNICH – A consortium of Fraunhofer institutes and German industrial companies is developing a split-manufacturing approach for semiconductor production in the project "Distributed Manufacturing for Novel and Trustworthy Electronics T4T." This will enable the secure assembly of subsystems in Germany and safeguard supply chains.

The €16.44 million project was launched in January and is scheduled to be completed in March 2025.

Germany sees the secure supply of electronic components of growing strategic importance. The sector has been vulnerable to IP theft of circuit designs, and malware and espionage, due to higher reliance on IC manufacturing by foundries outside Europe. The T4T project aims to provide domestic industry with tools to access secure supply chains and trusted electronics. Subcomponents adapted to these requirements can still be accessed via existing supply chains (split manufacturing), but the assembly and encoding of the systems will take place in a trusted environment at the German site.

The new technical requirements of this split-manufacturing approach to packaging technology are to be visualized with the aid of various demonstrators. These will illustrate new design flows and methods, adapted manufacturing processes and the individual technical know-how of the project partners involved. In addition to Bosch, Osram, Audi and XFAB, these include NanoWired, Suess, DISCO and IHP as well as the Fraunhofer Institutes IZM-ASSID, IPMS, IIS/EAS and the Technical University of Dresden.

The knowledge gained from the project is intended to make a structural contribution to the standardization of processes in packaging and interconnection technology and, to this end, define new design specifications and tolerance rules for offset and structure sizes.

Zollner Plans New Location in Tunisia

ENFIDHA, TUNSIA – Zollner Elektronik will open an additional electronics manufacturing site on the east coast of Tunisia. The company plans to start production in Enfidha at the beginning of 2023 in a building it has leased while construction is underway on a new facility at the same location.

With the new plant in Tunisia, Zollner said it will be able to expand the capacity and resources in the medium- to long-term for the production of PCBs and electronic modules in an industrial environment for the European market (EMEA).

Production will start at the temporarily leased 2,500m² of production space at the beginning of 2023 with around 100 employees. Almost simultaneously, preparatory activities will begin for the construction of the company's own manufacturing facility. Zollner said around 10,000m² of production space will be created in its first step, and the facility should be completed in 2024. (TH)

Icape has acquired PCB supplier **Lusodabel,** which will continue to operate in Portugal and Spain under the name Icape Lusodabel. In 2021, Lusodabel generated annual net sales of more than €6.1 million and an EBIT of about €1.2 million.

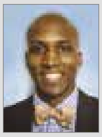
JITX, a developer of a compiler that turns programming code into circuit board designs, has raised a $12 million in Series A funding.

Molex is expanding its existing manufacturing operations in Hanoi to include a new 16,000 sq. meter facility.

Showa Electric increased production in Taiwan and Japan to double its copper foil substrate production capacity.

SnapEDA is launching an ecosystem of over 30 distribution partners, including electronic component distributors, PCB tool makers, and engineering media sites.

CA People



BTU named **Isaiah Smith** regional sales manager, responsible for the central US and Canada. He has held sales roles for related SMT process equipment including printers and inspection with ITW EAE and Koh Young America.

Hanza named **Tom Dahlén** group sales director. He spent the past 20 years in different managerial positions at Arrow Electronics.

Indium announced **Nate Discavage** as talent acquisition supervisor. He was a recruiter at the Resource Center for Independent Living.

Lacroix appointed **Stéphane Klajzyngier** president of Lacroix North America, **Louis Pourdieu** executive general manager of EMEA electronics activity, and **Serge Laverdure** manager, Lacroix design center.

Naprotek appointed **Mike Lee** chief financial officer. He has 25 years' experience driving profitability, productivity, and operational excellence within diverse manufacturing organizations, including Fiber Materials and Fairchild Semiconductor.

Neways appointed **Hans Büthker** chief executive officer. He was previously CEO at Fokker and GKN Aerospace, and served as chief operating officer at Fokker and chief procurement officer at Stork.

VJ Electronix named **Paul Pazareskis** global service manager.

CA Briefs

Advanced Semiconductor Engineering unveiled plans for a 5G mmWave NR-DC SA (New Radio-Dual Connectivity Standalone) smart factory supported by the **Industrial Development Bureau** and **Qualcomm.**

Bentec appointed **C.H.Erbslöh** SurfX distributor in Poland.

Circuit Technology Center commissioned a second **Heller** 1707-MK III inline solder reflow oven.

Cogiscan named **Realize SMT** and **Starbord Technologies** distributors in Eastern Canada.

Custom Electronics announced a value-added distribution partnership with EMS firm **Vasantha Advanced Systems** (VAS).

Enics last month opened a business development center in Baden, Switzerland.

Flex is expanding its four-building campus in Tczew, Poland, which is now 860,000 sq. ft.

Foxhole Group, a private investment firm, has acquired **OSDA,** a quickturn prototype PCB assembler, and **Argo EMS.**

The merger of **GPV** and **Enics** was completed in October, forming the second-largest Europe-based EMS.

Intel plans to expand the Intel Developer Cloud to allow customers to try a range of new chips before they hit the market, a move it hopes will lure more application developers to use its processors.

Kitron has entered a production agreement with **Ferroamp** worth approximately NOK90 million ($8 million) in 2023 and NOK350 million ($33 million) over a three-year period.

A **Kulicke and Soffa** subsidiary has signed a definitive agreement to acquire **Advanced Jet Automation,** a Taiwanese OEM of micro-dispensing equipment.

OK International announced **LÖKAST** as an official **Metcal** distributor.

Siemens Digital Industries Software will now offer the **Cybord AI** visual analytics solution.

Spectrum Assembly (SAI) has purchased a **Nordson** Assure x-ray component counter.

Tata is in talks with **Wistron** to establish an electronics manufacturing joint venture in India.

VVDN Technologies has entered a multi-year global strategic partnership with **Google Cloud.**

Inventec USA Sues Over Unauthorized Use of Amtech Brand

DEEP RIVER, CT – Inventec Performance Chemicals USA has filed a lawsuit in US District Court here against Optimal Services, Amtech Manufacturing and various other related entities, asserting violation of federal laws governing unfair competition, false designation of origin and false advertising, and violation of the Connecticut Unfair Trade Practice Act, arising from the alleged unauthorized use of Inventec USA's trademarks.

In the complaint, Inventec USA accuses a terminated distributor of the misappropriation of Inventec's Amtech trademarks and tradenames, as well as Inventec's entire product naming system.

Inventec alleges the distributor duplicated more than 50 product names, such as NC-559, RMA-223 and NWS-4200, which have been used by Inventec USA for years. Inventec USA has owned all such trademarks and tradenames since 2014 and has been manufacturing and selling its full AMTECH soldering portfolio from its factory located in Deep River, Connecticut.

According to Inventec, the terminated distributor's products are being deceptively passed off as Amtech "original" products, and the company filed the lawsuit to demonstrate its commitment to safeguard the quality, safety, and authenticity of its product and to protect the integrity of the market.

Inventec USA sells its Amtech products only through authorized representatives and distributors, a list of which is available on the company's website. Authentic Amtech products bear the mention "Inventec Performance Chemicals USA, LLC" on their upper right side.

The suit also names Amtech LLC, Amtech Distribution LLC and Mark Miller, an individual, and other unnamed defendants. (TH)

Optiemus to Open Third Factory in India

NEW DELHI – Optiemus Electronics will open a new factory for wearables in Noida by the end of December as part of its strategy to expand capacity to meet growing demand for smartwatches and truly wireless stereo (TWS) earbuds, said director Nitesh Gupta.

"We are looking at a rapid capacity expansion as the market is also growing at a very rapid pace. Next year, we are also planning to set up manufacturing in South India," said Gupta in an interview with Mint.

India's smartwatch market grew fourfold from a year earlier in the June quarter, while TWS shipments grew two and a half times, according to Counterpoint Research.

Optiemus currently manufactures wearables for homegrown brands such as Noise and Samsung unit Harman. According to Counterpoint, Noise was the second-highest selling smartwatch brand in India and fifth globally in the June quarter.

The new facility will boost Optiemus' manufacturing capacity by 2 million units per month. The company currently has two factories for wearables, also in Noida, with a combined capacity of 3.2 million units per month.

The expansion will also double the workforce for Optiemus. "The wearables segment is quite labor intensive. We currently employ 2,500 workers. We expect the headcount to grow to 5,000 with the expansion we have planned," said Gupta. (TH) ❑

Michael Creeden Receives 1st PCEA Leadership Award

SANTA CLARA, CA – PCEA on Oct. 4 announced Michael Creeden as recipient of the first PCEA Leadership Award, for his lifetime service in the pursuit of educating and training PCB design engineers. The announcement was made at the PCEA annual meeting in conjunction with the PCB West conference and exhibition.

Creeden, who is PCEA's first vice chairman, was instrumental in the launch of PCEA and the negotiation to acquire the assets of UP Media Group, including PCB West.

"More than anyone else, Mike Creeden willed this organization from creation to where it is today," said Stephen Chavez, chairman, PCEA, in announcing the award.

"His tireless optimism and determination helped overcome the challenges of launching a new all-volunteer organization right at the start of a pandemic, and his leadership brought us through a significant acquisition and to this point where we stand on the cusp of real industry influence. It gives me great pleasure to announce Michael Creeden as the inaugural recipient of the PCEA Leadership Award."

PCEA Chairman Steph Chavez (left) presents Mike Creeden with the PCEA Leadership Award.

Scott McCurdy Receives 2022 PCEA Membership Award

SANTA CLARA, CA – PCEA in October announced Scott McCurdy as recipient of the first PCEA Membership Award.

Scott McCurdy was PCEA's first Membership Committee chairman, and has been president of the Orange County chapter of the PCEA since its inception.

"The core of PCEA is its membership, and Scott McCurdy will be remembered as the first Membership chairman in PCEA history," said Stephen Chavez, chairman, PCEA.

"This is not an easy job. We are a chapter-based organization that was founded just as Covid was emerging. Scott has been a steady hand throughout, reminding all of us of the need to continue to make connections at the grass roots, and providing the template for chapters to develop their own unique culture.

"And so, for his dedication toward growing the PCEA Membership, I am pleased to announce Scott McCurdy as the first recipient of the PCEA Membership Award."

PCB WEST 2022
Conference & Exhibition

PCB West a Resounding Success

PEACHTREE CITY, GA – PCEA celebrated a very successful PCB West in October, its first since acquiring the industry-leading technical conference and trade show from UP Media Group in January.

Conference registration was at its highest point in more than 10 years, nearly 2,000 industry professionals registered for the exhibition, and more than 85 exhibitors filled the sold-out show floor.

Keynoter Dr. Brian Toleno, manager, Applied Materials at Meta's Reality Labs, gave a scintillating presentation on the opportunities the metaverses offer not just for users but for developers of computing devices. He looked at the novel innovations in materials and production that will be needed for printed circuit designs to meet the requirements for weight, size and functionality. "Games alone won't drive AR/VR," Toleno noted. "The next generation of Zoom will be 3-D avatars."

2023-24 Board Members Announced

PEACHTREE CITY, GA – PCEA members have elected the following persons as directors for the 2023-24 term: Stephen Chavez, Tomas Chester, Michael Creeden, Doug Dixon, Tara Dunn, Gary Ferrari, Justin Fleming, Richard Hartley, Scott McCurdy, Anaya Vardya, Susy Webb and Eriko Yamato. They are joined on the board by Michael Buetow, president of PCEA.

The following officers have been named as well: Chavez, chairman; Dunn, vice chairman; Fleming, secretary. Committee chairs include Chester, Education; and Creeden, Membership. ❑

Chapter News

Orange County. We held a Lunch-and-Learn on Oct. 19 in Santa Ana. Our featured speakers were Stephen Chavez of Siemens and Gerry Partida, VP of technology at Summit Interconnect. They discussed industry best practices within the design to fabrication process, along with the pros and cons that affect ROI when best practice recipes are implemented and when they are not implemented (the cost of doing nothing).

Europe. Our chapter is holding monthly web meetings using the Discord platform, where we discuss each other's PCB-related questions. We have been doing these highly informal gatherings for about 18 months, with the same core people.

Survey: Supply Chain Optimization Remains Challenging

LONDON – How emerging tech is used in supply-chain operations varies greatly, as do future investment plans. But 80% of respondents to a recent survey conducted by PwC say technology investments haven't fully delivered expected results. Furthermore, many reasons are to blame, respondents say.

Indeed, many challenges remain to fully optimize supply chains, says PwC's annual *Digital Trends in Supply Chain Survey.* Some 244 operations and information technology leaders, C-suite executives and other supply chain officers responded. Key findings:

- While companies focus on supply chain basics like increasing efficiency and managing costs, they're missing value creation opportunities in digitization, sustainability and transformation.
- Most respondents cite multiple supply attributes as moderate or major risks, yet few see increasing the number of suppliers, transforming procurement practices or increasing responsiveness and resilience as priorities – a significant disconnect.
- In digitizing their supply chains, companies need the most help stretching their budgets, but having the right talent and the right tech are issues as well.
- Many companies – 58% of respondents – are seeing higher-than-normal turnover among supply chain employees, and only 23% fully agree they have the necessary digital skills to meet future goals. Most also expect to make changes to their operational systems in the next year.
- Responding to regulatory changes and identifying supplier risks are top environmental, social and governance (ESG) challenges, but fewer companies are focusing on ESG reporting and metrics.

KEY COMPONENTS

	APR.	MAY	JUN.	JUL.	AUG.
EMS (North America)[1,3]	1.36	1.35	1.59	1.39	1.31
Semiconductors[2,3]	21.1%	18%	13.3%	7.2[r]	0.1%[p]
PCBs[1,3] (North America)	1.04	1.05	1.03	0.98	0.98

Sources: [1]IPC, [2]SIA, [3]3-month moving average, [p]preliminary, [r]revised

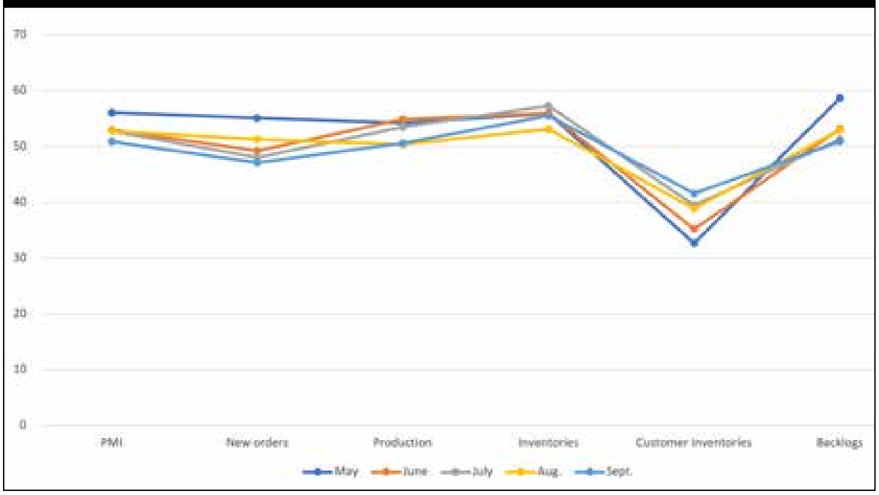
ON THE SIDE (% CHANGE)

Trends in the US electronics equipment market (shipments only).

