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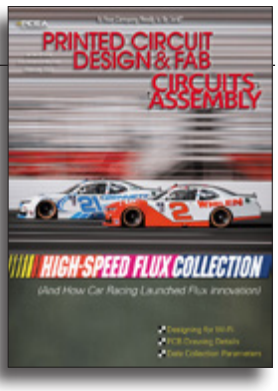
PRINTED CIRCUIT DESIGN & FAB CIRCUITS ASSEMBLY



FEATURES

DFM

Protecting Connectors on Zero Edge Clearance Boards

Not leaving enough clearance is a design oversight that can have costly consequences.
by AKBER ROY

QUALITY CONTROL

Statistical Process Control Charts: Sampling Frequency, Subgroups and Plans

Statistical process control charts are powerful tools, but it can be confusing to determine the appropriate data collection parameters. Understanding how to choose the proper sampling frequency, subgroups, and plans are crucial. Statistical process control sampling frequency, subgroups, and plan methods are reviewed.
by PATRICK VALENTINE, PH.D.

SMT SOLDERING *cover story*

Flux, Reflow Ovens, NASCAR and Moonshine

Until recently, reflow oven manufacturers had little choice in the design of flux collection systems due to cost, cooling efficiency, filters and space limitations. But the tried-and-true concepts of distillation and condensation are driving new innovation.
by FRED DIMOCK

ON THE MARKET

Is Your Company Ready to Be Sold?

Who has time to take the necessary steps to prepare a company for sale? A checklist for showing your company in its best light.
by BOB ROSSOW

ON PCB CHAT (pcbchat.com)

PCB Chat

WHAT'S AHEAD FOR THE PCBAA
with TRAVIS KELLY

LIQUID METAL IN ELECTRONICS
with MICHAEL DICKEY, PH.D.

THE LATEST ECAD MARKET DATA
with WALLY RHINES

INDUSTRY 4.0: WHAT HAPPENED?
with DAVID GRAHAM

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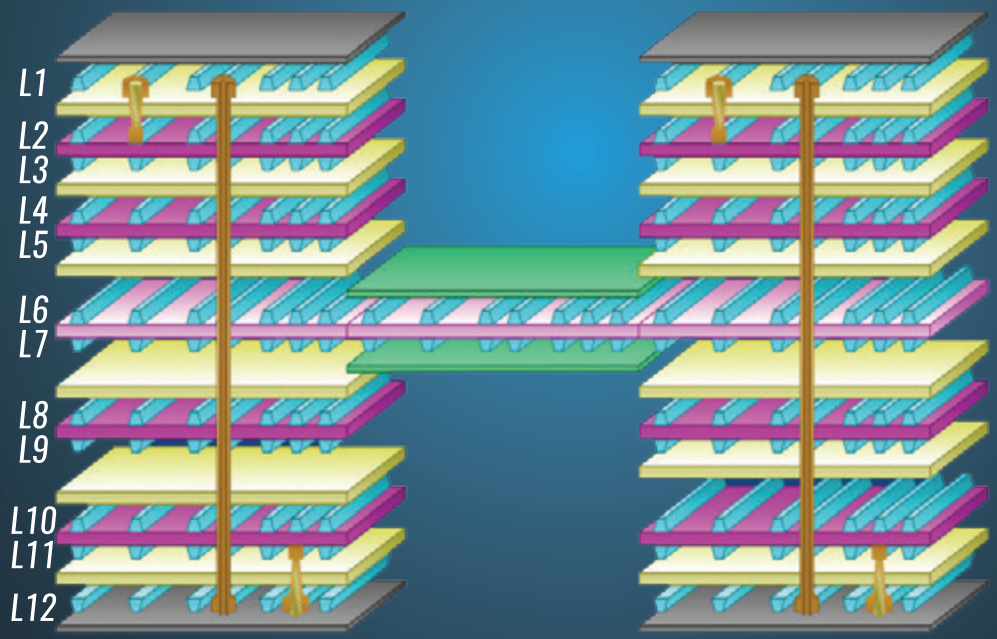

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New Cyber Policy a Shot in the Arm … but for Whom?

FOR MANY MANUFACTURERS and suppliers, Covid-19 is only the second-most feared pandemic. The ongoing threat of having internal systems hijacked and held for ransom – colloquially known as a ransomware attack – will surely outlive the specter of the virus shutting down a facility.

We know of a few instances where this has occurred in the printed circuit industry. A few years ago, a publicly traded board fabricator saw almost all its sites in North America hit, with the hijacked sites taken offline for a few days to a few weeks. Sales and deliveries were affected. In late 2020, Foxconn, the big daddy of the electronics industry, suffered a ransomware attack at its plant in Juarez, Mexico, where attackers stole some files, deleted others, and encrypted the manufacturer's servers. The hackers sought a reported $34 million to release the data. Compal, another top 10 EMS/ODM, was also hit. In all likelihood, it's happened more often than has been publicized.

Still, efforts to immunize the US defense supply chain and others against these hacks has been met with mixed reviews. One primary reason: cost. Bringing systems up to date and maintaining them over the long haul requires highly trained engineers who can cost $100,000 or more per year while not adding to the bottom line.

They may not have a choice.

A new policy being handed down from the Biden administration imposes mandatory regulations on American companies that service so-called critical infrastructure – which goes well beyond the Pentagon. As Travis Kelly, chairman of the Printed Circuit Board Association of America, noted on our PCB Chat podcast this month, critical infrastructure includes everything from financial services and healthcare to energy

and transportation; in short, anything connected to computer networks, and thus hackable.

At press time, a draft of the 35-page document titled "National Cybersecurity Strategy" was being circulated in Washington but had not been signed by President Biden and was not generally available. (It was due to be signed by the end of January.)

Media reports, however, from journalists who nabbed a copy of the draft indicate it calls for the US to take a new, more aggressive tack to "disrupt and dismantle" hacker networks

This effort will be coordinated by the FBI's National Cyber Investigations Joint Task Force as well as all the myriad US security agencies. And the private sector will also be called on to contribute, both as early warning assigns – sharing intrusion reports – and as an ancillary attack force.

The reports further indicate that the defensive cybersecurity regulations set forth in the new policy will almost assuredly be more comprehensive than ever before. Moreover, what was formerly voluntary is going to become mandatory.

The good news is that policymakers recognized – supposedly – that different industry sectors have different needs, and tried to tailor the regulations to fit each marketplace. The bad news is, as a supplier to every critical infrastructure segment, it's almost impossible to see how the electronics industry will avoid changes – and the related costs.

That's right: "Almost impossible." There's a chance the administration lacks the clear authority to impose regulations on manufacturing without Congressional approval.

Still, the frequency with which ransomware attacks are occurring is rising, and the likelihood that manufacturers can sidestep new controls – be they imposed by government or their own customers – probably just got lower.

mike@pcea.net
@mikebuetow

P.S. A warm welcome to Jacqueline Bress, our new events manager. She is a CMP (Certified Meeting Professional) with more than 10 years' experience planning conferences and shows of all sizes, and is based in Georgia.

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FTG to Acquire Holaday Circuits

TORONTO – Firan Technology Group announced on Dec. 28 an agreement to acquire Holaday Circuits, a Minnetonka, MN-based printed circuit board manufacturer focused on the aerospace and defense markets. Closing is subject to approval by US regulators and other customary closing conditions and is expected to take place in the first quarter of 2023.

Under terms of the deal, FTG will acquire 100% of Holaday for cash consideration of approximately C$24 million ($17.8 million), subject to typical closing adjustments. There is also an earn out provision of up to C$6 million ($4.4 million) based on future performance. Holaday had reported annual sales of over C$40 million ($29.6 million) in its audited financial statements prior to the pandemic, dropping to C$30 million during the pandemic.

"FTG had identified Holaday as an ideal fit with our product and market focus," said Brad Bourne, president and CEO, FTG. "This acquisition, if completed, will complement FTG's existing facilities, add new customers and expand our market share in the aerospace and defense market. The team at Holaday has built a great business with a strong reputation in the industry for quality products and excellent operational performance and we are excited to have them as part of FTG. We intend to continue to operate the business in its current facility."

Dennis Pulanco, executive vice president, Holaday, said: "With the passing of Marshall Lewis, my business partner for 40 years, it was time for an ownership change at Holaday. It was important to us that a new owner be aligned with our values, and I am pleased with the sale of Holaday to FTG, as I believe FTG will continue to build the business going forward to the benefit of Holaday's customers, employees and other stakeholders."

FTG also has entered into a sale/leaseback agreement for the facility in Chatsworth, CA,

acquired earlier this year. The closing is subject to completion of due diligence and various closing conditions. Closing is expected in the first quarter of 2023 and proceeds would be approximately C$8.5 million, less commissions and other expenses. The initial lease period will be through 2029, with two additional five-year options to extend the lease.

In November, FTG also announced a deal to acquire IMI, Inc., a printed circuit board fabricator in Haverhill, MA. That deal is expected to close in the first quarter 2023.

Doosan Starts work on New Flex CCL Plant

GIMJE, NORTH JEOLLA, SOUTH KOREA – Doosan in late December broke ground on a plant for manufacturing flexible copper-clad laminates. The company is investing nearly $50 million in the new campus, which is which is being built on a 13,000 sq. m. (140,000 sq. ft.) site.

According to the company, it will be complete in the second half of 2024.

Fastprint to Buy Ibiden's Beijing Unit

SHENZHEN – Chinese PCB manufacturer Fastprint Circuit Tech will be acquiring a Chinese subsidiary of Ibiden, a Japanese PCB maker, at a price of JPY17.7 billion (US$129 million).

Fastprint will be financing the acquisition itself, and plans to bring new investors to the Beijing-based subsidiary while also boosting its development efforts and increasing investments to upgrade the production process and equipment, the company said in a statement.

Ibiden's Beijing subsidiary has more than 1,300 employees and makes motherboards for

leading smartphone suppliers, and its acquisition will open Fastprint to the high-end smartphone market and improve existing partnerships, the company said.

EV Consortium to Build Site in Ohio

WARREN, OH – The Mobility in Harmony Consortium, an initiative by Foxconn, will establish an Innovation Hub near Foxconn's facility in Ohio.

The Innovation Hub will bring together global supply chain partners to share expertise and collaborate on electric vehicle (EV) and mobility projects, as well as new technologies and solutions for automakers. The plan for the effort is to accelerate EV innovation and revitalize American manufacturing by creating an EV ecosystem that spans the entire development process.

SwellFox Launces Educational Engineering Program

BOISE, ID – SwellFox in January announced the launch of its educational engineering platform CircuitBread.com. CircuitBread aims to make electronics, embedded systems, and electrical engineering easily accessible to anyone – from the general interest hobbyist or student to the seasoned expert – through the creation and publication of free electrical engineering resources ranging from content to tools.

"At SwellFox, we share a passion for education. We ultimately uncovered a common desire to create a free, easy-to-use engineering platform for students and engineers of all levels. We wanted CircuitBread to be among the highest quality singular sources for people to become familiar with electronics," said Joshua Bishop, CEO and lead engineer at SwellFox. "We bootstrapped the entire operation, drawing on our experience developing creative and marketing solutions for technology companies."

“From the beginning we wanted to look beyond traditional media and focus on delivering the best experience for our users by utilizing the latest technologies for streaming video, social media, instant messaging, and mobile friendly web browsing,” said Laren Dubkowski, cofounder and lead designer, SwellFox.

“Users come to CircuitBread to learn the basics about microcontrollers, op-amps, and resistors. They also come to use the tools and reference materials that they need regularly in their careers. Regardless of the skill level, we strive to ensure all tools and content are accurate and useful,” said Bishop.

FIT to Acquire Prettl SWH Group

TAIPEI – Foxconn Interconnect Technology has entered into an agreement to acquire Prettl SWH group, a German developer and manufacturer of sensor, connectivity and electrification solutions, as part of the company’s effort to expand its electronic vehicle development.

In a statement released by FIT, the company said it would be bringing Prettl wholly into its corporate umbrella as a subsidiary, and the 186 million euro ($198 million) acquisition should be completed by the second quarter of this year.

Through the acquisition, FIT said the company is expected to see an additional 350 million to 400 million euros ($371 million to $424 million) in annual sales and boost its gross profit margin, while Prettl’s presence is also expected to allow FIT to add the European market to its global sales map through the German firm’s three core business segments – sensor, connectivity, and electrification specialty components – which are used in EV production.

“The transaction will create synergy by combining Prettl’s high-quality module and component products with FIT’s current system,” FIT Hon Teng said. “Taken together, FIT and Prettl SWH will work hand-in-hand to offer comprehensive EV solutions. Also, Prettl SWH’s global network of manufacturing, sales, and R&D will enable FIT to expand its key EV component strength horizontally.”

StenTech Acquires Advanced Tooling Design, Expands to California

CLEVELAND — StenTech in January acquired fellow stencil and fixture designer Advanced Tooling Design for an undisclosed amount.

ATD designs and manufactures stencils, tooling, fixtures and related accessories used in the electronics assembly industry, with applications across a range of end-markets. Headquartered in San Jose, ATD expands StenTech's facility footprint into California, the largest market for stencil and pallet manufacturing in the US.

ATD was cofounded in 2009 by Vicki Hamada and Kiet Vo.

"We were looking for a partner who shared our commitment to SMT manufacturing excellence," said Vicki Hamada, president and CEO, ATD. "A combination with StenTech will carry on ATD's rich legacy while ensuring our customers continue to benefit from our intense focus on customer service while gaining access to the expanded resources and facility footprint of the broader StenTech platform."

"This acquisition is an important strategic step forward in the growth and evolution of StenTech. I'm thrilled to be joining forces with the team at ATD," said Brent Nolan, president and CEO, StenTech.

StenTech is owned by Align Capital Partners, which acquired the stencil maker in May 2022. The transaction marks the first add-on for the company.

ACP managing partner Chris Jones said, "We expect this to be the first of many growth opportunities for Stentech and we look forward to supporting the company through continued investments in technology, sales and operating resources."

APCT to Buy Advanced Circuits

santa clara, ca — APCT has agreed to purchase Aurora, CO-based PCB maker Advanced Circuits from Compass Diversified for around $220 million.

The deal is expected to be completed in February and is subject to certain working capital and other adjustments. Compass expects to realize a pretax gain on the sale of Advanced Circuits of $100 million to $110 million. Net proceeds will be used to pay off outstanding revolver borrowings.

Advanced Circuits had sales of about $90 million in 2022 and EBIDTA of about 30%, which would make the transaction worth about eight times EBIDTA. The combined company would make APCT competitive with Summit Interconnect for the second-largest PCB fabricator in the US, behind TTM.

“We partnered with John and Jeff Yacoub and the Advanced Circuits management team over sixteen years ago. They have been exceptional partners and friends over that period, and we are proud to have supported them as they built a true industry leader at Advanced Circuits,” Elias Sabo, CEO, Compass Diversified, said in a statement. “We believe our permanent capital structure and the longer holding period it afforded CODI in this partnership helped create significant value for our shareholders. APCT represents the right partner for the company in the next step of its journey and we wish them success.”

PCD&F

Aurubis is expanding its Augusta, GA, metal recycling plant to increase production of copper for PCBs, among other materials.

PCB distributor **Confidee** has announced its entry into the printed circuit industry, with a stated focus on developing, documenting and proving compliance in the supply chain.

Huizhou China Eagle Electronic Technology will invest CNY550 million ($79 million) to construct a PCB fabrication facility in Thailand to supply local automotive electronics, computer and electrical appliance makers.

Siber Circuits installed an **Atg Luther & Maelzer** A7a flying probe tester.

Wus Printed Circuit plans to set up a factory in Rojana Industrial Park in Thailand.

CA

Apple is reportedly close to entering an agreement with **Luxshare** to produce iPhones.

BTU appointed **Assembly Resource** exclusive distributor for reflow soldering systems in Northern California and Northern Nevada.

Cicor Technologies acquired German electronic components manufacturer **AFT Microwave.**

Dell plans to phase out use of all Chinese-made semiconductors by next year, according to reports.

