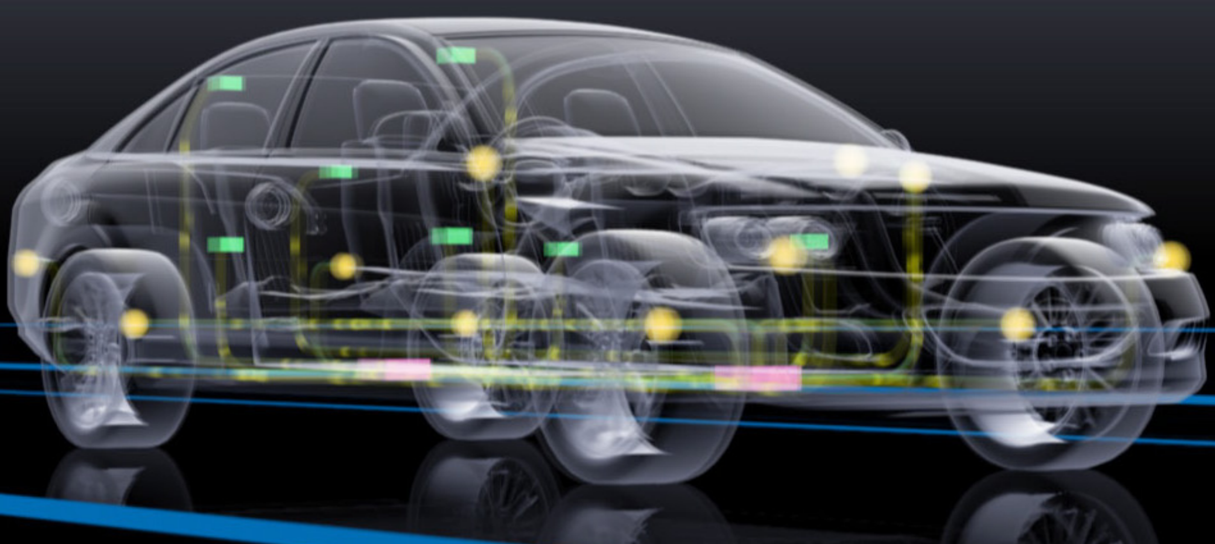
PCB007 PRESENTS

October 2013

the pcb magazine

AN I-CONNECT007 PUBLICATION

Automotive & Transportation



PCBs for Automobiles: A Turbo Boost for Sales?

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OCTOBER FEATURED CONTENT

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This month, features from Saturn, BPA Consultants, Zuken and Delphi take on some big questions, beginning with whether or not a PCB manufacturer should even pursue the automotive electronics market, to the power of MiB, and other design challenges.