	JUN.	JUL.[r]	AUG.*	YTD%
Computers and electronics products	1.6	0.5	0.4	6.1
Computers	1.4	3.5	-1.9	-0.3
Storage devices	1.1	0.0	1.3	14.0
Other peripheral equipment	26.0	26.9	3.3	23.2
Nondefense communications equipment	1.4	1.8	-2.2	10.6
Defense communications equipment	1.5	3.3	-0.5	7.1
A/V equipment	-15.0	10.9	0.8	30.5
Components[1]	-0.7	1.1	1.1	15.2
Nondefense search and navigation equipment	1.4	0.8	-0.4	1.9
Defense search and navigation equipment	-1.1	-0.8	2.1	0.4
Medical, measurement and control	3.8	-0.8	0.7	3.8

[r]Revised. *Preliminary. [1]Includes semiconductors. Seasonally adjusted.
Source: U.S. Dept. of Commerce Census Bureau, Oct. 4, 2022

US MANUFACTURING INDICES



Source: Institute for Supply Management, Oct. 3, 2022

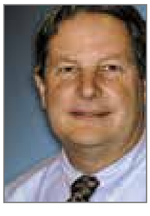
Hot Takes

- **PCB and MCM design software sales** rose 22% year-over-year in the second quarter to $347.1 million. The four-quarter moving average for PCB and MCM, which compares the most recent four quarters to the prior four, rose 12.9%. (ESD Alliance)
- The **Electronic Component Sales Trend index** fell from 86 in August to 82.3 in September measurement. Electromechanical components declined 16.7 points, semiconductors rose 7.2 points, and passives dipped 1.7 points. (ECIA)
- **Japan's PCB production** rose 12% in July to 64 billion yen ($441 million), the 23rd straight month of growth. (JPCA)
- **Global semiconductor equipment billings** rose 7% sequentially in the second quarter and 6% year-over-year. (SEMI)
- **North American fabricators** reported the 90-day moving average PCB shipments in August rose 15.1% from a year ago. Compared to the preceding month, shipments rose 7.5%. (IPC)
- A vigorous **DRAM market** upturn that started in the last half of 2020 and continued through May 2022 is over, as revenues sank 36% year-over-year in June and 21% in July. (IC Insights)
- **Global wearables shipments** declined 6.9% year-over-year in the second quarter to 107.4 million units. (IDC)
- **Global fab equipment spending** for front-end facilities is expected to increase approximately 9% year-over-year to an all-time high of $99 billion in 2022. (SEMI)
- Twenty-eight percent of **consumers are planning to spend less** this holiday season and 10% plan to spend more than previous years. (Gartner)

All Worked Up

Widespread critical staffing needs call for a cross-industry effort to promote manufacturing.

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



WITH THIS TIME of year come many opportunities to attend industry gatherings, catch up with industry colleagues, and find out what's happening in the macro circuit board supply chain. Over the past couple months, I have seen many old friends. And, I have had more than a few opportunities to reflect on our industry, the state of the supply chain, and what is "critical" versus just "important."

For the record, I have been in the "printed circuit board" industry for over three decades. Each decade had a distinct – and different – feel. During the 1990s our industry was in a go-go stage, and everyone – from designer through material and equipment supplier to fabricator to assembler – shared an attitude, perhaps even a swagger, that the future was limitless. Back then, some companies invested heavily in capacity and capability with the blind faith that if you build it, customers will come.

As one millennium passed to the next, harsh reality set it. Just after we ushered in Y2K, the party crashed to an end. Customers migrated production en masse to Asia, which offered comparable quality at a much lower cost. As manufacturers shuttered operations in Europe and North America, talent departed to other industries that offered more security, if not growth.

Over the past decade the new norm of the Western industry is smaller size and scope. New technologies and automation are adopted to maintain volumes and add some capability and capacity. The Western PCB industry, as have most manufacturing industries, has focused on survival; get through the next quarter and leave long-term concerns on the back burner.

Yet today, globally far more printed circuit boards are designed, fabricated and assembled than ever. Likewise, more laminate, chemistry and supplies are purchased, and there are more end-customers and product applications. A combination of circus-like politics, a European war, new Controlled Unclassified Information (CUI) regulations, and strained global supply chains, is shifting the pendulum from buying cheaply to buying from secure, trusted sources. Amid the good news that North American companies want, or are being told they must, purchase from secure, trusted North American suppliers, however, is a new realization of what is "critical."

Steps taken over the past two decades to "right-size" operations, with a focus on strengths rather than trying to provide all technologies to all types of customers, were indeed important. Without short-term survival there is no long term! Once that task was completed, however, too many returned to the "good enough" mantra: Keep doing what you are doing with whom you are doing it with. Regrettably, this again has provided a false sense of security.

Then Covid shocked the industry as well as the entire economy. Supply-chain shortages created serious and previously unforeseen challenges. But possibly the biggest shock in manufacturing, especially in electronics, was the combination of an aging work force, many of whom chose to retire early to reduce the chance of contracting Covid, and the lack of interest of younger generations to consider any manufacturing job, let alone a career.

With the supply chain easing a bit, and governments passing legislation to invest in critical industries (which printed circuit boards and electronics certainly are), the big question is, "Who will be the people who manufacture the critical products?"

What is needed, now, to address the staffing issue is a cross-industry effort to promote manufacturing. Promote it as essential, yes, but more importantly, promote how individuals from the design to the shop floor can impact the success of a technology, product and company – perhaps more so than other professions, and certainly over working at the mall or fixing cars. Manufacturing requires creative people and provides lucrative long-term careers. All manufacturing industries would benefit from that message being repeated over and over.

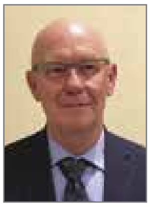
Important as it is that workers at the start of their careers hear about manufacturing, academia also needs to understand the skills needed. Too many teaching courses, such as CAD, do not understand the same skills are needed to be successful in CAM. Effort needs to center on educating the educators on industry's needs and how to teach skills that are needed immediately by employers.

Enthusiasm, a positive attitude, a "can-do" approach: all are hallmarks of our industry's entrepreneurial past. Those traits are needed more than ever if, long term, we are to have the talented workforce to fabricate and assemble the critical products that customers want from secure, trusted suppliers. If we can work together with other manufacturing industries to successfully attract the people to meet this critical need, we may regain the swagger of a few decades back. Those thoughts were contagious. Now is the time to focus on the critical. We have successfully accomplished the "important" with hard work and focus. But showing up every day and doing the same with the same will not at this point in time address the critical need of our industry to promote manufacturing and attract the next generation of circuit board talent. ❑

Creating a Documentation Package

Communicating the design intent, clearly and concisely.

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.



THE CAD SYSTEM can do a lot for you; then you're on your own. Eyeballing the layers two or three at a time will help you find the hidden traps. A camera-ready board is just the beginning. Documenting the PCB requirements with dimensions and other details, including hole chart(s), stack up diagram(s), a list of intentional shorts, etc., puts the necessary guardrails around the fabrication and assembly.

Fabrication notes will change with the technology used for the PCB. The general thrust of this list of example notes is for a multilayer board targeted for consumer electronics with components on both sides and controlled impedance on inner- and outer layers.

Flex circuits or high-reliability boards would have significantly different callouts. In any case, all the attributes of the drawing need traceability. When calling out a specific process, such as cleaning with "ultra pure water," it should be accompanied by a requirement for a Certificate of Conformance. Otherwise, who could tell if the process was followed?

Note 1A (below) covers a lot of ground by itself. The notes that follow are best used to describe options within the spec and exceptions to the spec. For instance, you may call for "Class 2 (as shown)" but do not want to allow 90° break-out of the drilled hole from the pad. In that case, a note calling for "no break-out, tangency permitted" would be necessary and sufficient for that exception to the general Class 2 fabrication rules. If that option is requested, make sure it is possible by increasing the pad size so that the tolerance stack makes sense.

Standard fabrication notes (unless otherwise specified).

1. Standards:
   a. Fabricate PCB in accordance with current revision of IPC-6012, Class 2.
   b. Interpret dimensions and tolerances in accordance with the current revision of ASME Y14.5.
   c. Do not scale drawing.
2. Material:
   a. Laminate and prepreg material shall be woven "E" glass/epoxy in accordance with IPC-4101/126 or equivalent.
   b. Equivalent material shall be RoHS compliant, halogen-free, with a minimum Tg of 170°C and approved by company.
   c. Thickness of individual copper-clad sheets shall be as defined in stack-up diagram.
3. Flatness:
   a. Bow and twist of assembly subpanel or singulated PWB shall not exceed 0.025cm per cm.
   b. Test in accordance with current revision of IPC-TM-650, method 2.4.22.
4. Etch geometry:
   a. Measure width from the base of the metallization.
   b. Minimum line width: 0.nn mm outer, 0.nn mm innerlayers.
   c. Finished line width and terminal area shall not deviate from the 1:1 master pattern image by more than +/-0.025mm or 20%, whichever is less.
5. Surface finish (select appropriate finish):
   a. ENEPIG plating in accordance with current revi-

FIGURE 1. A gleaming high-tech sensor factory.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sion of IPC-4556. Exposed metal shall have 118 to 236 microinches electroless nickel, 2 to 6 microinches electroless palladium, and 1.2 microinches gold.

b. ENIG plating per current revision of IPC-4552. Exposed metal shall have 118 to 236 microinches electroless nickel and 2 to 5 microinches gold.

6. Destructive testing:
   a. Microsection sample and report shall be provided to company design engineering.
   b. Solder sample processed through lead-free soldering shall be included with each shipment.
   c. X-out panels may be used for solder sample.
7. Holes:
   a. Plating in holes shall be continuous electrolytic copper with 0.025mm minimum barrel thickness.
   b. Minimum finished hole size: 0.nn mm.
   c. Hole size measured after plating.
   d. See drill chart for finished hole size and tolerance.
   e. All holes shall be located within 0.08mm of true position as supplied in CAD data.
8. Solder mask:
   a. Solder mask over bare copper (SMOBC) on primary and secondary sides using supplied artwork in accordance with current revision of IPC-SM-840 type B.
   b. Color: matte green.
   c. Liquid photoimageable (LPI) 0.001mm to 0.002mm thickness, halogen-free.
   d. No bleed-out allowed over exposed SMD pads.
   e. No exposed traces.
9. Silkscreen:
   a. Silkscreen primary and secondary side with white epoxy, nonconductive, non nutrient ink.
   b. Any unspecified stroke width shall be 0.13mm.
   c. Clip silkscreen away from any exposed metal.
   d. Vendor date code, logo, UL and any additional marking to be located on secondary side.
   e. Bag and tag acceptable for PWBs that are too small for marking.
10. Remove all burrs and break sharp edges R0.01 min.
11. Nondestructive evaluation:
    a. All PCBs shall pass 100% electrical test using supplied IPC-356 netlist in accordance with current revision of IPC-9252, Class 2.
    b. Certificate of conformance shall be supplied with each shipment.
12. X-outs:
    a. X-out boards that do not meet all specifications using permanent marking on both sides of affected PCB.
    b. Panels that do not have any X-outs shall be packaged together.
    c. Panels that have *n* or fewer X-outs shall be packaged separately from non-X-out panels.
    d. Panels with more than *n* X-outs shall be rejected.
13. Packaging requirements:
    a. PWBs shall be packaged in vacuum-sealed inner containers.
    b. Outer containers shall be sufficient to prevent damage during shipping and handling.
14. Impedance (all tolerances +/-10%):
    a. All 0.nn mm wide traces on outer layers shall be 50Ω.
    b. All 0.nn mm wide/0.nn mm space pairs on outer layers shall be 90Ω.
    c. All 0.nn mm wide/0.nn mm space pairs on inner layers shall be 90Ω.
    d. Vendor may adjust design geometries up to +/-20% to achieve target impedance. Adjustments beyond 20% of line width, spacing or dielectric thickness shall require approval from company engineering.

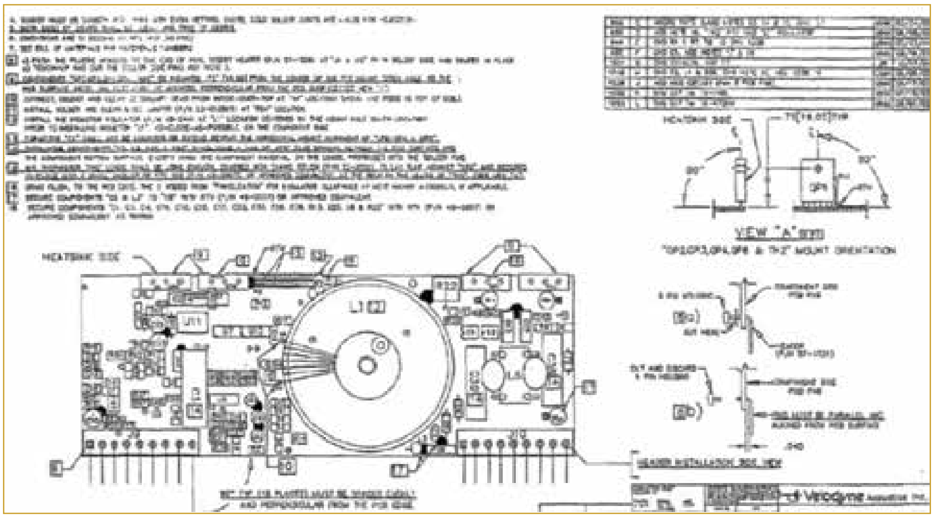

FIGURE 2. Assembly drawings come in two main types: SMT assembly and (like this one) second-operation drawings. Note that the details use third angle projection. (Source: Velodyne)

Assembly drawings. Another inspection document is the assembly drawing **(FIGURE 2)**. The primary goal is to show what the finished assembly looks like. If you read my columns, you probably know that I insist that this is a what-is, not a how-to document. How-to documents are subject to frequent revision as the process evolves through continuous improvement. Don’t get yourself wrapped around that axle.

Projecting views. There will always be a topside plan view of the PCB outline. It may be augmented with a side or cutaway view to show details, such as the beveled edge for gold fingers. The US, Australia and possibly some other locations use what is called “third angle projection,” while “first angle projection” is the norm in Europe and elsewhere **(FIGURE 3)**.

For third angle projection, imagine the board at the bot-

tom of a bowl. The top and side views are created by sliding and rotating the view up the sides of the bowl, so the side seen in the edge view faces toward the plan view. On the other hand, first angle projection inverts the imaginary bowl and allows the additional views to slide off the bowl.