Eurocircuits is moving to a new facility and expanding its assembly operations in Hungary.

Flex expanded its footprint at its logistics hub in Lodz, Poland.

Foxconn's subsidiary in China has agreed to sell its entire equity stake in Chinese chip conglomerate **Tsinghua Unigroup.**

Laon People, a South Korean company specializing in AI-based vision inspection solutions, has registered a patent in China for a "defect detection device and methods" in relation to AI vision inspection.

MicroCare opened a warehouse and distribution center in Leeds, West Yorkshire, England.

The **National Center for Manufacturing Sciences (NCMS)** announced publication of a new Technology Brief focused on advances in predictive maintenance, also known as condition-based maintenance (CBM+).

OiTec, a Finnish expert in electronics testing, has joined Goepel's strategic partnership program GATE (GOEPEL Associated Technical Experts).

Quanta Computer is reportedly planning to set up a plant in northern Vietnam to produce Apple MacBooks.

Scanfil added a 2,000 sq. m. (21,500 sq. ft.) expansion to its factory in Malmö, Sweden.

Specialty Coating Systems' Indianapolis coating facility has achieved Nadcap accreditation for conformal coating of electronics – printed board assemblies.

Thermaltronics USA announced the addition of three dedicated demonstration facilities in the US, UK and China.

TTM Technologies purchased a **Hentec Industries/RPS Automation** Pulsar solderability testing system.

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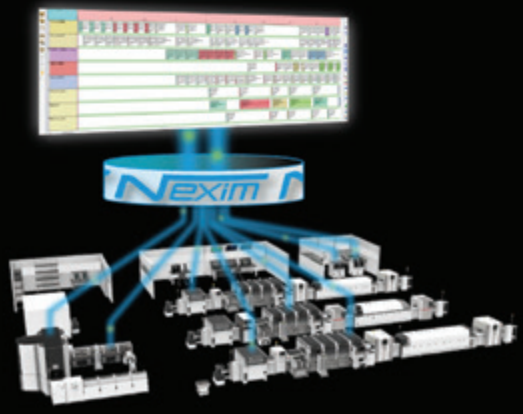

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PCD&F

Jack Fisher, former engineer at IBM and later the technical director for ITRI and HDPUG, passed away. correct size of PCDF and CA to match PCEA. ATF Microwave needs to be RED.

Biamp named **Justin Fleming** PCB design developer. He has 20 years' experience in electronics design, manufacturing and engineering with LiveWire, Harley Davidson, FL:IS and Celestica, among others, and is a director of PCEA.

Garmin promoted **Aaron Parker** to senior printed circuit board designer.

Global LamTech named **Jack Pattie** president. He has more than 30 years' experience in laminate sales, most recently as CEO of Ventec USA.PCB designer

Summit Interconnect named **Jesse Vaughn** senior account manager.

Trackwise Designs appointed **Andrew Lapping** nonexecutive chairman.

CA

AIM appointed **Mehak Sharma** Canadian national sales manager. She holds a bachelor's in electronics and a master's in microelectronics, and has over 10 years' sales and support experience in electronics.

Arch Systems appointed **Joel Eterovich** VP, global sales. He has 25 years of operations and sales experience across multiple global industries. He started his career at Rockwell Automation, working in its electronics manufacturing factories.

AIM appointed **Mehak Sharma** Canadian national sales manager. She holds a bachelor's in electronics and a master's in microelectronics, and has over 10 years' sales and support experience in electronics.

Arch Systems appointed **Joel Eterovich** VP, global sales. He has 25 years of operations and sales experience across multiple global industries. He started his career at Rockwell Automation, working in its electronics manufacturing factories.

Richard McDonough material research scientist, **Shital Rijal** product specialist, and **Robert Atwood** senior manager corporate quality.

Intervala named **Ken Morris** director of operations for its cable and harness manufacturing facility in Hudson, NH. Morris' career in the EMS industry spans four decades with extensive experience in the cable and harness manufacturing arena, serving customers in high-reliability, technology-driven markets, including medical devices, aerospace and defense, and industrial.

Kimball Electronics announced that **Don Charron**, chairman and chief executive, will retire Feb. 28.

Koh Young promoted **Heriberto Cuevas Velazquez** to regional sales manager, Mexico. He was previously applications engineering project manager, and also spent a decade with an EMS provider in Mexico. **Ramiro Mora** will be Mexico applications team leader. He spent 16 years with Tier 1 EMS providers in Mexico, and five years with Koh Young as field service engineer and application engineer.

Technical Conference Program Set for PCB East 2023

PEACHTREE CITY, GA – The PCEA Conferences Task Group on Jan. 20 announced the technical program for PCB East 2023, featuring more than 60 hours of in-depth electronics engineering training.

Lee Ritchey, Rick Hartley, Susy Webb and Dan Beeker are among the headliners of this year's show. The conference will be held May 9 to 12 at the Boxboro Hotel and Conference Center in Boxborough, MA. It features classes for every level of experience, from novice to expert.

The scope of classes ranges from basics on design engineering and circuit grounding, to EMS, power delivery systems, board stackup, RF and flex circuit design and fabrication, thermal management, and materials selection.

New courses this year include how to modularize IoT designs and build systems for the future, PCB cost drivers, differential pair design, and layout strategies for heat management, among others.

"Last year's conference underscored the need to bring technical experts to the doors of the New England electronics industry, which is burgeoning with blue chip OEMs and startups alike," said Mike Buetow, conference director, PCB East. "This year's event matches the leading experts in printed circuit design engineering and manufacturing with the subjects that matter most to those creating electronics equipment."

Registration is now open for both the technical conference and the exhibition at pcbeast.com.

Registrants who sign up by April 7 can take advantage of the Early Bird Special discounts for the conference.

The program was developed by the PCEA Conferences Task Group from nearly 60 abstracts submitted. The task group is made up of nine industry veterans with more than 270 years of cumulative experience in the printed circuit industry.

An exhibition featuring more than 50 leading suppliers to the electronics design and manufacturing industry will be held May 10.

In January, we welcomed the addition of Jacqueline Bress, our new events manager. She is a CMP (Certified Meeting Professional) with more than 10 years' experience planning conferences and shows of all sizes, and is based in Georgia.

Committee Updates

Membership. Corporate membership is currently 15, up six from last month.

Mike Creeden and Mike Buetow were guests on the Altium OnTrack podcast on January 4. We promoted membership and the conferences, among other things.

Chapter News

Silicon Valley. The Silicon Valley chapter is exploring holding a meeting in late February or sometime in March. No date, venue, topic or speaker(s) have been confirmed as of yet, but feelers have been sent out.

Orange County. The Orange County chapter hopes to hold its next meeting in late February.

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Report: Sustainability, Mobility to Drive Semi Growth

Three-quarters (76%) of semiconductor executives expect the industry's supply chain challenges to ease by 2024, yet companies need to be prepared to withstand other market pressures by focusing on investments that will help drive future growth, according to a new study from Accenture. The firm's "2022 Technology Vision" report, based on feedback from 300 global semiconductor executives, found 45% believe the metaverse will have a transformational impact on their organization, and 90% believe it will be in the next four years.

"Traditional" vehicles are undergoing a renaissance, and autonomous vehicles could be mainstream for mass transportation by 2024, according to 32% of respondents. Some 41% of respondents indicated that almost a third of their capex/opex budgets are dedicated to sustainable programs. And 21% of respondents believe that increased health education and literacy is the most important aspect enabled by semiconductor innovation.

Hot Takes

- Global **shipments of notebook computers** (from ODMs) reached around 186 million units for 2022, a year-over-year drop of 25%. Shipments are projected to drop 8% in 2023 to 171 million units. (Trendforce)
- **Taiwanese PCB fabricators** recorded record revenues of NT$249 billion ($8.2 billion) in the third quarter. (TPCA)
- The **wearables market** grew 1.7% year-over-year in the third quarter, but global shipments for full year 2022 are forecast to decline 3.3% to 515.6 million units, the first full year of decline since 2013. (IDC)

- **Copper-clad laminates and other PCB materials** suppliers expect customer demand to rebound after the second quarter of 2023. (DigiTimes)
- **The Philippines** hopes to attain $50 billion in revenues this year, up from $45.6 billion in 2022. (SEIPI)
- The **North American electronic components sales sentiment** increased 7.7 points to 65.8 in December, and the index outlook for January was 80. (ECIA)
- **Global PC shipments** in the fourth quarter fell 28% from a year ago to 67.2 million units. (IDC)
- **DRAM prices** are poised to continue their slide in the first quarter, with mainstream DDR4 prices declining 15-20%. (DigiTimes)
- Most **Nand flash** suppliers have started to scale back production. (Trendforce)
- Nearly 60% of the **world's servers** were produced in China in 2022, down from 70-80% before the US-China trade war. (DigiTimes)

TUNED IN

Trends in the US electronics equipment market (shipments only)

	% CHANGE			
	SEPT.	OCT.[r]	NOV.[p]	YTD
Computers and electronics products	0.6	0.6	0.3	6.7
Computers	-2.4	-0.4	0.8	0.5
Storage devices	-1.4	1.1	-1.2	13.5
Other peripheral equipment	4.0	12.3	4.0	45.9
Nondefense communications equipment	-1.2	0.8	-1.1	9.2
Defense communications equipment	-0.9	1.4	0.5	6.3
A/V equipment	-2.1	-3.8	5.0	20.0
Components[1]	0.1	0.3	1.7	13.4
Nondefense search and navigation equipment	-0.8	1.5	0.5	1.9
Defense search and navigation equipment	1.0	0.3	-0.1	1.1
Electromedical, measurement and control	-0.1	0.5	-1.0	5.0

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

Source: US Department of Commerce Census Bureau, Jan. 6, 2023

KEY COMPONENTS

	JUL.	AUG.	SEP.	OCT.	NOV.
EMS (North America)[1,3]	1.39	1.31	1.29	1.30[r]	1.38[p]
Semiconductors[2,3]	7.20%	0.00%	3.00%	0.3%[r]	2.9%[p]
PCBs[1,3] (North America)	0.98	0.98	1.12	1.29[r]	1.0[p]

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

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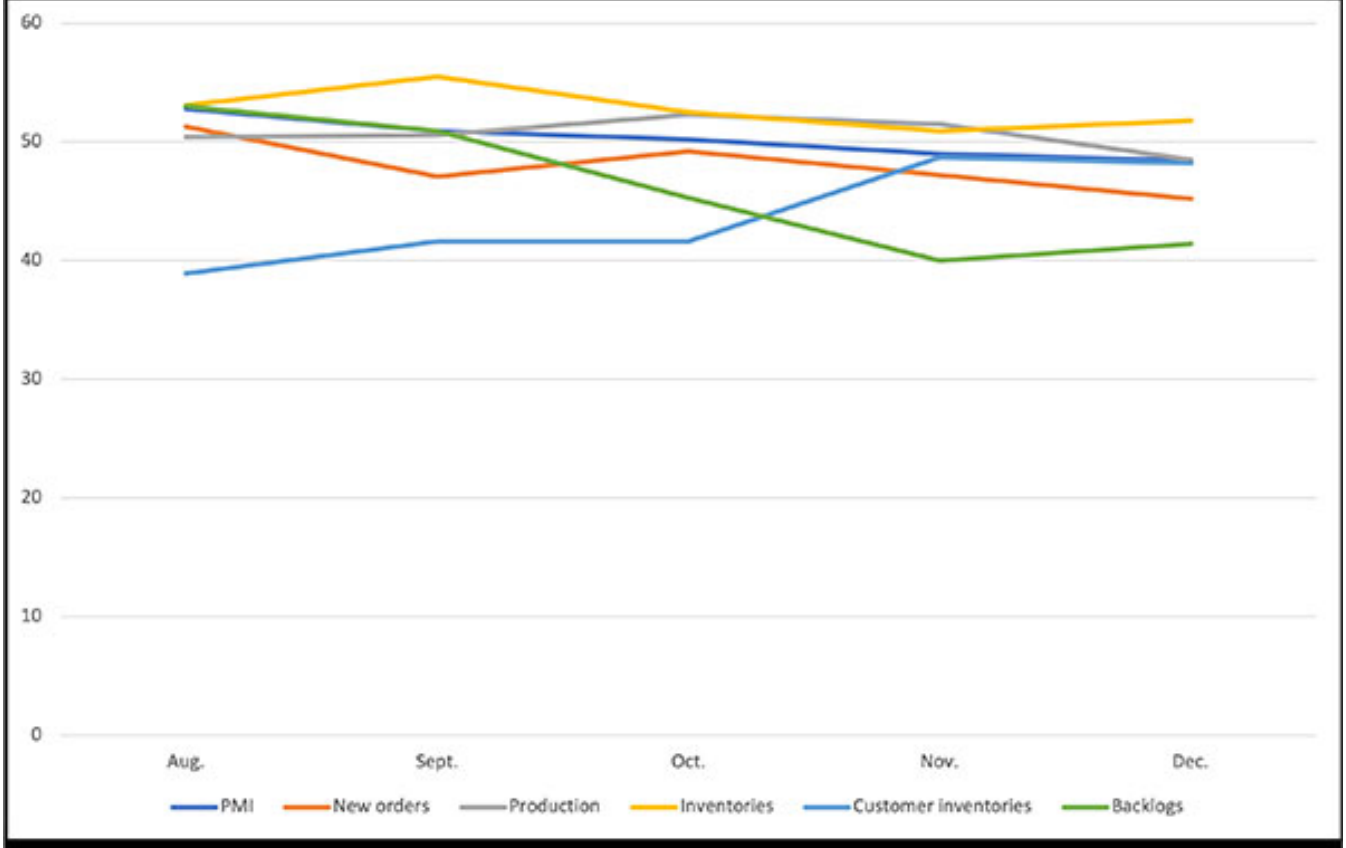

Source: Institute for Supply Management, Jan. 4, 2023

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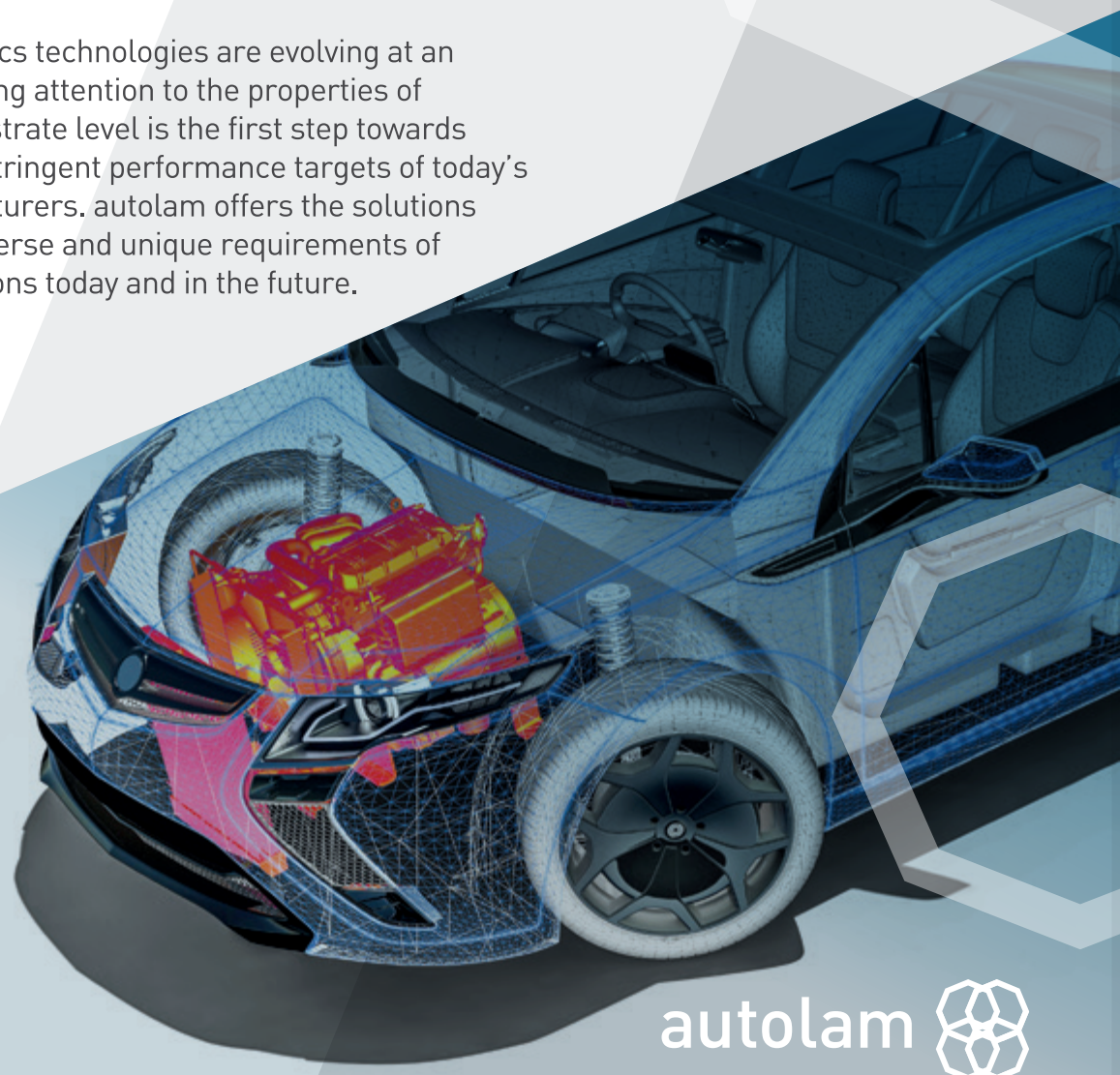

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Striking a Balance in Capex Decisions

> Exclusively staying ahead or behind the technological curve can lead to misfortune.