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AUTOMOTIVE & TRANSPORTATION

The Market, Top 100 and EIT

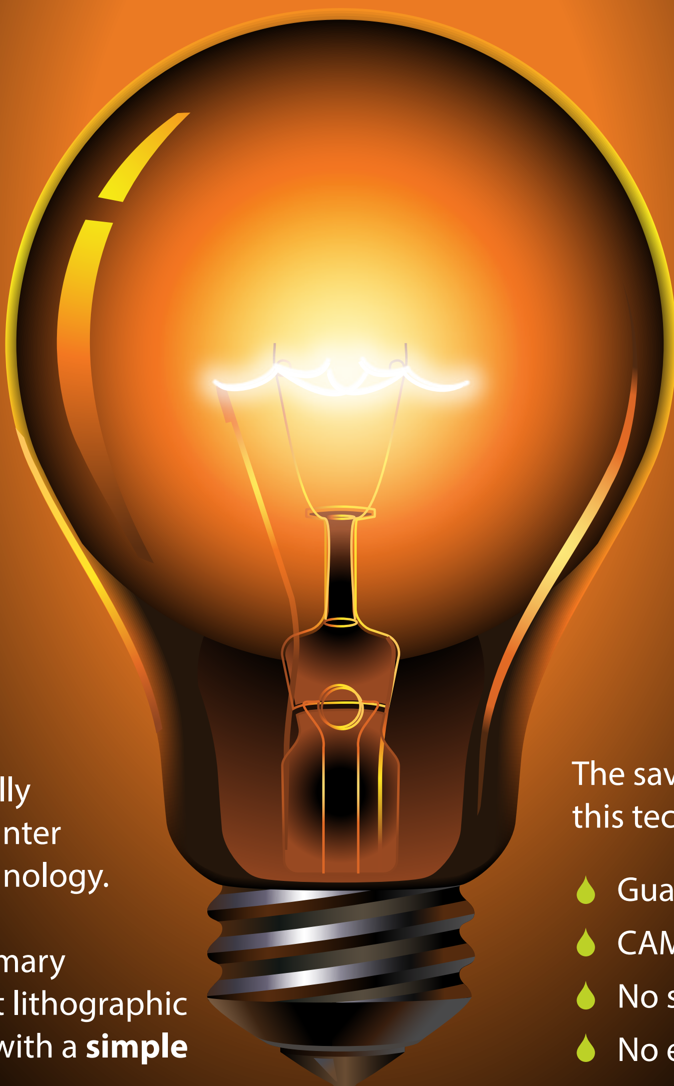
by Ray Rasmussen
I-CONNECT007

Last month I wrote about China's economy and how they seem to be in a tough spot. Since that column was written, Marcy LaRont conducted an interview with Hamed El-Abd of WKK, where he provides insights into the Chinese market. WKK sells capital equipment to fabricators and EMS providers in China/Asia. He takes my comments about China's issues down to a more practical level, as he's in the trenches and has a keen sense of what's going on.

In an August report, MAPI says that China's export growth went from 19% in Q1 to 3% in Q2. It reaffirms what I wrote last month. Still, many see this as a blip and expect China's export growth to get back on track this fall. We'll see.

Europe out of Recession

Great news out of Europe: It's official—the recession is over. According to the EU's Eurostat, Q2 GDP grew 0.3% after a -0.5% decline in Q1. The Conference Board Leading Economic Index for the Euro area increased 1% in July and now stands at 108.4, after increasing 0.4% in both May and June. As the planet's largest consumer market, getting their economy back on track will have a profound effect on the rest of us. Along with the U.S. economy picking up speed, we have a solid start to a good global recovery. We need to keep an eye on the other two giant economies, China and Japan. Japan's latest economic indicators are down. Let's hope they turn around in the coming months. So, it's not all rosy, but it's better than it's been.



Naka's Top 100 for 2012

Although Hayao Nakahara's top 100 PCB listing appeared (as it always does) in *Printed Circuit Design and Fab* (a competing publication), I still have to mention it here. It's always an interesting piece and eagerly anticipated by many as they look to see how they rank in this $60 billion industry. The top dogs are all in Asia, of course, with Japan's Nippon Mektron taking the top spot with $2.8 billion in sales. Taiwan's Unimicron took second with $2.4 billion in revenue. TTM came in at #8 with about $1.4 billion, and Viasystems made the 12th spot at $1 billion. A total of six U.S. companies made the list for 2012.

Out of Europe, Austria's AT&S grabbed the 22nd spot, Germany's Wurth and Schweizer came in at #79 and #90 respectively. Italy's Somacis received an honorable mention at #104.

Keep in mind that the dollars reflect the country of ownership, not the volume of PCBs produced in each country.

Naka's commentary is always good to read. He has some good insights into the different markets. No one else has been willing to take on the daunting job of making sense out of this ever-changing industry.

I'm sure many of you know this, but although there are lots of PCBs being built in China, there are only a few purely Chinese companies on the list. Naka combines both Hong Kong and China into one group, which brings their total production to around $5.7B. Take away Hong Kong, and Chinese companies make very few PCBs. The Japanese, Taiwanese, Americans, Europeans or Koreans control the rest of PCB production in China.

EIT is Gone

For years, Endicott Interconnect Technologies seemed to be a shining star in the declining U.S. PCB market. They looked to be one of the only fabricators who were building products immune to the onslaught of PCBs out of China. They were above the fray. They had the right formula at the right time. Well, after filing for Chapter 11 bankruptcy protection in July, the company has auctioned off its assets to pay creditors. It seems that this privately held company hasn't been profitable since 2008, and now it is gone.

> "*It was the single largest PCB facility I'd ever been in by far. It wasn't something I was used to. It was a world-class factory as opposed to the PCB shops I was used to. Everything was engineered to IBM standards, which demanded only the best.*"

Back when IBM was looking to reduce costs in the early '90s, it gave its PCB division in Endicott, New York, a chance to make it on its own by expanding their capabilities to the broader market. Back then I took a tour of the facility. I was writing a feature on the company for CircuiTree and as part of the deal, I was given an in-depth look at what would later become independent EIT. It was the single largest PCB facility I'd ever been in by far. It wasn't something I was used to. It was a world-class factory as opposed to the PCB shops I was used to. Everything was engineered to IBM standards, which demanded only the best. Of course, the best is expensive to procure, maintain and operate, which made the division a cost-cutting target as IBM looked for ways to reduce cost and remain competitive.

Today, you can see these mega-factories all over China, which is what IBM's PCB factory looked like back then. And because they were IBM, the factory was filled with degreed engineers working on the equipment and processes to build the very sophisticated backplanes used for their huge servers. As I was told back then, when the factory was built, money wasn't an issue when it came to building the PCBs. That cost was absorbed into the price of the mainframes. The boards needed to be huge, dense and very reliable. That's all. Of course, as others (Hadco, Sanmina, etc.) came up to speed with their capabilities, delivering sophisticated boards on par with IBM's internal resource at a lower price, the pressure mounted.