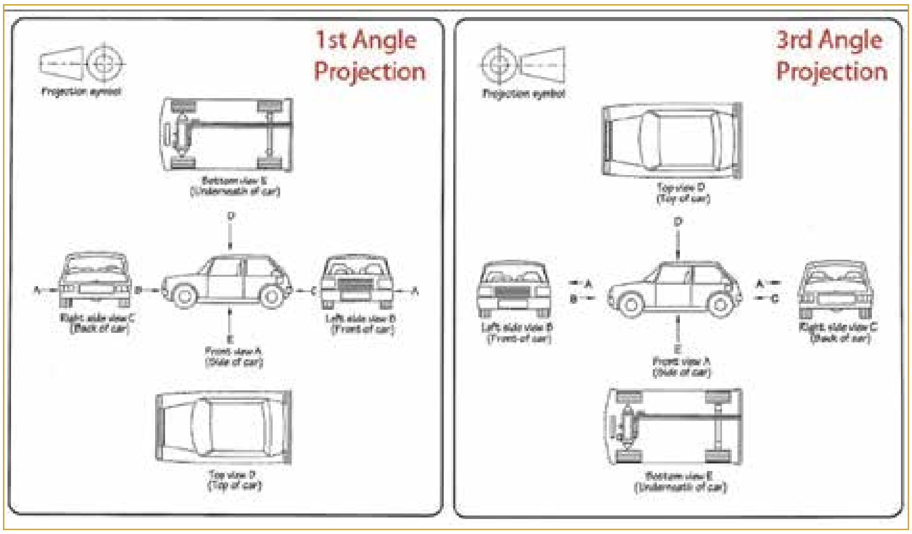

FIGURE 3. The graphics in the upper left corner of these views are included in the title block to establish the projection of various views. (Source: Practical Machinist)

Standard assembly notes (unless otherwise specified).

1. Interpret drawing in accordance with ASME Y14.5M, 1994.
2. Workmanship shall be in accordance with current revision of J-STD-001 and IPC-HDBK-001.
3. Inspection shall be in accordance with current revision of IPC-A-610, Class 2.
4. The controlling document for component placement shall be xy-nnn-nnnn-nn.
5. Mark dash and revision level in permanent black ink as shown.
6. Affix barcode, date code and serial number labels on secondary side as shown. Bag and tag acceptable for assemblies that are too small for labels.
7. Company reference documents as follows:

- Bill of material nnn-nnnn-nn
- Placement file nnn-nnnn-nn
- Paste stencil nnn-nnnn-nn
- Schematic nnn-nnnn-nn
- FPGA programming nnn-nnnn-nn
- Test procedure nnn-nnnn-nn
- Whatever else is relevant and not documented elsewhere.

Formatting data. The industry has used Gerber data about as long as it has used computers to aid our design efforts. Gerber data has evolved to permit unlimited apertures. Originally, this was a mechanical process that involved aperture wheels with 24 different openings used to generate the phototools.

The aperture wheels evolved to an electronic equivalent. Every PCB design was taped out with a separate file for the apertures. The aperture list is now embedded with each artwork layer to make it more resilient. The information conveyed in this standard is just the raw geometry. File names supplemented with a *readme.doc* help the fabricator determine how to use the data.

Eventually, a de facto standard came along from Valor (now part of Siemens). It is native to the software used in the front-end of the fabrication process. The format is called ODB++ and it has some intelligence along with the geometry data. Fabrication and assembly data can be combined in a single archive. Most PCB factories prefer this type of data. This was acceptable when Valor was a standalone enterprise.

The ECAD industry has come together around a new specification that adds more intelligence and is not encumbered by commercial interests. This new spec is IPC-2581. Want a good time? Hook up with an outfit that will talk IPC-2581 with you. The artwork still must be camera-ready; it's not doing your drawings. What it will do is a thorough extraction and allow the designer to define what goes to the manufacturing partner.

According to my colleague, Hemant Shah, "IPC-2581 not only makes design data handoff efficient, it also makes manufacturing the board more efficient. IPC-2581 connects to IPC-CFX to help with smart factory automation. With IPC-2581 revision C, manufacturing partners can provide technical queries in the 2581 format, making it very easy to cross-probe, track, resolve, approve and reject TQs."

Many fabricators rely on Gerber data because they have a different CAM tool. A majority of high-capability shops use ODB++ and prefer it. It will be up to us, the design community, to help launch the new CAD-neutral IPC format. □

Related documents. Standards and specifications that cover PCB documentation and electronics data transfer include:

- IPC-D-325, *Documentation Requirements for Printed Boards.*
- IPC-2581, *Generic Requirements for Printed Board Assembly Products Manufacturing Description Data and Transfer Methodology.*
- IPC-D-310, *Guidelines for Phototool Generation and Measurement Techniques.*
- IPC-2514, *Printed Board Manufacturing Data Description.*
- IPC-2513, *Drawing Methods for Manufacturing Data Description.*
- IPC-2615, *Printed Board Dimensions and Tolerances.*

What Will 6G Bring to Our Lives?

While 5G has only shown a fraction of its potential, will the world ever be ready for the next generation?

MUCH OF THE world seems to have changed beyond recognition since the pandemic began. With numerous economic and environmental uncertainties, however, one thing remains constant: our appetite for what comes next – and our impatience – are undiminished. The rollout of 5G cellular networks has barely begun – after a huge development effort to define the standards and do the engineering – yet, already, excitement is building around 6G. The first standardization phase for this will begin in 2023 and services should be available around 2030.

Some of us remember the arrival of the first digital cellular networks, in 1993. This was the point when MNOs were able to begin offering data services in addition to voice. Data rates were laughable by today's standards, starting at about 9.6 kbaud. Some of today's dominant trends, however, such as remote working, can trace their origins back to here. With these primitive data services, we were able to use our phones to connect remotely to factory data systems and do rudimentary work wherever we were.

Today, 2G data services are perfect for connecting IoT devices and for M2M communication, although network operators are keen to switch off legacy infrastructure to concentrate resources on 4G and 5G services for consumers. It's likely that 3G turnoff will be completed first. Certainly it will in Europe, where 2G services could be maintained until 2030 or beyond.

Right now, many are uncertain what advantages 5G will bring. We know it will support high data rates and very low latency, and it's also clear that delivering the most advanced 5G services to rural areas will be a great challenge due to the nature of the signal physics and infrastructure requirements. 5G requires many more access points, which can be installed far more easily in urban areas by mounting on lamp posts and other street furniture, whereas the practical challenges, and the costs, are greater in rural areas

We can safely assume that 6G will be even bigger and better, with faster data speeds and such low latency that the smartphone screen will be the single largest source of lag in the system. It may be hard to imagine now, but the time this arrives we will be ready for the new services that will emerge.

Some of the most powerful applications that could take advantage of 6G's speed and scale include modelling large systems like entire cities digitally, using billions of sensors to gather data and actuators to allow control of the system.

It may become technically feasible to manage the world as a single system, to digitally track production and waste, and manage access to goods and services to ensure inclusion and protect the environment. While this could enable us to achieve social goals that recognize the interdependencies between people and our overall dependence on the planet and its finite resources, it would be critically reliant on machines that can detect and respond to our actions almost instantaneously. Some freedoms we enjoy today have been born in the counter-cultures of previous generations, and clumsy programming of those machines could stifle any further social evolution. Personally, I have always seen advanced technologies like these as empowering for humanity, particularly in their ability to support better healthcare and to help focus industrial activities. The prospects for handing instant agency to autonomous machines could indeed see the IoT and AI become a great threat to humanity.

While contemplating what 6G could mean for humanity, we also need to consider our industry's role in realizing the infrastructure and terminal equipment. In the PCB industry, we have already begun to analyze key technology drivers and likely responses in terms of PCB performance and laminate characteristics. I'm fortunate to be engaged in this with leading infrastructure companies and recently attended an event that went into some detail about the likely impact on PCB design, laminate properties and manufacturing processes. Expected key demands include larger PCBs, increased temperature capability while ensuring stable loss characteristics, and tighter tolerances. With larger PCBs will come greater reliability challenges due to CTE mismatch between components and the substrate. The industry must also seek new materials that have very low losses at multi-gigahertz frequencies, without overheating or incurring excessive signal loss. Right now, PTFE is the lowest-loss material class we have, although we will need alternatives that have multilayer capability. Critical properties will include dielectric constant (Dk) below 3.0 and dissipation factor (Df) better than 0.003, while the preparation of copper foils capable of handling signal frequencies of 50GHz and higher will require careful consideration. At the same time, manufacturing tolerances on parameters like line width, layer-to-layer registration, and impedance are expected to be at least 50% tighter.

Today's 5G rollouts are the culmination of an incredible engineering achievement that has driven our

continued on pg. 44

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

Designing an LVD/IR Printed Circuit Board

Will a "universal" footprint work for various-sized passives?

by JAMES O. JACKSON

This details the design of an LED constant-current driver PCB. I am trying to make this design as "universal" as possible. Described here are some of the features and reasons I created the layout as I did.

The outside dimensions of the PCB are 3.35" x 2.175". The PCB was designed so that all surface mount (SMT) parts are mounted on the topside **(FIGURE 1)** and through-hole (PTH) parts mounted on the bottom **(FIGURE 2)**.

The PCB was designed to fit into a single-gang plastic electrical box. A box this size permits easy use in home construction. (Not to mention that plastic boxes are inexpensive and readily available at any hardware store that carries electrical supplies.)

Dual power input connectors. Power input is in lower left corner of the PCB and aligns with the knockout in the electrical box. I used two connectors to permit multiple ways to provide power to the PCB.

The first method is using a 2mm barrel connector. This permits use of either a power brick or a 2mm barrel plug wired into the solar system's wiring.

The second method is the terminal block that permits two wires to be wired to the PCB. Notice there are four connections on the terminal block **(FIGURE 3)**. This is by design. Two can be used for power input, and two can be daisy-chained to another controller down the line.

While the present implementation of this design is used with a 12V input, it was designed to also be used with a 24V input with very few (if any) minor tweaks to the BoM.

Dual footprint for speakers. When designing the board, I saw two different speakers available **(FIGURE 4)**. I was not sure which would make it to final production, and determined if one were out of stock, I could use the other. Both speakers have been shown to work well in the design.

Dual footprint for microprocessor. Two versions of the microprocessor are available. The microprocessor is a PIC chip programmed with a version of Basic. It is easy to program using a serial umbilical that attaches to a 3-pin header on the PCB.

I placed the SMT version of the microprocessor on the topside of the PCB **(FIGURE 5)** and the PTH version on the bottom **(FIGURE 6)**. Two microprocessor versions were included

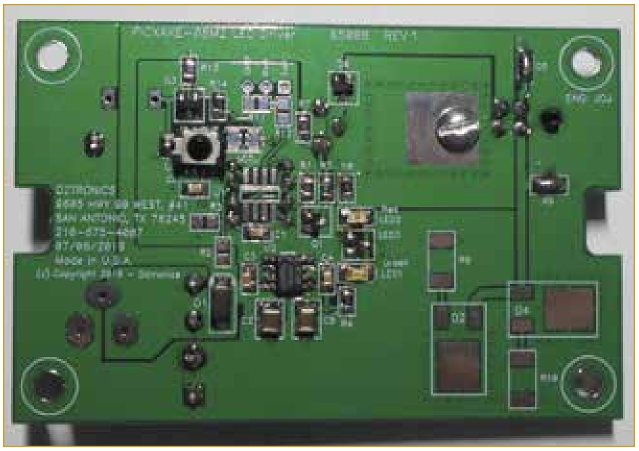

FIGURE 1. Topside of PCB showing SMT parts.

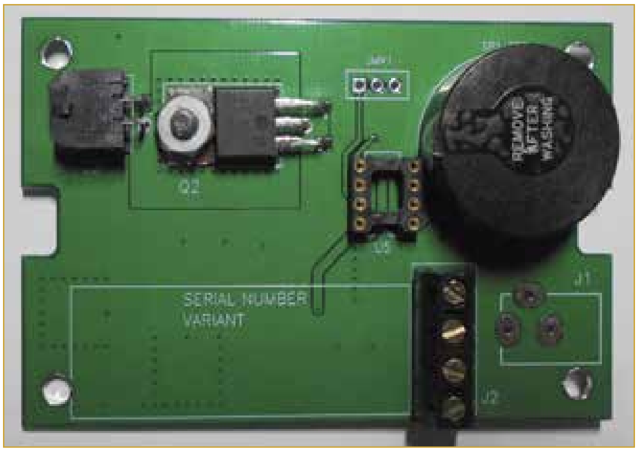

FIGURE 2. Bottom-side of PCB showing PTH parts.

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Lam Cycles:	Up to 8x
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FLEX / RIGID-FLEX

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

LEAD TIMES

RIGID THROUGH-HOLE

Standard:	20 Days
2 – 10 Layers:	24 Hours
12 – 24 Layers:	48 Hours

HDI; BLIND/BURIED/STACKED VIA

Via in Pad Standard:	20 Days
Via in Pad Expedited:	3 Days
HDI Standard:	25 Days
HDI Expedited:	5 – 12 Days

FLEX / RIGID-FLEX

Flex 1 – 6 Layers Standard:	25 Days
Flex 1 – 6 Layers Expedited:	5-15 Days
Rigid Flex 4-22 Layers Standard:	25 Days
Rigid Flex 4-22 Layers Expedited:	20+ Days
Rigid Flex HDI 2x Lam Cycles:	30 Days

CERTIFICATIONS

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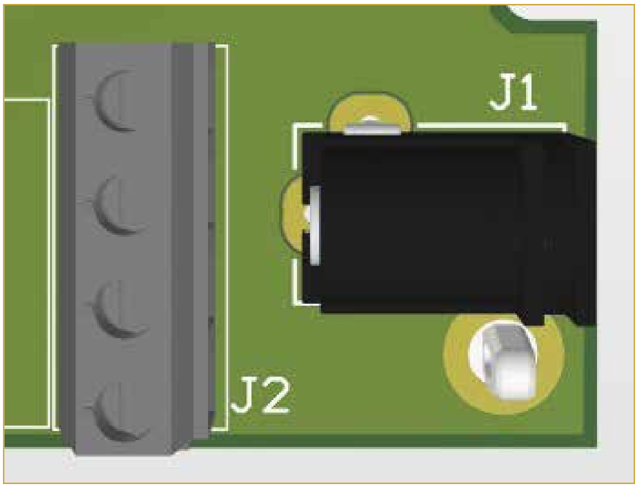

FIGURE 3. The four connections on the terminal block accommodate power input and connections to additional controllers.