OVER THE PAST decades, it has been my experience that there are two basic categories of technology: "cutting-edge" and "behind the curve." Electric (rechargeable) automobiles, for instance, would be considered cutting-edge while hybrid (gasoline and battery) automobiles are behind the curve.

Interestingly, when it comes to technology adoption, there also seem to be two types of users. There are those who must be ahead of the curve, always first with the latest technology regardless of how well it may work or how much it costs. And there are those who use only proven technology that is reliable, cost-effective and offers value.

Back in 2013, a friend took delivery of an early Tesla Model S. He was so excited to finally have an electric car, and it sure was a beauty. I remember asking him how it drove. "Like nothing else I have ever driven," he responded. But when I asked how far it could go between charges, he replied "I do not know."

"There are no charging stations yet," he continued. "I have to do it at my house, so I'm afraid to take it too far." When I asked how long it took to fully charge, he responded, "All night in my garage." As one of those "ahead of the curve" users, his pursuit of cutting-edge technology meant putting up with the possible inconvenience and paying a premium for the honor.

Meanwhile, several friends bought Toyota Priuses because they wanted better fuel economy without being limited in driving range or worrying about finding a charging station. These are my "behind the curve" friends who want only proven technology. Both the "ahead of the

curve" and "behind the curve" friends adopted technology and were satisfied by the type they embraced, but did so in very different ways.

Our industry is at the epicenter of technology, running the gamut from cutting-edge to proven technology that is reliable and cost-effective. We contribute to the development of all technology types and levels, while also buying from companies that develop and sell all technology types and levels. Over the years, I have known owners of printed circuit board companies who must be ahead of the curve with the technology they invest in, as well as those who want only proven technology when investing their money.

At the end of the last millennium, some managers of printed circuit board companies would invest only in the cutting-edge technologies of that time to ensure they were ahead of the curve if or when that technology became mainstream. I also knew managers of companies who would not invest in any new technology until it was so tried and true that the next generation was about to be introduced – at which point they would again wait to see how that panned out.

Regrettably, those investing to be exclusively ahead of the curve as well as those doggedly behind it both ended up in the same situation: out of business because of their singular, albeit different, approaches to technology investment.

Most people tend to be either more comfortable being ahead of the curve or more comfortable behind it, waiting for more proven options. The trick to achieve greater success is to find a balance between the two.

Most of the capital investment in a manufacturing company goes into technological assets that help it operate and build products. Even tried-and-true "manual" processes, such as printed circuit board plating, now utilize sensors and other technologies for better control and monitoring. In other cases, cutting-edge innovations such as direct imaging were a distant concept a couple decades back, but today are proven, cost-effective technology.

Investment in any business needs to be a disciplined process. It is easy to go to an industry event and be wowed by a new process or machine that looks and sounds swell but may not

have a practical application in your business or for your customers. Indeed, sometimes those unglamorous pieces of older equipment are the best fit because they have a proven track record to accomplish what is currently needed. The time to be ahead of the curve is when replacing older technology with an emerging one, where the new one will not only fill the role of the older one but also adds considerable capability or throughput that you currently need. That's where spending a premium may be a shrewd investment.

As with any type of investment however, staying clearheaded about the need, being open to what is new and available, and matching it all to your budget as well as your immediate and anticipated needs is essential to maximize long-term financial success. Don't fall for the desire to be ahead of the curve. Being in businesses that are at the center of technology requires that much more focus on ensuring the right technology for the situation is deployed, and long-term success can be achieved by embracing the balance between cutting-edge and proven.

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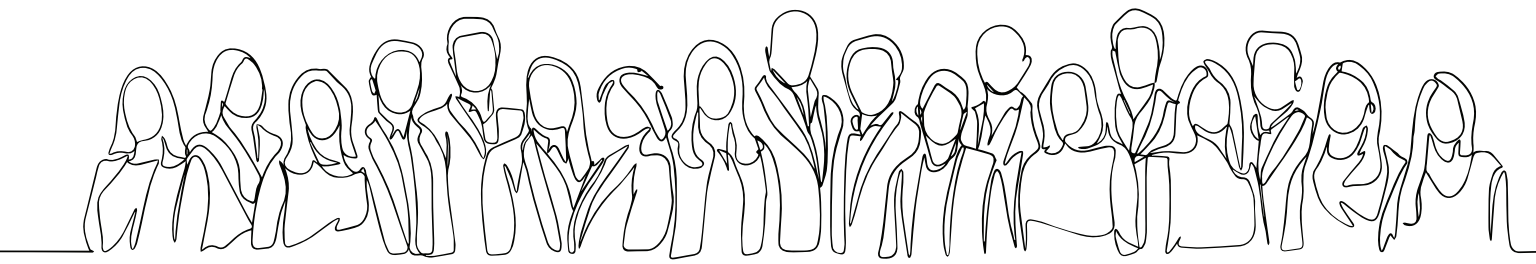

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What Keeps Your Customers Up at Night?

Embracing the fear-based sell.

IN TIMES OF uncertainty, the fear-based sell can be very effective in the electronics manufacturing services industry. There is no question that the past two years – and the current one – qualify as times with a lot of uncertainty. The difference between the prior two years and this one is that the uncertainty factor was so high in 2021-22, many customers were afraid to rationalize their EMS supply-chain strategy due to component availability concerns. OEMs are shopping now, however. The question becomes: How do you differentiate your company from the rest of the industry? The solution lies in the fear-based sell. In its barest form, the fear-based sell advertises a fear that keeps customers up at night and then discusses how your company keeps that from happening. The differentiating value proposition can be more elaborate, however.

Years ago, when I was vice president sales & marketing at Elamex in Mexico, we had a similar situation. Demand for Mexico was high, yet inconsistency was prevalent among EMS operations in Mexico. Some were excellent. Others were not. We focused on the high-mix, medium-volume market, while most Tier Ones at the time were focused entirely on high volume. Enough horror stories had made the rounds about indigenous Mexican EMS companies that OEMs were very concerned about outsourcing in Mexico. Our team looked at that fear factor and built a plant tour designed to address it.

We created a team focused entirely on new product introduction (NPI) and they built a generic Gantt chart that covered about 330 line items, from product customs qualification issues to regular production concerns to outbound logistics. We printed it as a D-sized drawing. During the tour, the NPI team would give a presentation on their process and then

lay the drawing on the table. The rest of the meeting migrated to the OEM team asking questions about those line items relative to their product. We won just about every account competitors was selling a strong NPI approach.

The fear today centers more on material availability. It's a little early to promise the ability to get any part, or not require longer-than-usual forecasts. It isn't too early, however, to start discussing systems, support engineering and supply-chain expertise. Just like the NPI process example, the better you can illustrate a repeatable process for how material-related issues will be identified in NPI and dealt with, the better off you will be. Many EMS providers have developed good IT solutions to deal with material challenges. Many larger EMS companies also have engineering support resources who can be thrown into the mix. The ability to be able to tell stories of how challenges are getting solved is important right now. So is the ability to demonstrate repeatable processes for dealing with those challenges, versus a reactive, fire-fighting approach. OEMs in shopping mode aren't looking for a silver bullet. They are looking for consistency.

It's also important to discuss what's ahead. Demand in industries that were causing a lot of the supply-chain imbalances has dropped. A recessionary environment will cause demand to drop more. Another thing keeping customers (and EMS providers) up at night is the huge amount of inventory that has built up across the industry. It is important to demonstrate the systems in place that monitor that liability and the plans for ensuring inventory levels drop as material availability increases. Companies that discuss that element will likely differentiate themselves in selection processes. Feast always follows famine in the electronics industry, so good processes in this area will not be a wasted investment of time.

Other areas to highlight in sales presentations and plant tours that tie to OEM concerns include:

- Bench strength – how are you retaining and recruiting the talent you need?
- Continuous improvement – costs are going up no matter what, but what is your team doing to improve efficiency and quality to eliminate unnecessary cost in the areas you do control?

- Sustainability – what redundancies are built into the manufacturing location; how do you address the potential for disruptions?
- Specific solutions – how do your facilities address the need for shortened supply chains, cost reduction or specialized builds?
- Best in class performance – where do your systems, equipment, processes or personnel stand out from what is commonly available in your segment of the industry?

OEMs are shopping, but it is a cautious process. Understanding what keeps those customers up at night and tailoring your sales presentation and plant tour to address those fears will make your team stand out. Never overstate capabilities, because this is a long-term relationship where the OEM will quickly separate fact from fiction. Think through the processes you want to highlight: a well-crafted, repeatable process or system that actually improves outcomes is both a powerful selling tool and money in the bank, in terms of the profits it can drive.

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

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Protecting Your Supply Chain

Eight things you should do when your PCB vendor has been acquired.

YOUR PRINTED CIRCUIT board supplier has been acquired. Will this acquisition benefit you as a board buyer? Or will it lead to higher prices and a reduced level of service?

The reality is that your relationship with the supplier and the level of service will likely change. Here are steps you can take to protect your PCB supply chain.

1. Don't wait to be visited by the new supplier team, especially if the acquired firm was a big part of your PCB spend. Request a meeting sooner rather than later. Pay attention to how receptive the new supplier is to the meeting and be ready to ask as many questions as you need to get the lay of the land.
2. Ascertain where your orders stand with the larger entity. What often happens when a larger supplier swallows a smaller competitor that builds a similar product is that customers immediately become smaller fish in a bigger pond. What was 5% before may now be only 0.5%. Ask the new entity what percentage your sales represent for them. The larger the percentage of business you have with the acquired vendor, the better.
3. Will you still be considered a target account for the larger vendor? Will the potential for superior PCB buying power of the larger entity offset your company's (potentially) reduced significance? Be prepared that you will no longer have as much leverage on pricing and service. In fact, the newly enlarged supplier may even raise prices to politely shed customers no longer seen as desirable.
4. Plan on personnel changes after a merger. Ask how the new vendor intends to ensure a smooth customer service transition. The support staff you've worked with for years may be laid off to avoid duplication of costly services. The supplier's sales representatives may

now operate under a different incentive structure that makes their relationship with you less important, or be let go because the acquiring company already has a sales force in place.

5. Review any written agreements with the supplier and those with your customers. Do they contain a clause about changing possible subcontractors? Once a broker is acquired, the new company is likely to try to move your business to PCB manufacturing locations that support its business operations – not necessarily to those best for your orders. Because of your customers' specific requirements, let the new vendor know which orders can't be moved and get it in writing that they will comply.

6. Update and review whether the new entity can maintain the nondisclosure, hold-harmless, and service-level agreements you require. Are payment terms the same? Delivery times? What about the RMA process? Does the new entity have a different warranty policy? Who oversees quality? And be sure to give the new supplier a copy of your most recent PCB fabrication spec. (If you don't have a fab spec, make it a priority to create one.)

7. Develop a Plan B, especially if both vendors involved in the acquisition had been supplying PCBs to your company. Instead of two companies competing for your orders, you now have only one vendor that may not be as motivated to remain price-sensitive.

8. Reach out to alternative PCB vendors for quotes, as they may be eager to give you price breaks and offer you a higher level of service, regardless of your annual PCB buy. At the very least, having an alternate source for your PCBs gives you more leverage with your new, larger vendor.

If the acquisition experience is not a good one for your company, cut the supplier loose by slowly migrating business elsewhere. Seek out other manufacturers. If the supplier is a broker, you can bypass the middleman altogether and deal directly with offshore manufacturers. That is now easier than ever.

GREG PAPANDREW has more than 25 years' experience selling PCBs directly for various fabricators and as founder of a leading distributor. He is cofounder of DirectPCB and can be reached at greg@directpcb.com.

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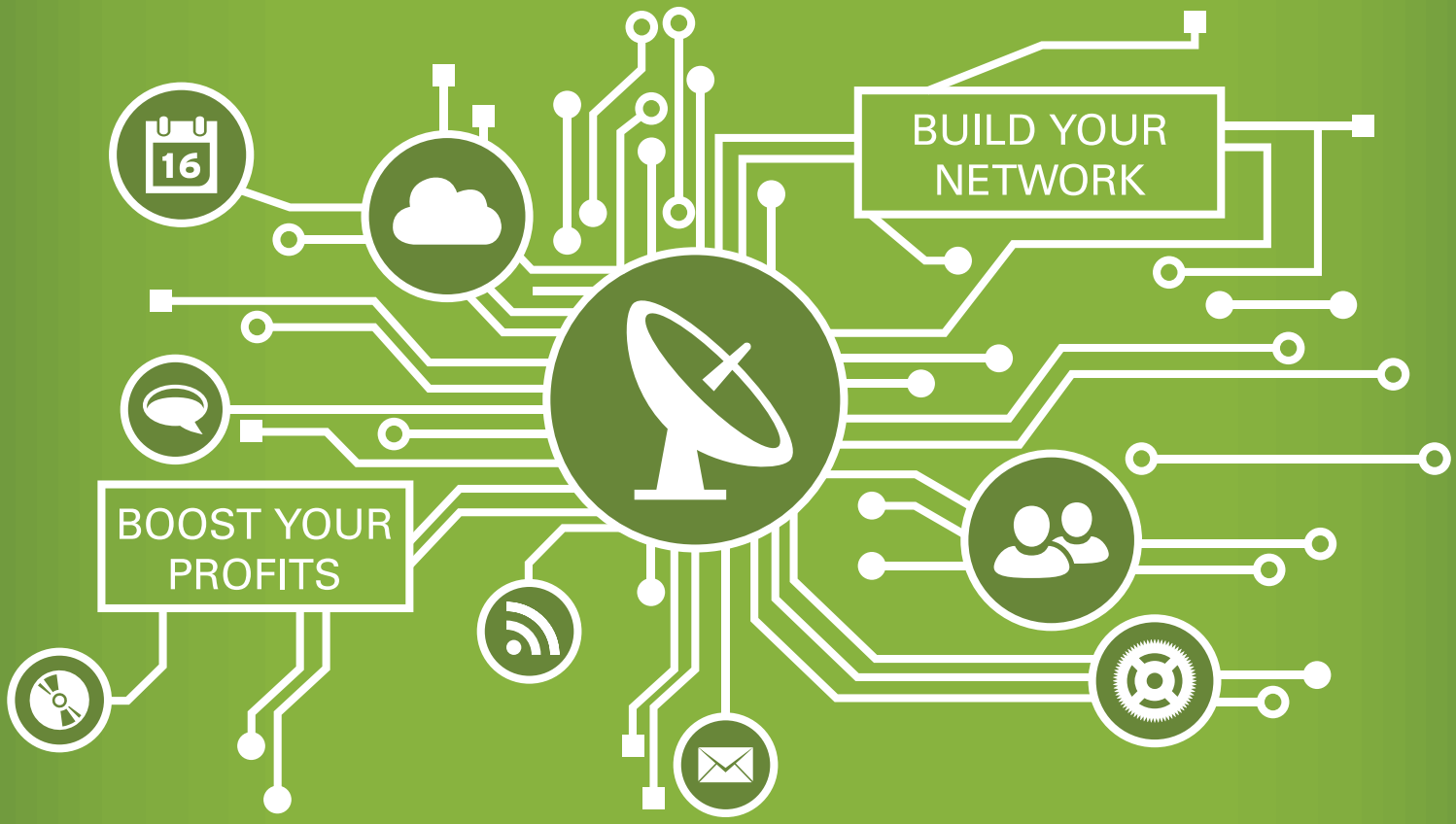

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A PCB Designer's Guide to Wi-Fi

At 5GHz, take additional care with transmission lines.