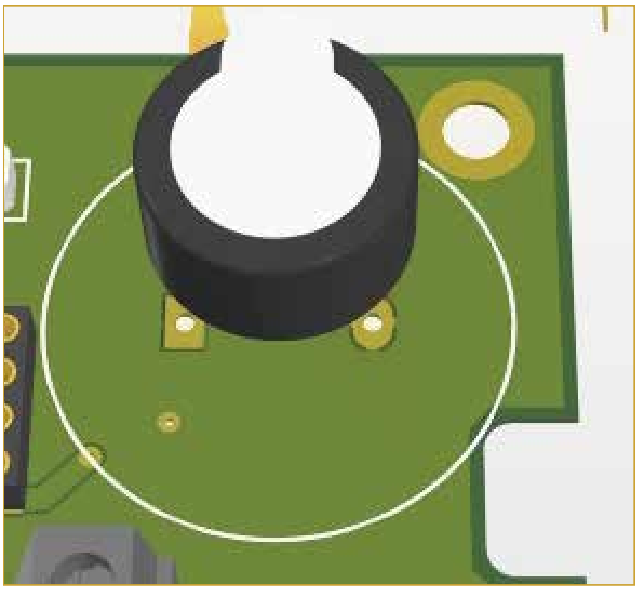

FIGURE 4. Speaker layout.

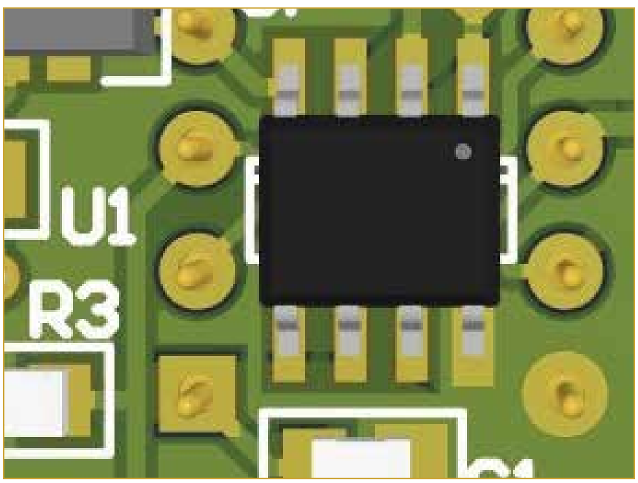

FIGURE 5. SMT microprocessor, used for production build.

so the PTH version of the chip may be used during prototype development and the SMT version during production without a redesign of the PCB.

Note the SMT version of the footprint is placed under the PTH version, but at a 90° rotation. I did this to allow easier routing of the traces.

'Universal' footprint. One of the footprints on the PCB is what I call a "universal" footprint (FIGURE 7). I designed a special footprint that permits the installation of any 0603, 0805, 1206 or 1210-sized resistor or capacitor. This was an experiment to see if I could do it. It turns out it works! Each pad is designed to have slots to prevent excess solder from the pads. The universal footprint is not needed on this PCB and will probably be removed in a future respin.

LED output connector. The LED output connector is in the upper right corner (FIGURE 8) and aligns with the other knockout in the electrical box. A different 4-pin connector was used, as it is readily available and there are mating 4-pin wiring harnesses available from the same vendor. Two different LED outputs are on this connector. One connects to the medium-to-high-current LED lighting, and the other output connects to the low-current LEDs that are on 24/7 and make up the night light.

FET switch. The FET for the LED switch is a PTH component mounted on the bottom side. It is an FET with a low rDS value and is rated at about 11A. This is more than enough current for the LED switch. I put copper around the FET and placed thermal vias around the perimeter of the FET, connecting the top copper to a heatsink on the bottom side, which should help dissipate heat.

Looking at what is available from vendors, many of my choices have now become unavailable or obsolete. The FET is not critical, other than it needs to be a P-FET with a Vds greater than 30V and capable of currents around 10A maximum. The lower the rDS, the better. The footprint needs to be a TO-252 to fit on the current layout.

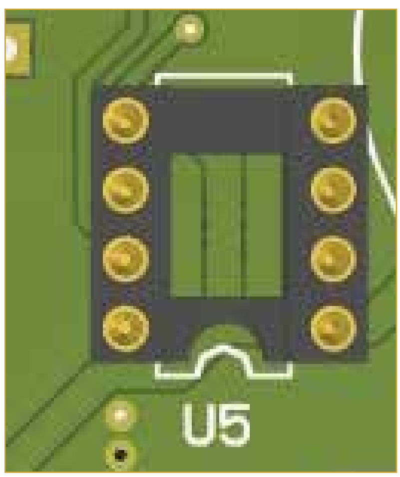

FIGURE 6. PTH microprocessor, used for the prototype.

Note how the three leads are bent (FIGURES 9 and 10). The center lead (source) is offset from the outer two pins. I did this to permit better separation of the leads.

Constant-current regulator (CCR). This brings me to the LED driver output design. I planned and designed the circuitry so that I do

not have to use the CCR. I did this by adding a series resistor that can be used if CCRs are not populated. This also means I can drive the LEDs with currents that are limited only by what they can handle, within reason. The narrowest trace is 80 mils, which should be able to handle 2A to 3A of current. (I will make this wider in the next spin of the board.)

I expect to switch only 700mA using the CCR NSI45x series parts, which are currently not available or in limited supply. The two CCR footprints can be populated and run in parallel for increased output current.

The series of CCRs permit use of a current-setting resistor. Four part numbers can be used for this design **(FIGURE 11)**. The first permits currents from 60mA to 100mA. The second permits currents from 90mA to 160mA. The third permits currents from 150mA to 350mA. The fourth does not permit an adjustable current and is internally set to 350mA.

With this in mind, the output current may be set from a variety of values of 60mA to 700mA (two 350mA parts in parallel).

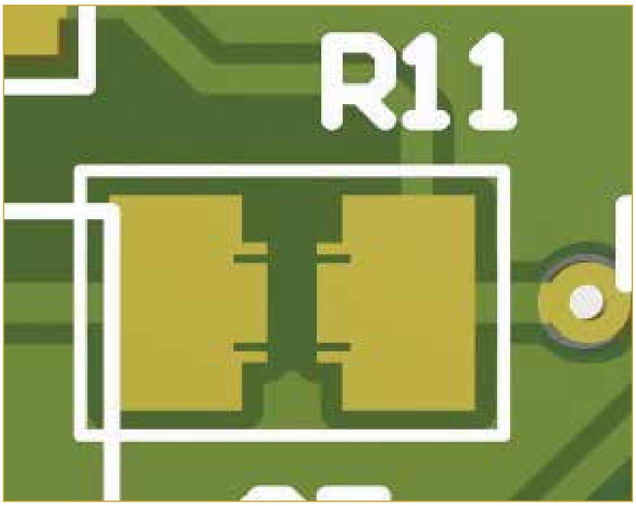

FIGURE 7. A "universal" footprint was designed to permit installation of any 0603 to 1210-sized resistor or capacitor. The slots prevent excess solder from the pads.

Microprocessor details. The microprocessor, as mentioned, is an 8-pin PIC processor with a version of Basic burned into it. Using a free program, I can write a Basic program that controls various external devices that are attached.

Two of the pins are used for power and ground. Two more pins are used for serial communication and programming the device. This leaves four pins on the processor for various I/O functions.

This particular design **(FIGURE 12)** uses one pin for infrared input, one for a speaker output, one for a voltage-divider input and the last pin for the LED ON/OFF control.

Firmware. The Basic code for this design is not complex but performs the necessary functions. There are 2,048 bytes available in the PICAXE chip, and I am using 325B, which permits more features to be added.

When the board is first powered up, a welcome tune is played, with output to the speaker, to give an "I'm alive" indication. It then goes into a loop, waiting for an input signal from the IR input.

When it receives an IR input, it decodes the command. It can be an ON/OFF command or a command to set parameters within the device.

I also monitor the voltage on the voltage divider, and if it gets to 12.5V, the speaker emits a warning and the load (LED lighting) is disconnected to protect the battery.

One feature of this design is the OFF-Delay. This can be set to a value from 0 to 9. This equates to seconds before the LED lighting turns off. 0 equals Disabled, and 1 to 9 equals 1 to 9 seconds delay. While counting down to 0, the speaker emits a beep, giving an aural indication. I usually set the delay to 9.

continued on pg. 56

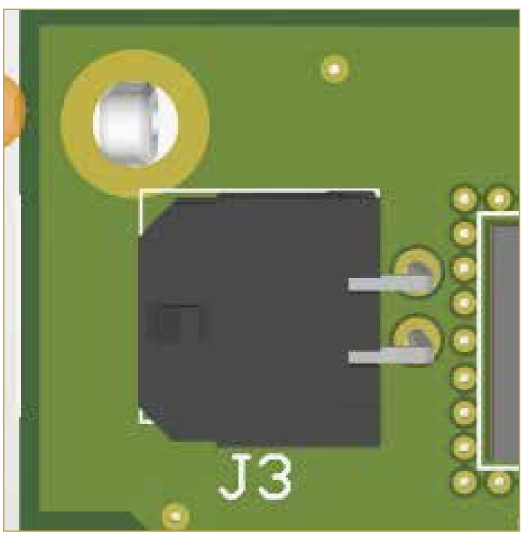

FIGURE 8. LED output connector.

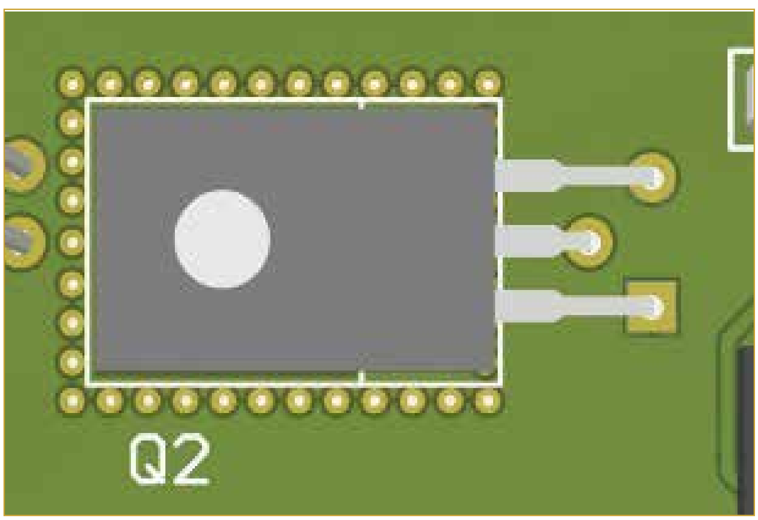

FIGURE 9. The FET's center lead (source) is offset from the outer two pins to permit better separation of the leads.

Practical STATISTICAL TOOLS for Process Engineers

A review of five useful tools and the basis for using each.

by PATRICK VALENTINE, PH.D.

What is the prominent skill process engineers are on the payroll for? It's their problem-solving skills. Therefore, the process engineer's function is to solve problems and add value. The better the process engineer becomes at doing this, the more valuable they become. The scientific method is a structured approach to problem-solving that can aid the process engineer in this endeavor.

The scientific method involves looking at the process around you, coming up with an explanation for what you observe, testing your explanation to see if it could be valid, and then either accepting your explanation (for the time being, something better might come along!) or rejecting the explanation and trying to come up with a better one. There are five steps to the scientific method: 1) make observations, develop a theory, 2) propose a hypothesis, 3) design and perform an experiment to test the hypothesis, 4) test your data to determine whether to accept or reject the hypothesis, and 5) if necessary, propose and test a new hypothesis. Let's define the first four steps in scientific terms.

- Theory – ideas intended to explain what we see and justify a course of action
- Hypothesis – a proposed mechanism of the theory that can be tested
- Experiment – a scientific procedure undertaken to test the hypothesis
- Test – a statistical test used to determine the plausibility of the hypothesis.

Statistics is a branch of mathematics that deals with collecting, analyzing, interpreting and presenting numerical data. Statistics is not merely the science of analyzing data, but the art and science of collecting and analyzing data. Statistics are only tools to help us; they do not replace the process engineer's skill and intelligence. Statistics use hypotheses, experiments and hypothesis testing.

With hypothesis, there is a null (H0) and an alternative (H1). In general, the null hypothesis is a statement that two population means are equal. In general, the alternative hypothesis is a statement that two population means are not equal. Formally, the null and alternative hypotheses are written as:

$$H_0 : \mu_1 = \mu_2$$
$$H_1 : \mu_1 \neq \mu_2$$

With hypothesis testing, in colloquial terms, we either accept the null hypothesis or accept the alternative hypothesis based on a probability value (p-value). Probability is a branch of mathematics that deals with the occurrence of a random event. P-values are expressed from zero to one and are the probability of an event having occurred. The general interpretation of p-values is as follows:

- < 0.05 are statistically significant
- $0.05 \leq$ p-value ≤ 0.10 may have a practical difference
- 0.10 are generally considered non-significant

Statistically significant means that the results in the data are not likely explainable by chance alone. Practical difference requires the process engineer to logically determine if the population mean differences have any practical value. Non-significant means the results in the data lie within the limits of chance.

There are five practical statistical tools the process engineer should be familiar with. These five tools are the Bland-Altman Plot, Tukey End Count, Mann-Kendall Trend, Bayesian Inference Box, and the Reliability by Confidence (R by C) Table. These five statistical tools can answer such questions as: How close do two different measurement devices agree on measurements? Do these data samples have the same distributions? Is there a trend in the data? How can I conduct a simple experiment and data analysis? How do I interpret test data in the context of reliability?

The Bland-Altman Plot is used to visualize the measurement differences between two instruments.[1] The plot is helpful for determining two things: What is the average difference in measurements between the two instruments? What is the typical range of agreement between the two instruments? The plots have

the following three lines: The average difference in measurements between the two instruments, or "bias"; the 95% upper confidence limit for the average difference, or "limit of agreement"; and the 95% lower confidence limit for the average difference, or "limits of agreement."

In general, 95% of the differences between the two instruments fall within the limits. Whether to accept that the two instruments agree depends on the level of precision needed in a particular domain. For example, the process engineer measures the same 10 pads from various PCBs plated with electroless nickel immersion gold (ENIG) on two different XRF machines. The process engineer is interested in the gold thicknesses **(TABLE 1)**.

TABLE 1. Gold Measurements (microinches)

XRF 1	XRF 2
1.50	1.51
1.80	1.81
2.20	2.29
2.50	2.59
2.90	2.94
3.30	3.29
3.60	3.65
2.65	2.70
2.95	3.00
2.65	2.63

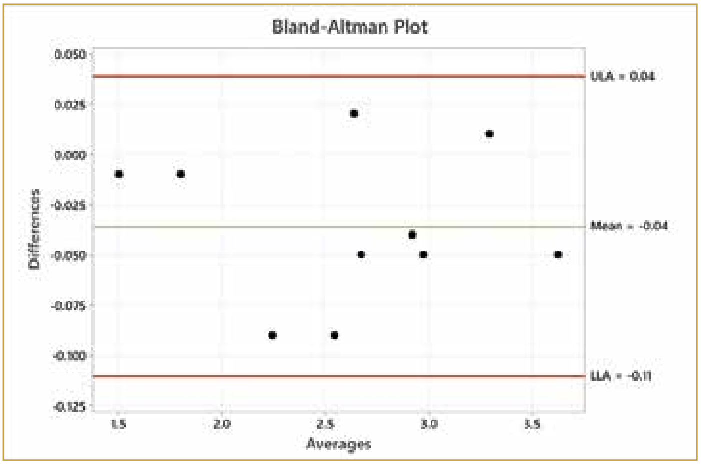

FIGURE 1. Bland-Altman plot.