CUTTING THE CORD has been a liberating step for we the people. Wireless technology under the aegis of the IEEE 802.11 specification has been around for some time now. It's been so long, in fact, the standards body has adopted more protocols than there are letters in the alphabet. One by one, standards have been improved or regionalized to the point where the newer technology gets two initials instead of just one. For Wi-Fi, 802.11a/b/g/n **(FIGURE 1)** is a typical combination of different standards, while 802.11ac refers to a single standard. That's the one you're likely to find in a new mobile device if there is only one type on board. There's a lot to unpack here so let's get started.

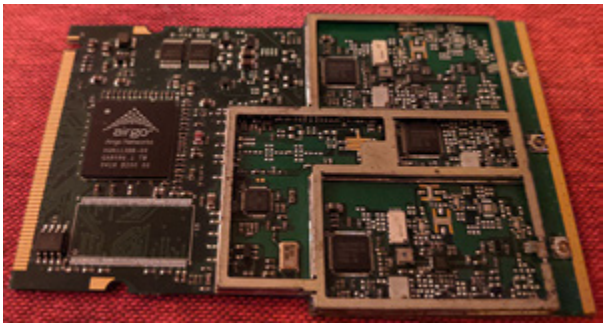


Figure 1. An 802.11n 3×2 MIMO router card, antennae sold separately.

Legacy devices use the crowded 2.4GHz band. It's crowded because anyone can build things that use the frequency range. Microwave ovens were among the first to use it because of the way water molecules get rather excited in the presence of the wavelengths ("Don't watch the food cook!"). Ovens use a kilowatt or more while wireless uses milliwatts.

RC toys, cordless phones, key fobs, baby monitors and other sundry items play in this space. Revisionist historians might refer to this standard as Wi-Fi 1. Some of the original Wi-Fi routers used this wavelength and labeled it 802.11b since 802.11a was taken. In every case, bring-up includes a walk-test where we see how the device performs wherever it may be placed. Who can forget the famous last words: "You're holding it wrong?" It's one part engineering, two parts sorcery.

Dual band devices add the 5GHz frequencies, calling it 802.11a-band or Wi-Fi 2 to be cute. (This is not the much-hyped 5G, which is an evolution of LTE 4G.) Running at 5GHz, additional care should be taken with the transmission lines. By that, I mean more space and more ground vias along the traces. The 2.4GHz and 5GHz bands require separate antennas. When a dual band radio is in use, the 50Ω single-ended traces can be combined near the RF amplifier using a diplexer. The system will determine the strongest signal and use it.

A few years later, 802.11g became the new thing, retroactively called Wi-Fi 3. It's kind of a mashup of a-band and b-band as it uses orthogonal frequency division multiplexing (OFDM) modulation of a-band while working at the longer and stronger frequencies of b-band **(FIGURE 2)**. While b-band has an upper limit of 11MB per second, g-band is good for up to 24MB/s. In terms of hardware, you basically get the speed of 5GHz for the price of 2.4GHz. G-band was the one to get as it would function in the legacy networks, albeit throttled by the weakest link. That's how backward compatibility usually works. The above cases all used 20MHz per channel.

Figure 2. 802.11n Wi-Fi dongles and routers incorporated MIMO OFDM technology. (Credit: Admire Edge)

Next came 802.11n. This is where I came in. Airgo Networks was a small startup with big ambitions. We called them N-routers; nothing about Wi-Fi 4. The main wrinkle was to use more receivers and transmitters instead of one of each. Multiple input and multiple output, shortened to MIMO, was added on top of the OFDM technology. Bandwidth increased to 40MHz, which was multiplied by the number of channels. The sweet spot was using three receivers and two transmitters. This leads to some interesting RF shields. It also leads to routers with two or more antennas poking out of the enclosure.

802.11n: Wi-Fi 4: The specification for HT (high throughput) Wi-Fi (mainly) in the 2.4GHz band (also operates in the 5GHz band). Wireless-N routers used 2.4GHz and 5Ghz transceivers, dynamically switching depending on the situation. The range was outstanding. The data rate exceeded that of 100Base-T Ethernet, a Wi-Fi industry first. I still remember the time at Best Buy when the sales dude was upselling someone from a $50 router to a $200 router with "Airgo Inside." Qualcomm liked us too. Our IP would keep them out of court with their favorite rival, Broadcom.

Instead of a modem chip company, we became a phone chip team, to be combined with other teams in a building Qualcomm bought along with its tenant Atheros. Besides getting shuffled around as a team, the chips got a lot smaller, requiring high-tech board designs. They made a pivot to the Internet of Things long before that became a trending buzzword.

The 802.11abgn standards held court for a while, but all things go obsolete eventually. A good number of standards have been paraded out with their own alphabet. Wi-Fi 5 is a marketing term for 802.11ac, mentioned above. It has been growing and is the mainstream Wi-Fi sold today. That statement is based on a rainy-day search and comparison of new phones, tablets, laptops and gaming devices.

Figure 3. Single-ended 50Ω in 100Ω differential out. (Credit: Atheros)

802.11ac: Wi-Fi 5: The specification for VHT (very high throughput) Wi-Fi in the 5GHz band. I've looked at enough product specs to ensure that I'll be seeing sidebar advertising for all those things well into the future. I'm also confident that Broadcom's chipset is doing really well in this space. We can't ignore Cisco either.

The particulars of 802.11ac devices borrow from N specs but use only 5GHz. Bandwidth increased substantially, up to 160MHz, by combining two 80MHz channels with a maximum of eight channels rather than four. All of that and more puts these units well into the gigabit per second range. Beamforming permits more than one device to access this additional spectrum. This is known as multiple user, or MU-MIMO. The modulation scheme sees an upgrade to 256-QAM. The basic principle of quadrature amplitude modulation is to transmit two signals on the same frequency but out of phase with each other. That's what MIMO is all about.

If you really want to spend the day geeking out on Wi-Fi, this paper (www.duckware.com/tech/wifi-in-the-us.html) cuts through the hype and names names. Bottom line: Believe about half of what I'm telling you in terms of actual data rates.

802.11ax: Wi-Fi 6: The specification for HE (high efficiency) Wi-Fi 6.The future is here. 802.11ax is in the house! Wi-Fi 6 has some neat tricks up its sleeve. When more people are living or working in close proximity, the network can become congested. An apartment tower can feel like an RF war zone with so many routers competing for the same bandwidth. Only so many channels are to be had.

802.11ad: The specification for Wi-Fi around the 60GHz band. A new spectrum is allocated for a special type of Wi-Fi. The 802.11ad standard uses millimeter wave radios for hyperspeed. This will most likely happen on a module that uses nonstandard dielectrics normally associated with chip antennas or data center devices. Intel and others promote this as WiGig. If you want to spend $500 on a tri-band router where an amendment to the ad spec dubbed 802.11ay is still in development (as of early 2020), go for it **(FIGURE 4)**.

Figure 4. You expect this thing to fly around the house on its own. (Credit: Netgear)

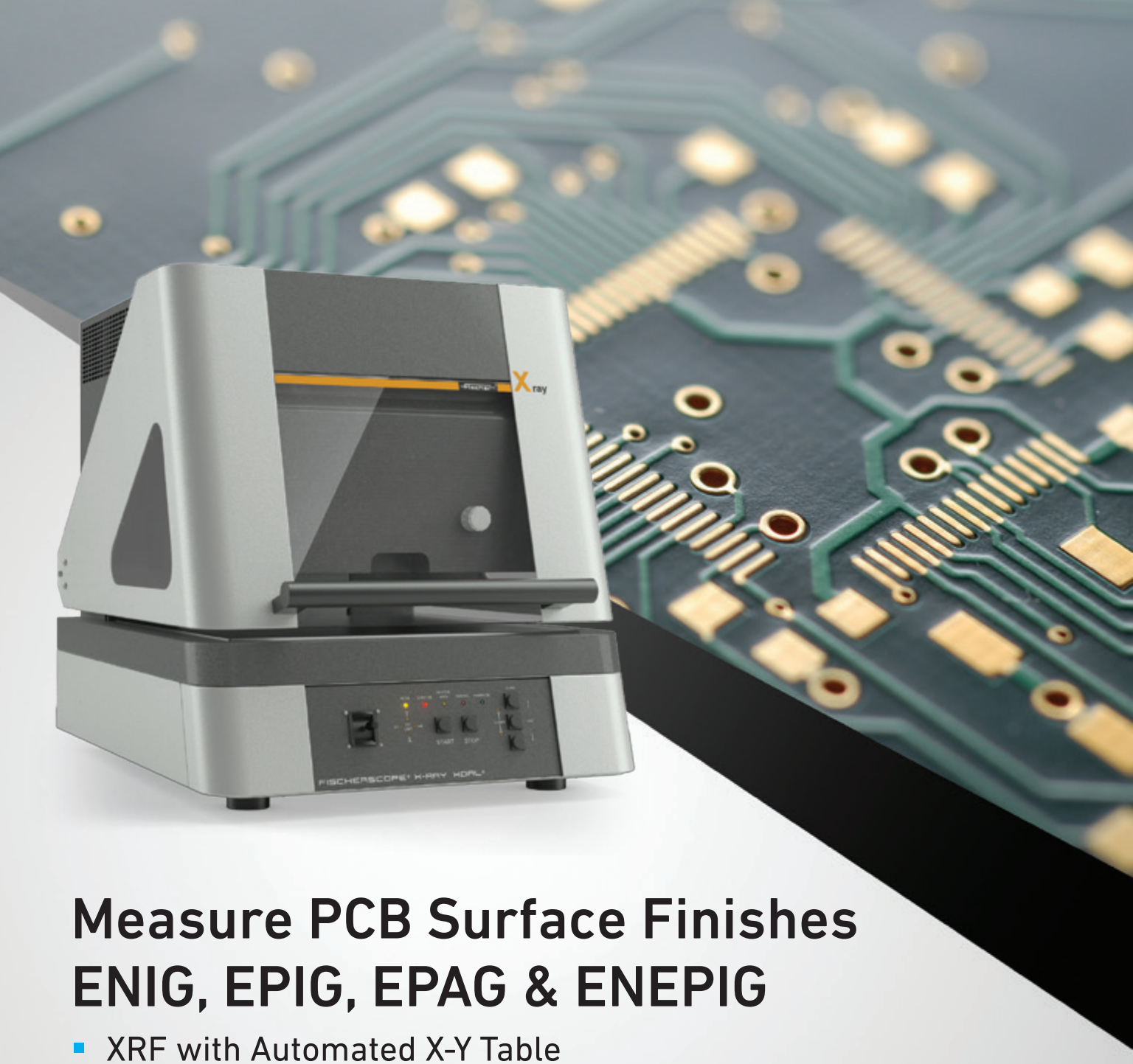
This is a line-of-sight type of transmission technique and only for the very nearsighted. Nice long waves of 2.4GHz and even 5GHz will pass through walls. Not so with 60GHz. It has enough trouble with air molecules to reduce the range to the dimensions of an average living room. The physics work out well in a crowded area. It talks fast but is almost inaudible outside of your personal space.

The "killer app" would be to cut the HDMI cord, which goes above and beyond cutting the standard Ethernet cable. If you're streaming uncompressed HD video from your portable device to the wide screen of donning a AR/VR headset in the land of make-believe, this might be right up your virtual ally.

In all cases, board design calls for making multiple radios play together with a baseband section that interacts with the wired connections. Sensitive signals at low power will make the voltage supplies one of the most dramatic facets of the design. Star routing, where a few pins share a specific capacitor, takes organizational skills. Instead of highlighting nets, you're highlighting pins across the common voltage domain.

Isolating the controlled impedance is a given. That job is up to you, while the power will more than likely be a team effort. RF antennas remain an almost inscrutable science. The internet of faster things is coming. By getting up to speed on the nuances, you can help your team succeed.

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



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Completing Your Drawing

Know what details to include – or not include – in the flexible circuit drawing.

SINCE OUR MOST recent column covered drawing notes for flexible circuits, this may be a good time to go over many of the other features a good flexible circuit drawing should include, and maybe a few things to avoid.

Along with the drawing notes, the rest of the drawing features help define the details of the part as well as some of the acceptability requirements.

For starters, drill tables are important to help describe via structures. The manufacturer needs to know which holes are which. If there are filled vias and/or via-in-pad-plated-over (VIPPO), for instance, they are identifiable with a flag note, or segregate filled from non-filled holes on the table.

Fabricators need to understand your via strategy. Is this a simple through-hole construction, or are buried, blind and/or microvias employed? Sometimes we see blind vias overlapping layers; for example, one blind via from layer 1 to 8 and another from layer 12 to 6. Sounds cool on paper (or in CAD), but we can't do that. The fabricator can help you align the via choices with cost and reliability.

Multiple via structures will dictate how many times a particular layer is copper plated. This will impact the ability to etch those layers once plating is performed. You may receive feedback on the line widths and spaces on these plated layers.

Tolerances on the drilled holes are important, too. Most plated component holes are toleranced as +/-0.003″ (+/-75µm). Some may be +/-0.002″ (+/-50µm) if they are receiving compliant pins at assembly. If so, please note that sometimes the pin manufacturer not only

defines the finished hole size, but the drill size as well. This is to ensure proper insertion and retention force.

For vias, it is common to permit a +0.003″ (75µm)/- nominal. This permits the fabricator to drill vias at nominal and reduce in size with copper plating and final finish. This can maximize annular ring.

Board profile and hole location tolerances are also important. This is a place where it can be tempting to be too conservative. Tight tolerances can lead to unnecessary scrap. Note that these are flex and rigid-flex circuits; unlike a rigid PCB, they can bend and move. Build slack into your design. Most assemblies can easily accommodate a 0.020″ (500µm) profile tolerance on the part outline. Exceptions can be noted where needed.

Hole true position can be another spot to get tripped up. For flex, the guidance is to have different datums for each rigid or stiffened area, and a loose tolerance from datum to datum. This becomes more important as the part gets larger. Flex materials can expand and contract upwards of 0.001″ per inch of length due to changing environmental conditions. I have seen cases of long parts with tight tolerances end to end that could not meet the tolerance due to stretch and shrink. The parts still worked fine in the application, but could not get past receiving inspection.

Conversely, if the part shrinks and no longer can be installed, it probably was not designed long enough as a nominal. You don't want the part to be pulled tight like a banjo string from connection point to connection point. Add some service and install length. Flex can be your friend – it should be the thing that accommodates all the other tolerances in the assembly, not the other way around.

While a drawing should always show a part in its flat state, including an isometric view of the part in its installed shape is helpful. This gives the fabricator insight into the intended use, and may spark conversations about how the part is bent and if the stackup is compatible with that. I have seen cases where a short flex region was expected to bend 180° while the layer count was four or more layers fully bonded. It became obvious the bend radius was going to put excessive strain on the outside radius of the flex.

If the part is a flex with stiffeners added, top, bottom and side views can be beneficial to clearly note which side of the part the stiffeners should be added. Same goes for countersunk holes: fabricators need to know which side to countersink from and what diameter and angle on the countersink.

In "the old days," designers would provide drawings chock full of dimensions. This communicated to the fabricator exactly where all the holes were, where a part edge was, where a radius was located or where a chamfer started. It could show dimensions of rigid to flex transitions and everything else. Today, we have CAD. All that information is embedded in the data files. There's no need to duplicate it on the drawing. It can be a cause for a drawing discrepancy if the drawing doesn't match the data – and trust me, that happens daily. It also means that for any AS9100 qualification or first article, every one of those dimensions needs to be inspected, adding time and cost.

Another dimension to consider is board thickness. With flex and rigid-flex, we may have different thicknesses in different areas of the board. Some designers define nominals with a tolerance for each thickness. This can be appropriate if fitment is critical or when there are through-hole components with leads of a certain length. If you are more concerned about a maximum thickness, however, note that. Often, the fabricator can devise a stackup that can be thinner and save on volume and weight.

For the flex sections, I suggest noting a reference thickness if you can. Often, the finished flex region may end up thinner than expected and could fall out the bottom of a tolerance window. This usually means the part is just a little more flexible – who doesn't want that?

In the end, identifying the things that are critical to the assembly and performance are where you should concentrate and communicate your needs. Where you have latitude to be more "tolerant" with your tolerances, please do. Doing so will get you a product that works as intended without unnecessary costs or delays.

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

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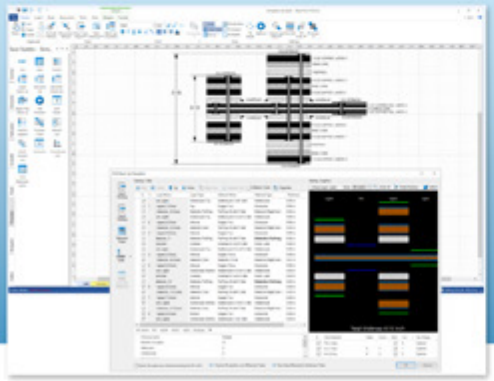
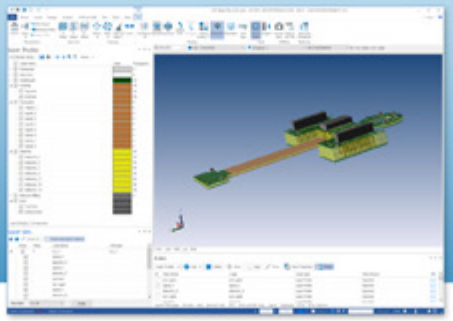
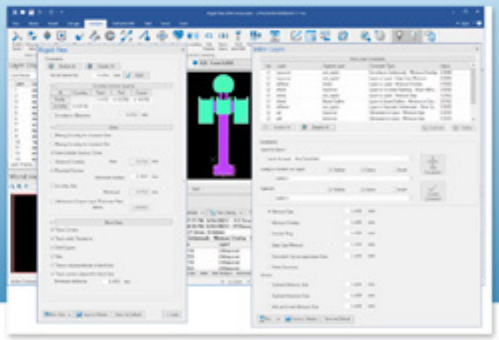


Use Stack Up Visualizer and Blueprint's Rigid-Flex Stackup template to easily manage and document rigid-flex stackups.



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



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Statistical Process Control Charts: Sampling Frequency, Subgroups and Plans

Taking the confusion out of determining appropriate data collection parameters. by PATRICK VALENTINE, PH.D.

In 1924, Dr. Walter Shewhart was working at Bell Telephone Laboratories. On May 16 of that year, Dr. Shewhart wrote a memorandum in which he presented and proposed the process control chart to his superiors. Bell Telephone Laboratories believed this memorandum gave it a competitive advantage and held this paper internally. In 1931, Dr. Shewhart published his book *Economic Control of Quality of Manufactured Product.* In this book, Dr. Shewhart explained in detail the fundamental concepts and benefits of statistical process control. This seminal work laid the foundation for the modern quality control discipline, and the process control chart became the bedrock of quality control systems.

The most critical assumption made concerning statistical process control (SPC) charts, i.e., Shewhart Control Charts, is that of data independence from one observation to the next (not autocorrelated).[1,2] The second assumption is that the individual observations are approximately normally distributed.[1,2] The tabled constants used to calculate the SPC chart limits are constructed under the assumption of independence and normality.

Conventional SPC charts do not work well if the quality attributes charted exhibit even low levels of correlation over time. Correlated data produce too many false alarms. Of important note on the Shewhart +/-3-sigma SPC chart is that 99.73% of the data are contained within this interval. The 99.73%, or 0.9973, is the probability of not receiving a signal when the process is in control, the data are not autocorrelated, and normality is assumed.

Many printed circuit board chemical manufacturing processes can violate the assumption of uncorrelated observations (autocorrelation). This is because inertial elements drive reduction-oxidation (redox) chemical processes. When the interval between samples becomes small relative to the inertial elements, the sequential observations of the process will be correlated over time. Autocorrelation can result from assignable causes, too; e.g., malfunctioning equipment, wrong adds.

Sampling Frequency

Sampling frequency depends upon the cost of sampling, the losses associated with allowing the process to operate out of control, the rate of production, and the potential for process shifts to occur. There are no hard rules that one needs to sample *n* consecutive samples every *x* number of cycles. The general belief is that if the interval between samples is too great, defective products could be produced before another opportunity to detect the process shift occurs.

The most feasible way to detect mean shifts is to take large samples frequently, which is usually not economically viable. Generally, we take small samples at short intervals or larger samples at longer intervals. Current industry practice favors smaller, more frequent samples, particularly in high-volume manufacturing processes or where multiple assignable causes can occur.

According to the US DoD Handbook Companion Document to Mil-Std-1916, the following factors should be considered when determining sampling frequency[3]:

Process change rapidity. The smaller the interval between inherent process changes, the smaller the interval between subgroups.

Relative variability of the process. If the process variability is minimal and the chance of producing an out-of-specification product is negligible, then such a process may be monitored infrequently. This is beneficial when the cost of sampling and testing is high.

Initial data collection. At first, it may be desirable to sample frequently to arrive at conclusions quickly. After sufficient process knowledge is gained, reducing the frequency of sampling may be advisable.

Potential nonconforming product. How much product a supplier can produce between the beginning of a change in process average and the detection of that change should influence the sampling interval. This relates to factors such as production rates and inspection and rework costs.

Sampling Subgroup

Rational subgroups should be selected so that if assignable causes are present, the chance for differences *between* subgroups will be maximized, while differences due to assignable causes *within* a subgroup will be minimized.[1] The preferred method for subgrouping consists of parts produced at the same time (or as close together as possible), ideally taking consecutive production units. Data from different operators, shifts and machines should not be mixed.[2] Taking repeated measurements on a single part is not a rational subgroup.

Choosing the subgroup size is primarily based on allocating sampling effort. The available resources must be considered when determining subgroup size. Therefore, the subgroup size is generally not determined analytically but rather by convenience.[2] In general, larger subgroup sizes will make detecting smaller shifts in the process easier. Many processes do not require great sensitivity in the detection of small shifts as these may occur from day to day. Hence, using larger subgroups may be counterproductive when too much time is spent checking the process for insignificant changes signaled by an oversensitive chart. Subgroups between 3 and 5 for x-bar charts and a subgroup of 1 for individual moving range charts are standard.

Subgroup sizes can be calculated using **EQUATION 1.2** Detecting shifts in control charts is known as Power – the probability of detecting an out-of-control condition when the process is unstable. Power is calculated as 1– β (beta).

$$n = \frac{(Z_{\alpha/2}+Z_{\beta})^2\sigma^2}{D^2}$$

where:

n = subgroup size

$Z_{\alpha/2}$ = Type I error probability (out-of-control signal, but the process is stable)

Z_{β} = Type II error probability (failure to detect an out-of-control condition when the process is unstable)

σ = standard deviation of the characteristic being charted

D = difference to detect

Z values can be found in a standard normal table in any statistics textbook. There are no hard-and-fast rules about how much power is enough, but there does seem to be a consensus. Power should be greater than 50%, power of 80% is judged to be adequate, and power greater than 90% may waste resources.

Using an alpha (α) value of 0.0027 (corresponding to a standard Shewhart +/-3-sigma control chart) and holding the beta (β) values at 0.50 (power = 1 – 0.5 = 50%) and 0.20 (power = 1 – 0.2 = 80%), the charts in **FIGURES 1** and **2** were produced for comparison purposes.

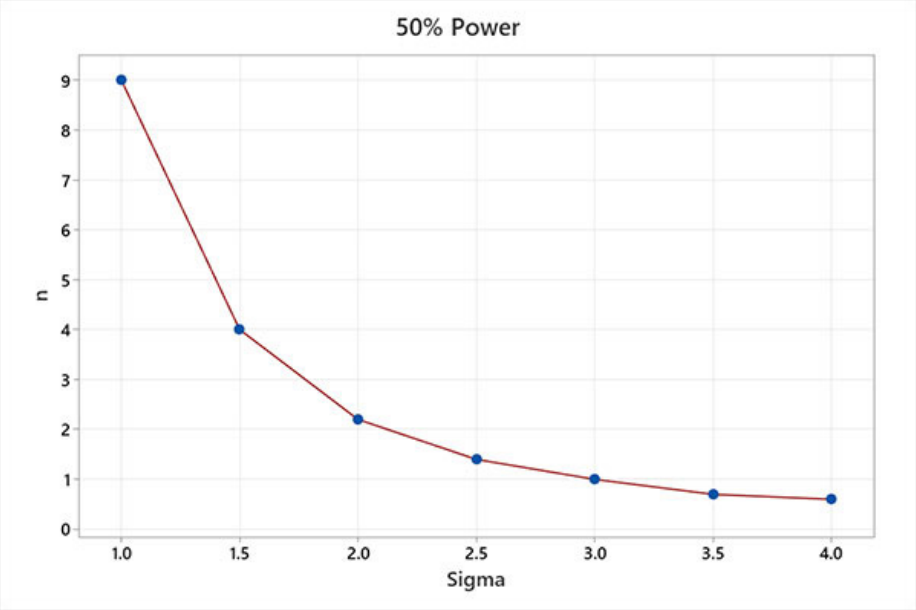

Figure 1. Subgroup size (n) with 50% power to detect a given sigma shift (x).

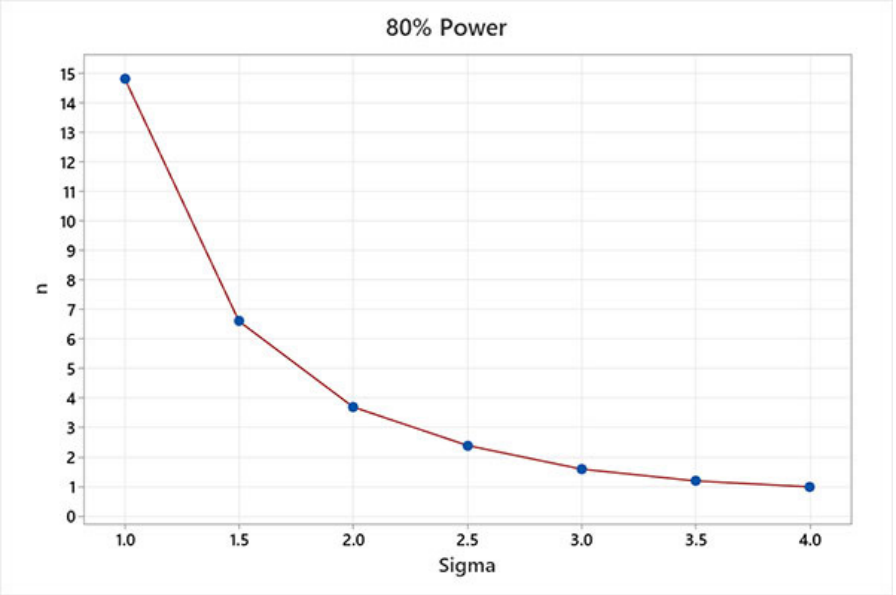

Figure 2. Subgroup size (n) with 80% power to detect a given sigma shift (x).

For example, using a subgroup of $n = 1$, a SPC chart has 50% power to detect a 3-sigma mean process shift on the first sample following the shift. The same chart has 80% power to detect a 4-sigma mean process shift on the first sample following the shift. The probability of detecting the shift increases with each consecutive sample.

Sampling Plan

A general starting point for discussing sampling plans is to use a sampling rate per unit of time of $n/d = 1.0$, where n = the number of samples in the subgroup and d = the sampling interval. The choices of n and d affect the costs associated with the sampling plan and the ability of the control chart to detect process changes. A critical decision in designing the sampling plan is choosing between taking subgroup sizes of $n = 1$ or $n > 1$.

When detecting a sustained shift is of interest, the best performance is obtained using subgroups of moderate sizes, such as $n = 4$ and $d = 4$, with rational subgrouping employed. When detecting transient shifts of short duration is of interest ($t < 4$, where t = time units), the best performance is obtained using a subgroup of small sizes, such as $n = 1$ and $d = 1$. For PCB wet chemical process manufacturing, a general starting point for discussing the sampling plan is to use a sampling rate per unit of time of $n/d = 0.25$, where $n = 1$, and $d = 4$hr, or $n/d = 0.50$, where $n = 3$, and $d = 6$hr. Once the sampling plan has been established, one can move to Phase 1 and, ultimately, Phase 2 of statistical process control.

Phase 1, retrospective analysis, is designed to bring a process into a state of statistical control. This is accomplished by collecting 20 to 25 subgroups of size *n*, computing the control limits, and plotting the data. Note: Fewer than 20 subgroups produce control limits that are not as reliable.

These control limits are considered trial control limits and allow determination of whether the process was in control when the initial samples were selected. Points that are outside the control limits are investigated for assignable causes. Points with assignable causes that can be corrected by engineering and operators are removed. Control limits are then recalculated, and new data are collected and charted. Sometimes this will take several cycles in which the control chart is created, assignable causes are detected and corrected, revised control limits are calculated, and new data are collected and charted. Suppose all original data points plot inside the control limits and no systematic behavior is evident. In that case, one can conclude that the process was in control and the trial control limits are suitable for controlling future production. Once a clean set of data that represents in-control process performance has been demonstrated, one can move to Phase 2.

Phase 2, process monitoring, has an established set of reliable control limits. The control chart can be used for monitoring future production. Effectively using control charts requires periodic review and potential revision of the control limits and center line. One should establish regular periods for this review and possible modification of control chart limits, such as every month, every six months, or every 50 or 100 samples. When revising control limits, remember that using at least 25 subgroups for computing control limits is highly recommended.

Conclusions

Statistical process control charts have been in use for nearly 100 years. These charts are powerful tools, but it can be confusing to determine the appropriate data collection parameters.

Understanding the tradeoffs of the sampling frequency, subgroups, and plans is critical for controlling PCB manufacturing processes. As a starting point for discussing the sampling

plan, using a sampling rate per unit of time of $n/d = 0.25$, where $n = 1$, $d = 4$ hours, or $n/d = 0.50$, where $n = 3$, and $d = 6$ hours is recommended. Systematically moving from Phase 1 to Phase 2 ensures establishing proper control limits and maintaining them. Regular periods for review and revision of control chart limits enhance continuous improvement efforts.

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1. D. Montgomery, *Introduction to Statistical Quality Control, 6th Ed.,* John Wiley & Sons, 2009.

2. T. Ryan, *Statistical Methods for Quality Improvement, 2nd Ed.,* John Wiley & Sons, 2000.

US Department of Defense, *Handbook Companion Document to Mil-Std-1916* (DoD Publication No. MIL-HDBK-1916), 1999.