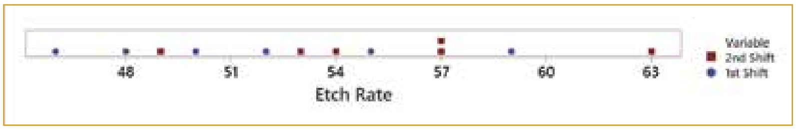

FIGURE 2. Dot plot of Tukey End Count.

The process engineer plots the data on a Bland-Altman Plot **(FIGURE 1)**. The average difference between XRF measurements is -0.04 microinches, and the absolute range of agreement is 0.15 microinches. These values are reasonable. The process engineer concludes to accept that the two instruments agree.

The Tukey End Count is a nonparametric hypothesis test that compares two independent sample medians.[2] Each independent sample size needs to be $n \geq 5$. The two datasets are ordered, and a count of the number of nonoverlapping points (end count) is used to determine if the samples have different medians. An end count of ≥ 7 provides 95% confidence there is a statistical difference. The end count test does not work on all problems; if one sample contains both the highest and lowest values, there is no end count. For example, the process engineer gathers etch rate data from two shifts. The process engineer is interested if the first and second shifts are statistically etching the same amount of copper **(TABLE 2)**.

TABLE 2. Etch Rate Measurements (microinches)

1st Shift	2nd Shift
55.0	49.0
46.0	63.0
50.0	53.0
59.0	57.0
48.0	57.0
52.0	54.0

TABLE 3. Process Yield Data

Yield %
93.3
96.3
96.4
94.7
96.5
96.7
94.8
96.8
93.2
94.0

The process engineer plots the data on a dot plot **(FIGURE 2)**. The number of nonoverlapping points on the left is two, and the number of nonoverlapping points on the right is one. The end count is $2 + 1 = 3$, which is < 7. The process engineer concludes there is no statistical difference in etching between first and second shifts.

The Mann-Kendall Trend test is a nonparametric hypothesis test for trends.[3] The data are arranged in chronological order, compared pairwise, and coded "+" or "-" depending on whether the preceding number is greater or less than the postceding number. The test involves computing a statistic, *S*, which is the difference between the number of pairwise differences ("+" or "-") that are positive minus the number that are negative. If *S* is a large positive value, then there is evidence of an increasing trend in the data. If *S* is a large negative value, there is evidence of a decreasing trend

TABLE 4. Yield Data Pairwise Differences

Yield %	93.3	96.3	96.4	94.7	96.5	96.7	94.8	96.8	93.2	94.0	+	-
93.3	n/a	+	+	+	+	+	+	+	-	+	8	1
96.3			+	-	+	+	-	+	-	-	4	4
96.4				-	+	+	-	+	-	-	3	4
94.7					+	+	+	+	-	-	4	2
96.5						+	-	+	-	-	2	3
96.7							-	+	-	-	1	3
94.8								+	-	-	1	2
96.8									-	-	0	2
93.3										+	1	0
94.0										n/a	--	--
											24	21
											S =	3
											p-value	0.43

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in the data. The null hypothesis is that there is no trend in the data values.

For example, the process engineer gathers daily process yield data for the past 10 days. The process engineer is interested if there is a trend in the yield data **(TABLE 3)**.

The process engineer computes the pairwise difference **(TABLE 4)**. The computed S statistic is 3, with a corresponding p-value of 0.43, which is significantly above 0.05. The process engineer concludes there is no statistical trend in the yield data.

The Bayesian Inference Box is based on Bayes' theorem, which deals with sequential events.[4] When new information is obtained for a subsequent event, that new information is used to revise the probability of the initial event. Bayes' theorem uses conditional probability. We use *P(B|A)* to denote the conditional probability of event *B* occurring, given that event *A* has already occurred. There are three sections of a Bayesian Inference Box.

Prior: Describes how sure we are that each hypothesis is true. Note: Two or more hypotheses can be tested, and they all must sum to 1.

Likelihood: Imagine each hypothesis is true and ask: "What is the probability of getting the data that I observed?" Note: The likelihood does not need to sum to 100.

Posterior: How confident are we that hypothesis "H" is true, given that we have observed data "D?"

For example, the process engineer reviews a cross-section of an ENEPIG-plated printed circuit board with a potential nickel hyper-corrosion defect **(FIGURE 3)**. The process engineer builds a Bayesian Inference Box with two hypotheses (H_1 and H_2) and assigns prior probabilities (0.80 and 0.20) based on their experience. The process engineer knows that nickel hyper-corrosion enriches the percent phosphorous in the defect area, so the process engineer collects scanning electron microscope-energy dispersive spectroscopy (SEM-EDS) data on the bulk

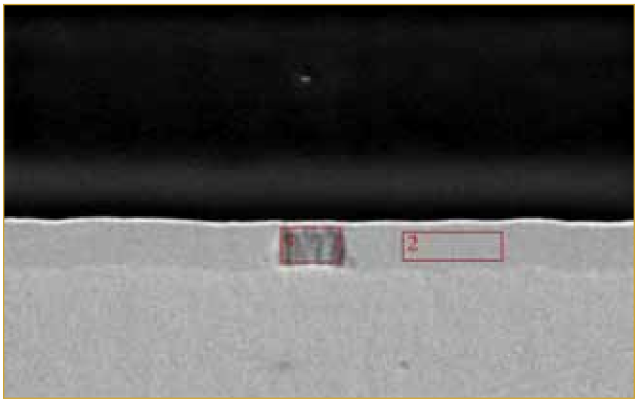

FIGURE 3. Potential hyper-corrosion defect.

TABLE 5. Bayesian Inference Box

Nickel Hyper-Corrosion

Hypothesis	Prior	Likelihood	P*L	Posterior
H1	0.80	95.0	76.00	0.99
H2	0.20	4.0	0.80	0.01
	1.00		76.80	

H1 Nickel hyper-corrosion is present
H2 Nickel hyper-corrosion is not present

Data: SEM/EDS %P enrichment

Site 1 %P:	13.9
Site 2 %P:	7.5

TABLE 6. Reliability by Confidence Table

Confidence Level = 0.95
Alpha = 0.05

Number of Failures	Sample Size																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	100
0	5	22	37	47	55	61	65	69	72	74	76	78	79	81	82	83	84	85	85	86	97
1		3	14	25	34	42	48	53	57	61	64	66	68	70	72	74	75	76	77	78	95
2			2	10	19	27	34	40	45	49	53	56	59	61	64	66	67	69	70	72	94
3				1	8	15	23	29	34	39	44	47	51	53	56	58	60	62	64	66	92
4					1	6	13	19	25	30	35	39	43	46	49	52	54	56	58	60	91
5						1	5	11	16	21	26	30	34	37	41	43	46	48	51	53	89
6							1	5	10	15	20	25	29	33	36	39	42	45	47	49	89
7								1	4	9	14	18	22	26	30	33	36	39	42	44	87
8									1	4	8	12	17	21	24	28	31	34	37	39	86
9										1	3	7	11	15	19	23	26	29	32	35	85
10											0	3	7	10	14	18	21	24	27	30	84
11												0	3	6	10	13	17	20	23	26	82
12													0	3	6	9	12	16	19	22	81
13														0	2	5	8	12	15	18	80
14															0	2	5	8	11	14	79
15																0	2	5	8	10	78
16																	0	2	4	7	77
17																		0	2	4	76
18																			0	2	74
19																				0	73
20																					72
0																					97

percent phosphorous in the defect area and a normal nickel deposit area. The process engineer imagines each hypothesis is true and asks: "What is the probability of getting the data that I observed?" They then assign a likelihood (95 and 4) based on the observed data. The process engineer calculates the posterior and concludes with 99% confidence there is nickel hyper-corrosion **(TABLE 5)**.

The Reliability by Confidence Table provides valuable information about sample size and uncertainty.[5] The R by C notation signifies what reliability requirement *(R)* at time *(t)* we want to meet with a level of confidence *(C)*. An R95C95 means a 95% probability of survival, *R(t)*, with 95% confidence in achieving that requirement. *R(t)* is viewed as a lower confidence limit on reliability, denoted as *RL*. For example, the process engineer thermal cycles six parts for 200 cycles with zero failures. Sample size is $n = 6$, with 0 failures, R by C = 61. Interpretation: We are 95% confident the probability of survival at 200 cycles is at least 61% (R61C95), or we are 95% confident the failure rate at 200 cycles is no more than 39% (100% - 61% = 39%) **(TABLE 6)**.

Conclusions

The process engineer's function is to solve problems and add value. The scientific method is a structured approach to problem-solving that can aid the process engineer in this endeavor. Statistics are powerful tools. Choosing, using and interpreting the proper statistical tool is critical for the process engineer. There are five practical statistical tools the process engineer should be familiar with. These five tools are the Bland-Altman Plot, Tukey End Count test, Mann-Kendall Trend test, Bayesian Inference Box and the Reliability by Confidence (R by C) Table. ▫

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Material Gains, continued from pg. 28

technical capabilities to new heights. 6G will represent another enormous leap forward and many are sure to question whether we need – or even want – such an all-pervasive and potentially all-knowing and autonomous network so closely connected with all aspects of our lives. Many ethical questions are likely to arise. We are only beginning to find out what 5G can do for us. When our engineering is ready to realize 6G, I'm sure we will be more than ready for the services it will enable. ▫

The Heat is Off: Could a New Platform REVOLUTIONIZE SOLDERING?

New technology from Safi-Tech means cold solder joints might no longer mean defects. by **MIKE BUETOW**

I've been covering the soldering industry for more than 30 years. During that time, I've seen lots of innovations come and go. I remember when an engineer from Hughes was using citric acid from oranges as a flux. And when Bell Labs introduced its first water-soluble flux. I recall when nitrogen was first used in convection reflow environments and when no-clean pastes were rolled out and dismissed as lab curiosities.

Last July, Indium Corporation announced a partnership with Safi-Tech, Iowa-based startup that is creating no-heat and low-heat soldering and metallic joining products.

They call these supercooled molten metal products, and they have direct application to electronic soldering.

Dr. Ian Tevis, president and cofounder of Safi-Tech (safi-tech.com), and Dr. Andy Mackie of Indium Corp. (indium.com) discussed this supercooling platform with PCD&F/CIRCUITS ASSEMBLY in September.

Mike Buetow: The electronics industry has been chasing lower-temperature solders for decades. That effort really sped up as SAC solders took hold in the wake of the European mandates to eliminate lead But tin-lead has a higher melting point than lead, so the transition away from tin-lead eutectic or 60/40 meant higher reflow temperatures, which in turn means more stress on the bare board laminate, the typically plastic component packages and so on, not to mention the higher processing costs due to the increase in energy consumption.

Naturally, then, it would be a big deal if we could process solder with SAC 305 characteristics at a much lower temperature. Ian, what exactly is this new platform you've created?

Ian Tevis: This supercooled liquid metal product is a new form factor for soldered metal alloys. It's a core shell microcapsule. We call it a microcapsule; others might call it a particle or a solder ball. It looks just like a regular solder ball, just a little bit smaller with a little bit extra on the shell.

It's a core shell structure, meaning the solder on the inside is the metal alloys that you know and maybe love – SAC 305 and other metal alloys – and we put a proprietary shell on that. That gives users of the solder material access to the supercooled liquid state that, instead of being a liquid above the melting point, is a liquid below the melting point. That's what's being called a "supercooled liquid state."

We stabilize that so users can access it and use a liquid version of SAC, bismuth-tin or other different alloys at much lower temperatures than normal.

MB: So the IP is in the shell?

IT: The IP goes toward the shell, which is like the magic that makes the technology happen, but there's also some unique application-specific IP. There's new ways of using it. We have a chemical-based process like a solder paste would have: a chemical-based flux to remove our oxide organic shell.

Also, there's IP on what we call mechanical activation, or compression-based techniques, where we take a little squishy microcapsule and squeeze out all the liquid metal, and it can flow out and form the solder joint that way. (Ed.: A video of showing a supercooled metal ink particle poked with a sharp metal probe that triggers the ink particle to turn solid can be seen here: https://www.youtube.com/watch?v=XYXEihvD78o.)

MB: You've started with SAC 305. Are you working on any other solder types?

IT: The technology is really a platform, and SAC 305 is the biggest target, but we've applied it to successfully to other platforms, bismuth-tin being one. There's growing early interest in lower-temperature solders, and bismuth-based solders are easily accessible because of their lower melting point.

We've also looked at some lead-based solders because there's still a need. If you could process a tin-lead solder joint at lower temperatures there's a benefit. But, it's primarily been SAC 305 and tin-bismuth.

MB: What solder powder sizes have been tested to date?

IT: The key to the way the technology works is the solder spheres have to be small. We're talking one to 10 micrometers in diameter. We can go a little bit bigger. We don't really go smaller than that. And I'm not even sure if there are specifications about what sizes those are yet, but that's about the size we work on. Maybe Andy can speak more toward if type 9 and type 10 powder sizes have been truly defined.

MB: Type 9 or type 10?

AM: I've seen it. It's been talked about in song and legend. One of our competitors was talking about this about 15 years ago when I first started at Indium, and we're still sort of not seeing that powder size out in the market for standard system-in-package and those kinds of applications. Having said that, the technology itself is something that we've been working on with Safi-Tech for about six years.

We've been working together quietly in the background of finding applications for this. We really got excited about six months ago when we realized that this was going to be potentially usable in some real-life situations. It was no longer a laboratory curiosity. It was going into the real world, and it's at this point that I made the decision to jump in and work together to actively promote this to the electronics assembly industry.

MB: Where do you stand in the testing, and what types of machines have you used this on so far?

IT: We're early in the testing. We have done some basic-level die shear-type tests and thermal shock for our SAC 305 prototype. We've sent them out for external testing for thermal shock at-40° to 110°C, 30 minutes each for thermal shock at 1000 cycles. This is a BGA attached on immersion silver FR-4, so it's kind of our test vehicle.

The BGA works well with our system. Immersion silver gives a nice surface finish for us to do our attach, so they're surviving the 1000 cycles. There's a little bit of voiding that's occurring, but no full cracks. That early-level testing is promising for that, and we're working on the flux. The flux being used on a SAC 305 microcapsule now at 180°C, versus 240°C; that flux will look different and similar in some ways, but it has to be designed to work on our shell and at a lower temperature. Some development needs to go on there, as well as print development. We're experts at making microcapsules, but supercooling flux development is its own separate beast to tame.

MB: What soldering temperature are we talking about?

IT: For SAC 305, we're doing some processing at 180°C, and as low as 165°C. It's still in prototype. For some select customers, we are doing trials and demos, but for bismuth-tin, which is normally processed at 165°C – I think some of them are getting closer to 150°C – we're at 135°C to process that.

MB: I think it's safe to say that the reflow profile looks significantly different than that for SAC 305.