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Flux, Reflow Ovens, NASCAR and Moonshine

The connection between flux and reflow ovens is obvious, but are there ties to stills and race cars too? by **FRED DIMOCK**

When my wife and I moved to Raleigh, NC, we soon realized we landed in the center of the universe for NASCAR fans. Richard Petty, Richard Childress, Dale Earnhardt, Junior Johnson, Dale Jarrett, Austin Dillon, J.D. McDuffee, Bobby Isaac and Rick Hendrick are a few of the well-known figures from NC. NASCAR race shops are all over the state. Towns such as Level Cross, Welcome, Kannapolis, Charlotte, Mooresville, Concord and Randleman are on every fan's destination bucket list. Racetracks such as Bowman Gray, Charlotte, Rockingham, Ashville, Caraway, Fayetteville, North Wilkesboro, Orange County, Hickory, South Boston (VA), etc. are within a couple hours' drive of our NC home.[1]

The roots of NASCAR are deeply embedded in bootlegging, where souped-up, high-performance cars were used to transport illegal liquor. Although prohibition ended in 1933, production of illegal whisky continued for years, as bootleggers sought to avoid taxes and sustain their families. Someone once said that the first automobile race came about when the second car was built and the bootleggers soon began racing to prove their modified car was the best. This backwoods racing went on for years in farm fields and independent tracks until Bill France Sr. organized many of them into NASCAR in 1948.[2]

Figure 1. View of the start of a NASCAR race from the pits at New Hampshire International Speedway.

So, how do we get from moonshine and NASCAR to solder reflow?

We need to look closely at North Carolina to get an answer. North Carolina is known as the Tar Heel State because of pine tar, the basis of rosins and resins used in many fluxes. It started with the abundance of pine trees that were in the area when Europeans first began settling North America. In the May 2015 issue of *HOMES & GARDEN,* Andrew Kenney explains how the Tar Heel name came about:

> Lawrence Earley writes in *Looking for Longleaf*, "In 1584, that two captains told Sir Walter Raleigh that these 'trees could supply the English Navy with enough tar and pitch to make our Queen the ruler of the seas.' The seamen were referring to pine tar – the viscous fluid that leaks from heated pine, used to secure masts and sails, and used on boat bottoms for waterproofing. These products helped to foster a backwoods industry – and turned NC into the home of the Tar Heels. The nickname stuck, as one tale has it, when the gluey stuff met poor workers' bare feet in farms and distilleries.
>
> According to Timothy Prizer's 2009 thesis "Pining for Turpentine," North Carolina accounted for up to 96 percent of the nation's "naval stores," relying heavily on slave laborers throughout the 1800s. The longleaf trees also yielded the sturdy beams that braced mills and warehouses, some of which still stand today.

Being from New England, I thought that Maine was the Pine Tree State. A bit of research revealed that while at one time Maine had an abundance of pine trees, they slowly disappeared as the first colonists used the wood to build homes and ships, and the pine pitch – the glue processed from pine tar – for candles and sealing ships. By the 1800s, the vast supply of Maine trees had diminished, and production of pine tar switched to the Carolinas. There, the longleaf trees (southern pine), whose needles approach 18″ long, are slightly different than the shorter needle New England white pines **(FIGURE 2)**.

Figure 2. North Carolina longleaf pines.

When one looks closely at pine trees, they see that the pitch is usually translucent and amber in color with some white crystals, just like the residue we see in dirty reflow ovens. In fact, a major component of solder paste is rosins and resins that are combined with solvents to make the flux. These rosins and resins are generally made up of derivatives of pine pitch.

According to Karl Seelig of AIM, solder paste is about 50% flux and 50% metal by volume, with about half the flux composed of resins and rosins **(FIGURE 3)**. Seelig also reports that about 50% of the flux remains on the board after reflow and that 50% is mostly the resin and rosins. Therefore, most of the components of flux that enter the oven atmosphere during reflow are the activators/solvents and AIM's other magic additives.

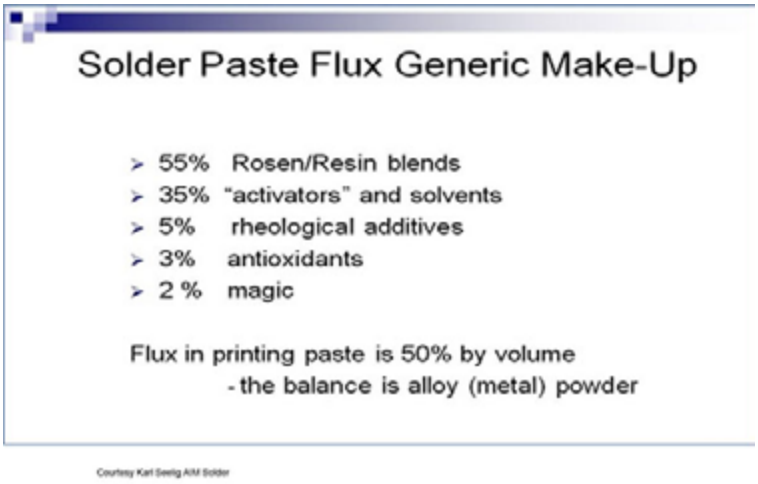

Figure 3. Composition of flux. (Courtesy Karl Seelig)

Condensation Principles

Moonshine stills work on the same principle of condensation as most flux collection systems. The solvents and many of the additives have a low vapor pressure and enter the oven atmosphere in the early parts of the thermal cycle (the first few zones). This flux-laden nitrogen is then moved to the collection system, cooled and filtered, and the "somewhat" clean nitrogen is returned to the oven. The nitrogen is called "somewhat clean" because condensation systems are usually about 30% efficient. This means that about two-thirds of the flux is returned to the oven with the gas **(FIGURE 4)**, and must be cycled through the collection system numerous times to attain desirable levels. This is why some high-volume reflow ovens have dual heat exchangers and some high-volume manufacturers have dual flux collections systems.

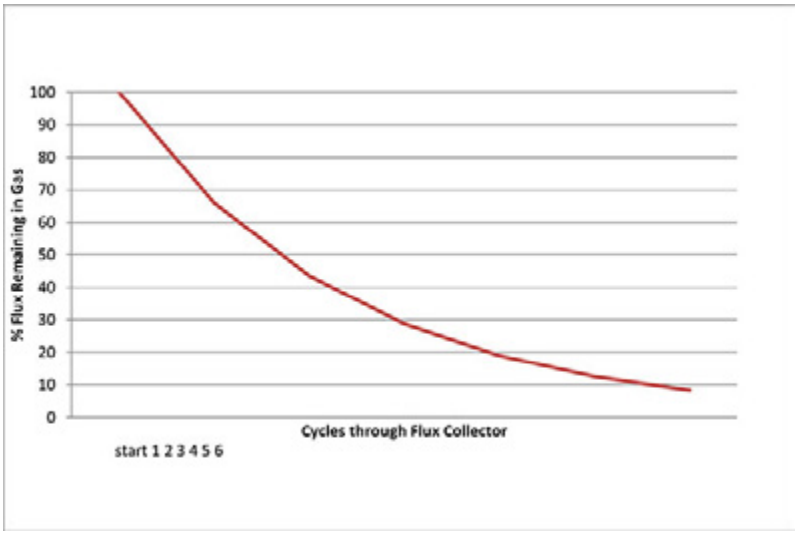

Figure 4. Percent of flux remaining in the gas after cycling through the flux collector.

The goal of a moonshine still is to separate the product (condensate) from the heated gas and put it in bottles for distribution, while the goal of a flux collection system is to clean the gas for reuse. The sticky condensate is discarded. Although the goals are different, the condensation technology is the same. But the residue in a flux collection system adds a burden to the system because the condensate clogs the heat exchangers and filters instead of flowing into jugs like moonshine. This sticky stuff needs to be removed from the system; otherwise, its efficiency is degraded and it removes less than 30% of the flux during each pass. In many cases this maintenance or cleaning requires hours of oven downtime each week (depending on the production rate) and the byproducts of cleaning are difficult to dispose of. (No moonshiner would run a still that took hours to clean.)

Until recently, reflow oven manufacturers had little choice in the design of flux collection systems due to cost, cooling efficiency, filters and space limitations. Collection systems based on burning the flux are available (pyrolysis), but are cumbersome and expensive to operate. But like NASCAR innovation, oven OEM engineers have found a way to increase flux collection efficiency, significantly decrease maintenance time, and make it easy to dispose of the cleaning byproducts. This system is based on wet gas scrubber technology like that used to clean ash from the exhaust of coal plants. In these systems, the polluted gas stream (nitrogen-containing flux particles) is brought into contact with a liquid which traps the particles. Then the clean gas exits the collection system and returns to the oven. The liquid may also lower the temperature of the gas, thus attaining higher collection efficiencies. To the joy of the maintenance staff, once the cleaning liquid becomes dirty, it can easily be replaced and disposed of.

Detailed explanations of the gas wash system are available in the following papers:

- Paul Richter, “High-Efficiency, Low-Maintenance Flux Removal Method for Reflow Ovens,” SMTAI Proceedings, 2020.
- Fred Dimock, “Flux and Flux Management in a Nitrogen Reflow Oven,” SMTAI Proceedings, 2020.

Richter concludes that flux collection efficiencies approaching 90% have been achieved with the gas wash system, and operating expenses – including depreciation – are significantly less.

Therefore, flux, reflow ovens, NASCAR and moonshine are connected through distillation, condensation and innovation. Best of all, like the NASCAR pit stops, the efficiency and maintenance of the flux collection systems has been made easy and fast **(FIGURE 5)**.

Figure 5. SMT reflow oven maintenance might not be as fast as the 15-sec. NASCAR pit stop, but it can improve with available technology.

NOTES

1. Bowman Gray, in Winston-Salem, NC, has been running weekly races in a "football stadium" (yes, football stadium) for close to 75 years and is nicknamed "The Madhouse" for excellent reasons. The racing is insane, the stands are packed, and adult admission is less than $15.
2. In the 1950s illegal shine was produced in northern Wake County, just outside Raleigh. The moonshine stills were legalized in the early 1970s when the gas shortage generated a need for stills to produce gasohol. These stills were operated until 1976 when Raleigh's municipal expansion got in the way.

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Is Your Company Ready to Be Sold?

What owners should do to ensure an attractive price when they sell their company. by BOB ROSSOW

It's not easy owning an EMS company these days … if it ever actually was. And by all reports it's getting even harder. Covid, the dysfunctional supply chain, inflation, tight delivery schedules, just finding qualified employees – all these problems and others have combined to challenge even the most seasoned owners. Given all this, who has time to take the necessary steps to prepare a company for sale?

The bad news is this article won't give you more hours in the day or more days in the week to do it. But it does list some of the things, maybe improvements, needed to show your company in its best light when you are ready to sell. And one thing to remember is that these goals are best accomplished over time. Trying to do it all at once as some kind of crash project is not the method of choice.

This list is by no means comprehensive, of course, but tries to highlight some of the major areas buyers will consider. And, as the owner, you may wish to step out of your role for a bit and think of yourself as a potential buyer. Put a critical eye to it. What would you like to see improved if the shoe were on the other foot? The following are points for your consideration.

Finances. Generally, the first thing a buyer wants to see are the financials. They want a profit and loss (P&L) statement and a balance sheet at minimum, plus a cash flow breakdown, if you have one. Typically, these should reflect the past three years. The more professional and inclusive these appear, the better the reception. A qualified accountant or a CPA is

usually best used for this work. You will need these documents before you put the company on the market.

Customer list. Prospective buyers will want to know who you sell to. They will want a history of orders by the larger customers. What is your margin on these orders? What percentage of your entire business does each of the larger customers make up? The customers do not have to be named, *per se.* They can be identified as a large medical OEM, a small aerospace government contractor, etc.

Employees. Is your workforce adequate and stable? You may be asked to provide a list by title or job function with dates of employment, wages and other pertinent information. An organization chart, usually quick and easy to make, is very helpful as well. To a buyer, this is the classic "picture worth a thousand words."

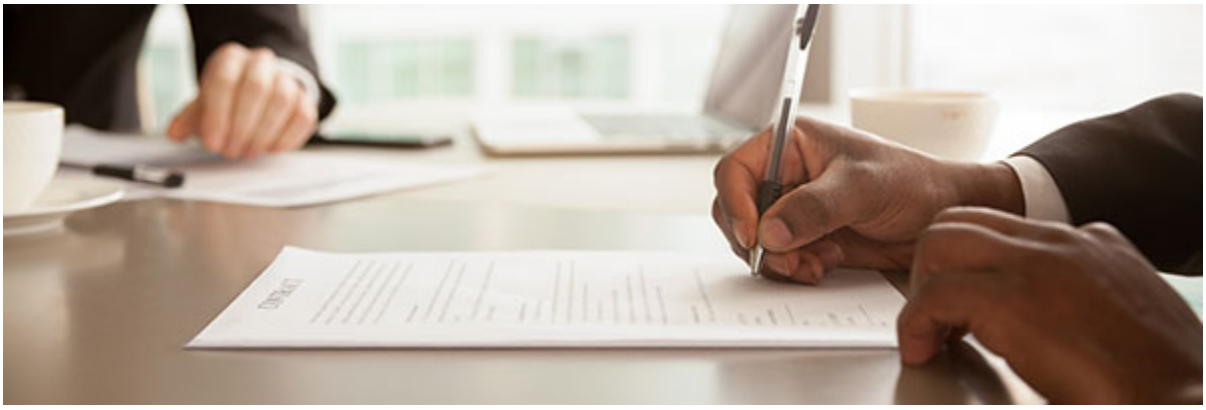

Figure 1. To get a signature on the bottom line, look at your company through the buyer's eyes.

Ongoing management. Will you be available to stay on for six months or longer after the sale? Is there someone in place to take over your job when you leave? How about other key managers? In many cases, the owner of a small- or mid-sized EMS company is also the chief technical officer. If this is you, prospective buyers may determine that you will have to be replaced by two different individuals. This can be a serious obstacle and could end up nixing the sale. If this is your situation, consider hiring an engineer as an understudy for the eventual transition prior to a sale.

Relocation of the work. Some buyers will be interested in buying your company only if

they can relocate the work to their own plant. For many owners, this is not something they are prepared to allow. They want to keep the work in place, typically for the benefit of their employees, and continue payroll as is. But if you are open to moving the work, you might want to look at each of your customers and determine if their programs could be relocated.

While there may not be much you can do about changing the existing order base, you may wish to look at future work with an eye in this direction.

Supply chain. With the frustrating state of this essential part of the EMS business right now, how is your company coping with getting needed inventory to make product? How has this affected delivery times? Is there a risk of losing any business as a result of long lead times? How much work in process (WIP) is being held up by a shortage of parts? Are you working on improving your methods for getting components faster and reducing lead times?

If you are one of the few not already working on this or don't know how to go about it, you may wish to hire a consultant to advise you. And whether or not you sell the business, reducing lead times is only a positive down the line.

Equipment list. Most companies have an equipment list, but if not, you will want one for prospective buyers. It may be the second most-asked-for document on the request list. It is helpful to include brand, model number, date of manufacture, etc., for the whole picture. Equipment is not typically the biggest factor in a sale, but buyers want to know what exactly you have and how it will fit into their own organization's list. A date on this record will show a buyer how current it is.

Certifications. In most cases, smaller EMS companies have few or no certifications. Presently, this does not seem to be an obstacle to a company's sale, as customers of the certifications are increasingly required, the picture changes. ISO 9000 registration may be needed, especially in the medical and defense markets.

The downside of certs may be cost and maintenance time, but I believe they bolster confidence with buyers. It is for something an owner to consider prior to selling.

Sales program. Of all the items listed here, this could be the most interesting. How is new

business brought in? Or is everything organic, with longtime customers simply increasing business? Is anyone dedicated to sales (either an employee or a manufacturers' rep group)? Or is the owner responsible for bringing in new business? If the latter, what happens to new business growth if they are out of the picture?

Potential buyers are almost always interested in ways to increase sales. If they see an active, successful sales force, they might see the potential of integrating it into their own organization. Alternately, they might see cost savings in scale by reducing or eliminating these positions in favor of their existing salesforce adding the acquired company's offerings to their own portfolios.

On the other hand, if sales growth has taken a backseat over the years, they might determine a little more effort in that direction could yield considerable new business.

As the owner, you should be prepared to speak to this. Buyers will be sure to ask.

How does the company show? One of the easier things to enhance the company's image is to make it show better. Think of a customer visit. Are the floors painted? Is your inventory organized? Does your office look reasonably modern and up to date? Details are important. When you walk in the front door and look around, ask yourself if this is a business you would buy (or buy from). Your answer could be the same as any prospective buyer's.

Your website. Is it crisp, cutting-edge, with video and good graphics? Does it tell your story properly? Does it look professional? A fair number of smaller EMS companies have what appear to be home-grown, somewhat older sites. This goes to image – and what you are selling is at least partially based on perception. Think about it. If you are trying to buy something online, does a poor website really invite your order?

Cost-cutting. Here is an area that can be worked on at any time (even today!) and yield results, in some cases immediately. If profit is the largest single driver of business, assuming other factors remain the same, by cutting costs you will increase profit. And higher profit will *always* push a higher sales price. Look around, if you haven't lately. It could easily be worth your while, whether you sell or not. Your workforce and methods might be the first place to start.

Reputation. Last, big or small, any serious potential buyer will do some kind of due diligence. Does your standing with customers, suppliers, employees or community need repairs? See what you can do to fix whatever can be fixed. This is best taken care of now, not later. Like concrete, the longer it sits, the more it sets.

In summary, this list is not in any special order, but is meant to draw attention to areas that might well be looked at in the normal course of business. As mentioned, trying to do it all with a deadline just before putting a company on the market is a tough job. Do it as time goes by, and it will pay big dividends down the road.

Good luck and all the best in the new year.

BOB ROSSOW is founder of E/Search International (esearch21.com), an EMS business broker firm with an active buyers list of about 80 potential buyers interested in EMS companies; esearch21@gmail.com.

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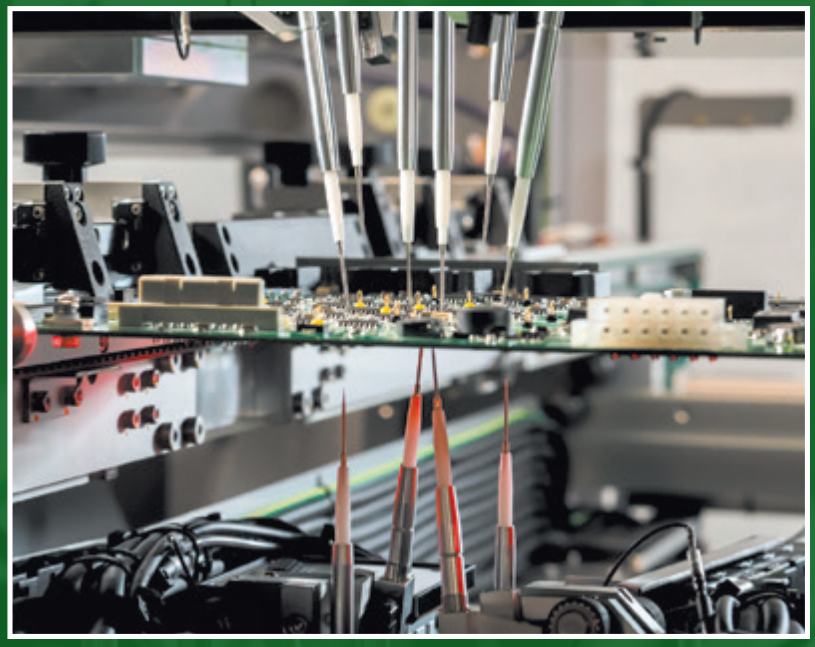

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Protecting Connectors on Zero Edge Clearance Boards

Not leaving enough clearance is a design oversight that can have costly consequences. **by AKBER ROY**

As PCB designers, fabricators and assemblers, we wear a lot of hats at Rush PCB. We're always working to design and build PCBAs that are the best they can be. But sometimes we are consigned product to assemble that wasn't designed by our team, and every so often we get boards that tempt us to say, "The designer clearly wasn't thinking about how we are going to build this!"

Design for manufacturing (DfM) principles are critical, and can make the difference between an assembly that is easy to build and one that is nearly impossible. As SMT PCBs become more compact, and components are large or odd-form, designers need to account for the special needs and limitations of the automated assembly equipment in the workstations, because few – if any – assemblies can be cost-effectively assembled by hand. It's always important for electronics designers to talk to the manufacturing engineers at the assembler where the parts will be consigned. Working together saves a million headaches.

In one instance, we were consigned to build a PCB assembly that, upon examination, had zero edge clearance. How is that possible? The assembly had five edge mount connectors (PMolex 1-5) that extended out from the board approximately 1.5mm on each of the four sides of the board. But all the equipment we use to assemble products must be capable of holding the board by at least two of its edges and require a clearance of approximately 5-10mm. As a result, these PCB assemblies had effectively zero edge clearance, as shown in **FIGURE 1**, where the interference caused by the connectors is obvious.

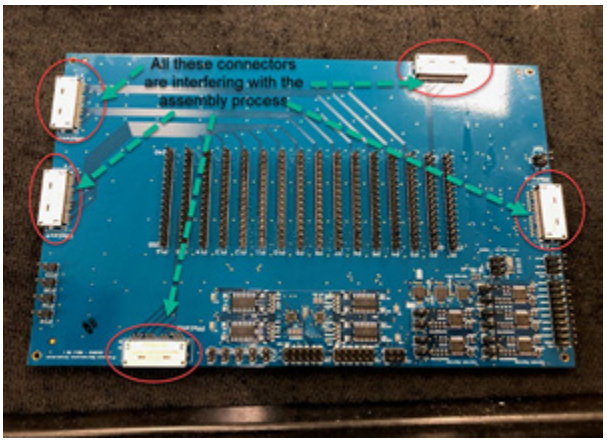


Figure 1. Processing the PCBA is impossible with large connectors in the way. Processing equipment requires appropriate edge clearances.

As a result of this design oversight, the assembly process would have been very difficult – if not impossible – because we couldn't hold the PCBA properly and some of the connectors contacted or "bumped" the reflow conveyor. That is unacceptable because it could result in component misalignment or open solder joints, requiring costly rework and delaying shipping deadlines. Not leaving enough clearance is a design oversight that can have costly consequences.

Mission: Impossible? Not really, because this case had both a great solution and a not-so-great one. In the first and best solution, 10mm wide breakaways could be added all around the edges of the board and connected with 2.5-3mm long "mouse bites." This solution, shown in **FIGURE 2**, would speed the assembly the process, protect the connectors, and prevent the need for rework due to misalignments or open solder joints.

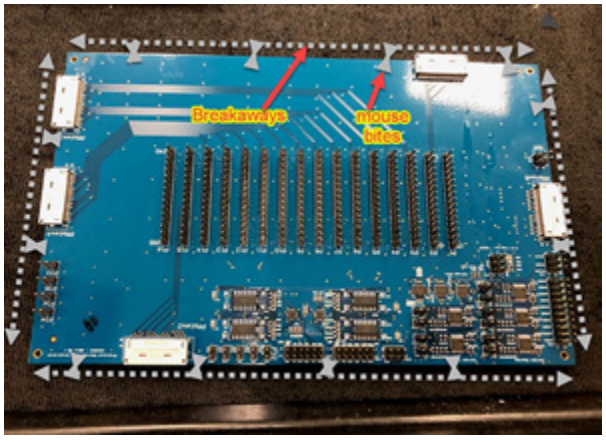
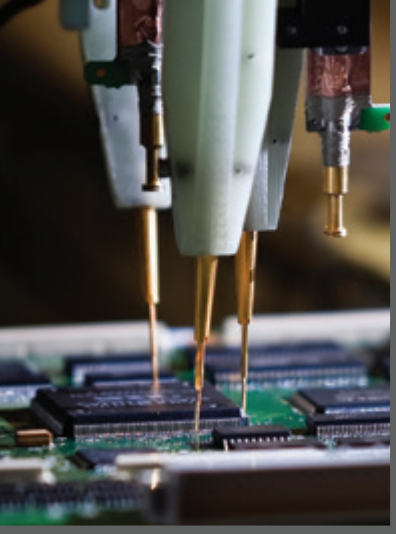
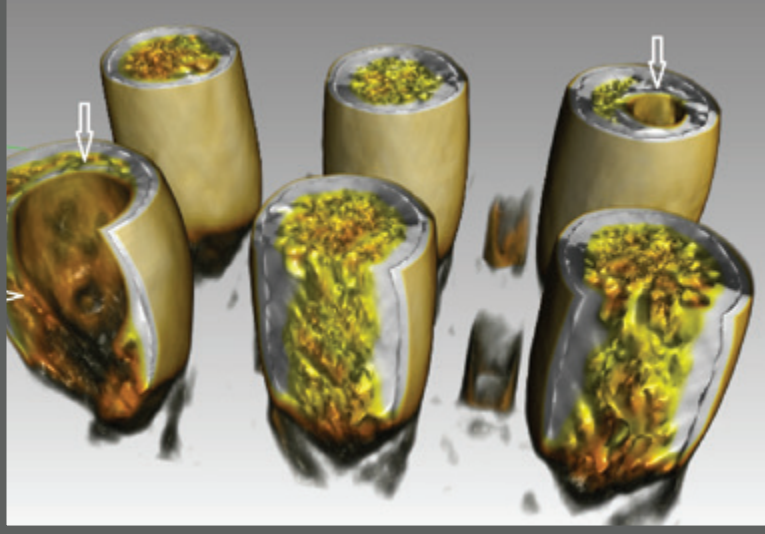


Figure 2. Breakaways and "mouse bites" to hold them in place eliminate the need for fixturing and potential rework while providing needed edge clearance.

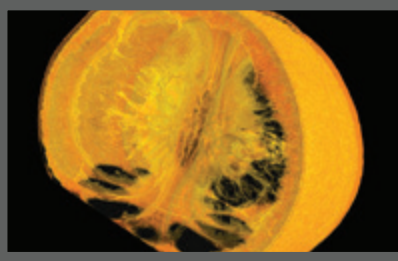
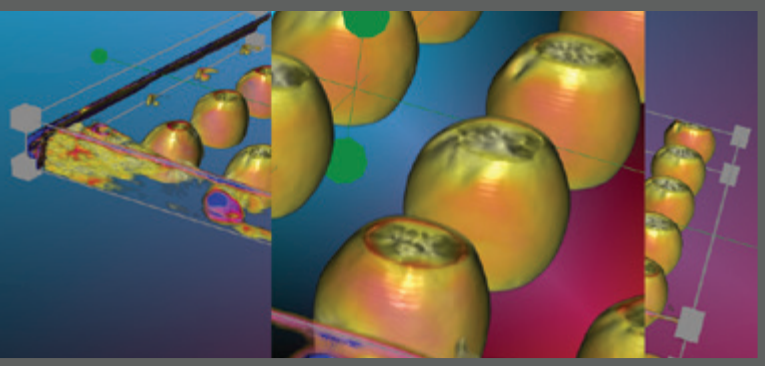
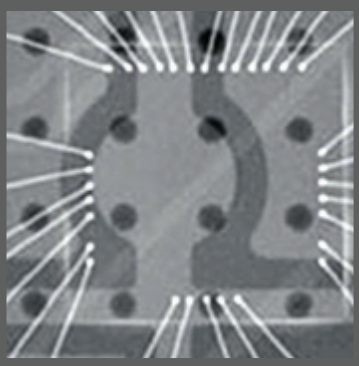
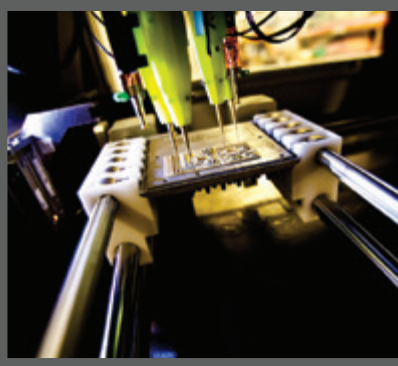
The less-desirable solution would be to ask the customer to pay for fixtures to accommodate the PCBAs for passage through the pick-and-place, reflow and AOI systems. Clearly, the first solution described would be better since it is cheaper than fixturing.

AKBER ROY is chief executive officer of Rush PCB Inc., a printed circuit design, fabrication and assembly company (rushpcb.com); roy@rushpcb.com.






Varied Problems Many Unique Solutions

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Oft-Forgotten Stencil Solution 'Lights' the Way

Multiple advanced printing capabilities converge for next-gen LED technology.

WHAT'S BEHIND THAT TV panel? Light-emitting diodes – or LEDs. LEDs are found in just about every display, from flatscreen televisions to high-end desktops and all kinds of products in between. The most common type of display – the liquid crystal display, or LCD – relies on light from LEDs for illumination, as an LCD pixel cannot illuminate itself, unlike an organic LED (OLED). Behind the LCD screen, areas are divided into zones of LEDs that are switched on to backlight the colors. And, in areas where the screen is to remain black, no light is emitted through those zones. Older designs or lower-end LCDs, however, may suffer from zone leaching. This is when the light in a specific zone may be switched off, but light from an adjacent zone crosses into the black, unlit zone. This results in a haloing effect.

For high-end desktops, ultra-high resolution flatscreens, and other display electronics, black must be black to deliver tight contrast. And, as with all things electronic, the answer seems to come from miniaturization. To overcome the definition dilemma, a newer technology, Mini Backlight LEDs – or Mini LEDs – provide a solution. Ranging in size from 50µm to 150µm, these small devices provide the tight dimensions needed for exceptional contrast and fine lines. Instead of the coarseness of the previously described traditional LED zones, Mini LEDs can be individually turned on or off to provide intense granularity and sharpness.

"How does this relate to SMT?" you ask. Currently, classic SMT processing is the most efficient and effective way to manufacture Mini LED panels, but it requires reviving some historical stencil technology and combining it with current advanced printing platform capabilities. Although the panel tends to be homogenous – unlike heterogeneous SMT – the

dimensions present some obstacles. The tiniest of these LED apertures measures 50µm with a 50µm interspace. Coupled with ultra-high-density assemblies, a standard stainless steel, laser-cut stencil will not get the job done. The repeatable aperture size limit for most laser-cut stencils is about 100µm. The thinnest piece of steel foil available today is around 50µm. Enter electroform, or Eform, stencils. Once thought the answer for miniaturized SMT, the higher cost and manufacturing time (compared to laser-cut stainless steel) for Eform stencils pushed them to the exotic application/semiconductor side of the ledger. But this stencil technology is proving to be a solution for Mini LED processing.

For those unfamiliar, Eform stencils are produced using an additive process where the nickel stencil is grown on a mandrel in an electroplating process. This enables ultra-fine aperture features, remarkably smooth aperture walls, and very thin stencils, down to 23µm or thinner in some cases. With Eform, area ratios can be maintained even with the tiny aperture dimensions and tight pitches, permitting traditional SMT processes to be used for production. While the cost for an Eform stencil may be slightly higher than a traditional stainless-steel stencil, the economies-of-scale achieved by the ability to mass produce these Mini LED panels are tremendous.

Other considerations for stencil-printing Mini LEDs are the solder paste materials and, naturally, the printing equipment capability. Because this is SMT, conventional protocols apply. A Type 6 solder paste is necessary to adhere to the five-ball rule, which means the particle size needs to be such that five particles will fit side by side in the narrowest aperture. And, because Type 6 solder paste materials are quite a bit more costly than their counterparts, optimizing material use with paste management tools like paste roll height monitoring and automatic paste dispensing will help keep the cost benefits of high-volume production palatable.

Second is the print platform alignment accuracy. Mini LEDs are super small, and there are gracious plenty of them across each panel, so precision, precision, precision is the name of the game. A supremely accurate printer is a necessity. The industry once thought +/-12.5µm print accuracy was overkill. Not anymore! In addition to material waste-reducing technologies and alignment, the machine's handling capabilities must be state-of-the-art. Some substrates for Mini LEDs are glass, so a near-touchless handling system, including

board stops, has to be achieved optically and not physically. The machine's stability, coplanarity, and the flatness of the tooling solution are critical because, if everything is not perfectly flat, the substrate can fracture or break. A tooling solution such as porous aluminum will work for rigid substrates, whereas a flexible substrate may require third-party custom tooling.