IT: Yeah, it's a ramp-to-peak. We try to go as quickly as possible to that peak reflow temperature because that flux activity is always on, and when it's always on, a liquid metal microcapsule can actually get joining at 20°C. It's limited, but you can get a little joining and then that's it. Then you're done.

MB: Has the testing you've done to date been from boards that will run through convection reflow and, if so, was that nitrogen or just air environments? Or have you tried any other type, like vapor phase?

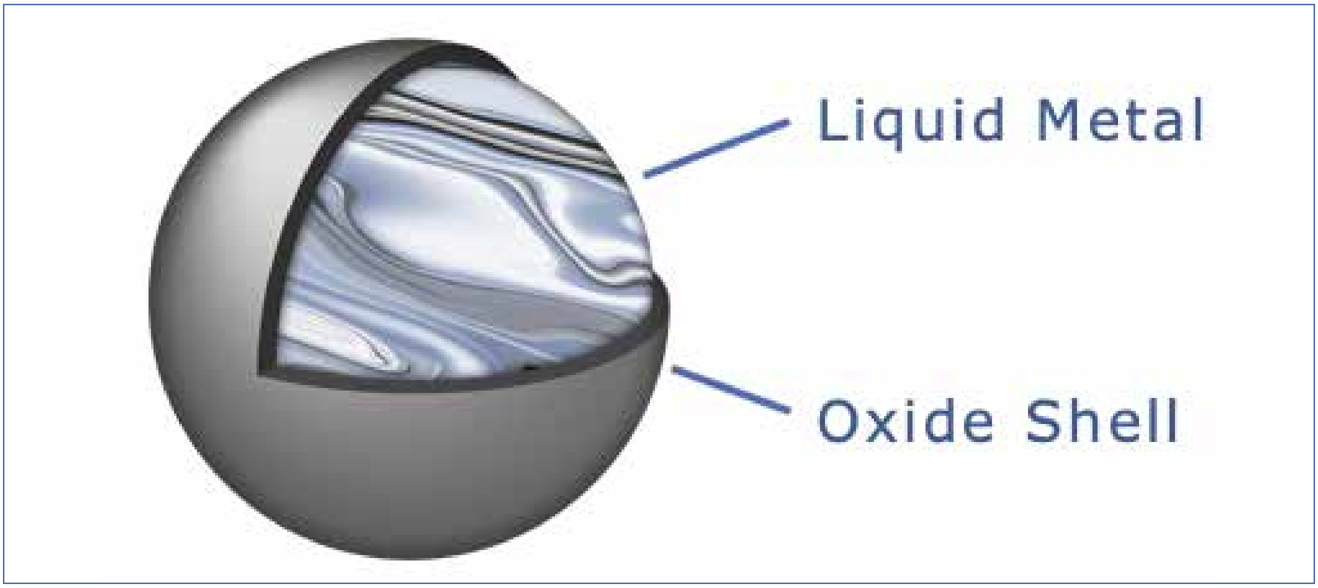

FIGURE 1. The oxide shell applied to molten alloy prevents nucleation and permits the metal particles to remain liquid at temperatures significantly below the freezing point.

IT: The boards that we're talking about for this thermal shock, they were put through a BGA rework station. We have a wonky process that involves printing solid SAC 305 microcapsules on a board, heat cycling the SAC 305 above its melting point, then cooling it to a lower temperature and then bringing a flux-dipped BGA in contact with the supercooled liquid SAC. It's a couple extra steps to do it, where we're doing flux dipping and heating and such. That system was originally done in air. Indium suggested we do it in nitrogen, and here's the PPM that we should be looking at. And we did it in nitrogen, to great effect. It does help quite a bit, mainly because with the lower temperature processing of the alloy, you have more viscosity, you have less ability to wet and move, and so you want to limit that oxide formation as much as you can.

MB: You mentioned the test vehicle earlier and that there's BGAs on it. What other parts are on it and was it designed just to look at the solderability of the platform, or were you also looking at the potential dispensing and other characteristics?

IT: The test vehicle was chosen to demonstrate all the parts, the printability of this material with the shell, to make sure that the shell isn't disrupted; it's the use of a flux, and to look at the soldered joint with these test vehicles have SAC 305 solder balls on them. They're a great test to show because the SAC 305 ball, if it's not melting, it won't collapse. And you can see that clearly on the micrographs of the cross-sections, and you're looking at IMC formation on our material, SAC 305 and the immersion silver FR-4.

If you have a thick intermetallic compound, five or more micrometers, you probably did that at a significantly higher temperature than 180C°. The basic science discussion at Safi-Tech is over. This is a real solder joint. It is continuous SAC 305 IMC formation. It survives thermal shock. Let's work together to finish this and bring it to market.

FIGURE 2. Dr. Ian Tevis, cofounder of Safi-Tech

MB: Andy, when did Safi-Tech first appear on your radar?

AM: Indium has been working with Safi-Tech for six years, but it was only about six months ago that we made a decision that there was something here, there was more signal than noise coming out of the data, and the potential applications for this also really started coming out there. Everyone is aware of the drive to use lower-energy reflow for cost savings as one major thing, but also a major push within heterogeneous integration, for example, is the use of step soldering and the overall thermal budget for the assembly processes. So you have a high-temperature assembly process, and a very low one – and then ultimately primarily caused by things like warpage and so on, you're going to want something that may want to be as low temperature as possible. That's something that the Safi-Tech technology really offers in a way that other materials absolutely do not have.

MB: Has Indium performed any in-house testing or with its customers of this solder yet?

AM: We done internal testing and had some very positive results, which again is one of the reasons why we are starting to be interested in working with the Safi-Tech team, because we see the feasibility of this in the real world.

MB: Are all the samples being made in Ames or has anybody else taken on responsibility?

IT: We make all the materials in Ames. That's all the solder microcapsules and any of the alloys. We have equipment designed for each of the different temperature ranges to manufacture them and our goal as a startup is to manufacture the material, and we draw a lot here on the Iowa State campus. We draw a lot of the resources here from the other tools available, but also the people here are well known for metals technology.

MB: How is this stored?

IT: There's a couple ways we store it. What's nice about the technologies is that the shell or the microcapsule, they're different, and you can freeze the core and you can melt the core And cool it back down into a supercooled liquid state. The process of heat cycling to recover the supercooled liquid state is called reconstitution. As long as that shell is intact, you can store it as a solid, and then get the liquid state back just by heat cycling. For example, bismuth-tin: We could freeze it in a -20°C freezer and then remelt it at 138°C and cool it back down to ambient, and 100% of those microcapsules are in the supercooled liquid state, which is nice for transportation and long-term storage. Once it's in the liquid state, we store it under nitrogen under ambient temperature, or we store it in a refrigerator setting. We're trying to prevent the nucleation of the metal inside, so you give it a little less energy to move around, it's a little bit harder for that metal inside to freeze. We sometimes store it in a refrigerator for up to four months in the liquid state.

MB: When it's stored in a refrigerator, would it be at typical temperatures or does it have to have its own refrigerator?

IT: We store it between 0° and 4°C. I think that's one of the differentiators between us and a normal solder paste: We can't quite get the -20°C storage temperatures for our products yet. That's one of the things we're working on. We know the cold chain and its importance in the solder paste world. Right now, it's stored as a separate system; the particles stored in one container; and the base vehicle, whatever it be, is stored in another. Then they're simply mixed right when they're going to be used.

MB: What's the process for mixing? With a typical jar of solder paste, you might stick a stick in there and swirl around a little bit.

IT: We have a process for mechanically activating or kind of squeezing them. That could be true if you're mixing too. So, the mixing process is important. We typically will add small amounts at a time and then fold it in, trying to use the liquid to mix in the solder balls without applying too much shear. Once they're coated in a liquid, then they can be really sheared, because once those particles can slip over each other, that kind of water balloon-like structure, that elastic shell on the surface of this squishy particle really prevents the metal from being sheared open during the process of mixing or printing.

MB: Ian, I know Safi-Tech is a startup, and you're funded by grants from the Department of Energy and SEMI-FlexTech and at least one private equity group. Are there any other organizations or companies providing funding at this time?

IT: Those are the three main sources: A VC that specializes in this deep tech, new emerging technologies that come out that are trying to get over the valley of death, and there's not a lot of organizations that fund in this particular space. The (US) government is one of them, and then the VCs are the next leg of that as they cross the valley of death. We've been very fortunate that SEMI-FlexTech, this private-public partnership, funded us for creating interconnects at PET-compatible temperatures for flexible hybrid electronics. That's where that bismuth-tin product I discussed came from. That was an 18-month project funded by Safi-Tech and SEMI-FlexTech.

Right now, we're working on a Department of Energy SBIR (Ed: SBIR stands for Small Business Innovation Research, a form of grant). Their high-energy physics has a need to replace bump bonding for their wafer-to-wafer to chip-to-wafer attach. They have these large formats, readout and sensor chips they use for high-energy physics like CERN and other places. It is difficult to assemble them because they're so large, and get all of the little I/Os or sensor bits on the sides to connect. You get deflection on the device edge from dynamic warpage because these are like 50 micrometers, 100 micrometers thick, so they have a lot of deflection that can occur. We have a unique approach using microcapsules in self-assembly to put the microcapsules down and solder them at a much lower temperature where the chip, and the sensor are relatively planar to one another, so we limit head-in-pillow and the opens on the device edge.

MB: Andy, in your long tenure in electronic materials, have you ever come across anything like this?

AM: It's fascinating. Going back to my physical chemist days, it's wonderful to see the nature of phase transition being absolutely turned on its head. I've seen this happen, for example, at IBM with its C4MP process – you see a subcooled alloy – you see these sort of little aliquots or little deposits of a subcooled tin-silver alloy, and they are cooled below the solidus point, but there's still liquid and then you can watch them spontaneously solidify, and do that magic kind of phase transition, but at a temperature that is well away from what you normally expect from the standard thermodynamic solidus temperature and all this is allowed by the kinetics of the phase transition. To see this being implemented in solder itself is absolutely mind-blowing, and I recommend Safi-Tech's video taking what appears to be a kind of a little solid grape, poking that with a microprobe, and this sort of grapelike object under the microscope, once its surface has been damaged and the solder leaks out a little bit, immediately solidifies. So it's actually the nature of the physical chemistry of the shell itself that Ian was alluding to actually maintains that liquid phase when your standard textbooks tell you, "It's below the solidus, it's going to be solid." It's absolutely fascinating.

There's fascination around the technology from a computer science point of view, but being able to turn that into something real and make money also excites my business brain.

FIGURE 3. Dr. Andy Mackie, principal engineer and manager, Indium Thermal Interface Materials Applications.

MB: Let's talk about the applications. This is currently getting funding from the US government. However, I would think that military applications are probably way down the list insofar as what would be the immediate end-product use.

IT: Yes, the requirements for MIL-spec and others are quite high for us to do. We are a startup and we have limited testing capabilities. We have Indium with a lot more capabilities to do the testing. You look forward toward those applications where they have a need for a lower-temperature solder. The military is excluded from the rules, and they can use that tin-lead, which is a great combination for solder and a great combination for supercooling. So there are opportunities there, but right now we're looking for a really good entry-level application where our uniqueness is unchallenged, where there's nothing else that can really do what we do, and the customers are in such a need and they're willing to try a process change or something a little different to make it make their products work.

AM: We were just talking to one of our local universities about the increasing overlap between some of the applications in medical, such as cardiac monitoring, and people on the battlefield, so that the need for the troops in action to have their vital signs monitored at the same time. Clearly the kinds of stresses, 10,000G-type stresses, that a hypersonic missile would need to withstand, will necessitate a tin-lead joint or something like

this, whereas some of these medical devices – and Ian already alluded to PET and maybe even lower-melting types of substrate – these medical-type devices are really necessitating low-temperature flexible substrates because the corollary to that is that it can't go above 120°C, 100°C, 150°C, so you really are limited. For the military aspect to this, there is clearly an overlap between the needs in the medical industry for flexibility, conformance to body shapes, and so on, and the battlefield, and all these kinds of crossovers are occurring.

MB: Andy, I understand from Safi-Tech's perspective why it would want to partner with a major solder company. What's in it for Indium?

AM: For Indium, it is the opportunity to be in at the ground level with an exciting new technology which we believe is probably never going to replace the whole of SAC 305 or any of the large-scale solders, but with the emergence of these lower-temperature requirements, step soldering, flex, flex circuitry, and so on, and frankly the wide-scale promulgation of these, particularly with an aging population, should we say, necessity for that, we can see now real applications for these solders going forward.

We wanted to be in at the basement level with Safi-Tech, with which we've been working quietly for many years. We're talking regularly to customers and equipment partners and so on to develop not just the materials for them, but also the processes that Ian's talked about that go into this. We have the whole wonderful triangle of the material and the equipment partner and the process ready, and then we have the customer need all kind of set up there. We want to be ready so that, once the scale-up comes, we (can) provide the ability to scale these materials.

MB: The anticipation, then, is that Indium would actually get into the manufacturing?

AM: Absolutely, yes.

MB: Ian, Iowa has been ground zero for a few significant advancements in solder materials. Ames Laboratory, which is part of the Department of Energy and a partner with Iowa State University, developed and licensed one of the first tin- silver-copper solders to become mainstream in electronic soldering. I have to ask, what's in the water there?

IT: (laughs) I know, I think there's something special here. They've really built such a great environment for metals technology. One of the inventors of that (original SAC) alloy, Dr. Iver Anderson, is one of our advisors. He really works closely with my partner, Professor Martin Thuo, both at the university and at Ames Lab. We know how important it is for these metallurgical advances to continue and the technology we invented, Iver's thesis was in supercooled metal alloys. This is a technology that has been there for a while. It was: How do we turn this into an actual material we can use?

MB: You have the ability to manufacture. You're proving out the platform. You have a major vendor as a partner. Andy referenced scaling a little bit ago. What's the next step?

IT: I think it's really deciding where do we want to go. We have this platform, and it can be used in a lot of different ways, in many different applications. We're a startup. I have precious few resources to bring a product to market. Indium is helping us with some of these customer interactions to ask the right questions, to say: "This is of interest to us and because of X,Y, and Z." It's like picking the target, and then customers have to touch it and try it, and then they have to lower their apprehension for it, then get it spec'd into what they're building.

MB: Are the industry standards as written today open to accommodating this type of technology, or will there be need to change?

AM: This is another reason why this is a perfect storm of wonderful. The current version of J-STD-20 speaks to the temperatures to which a hierarchy of solders in a single assembly are going to be subject to. There's a high temperature, a medium temperature and a low temperature, and there's an ultra-low temperature, and this is something that's actually falling out of the current version of J-STD-20, I think the F version of it.

The timing for this could not be better because it's going back a little to those times of the tin-lead solders and bismuth-tin solders and saying: "We've got to have a hierarchy of solder, so we've got to have a solder with a melting point somewhere around that of tin-lead, which is around 183°C, but it can't contain lead. What are the opportunities for this?" The next revision of J-STD-020 is going to include a three-tier system. Anyone who's looking at how to qualify a material into this process is going to have a "lookup" table: "So we need to do this with this specific package size because it's dealing mostly with the system-in-package type applications, heterogeneously integrated devices" and so on and so forth.

MB: I thought J-STD-020 was the component moisture sensitivity standard.

AM: That is absolutely correct, but it is so much more than that. Every customer that we talk to in system-in-package is asking: "What's the maximum reflow temperature I'm allowed within this, based on this specification?" And yes, it's moisture sensitivity, but it also as an adjunct to that, is now becoming this kind of stratification of the allowable maximum reflow temperature that, again, speaks to step soldering and the needs of heterogeneously integrated devices. ❑

Ed.: This transcript was adapted from a full interview for PCBChat.com. Safi-Tech's lab is located at the Iowa State University Research Park in Ames, IA. For more information, visit safi-tech.com.

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

The Death of the ‘TARGET CONDITION’

IPC workmanship standards are getting a definition revamp.

by LEO LAMBERT

IPC workmanship standards are used throughout the industry, in particular by OEMs and EMS companies as a way to ensure all those involved in producing printed circuit assemblies agree on what’s acceptable and what’s not.

For decades, the standards called for every solder joint on an electronics assembly to be classified as one of four categories:

- Target condition. A condition that is close to perfect/preferred. However, it is a desirable condition and not always achievable and may not be necessary to ensure reliability of the assembly in its service environment.
- Acceptable condition. Indicates a condition that, while not necessarily perfect, will maintain the integrity and reliability of the assembly in its service environment.
- Defect condition. A condition that may be insufficient to ensure the form, fit, or function of the assembly in its end-use environment. Defect conditions shall be dispositioned by the manufacturer based on design, service, and customer requirements. Disposition may be to rework, repair, scrap, or use as is. Repair or use as is may require customer concurrence. (A defect for Class 1 automatically implies a defect for Class 2 and 3. A defect for Class 2 implies a defect for Class 3.)
- Process indicator condition. A condition and not a defect. The characteristic of the assembly does not affect the form, fit or function of the assembly.

Given that target condition is defined as “close to perfect,” thousands of operators and quality assurance personnel through the years have naturally strived to meet this ideal.

The result, however, is sometimes deleterious to the actual reliability of the assembly. Why?

FIGURE 1. Changes to the longstanding definition for target condition started with the wire harness standard and were later adopted for PCB qualification criteria.

In practice, what happens is the inspector questions whether the solder joint meets “target” and takes actions to ensure it meets those criteria. Such actions may include reworking product to the target condition.

In many cases, the rework was performed for aesthetic purposes – in short, the changes were cosmetic in nature but not undertaken to improve the performance of the product.

That’s where Murphy’s Law would kick in. Not only was the attempt costing time and money, the reworked product, having undergone an additional thermal excursion, was potentially rendered less reliable.

The first standard to change was the IPC/WHMA-A-620, *Requirements and Acceptance for Cable and Wire Harness Assemblies*. The authoring IPC Task Group (7-31f) revamped the qualification criteria into three categories:

- Acceptable. Indicates a condition that, while not necessarily perfect, will maintain the integrity and reliability of the assembly in its service environment.
- Defect. Indicates a condition that fails to meet the acceptance criteria of this document or negatively affects the form, fit or function of the assembly in its end-use environment. The manufacturer shall document and disposition each defect.
- Process indicator. A condition (not a defect) that identifies a characteristic that does not affect the “form, fit or function or reliability” of a product.

In many cases, where a “target” condition was not covered under the “acceptable” criteria, the target condition was modified to be an acceptable condition. That said, sometimes the "target" is no longer acceptable, although in some places it should be.

The same change, for the same reasons, has been made to IPC-A-610H, *Acceptability of Electronic Assemblies*. Now it looks like "target condition" will be removed from IPC-A-600, *Acceptability of Printed Circuit Boards*. The rewritten criteria will meet the requirements of form, fit or function.

In short: If it's good, it's good, so leave it alone. □

LEO LAMBERT is vice president and technical director of EPTAC Corp., and a member of the IPC Raymond E. Prichard Hall of Fame Award for his contributions to the electronics industry; leo@eptac.com.

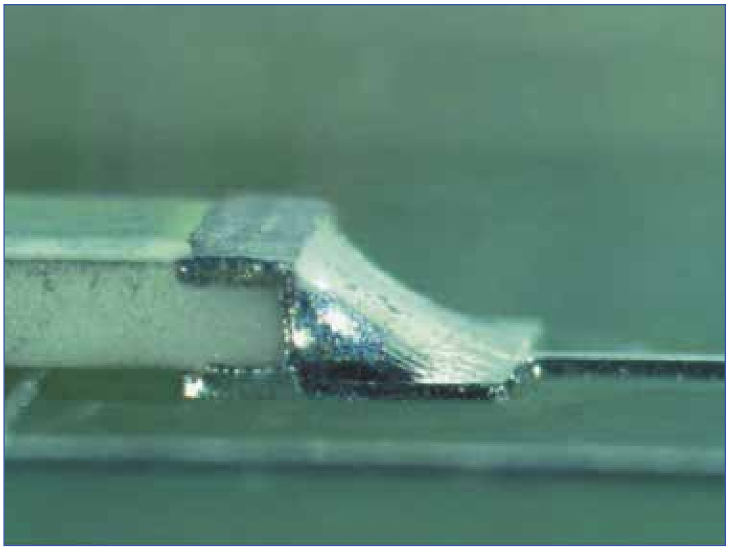

FIGURE 2. The "target condition" has morphed into "acceptable."

PCB Layout, continued from pg. 36

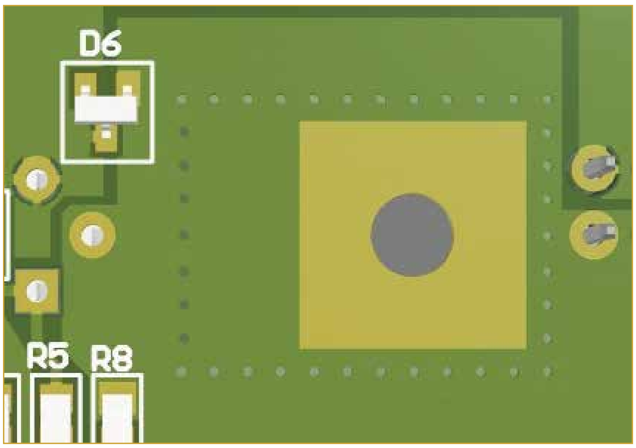

FIGURE 10. FET topside view.

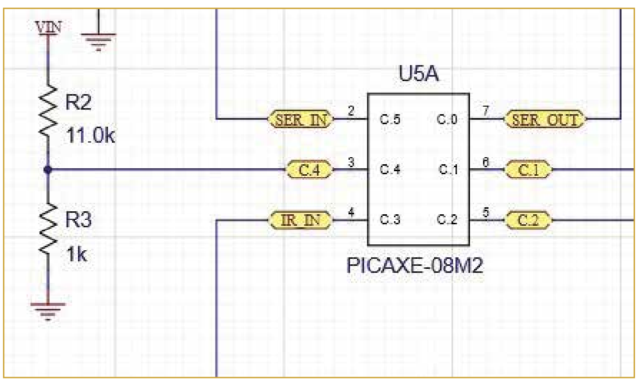

FIGURE 12. The microprocessor pins handle IR input, speaker output, voltage-divider input and the LED ON/OFF control, respectively.

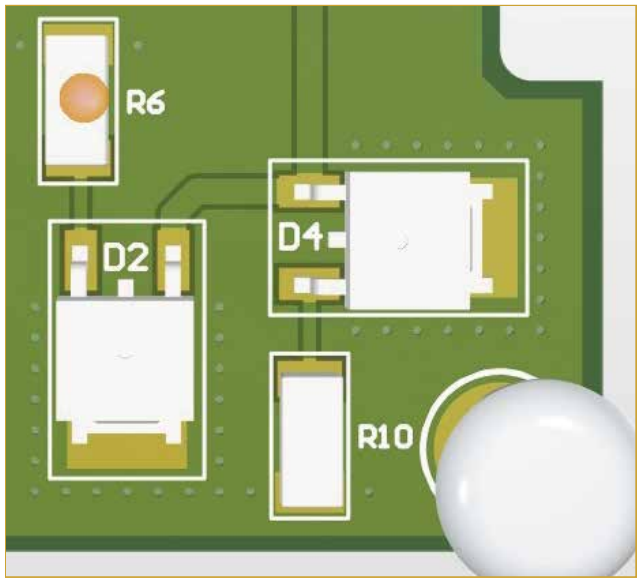

FIGURE 11. Current-setting resistors come in four part numbers of varying currents.

This feature allows the user to safely exit the room before the lights turn off.

Other features have been implemented as well but won't be detailed here.

In the future I will incorporate a PWM feature for "dimming" to the LED output. This will add more than ON/OFF to the LEDs. This will be controlled using the IR remote and pressing the volume UP / DOWN. □

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TUNING

Lean Manufacturing and Six Sigma: Are Both Needed?

Improving problem identification and resolution speed through dual disciplines.

FILEMON SAGRERO is continuous improvement engineer and a Six Sigma Black Belt at SigmaTron International's facility in Tijuana, Mexico; filemon.sagrero@sigmatronintl.com.

TEAMS AT MULTIPLE SigmaTron International facilities have been trained in Lean Six Sigma philosophy. However, some companies work from a pure Lean manufacturing philosophy without Six Sigma tools. This month, we look at the benefits of integrating these disciplines.

Any company embracing Lean manufacturing philosophy generally focus on eliminating the seven wastes:

1. Waste of overproducing (no immediate need for product being produced)
2. Waste of waiting (idle time between operations)
3. Waste of transport (product moving more than necessary)
4. Waste of processing (doing more than what has been agreed upon)
5. Waste of inventory (excess above what was required)
6. Waste of motion (any motion not necessary outside of production)
7. Waste of defects (producing defects requiring rework).

Done holistically in a normal materials-availability environment, this improves throughput while reducing inefficiency and the unplanned variations that lead to defects. Adding Six Sigma to the equation gives employees the tools and training to fine-tune this system. Simply put:

- Lean = capable (oriented to wastes)
- Six Sigma = effective (oriented to defects reduction)
- Lean Six Sigma = capable and effective.

In the electronics manufacturing services (EMS) industry, the bigger question is: What are the benefits of Lean Six Sigma to customers? EMS customers consider quality a given in the outsourcing relationship. In short, they often look at the result, rather than the disciplines used to achieve the result. That said, Lean Six Sigma provides specific benefits in the current environment. These include:

- Force-multiplying employees focused on continuous improvement. When employees have the tools and training to identify waste and correct the issue, programs run smoother.
- Smoother new product introduction (NPI). NPI has a large learning curve and resource demands for both customer and contract manufacturer teams. When the contract manufacturer team is working from a Lean Six Sigma perspective, issues tend to be better documented, and resolutions are identified and validated more quickly, thanks to core tools such as the Define, Measure, Analyze, Improve, Control (DMAIC) process. This can lower time demands on customers during this period.
- Faster issue identification/resolution. The current business environment has created many external drivers of defects, from materials quality issues due to supply/demand imbalances, to the production challenges created by unexpectedly steep spikes in product demand. Lean Six Sigma culture drives a focus on metrics that helps identify and correct these issues as they begin.
- Improved cycle time. Another dynamic in the current environment is that materials-availability delays impact production schedules on a regular basis. A Lean Six Sigma environment has faster line changeovers and more focus on eliminating the variation that impacts throughput, allowing a faster response to unplanned schedule changes.

There are also benefits at the employee level that improve productivity and retention:

- Greater opportunities for recognition of meaningful accomplishments. Because continuous improvement activities are team-based and well documented, the value of these activities is evident to a larger number of contributing employees and higher levels of the organization.
- Job enlargement/enrichment. Production activities are repetitive by design and that can create job dissatisfaction. Employees in a Lean Six Sigma environment receive the training and tools to increase skills and expertise over time, plus add the variation of kaizen events to their work environment.
- Improved quality focus. The more employees understand the "why" behind work instructions and process control metrics, the harder they are likely to work to ensure the process stays within control limits. A Lean Six Sigma culture helps distribute this knowledge across a wider employee base and create a bottom-up focus on driving positive results.

The bottom line is that a Lean Six Sigma approach helps create a workforce that better understands the results of their actions, is more able to identify emerging quality issues, and can more rapidly evaluate and implement viable solutions to the problems they identify. While Lean manufacturing alone can address much of this in terms of product and process design, the addition of Six Sigma tools and training helps improve problem identification and resolution speed by educating a larger pool of employees in these skill sets. This "working smarter" approach creates a more efficient, productive organization better able to adapt to the challenges facing manufacturers today. □

Printed Circuit Engineering Professional

Table of Contents:

Ratings Bonanzas

The AI-driven world of surveys could use a personal touch.

THOSE WHO USE ride sharing apps have doubtless noticed the ride is not the complete part of the story. Once you arrive, your app, somewhat intrusively, insists you complete a survey, rating the driver. The survey is Part Two of the journey. One must take care to answer it "correctly." Inquiries follow if one doesn't.

Which makes one wonder …

Deep learning (n, int): Techspeak for making something simple, often intuitively obvious, sound more sophisticated than it truly is. Faux profundity.

And ask this: Who gets to define "correctly?"

Further: What qualifies the person doing the defining?

"Thank you for choosing to enlist the expertise of the team at Abyss Technical Failure Analysis Services (ATFAS). If we could take a few moments of your time to complete the enclosed online service excellence survey, we'd be grateful for your candid feedback. We strive for continuous improvement, and your opinions are integral to that process. The following survey, activated by the link you clicked, will take only a few minutes. Many thanks for your business and, in advance, for your thoughtful answers."

You're welcome. Let's move on.

"First question: Did you use our 1) X-ray Services; 2) CT Scanning Services; 3) Destructive Failure Analysis Services; 4) SEM/EDS/EDX Services; 5) Flying Probe Test Services; or 6) Other Services. Please check one. If your answer is 6, please explain."

6

"Please explain."

We used flying probe testing services, in combination with x-ray analysis, to nondestructively validate the connectivity and robustness of solder connections at certain critical device locations on our PCBA.

A series of long gray dashes appear at the bottom of the screen, resembling extended Morse Code, or even blank spaces of an application, waiting to be filled in, signed and submitted.

"Second question: On a 1-5 scale, with 1 being not helpful at all and 5 being extremely helpful, how helpful did you find the services you selected at ATFAS?"

3

"Please explain."

You did a satisfactory job. You fulfilled our objectives and requirements. This is, in fact, what we paid you to do, and that is your job. Accordingly, you deserve neither condemnation nor praise. You simply performed to requirements, as you would be expected to do. Take our payment for services rendered and bank it.

The first, leftmost dash at the bottom of the page changes from gray to green.