Suffice it to say, there is much to consider for Mini LED processing. But one thing is clear: SMT processing is the most viable mass production approach. Who would have predicted that Eform would be lighting it up again for SMT? Full circle, indeed.

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

Amphenol RF Automate Type A Mini-Fakra Connectors

Automate Type A Mini-Fakra series now includes single and dual-port right-angle connectors, along with straight and right-angle configurations for the existing quad-port version. Offers RF performance up to 9GHz and features color-coded housing to prevent mismating. Manufactured from zinc alloy with a matte tin finish and gold-plated copper-nickel alloy contact. Mechanically keyed for foolproof installation and designed with a secondary locking mechanism to ensure secure mating. Supports data transmission rates up to 20Gbps. Engineered to provide space savings of up to 80% compared with traditional Fakra connectors, and are impact resistant and have notably low engagement forces.

Amphenol RF

amphenolrf.com

Altair Simulation 2022.2 Simulation Software

Simulation 2022.2's latest update offers an enhanced Altair One experience by providing users with access to solutions, applications, data, and compute, allowing users to launch tools like Altair HyperMesh, HyperView, SimLab, and Inspire in browsers or on the desktop/laptop. Also allows users to submit solver jobs covering structural, thermal, and computational fluid dynamics (CFD), and high/low frequency electromagnetics disciplines in Altair's cloud infrastructure, plus allows users to create pre-configured HPC appliances through a simple button click. Features tighter integration between Altair Flux, FluxMotor, SimLab, and Material Data Center, as well as significant improvements to HyperWorks, HyperMesh, Altair Pulse, and HyperWorks CFD.

Altair

altair.com

Kyocera AVX ASPGuard Series MLVs

ASPGuard Series MLVs meet IEEE 100BASE-T1 and 1000BASE-T1 testing requirements, come in small, ultra-low-profile surface-mount packages optimized for high-density designs, and exhibit high current and energy handling capabilities, bidirectional overvoltage protection, sub-nanosecond response times, and multi-strike capabilities. Also provide EMI/RFI attenuation in their off state, and offer lower insertion loss, lower leakage current, and high reliability. Are qualified to OPEN (One-Pair Ethernet) Alliance standards for automotive Ethernet applications and AEC-Q200. Come in 0402 and 0603 case sizes with maximum respective heights of 0.5±0.10mm and 0.80±0.15mm, and are rated for working voltages extending from 18–70VDC, capacitance values ranging from 1.5-4.7pF, energy transients spanning 0.02–0.04J, 1-3A of peak current, and operating temperatures from -55° to +150°C. Deliver up to 25kV of ESD protection per IEC 61000-4-2 and meet 48VDC jump start requirements.

Kyocera AVX

kyocera-avx.com

Mechnano Tough ESD

Tough ESD additive manufacturing (AM) resin utilizes discrete carbon nanotubes (dCNTs). Delivers isotropic electrostatic dissipative (ESD) properties to parts fabricated with VAT photopolymerization processes while also providing enhanced impact resistance, and is said to be a fit for many relevant applications including ESD tooling, assembly aids, enclosures and nozzles. Is for parts that undergo a higher level of abuse where breakage would occur with more rigid solutions.

Mechnano

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Tough ESD additive manufacturing (AM) resin utilizes discrete carbon nanotubes (dCNTs). Delivers isotropic electrostatic dissipative (ESD) properties to parts fabricated with VAT photopolymerization processes while also providing enhanced impact resistance, and is said

Peters Elpemer Solder Resist SD 2463 Flex-HF

Elpemer solder resist SD 2463 Flex-HF features state-of-the-art physical and mechanical properties, including ink that is flexible under bending stress when the circuit board is installed. Capable of reliably covering all areas of a PCB that shall not receive solder in subsequent soldering processes, and includes hardness and scratch resistance after final curing to protect the PCB from mechanical damage. Features a resolution of <40µm (direct exposure) and excellent dielectric properties, and can be used for ultra-fine conductors and in SMD technology as an alternative to flexible cover foils. Applied by horizontal or vertical double-sided screen printing and is aqueous-alkaline developed. Halogen-free and free from SVHC photoinitiators 369 and 907.

Peters

peters.de

Stackpole RNCF Thin Film Resistors

RNCF series of precision thin film resistors is designed for medical instrumentation and control, industrial and automotive controls, communications, and test & measurement applications. Offers exceptional precision with tolerances down to ±0.01% and TCRs as low as ±2ppm. AEC compliant and reportedly demonstrates very low resistance shifts of less than ±0.05% for industry standard load life, biased humidity, and short time overload tests.

Stackpole

seielect.com

Stackpole SM Molded SMD Wirewounds

SM Series of surface mount molded wirewounds offer power ratings from 2W to 4W with compliant terminations that eliminate the issues of cracking and solder joint failure. Also provide superior pulse and overload handling compared to film-based chip resistors, and are ideal for industrial applications, machine automation and control, power supply and motor

control, and traffic control, as well as safety and security systems.

Stackpole Electronics

seielect.com

Ventec VTM1000i Hydrocarbon Laminate

tec-speed 20.0 VTM1000i hydrocarbon laminate is designed for antenna and communication systems, radar, and aviation systems, and is available in a range of dielectric thickness, with 0.38mm through to 3.81mm options, while offering a high decomposition temperature (Td) of 426°C. Features high Dk value (9.8 ± 0.0245@10Ghz), and is said to offer an alternative option for specific application in the microwave and RF industry previously available only through PTFE laminates.

Ventec

venteclaminates.com

Anda TSV-400 Tabletop Dispenser

TSV-400 tabletop dispenser is a 400mm x 400mm automated x-y-z (3-axes) gantry system driven by ball screw and servo motors. Designed for selective coating and fluid dispensing applications and is easily portable for low-volume processes or laboratory tabletop applications.

Anda Technolgies

anda.us

Count On Tools Hybrid Yamaha Compliant Nozzles

Hybrid Yamaha Compliant Nozzles have custom Yamaha YS12/24 ESD-safe compliant rubber, dual ANE slots, spring loaded type 301 with 2.50 round compliant rubber tip. Come in a range of tip sizes from 0.75mm to 2.5mm, as well as other configurations with a fixed-style nozzle base.

Count on Tools

cotinc.com

Indium SiPaste C201HF Solder Paste

SiPaste C201HF combines non-wet open (NWO) performance with stencil print transfer efficiency to satisfy a range of process requirements and boost SPI yields. Leaves a cleanable residue or can be used as a standard no-clean paste in processes where post-reflow cleaning is not applicable. Features transfer efficiency on fine feature apertures, with consistent process yields below 80µm. Is said to deliver consistent and tight solder deposit spread across multiple prints, minimal voiding on tight-pitch components, excellent reflow performance on components that exhibit high warpage, and enhanced slump performance with minimal bridging.

Indium

indium.com

Master Bond Supreme 42HT-2ND Black Epoxy

Supreme 42HT-2ND Black is a two-part, non-drip epoxy designed for bonding, sealing and coating applications. Capable of withstanding temperatures up to 450°F (232°C) and provides a glass transition temperature (Tg) of 130-135°C. Meets NASA low outgassing standards and is recommended for applications that require vacuum compatibility. Electrically insulative with a volume resistivity greater than $10^{14}\Omega$-cm, has a Shore D Hardness of 75-85 at 75°F, and withstands rigorous thermal cycling. Passed damp heat reliability testing for 1,000 hr. at 85°C and 85% relative humidity and offers a high strength profile, with a tensile strength of 9,000-10,000psi and a tensile modulus of 300,000-350,000psi at 75°F. Can be easily applied with the use of a gun dispenser or spatula and cures at ambient temperature in 2-3 days, or faster with the addition of heat.

Master Bond

masterbond.com

Metcal MSA Series Smoke Absorbers

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Metcal MSA Series Smoke Absorbers

MSA Series smoke absorbers are space-saving compact workbench fans that use activated carbon filters to extract harmful flux fumes and smoke during hand soldering operations. MSA-35L is a dual-position benchtop fan designed for smaller spaces, which can be used horizontally or vertically for almost twice the airflow efficiency. MSA-25U is a smaller unit than the MSA-35L and features a USB plug that is compatible with any standard 5V USB power supply. Both are said to be very quiet when in use, offer easy filter replacement, and are ESD-compliant.

Metcal

metcal.com

Nihon Superior SN100CV Solder

SN100CV Ag-free reflow soldering alloy can outperform SAC 305 in reliability while being reflowable with the same thermal profile as SAC 305. Reliability and reflowability come from the addition of bismuth, but not so much as to affect performance in high strain rate loading. Is said to be as resistant to creep deformation after 1000 hr. as it was when freshly reflowed. When combined with a completely halogen-free flux medium, can deliver a cost-efficient, high yield assembly in a profile with a peak temperature under 240°C.

Nihon Superior

en.nihonsuperior.co.jp

Saki 3D-AOI Camera Head

3Di series high-speed camera head features an optical resolution of 15μm and achieves high-performance quality inspection with the industry's fastest cycle time. Minimizes standby time by parallelizing image capture, data processing and inspection, and is capable of handling complex inspections of high-density PCBs and mixed PCBs with extremely small and tall parts. Come as an option for latest 3Di series 3-D AOI, and can be quickly and easily switched with the existing 8μm head without the need to change the entire AOI within the production line.

Saki Corp.

sakicorp.com/en/

SCS PlasmaGuard Nanocoating Services

PlasmaGuard conformal coatings are applied through a plasma enhanced chemical vapor deposition process and provide splash-proof or waterproof moisture protection to devices such as wearables and consumer electronics. Are also halogen-free, for the protection of sustainable electronics.

Specialty Coating Systems

scscoatings.com

Transition Automation Permalex S Series Squeegees

Permalex S series of squeegees is designed for aqueous solder paste. Developed from a high grade of stainless steel that is harder than stainless steel often used for stencils and squeegees. Ground sharp – polished at the edge – and coated with the Permalex Teflon metal matrix. Shares many of the high-reliability aspects as the standard Permalex E series, including precision grind-polish-coat, laser part number and date code marking, and hermetically sealed, clean dust-free packaging.

Transition Automation

transitionautomation.com

Transition Automation Slim-Line Squeegee Holder

Slim-Line Tool Free Squeegee Holder System allows blade changes without use of screwdrivers, nut wrenches or other tools. Incorporates magnets to secure the main body of squeegee blade and unique end “locks” that have a very low profile, resulting in a complete smooth front blade surface without protruding elements that typically interfere with solder paste rolling. Also minimizes interstitial spaces where cleaning fluid and paste can be trapped,

and features Soft-Touch Paste Retainers. Designed for all SMT printers and maintains similar design outline as previous holder geometries.

Transition Automation

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In Case You Missed It

Nanoscale Printing

"Curvilinear Soft Electronics by Micromolding of Metal Nanowires in Capillaries"

Authors: Yuxuan Liu, *et al.*

Abstract: Soft electronics using metal nanowires have attracted notable attention attributed to their high electrical conductivity and mechanical flexibility. High-resolution complex patterning of metal nanowires on curvilinear substrates remains a challenge, however. Here, a micromolding-based method is reported for scalable printing of metal nanowires, which enables complex and highly conductive patterns on soft curvilinear and uneven substrates with high resolution and uniformity. Printing resolution of 20μm and conductivity of the printed patterns of ~6.3 × 106S/m are achieved. Printing of grid structures with uniform thickness for transparent conductive electrodes (TCEs) and direct printing of pressure sensors on curved surfaces such as glove and contact lens are also realized. The printed hybrid soft TCEs and smart contact lens show promising applications in optoelectronic devices and personal health monitoring, respectively. This printing method can be extended to other nanomaterials for large-scale printing of high-performance soft electronics. (*Science Advances,* Nov. 18, 2022; https://doi.org/10.1126/sciadv.add6996)

Solder Reliability

"Intermediate Low-Melting-Temperature Solder Thermal Cycling Enhancement Using Bismuth and Indium Microalloying"

Authors: Young-Woo Lee, Tae-Kyu Lee and Jae-Pil Jung

Abstract: In general, SnAgCu solder is widely used for interconnections in semiconductor device packaging. Recently, however, several factors have been considered to implement low-melting-temperature solder (LTS), which has a lower assembly temperature than conventional SnAgCu solder material. Implementation of LTS solder though has a different driving force per each industry sector. Consumer electronics seek lower energy consumption,

toward a carbon net-zero strategy, compared to the high-performance chip industry sector, which has a different reason based on larger component size-induced challenges, like dynamic warpage. Printed circuit board (PCB) and package components show deformation during reflow due to elevated temperatures. The behavior of dynamic component changes the package size, material characteristics and temperature range. Although most LTS are based on the low-melting-temperature range of 130°-140°C, a separate category of intermediate LTS is formed at around 180°-190°C to target an assembly peak temperature of 200°-210°C. The study presented here targets an LTS at an intermediate temperature assembly to avoid the most active dynamic warpage temperature region. LTS has significant benefits with less warpage and thermal damage toward the component and assembled board, due to the low reflow peak temperature. To improve thermal cycling performance by maintaining a low melting temperature, a small amount of indium is used as a microalloy element, with 12mm × 12mm ball grid array components on 62-mil-thick boards thermal cycled from -40° to 125°C with Sn-based LTS including In and Bi. The microstructure changes during thermal cycling are observed and electron-backscattered diffraction used to find a correlation between crack propagation and localized recrystallization. It was found that the added indium enhanced thermal cycling performance compared to conventional SnAgCu-based solders. To compare the paste-induced composition change which dilutes the indium-containing solder ball, a flux-only assembly has been compared. (*Journal of Electronic Materials,* Dec. 25, 2022; https://doi.org/10.1007/s11664-022-10121-y)

Sustainability

"A New Approach to Designing Easily Recyclable Printed Circuit Boards"
Authors: Dmitriy Khrustalev, *et al.*
Abstract: Due to the ever-increasing amount of electronic waste (e-waste) worldwide, the problem of the effective disposal of printed circuit board waste (WPCB), which are environmentally hazardous, difficult to recycle and economically valuable products, has become a major environmental challenge. Conventional WPCB recycling techniques have low efficiency and require tough processing, such as heat treatment and high pressure. This paper presents a new composite material for the manufacture of printed circuit boards (PCB) that can be easily recycled into their original components and reused. In addition, the most valuable PCB components (electronic components containing precious metals) can be easily

separated from the printed circuit board and reused. This study demonstrates the benefit of using biodegradable polymers as binders for PCBs in terms of environmentally friendly and efficient recycling. (*Scientific Reports,* Dec. 23, 2022; https://doi.org/10.1038/s41598-022-26677-y)

Wireless Electronics

"Wirelessly Powered Large-area Electronics for the Internet Of Things"
Authors: Luis Portilla*, et al.*
Abstract: Powering the increasing number of sensor nodes used in the Internet of Things creates a technological challenge. The economic and sustainability issues of battery-powered devices mean that wirelessly powered operation – combined with environmentally friendly circuit technologies – will be needed. Large-area electronics – which can be based on organic semiconductors, amorphous metal oxide semiconductors, semiconducting carbon nanotubes and two-dimensional semiconductors – could provide a solution. Here the authors examine the potential of large-area electronics technology in the development of sustainable, wirelessly powered IoT sensor nodes. They provide a system-level analysis of wirelessly powered sensor nodes, identifying the constraints faced by such devices and highlighting promising architectures and design approaches. They then explore the use of large-area electronics technology in wirelessly powered IoT sensor nodes, with a focus on low-power transistor circuits for digital processing and signal amplification, as well as high-speed diodes and printed antennas for data communication and radiofrequency energy harvesting. (*Nature Electronics,* Dec. 28, 2022; https://doi.org/10.1038/s41928-022-00898-5)