"Please explain further. Why did you select the rating number 3?"

Was the prior answer insufficient? Also, it is our habit not to provide superior ratings, as there is always room for improvement in any service or activity open to subjective evaluation.

A second dash morphs from gray to green.

"Why did you not select ratings 4 or 5?"

You didn't solve our problem. Your results were inconclusive. You did not pinpoint the source of failure at the I/O pins of the suspect BGA. Forgive the expression, but we were hoping/expecting to find a smoking gun, and you did not find one. Not entirely your fault, but expectations of success were high and went unfulfilled.

"What could we/should we do to deserve a higher rating for the services you used at ATFAS?"

Find our problem. That would rate a minimum of 4.

"What if our results are inconclusive, or we simply can't find the source of your problem?"

Then the rating of 3 stands. It's a results-driven world.

A caption suddenly emerges beneath the two green, formerly gray, dashes at the bottom of the screen. It says, "Good answer" also in green.

"Third question: On a 1-5 scale, with 1 being poor, and 5 being excellent or superior, how would you rate the level of customer care and service you received during your recent project with ATFAS?"

4

"Please explain."

We rarely if ever give the uppermost available rating to anything. As previously noted, there is always room for improvement. It's an imperfect world, in which many strive for perfection. Keep striving.

A third dash at the bottom of the page suddenly becomes green. Starting from the left margin, there are now three infiltrating green dashes, followed by a series of gray dashes.

"What could we/should we do in the area of customer service to enable you to raise your rating of ATFAS from 4 to 5?"

Cure cancer. Create permanent world peace. Eliminate poverty. Solve malnutrition and hunger. Tell us who really killed JFK. Little things.

"Please explain."

I was being facetious. Probably nothing you can

Robert Boguski is president of Datest Corp. (datest.com); rboguski@datest.com. His column runs bimonthly.

do to improve your rating at this point. You would have to provide tangible evidence of going significantly above and beyond customarily expected levels of service. I can't provide examples, but like the Supreme Court justice who once defined pornography, I'll know it when I see it.

"Please explain."

I don't know with certainty but will hazard some guesses. Answer emails promptly. Provide regular status reports ahead of my asking. Notify me of problems in process, their reasons, and your solutions to them. Explain the images I'm looking at on the screen to the satisfaction of colleagues who don't understand what they're looking at. Be patient with our crazy requests. Give us full value for the large amount of money we pay you (full value being defined and determined by us – again, we'll know it when we see it).

"Please explain."

I have nothing to add, other than to note that good service is something you should be providing anyway, and without the incentive and prodding contained in a customer survey. You collect money to do this, both in your revenue and in your salaries. This is not suburban Little League; there are no trophies for participation. Get used to it. The technical term is maturity, also known in the vernacular as adulthood. Which leads to professionalism. Doing the right things when nobody's looking. Nosy surveys don't change that.

The algorithm relents, finally. A fourth dash turns green. The caption beneath the Morse Code dashes suddenly changes from "Good answer" to "Very good answer." It's happy. Almost home.

"Fourth question: On a 1-5 scale, with 1 being inferior and 5 being superior, please compare ATFAS as a supplier with similar suppliers or services you have used in the past. Does your recent experience with ATFAS lead you to conclude our services are better or worse than comparable services you have previously used?"

3. No better and no worse than comparable services.

"Please explain."

We did exactly one order with you. Now you want our perspective on how your company fits the whole of human history, and commercial history to boot, after one order. Slow down, big fella. We're just getting to know you.

"Please explain."

We are basing our comparative rating of your company and its services on a sample size of exactly one. Accordingly, and because your service is new and mostly unfamiliar to us (other than this first order, which was fulfilled satisfactorily), we start you with what we believe is a fair rating, in the middle of the rating pack. You start from a neutral position, with nowhere to go but up, or down. Consider our rating as a challenge to do better. That's the definition of constructive criticism. You did ask us to rate you, didn't you? And now we must defend our choice of rating?

Just digest this: At this stage you are no better and no worse than other similar companies, with similar services performed. Work hard at earning our business, and adding to your sample size, and the ratings will take care of themselves and find their natural level.

A fifth dash immediately turns green. The machine is learning.

"Fifth question. Knowing what you know about ATFAS and its services, is there a service we lack that you need, or a shortcoming in our organization that you experienced, that in your opinion could use improvement? Please be as descriptive and as specific as you can."

Provide imaging services for large objects in the sub-5 micron resolution range. The technical term is microfocus imaging. By large objects I mean server boards in the 500mm x 550mm range, weight 30-50lbs (including heat sinks), with 50-80 processors in BGA packages. Also stuffed with QFNs. Identify microcracks and their propagation on each device. In plain English, pick up small stuff very clearly. Find the failure nondestructively, and decisively, and large amounts of money are saved in diagnosis and repair. Everybody wins. Today that is an unfilled niche.

Also, better integrate your services with Industry 4.0 standards and capabilities.

"Please explain."

Create the digital infrastructure to process large amounts of failure data (Exhibit A: the server board noted immediately above) and learn from it. Observe trends in the process of learning. Identify small problems from the learning before they grow into big problems. Pinpoint regressions from the mean before they violate control limits. Sentinel duty. Activate alarm bells when needed. Voilà: Failure analysis actually using big data and not simply warehousing it for marketing purposes.

A sixth dash turns green. The caption changes again, from "Good answer" to "Excellent answer."

"Sixth and final question: Do you have any additional remarks, comments, commendations, or criticisms you'd like to add, that were not covered by the previous questions or your previous answers?"

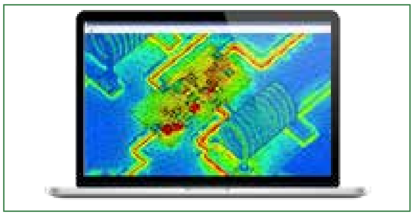
Abyss Technical Failure Analysis Services' services were adequate, to the extent that we have a second failure analysis project designated to send to you for inspection and evaluation. We hope you will apply the comments we've offered here in the spirit in which they were written, and this newest order will be subject to efforts at improved performance.

The entire dashed line at the bottom of the page turns green. And the caption now says, "Superior answer."

Does this entitle us to a free replay? Where's the happy face emoji? What have we won?

The algorithm is silent.

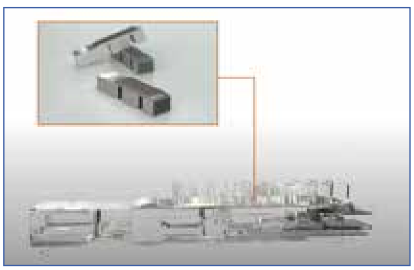
Words fail. ❑



KEYSIGHT PATHWAVE ADS 2023 DESIGN-TO-TEST SOFTWARE

PathWave ADS 2023, for high-speed digital (HSD) design, comes with new Memory Designer capabilities for modeling and simulation of next-generation interface standards such as DDR5. Ensures rapid simulation setup and advanced measurements while providing insights to overcome signal integrity challenges. Memory Designer constructs parameterized memory buses using new pre-layout builder, to show system tradeoffs that reduce design time and lower product development risk for DDR5, LPDDR5/5x, and GDDR6/7 memory systems. Predicts closure and equalization of the data eye: minimizes impact of jitter, ISI and crosstalk using single-ended I/O (Input-Output) buffer information specification algorithmic modeling interface (IBIS-AMI) modeling with forwarded clocking, DDR bus simulation and accurate EM extraction of PCB signal routing Shortens time-to-market with a single design environment that enables pathfinding in pre-silicon digital twins to address current integration requirements such as forwarded clocking and timing, IBIS-AMI modeling and compliance tests and future challenges like single-ended PAM4, for exploration of DDR6.

Keysight Technologies
keysight.com



HENKEL BERGQUIST MICROTIM MTIM 1000 TIM

Bergquist microTIM mTIM 1000 series micro-thermal interface coating portfolio has a new formulation to reduce functional heat experienced by optical transceivers, with the latest development addressing thermal challenges of 400, 600 and 800Gb pluggable optical modules (POMs). Withstands up to 500 pulls and insertions without performance degradation, and reduces operational temperatures per POM by as much as 0.18°C/W. Accommodates use of nickel-coated copper heat sinks often employed with higher-bandwidth modules. Can be coated on transceivers. 300°C temperature spike for a 30-minute duration had no adverse effect on coating performance.

Henkel
henkel-adhesives.com

INDIUM CW-818 NO-CLEAN FLUX-CORED WIRE

CW-818 no-clean, high-reliability flux-cored wire minimizes cycle times in manual and robotic soldering processes while delivering soldering speed and spread. Is halide-free, with clear/light-colored residue, charring resistance, and spatter control technology. Meets J-STD-004C high-reliability applications or applications where extra wetting power is needed to achieve a higher throughput. Is compatible with Pb-free and SnPb alloys, HASL, immersion silver, ENIG and OSP, and a good choice for legacy processes requiring an RMA-strength product.

Indium
indium.com/flux-cored-wire

MASTER BOND EP4CL-80MED EPOXY

EP4CL-80Med is a one-part, optically clear epoxy developed for use in medical device assembly applications. Withstands repeated sterilization cycles and passes ISO 10993-5 testing for non-cytotoxicity. Cures at moderate temperatures of around 80°-85°C within 60 to 90 min. and faster at slightly higher temperatures. A one-part, non-premixed and frozen system, contains no solvents, and has "unlimited" working life at room temperature. Suitable for bonding, sealing, impregnating and coating, provides a glass transition temperature of 155°-160°C and has a viscosity of 50-150cps at 25°C. Applies by brushing, spraying, and spin coating.

Has compressive strength of 12,000-14,000 psi and tensile modulus of 450,000-500,000 psi at room temperature. Is serviceable over temperature range of -62° to +232°C. Is an excellent electrical insulator with a volume resistivity of more than 10^{14} ohm-cm at room temperature and a refractive index of 1.52 at 25°C. EP4CL-80Med has good resistance to many sterilization methods, including autoclaving, dry heat, radiation, and chemical sterilants. Resists vaporized hydrogen peroxide. Bonds to a variety of substrates such as metals, composites, ceramics, and many plastics. Comes in jars, cans and syringes.

Master Bond
masterbond.com

MACDERMID ALPHA HITECH AD13-9910B ADHESIVE

Alpha HiTech AD13-9910B is a one-component, ultra-low temperature cure epoxy system. Cures at temperatures as low as 60°C, enabling excellent adhesion strength and a reduction in the defect rate on very temperature-sensitive parts and substrates. Is suitable for plastic parts or substrates that are very sensitive to high temperature exposure and exhibits excellent adhesion strength on stainless steel (SUS), nickel, PCBs and liquid crystal polymer (LCP). The product is recommended for use in camera modules, optical and other applications that are sensitive to high temperature exposure.

MacDermid Alpha Electronics Solutions
macdermidalpha.com

WELLER WXSMART SOLDERING STATIONS

WXsmart soldering stations feature connectivity features for consistent traceability and process control. Deliver data in real time and in multiple formats. Integrates into common ERP systems to improve transparency, streamline documentation, and allow better process control. Connectable to 16 tools.

Weller
weller-tools.com

In Case You Missed It

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

Flexible Electronics

"Layer-By-Layer Printing Strategy for High-Performance Flexible Electronic Devices with Low-Temperature Catalyzed Solution-Processed SiO_2"

Authors: Qingqing Sun, *et al.*

Abstract: Additive printing techniques have been widely investigated for fabricating multilayered electronic devices. In this work, a layer-by-layer printing strategy is developed to fabricate multilayered electronics, including 3-D conductive circuits and thin-film transistors (TFTs) with low-temperature catalyzed, solution-processed SiO_2 (LCSS) as the dielectric. Ultrafine, ultrasmooth LCSS films can be facilely formed at 90°C on a wide variety of organic and inorganic substrates, offering a versatile platform to construct complex heterojunction structures with layer-by-layer fashion at microscale. The high-resolution 3-D conductive circuits formed with gold nanoparticles inside the LCSS dielectric demonstrate a high-speed response to the transient voltage in less than 1μs. The TFTs with semiconducting single-wall carbon nanotubes can be operated with the accumulation mode at a low voltage of 1V and exhibit average field-effect mobility of $70cm^2\ V^{-1}\ s^{-1}$, on/off ratio of 107, small average hysteresis of 0.1V, and high yield (up to 100%), as well as long-term stability, high negative-gate bias stability, and good mechanical stability. Therefore, the layer-by-layer printing strategy with the LCSS film is promising to assemble large-scale, high-resolution, and high-performance flexible electronics and to provide a fundamental understanding for correlating dielectric properties with device performance. (*Small Methods,* May 21, 2021; https://onlinelibrary.wiley.com/doi/10.1002/smtd.202100263)

Solder

"Mechanical, Photoelectric and Thermal Reliability of SAC 307 Solder Joints with Ni-decorated MWCNTs for Flip-Chip LED Package Component During Aging"

Authors: Xinmeng Zhai, *et al.*

Abstract: This study aims to study the mechanical, photoelectric and thermal reliability of SAC 307 solder joints with Ni-decorated MWCNTs for flip-chip light-emitting diode (LED) package component during aging. By adding nanoparticles (Ni-multi-walled carbon nanotubes [MWCNTs]) to the solder paste, the shear strength and fatigue resistance of the brazed joint can be improved. However, the aging properties of Ni-modified MWCNTs composite solder joints have not been deeply studied. In this research, the mechanical, photoelectric and thermal reliability of SAC 307 packaged flip-chip LEDs with Ni-MWCNTs added during aging were studied. (*Soldering & Surface Mount Technology,* Sept. 23, 2022; https://www.emerald.com/insight/content/doi/10.1108/SSMT-08-2021-0059/full/html)

Sustainability

"Biobased Materials for Sustainable Printed Circuit Boards"

Authors: Oladele A. Ogunseitan, *et al.*

Abstract: Electronic waste, with printed circuit boards (PCBs) at its heart, is the fastest-growing category of hazardous solid waste in the world. New materials, in particular biobased materials, show great promise in solving some of the sustainability and toxicity problems associated with PCBs, although several challenges still prevent their practical application. (*Nature Reviews Materials,* September 2022; https://www.nature.com/articles/s41578-022-00485-2)

Wearable Electronics

"A Flexible Electronic Strain Sensor for the Real-Time Monitoring of Tumor Regression"

Authors: Alex Abramson, *et al.*

Abstract: The authors present a commercially scalable wearable electronic strain sensor that automates the *in vivo* testing of cancer therapeutics by continuously monitoring the micrometer-scale progression or regression of subcutaneously implanted tumors at the minute time scale. In two *in vivo* cancer mouse models, the sensor discerned differences in tumor volume dynamics between drug- and vehicle-treated tumors within 5 hr. following therapy initiation. These short-term regression measurements were validated through histology, and caliper and bioluminescence measurements taken over weeklong treatment periods demonstrated the correlation with longer-term treatment response. (*Science Advances,* Sept. 16, 2022, https://www.science.org/doi/10.1126/sciadv.abn6550)