That transition from captive to merchant PCB business was an eye-opener for those IBM execs and engineers used to following IBM's business model. The effort to become a merchant supplier of PCBs (with support from the parent) went on for a few years, until IBM sold its Endicott facility in July 2002 to an investor group, who paid $65 million for the operation. From a November 1, 2002 press release, this quote lays out the group's expectations for the acquisition.

"We believe we have a diamond in the rough," commented Bill Maines, co-chairman of the board for Endicott Interconnect Technologies. "With the people skills and technologies we have in place, we believe we can not only continue to provide valuable support services to IBM, but expand into other untapped opportunities as well. This is the beginning of a new chapter for Endicott."

Of course there are lots of experts out there, offering their opinions on what when wrong at EIT. It's too bad. They seemed to have it all. The right people, the right markets, and the right facility—just the wrong strategy, I guess. **PCB**

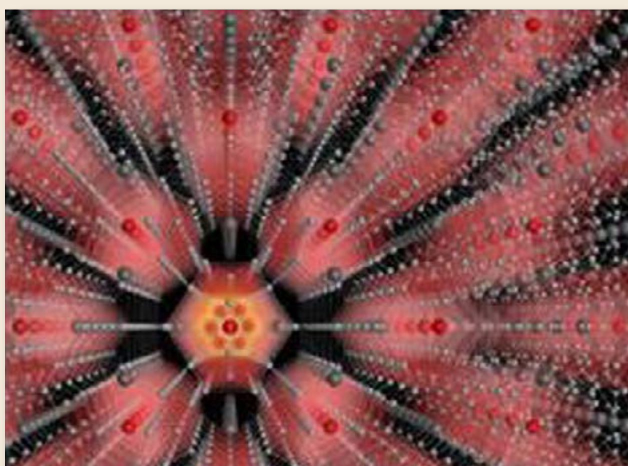
Ray Rasmussen is the publisher and chief editor for I-Connect007 publications. He has worked in the industry since 1978 and is the former publisher and chief editor of *CircuiTree Magazine.* Contact Rasmussen here.

Creating Electricity with Caged Atoms

A lot of energy is wasted when machines turn hot, unnecessarily heating up their environment. Some of this thermal energy could be harvested using thermoelectric materials; they create electric current when they are used to bridge hot and cold objects. At the Vienna University of Technology (TU Vienna), a new and considerably more efficient class of thermoelectric materials can now be produced. It is the material's very special crystal structure that does the trick, in connection with an astonishing new physical effect; in countless tiny cages within the crystal, cerium atoms are enclosed. These trapped magnetic atoms are constantly rattling the bars of their cage, and this rattling seems to be responsible for the material's exceptionally favourable properties.

"Clathrates" is the technical term for crystals, in which host atoms are enclosed in cage-like spaces. "These clathrates show remarkable thermal properties," says Professor Silke Bühler-Paschen (TU Vienna). The exact behaviour of the material depends on the interaction between the trapped atoms and the cage surrounding them. "We came up with the idea to trap cerium atoms, because their magnetic properties promised particularly interesting kinds of interaction," explains Bühler-Paschen.

For a long time, this task seemed impossible. All earlier attempts to incorporate magnetic atoms such as the rare-earth metal cerium into the clathrate structures failed. With the help of a sophisticated crystal growth technique in a mirror oven, Professor Andrey Prokofiev (TU Vienna) has now succeeded in creating clathrates made of barium, silicon, and gold, encapsulating single cerium atoms.



Clathrates: crystals enclosing single atoms.

Figure 2: Interior instrumentation panel of KITT. (Photo courtesy of Enterprise-dashboard.com)

PCBs for Automobiles: A Turbo Boost for Sales?

by Yash Sutariya
ALPHA CIRCUIT CORPORATION

***Summary:** With the projected trajectory of electronics content in vehicles, automotive PCBs are a global growth driver for our industry. And yet, the pressing question for any N.A. PCB manufacturer might be, do I even want to get in this race?*

As I began to write this article, the first thing that popped into my head was the classic '80s series, Knight Rider, featuring an artificially-intelligent black Pontiac Trans Am named KITT, with a dashboard full of esoteric lights, displays and dials. KITT overwhelmed and fascinated my young mind. While today's vehicles don't have most of those features, they have come a long way in terms of electronics content. While some is mandated by the NHTSA (safety, collision avoidance—mainly things you don't see), the content that has the biggest marketing impact for an automobile manufacturer is the stuff you do see—displays, entertainment systems, interactive information systems, etc.

The electronics content of a vehicle is increasing every year as engineers are able to jam more technology and features into the same four-wheeled space. As a result, automotive electronics are expected to generate a compound

Figure 1: Knight Rider's KITT. (Photo courtesy of Deviantart.com)

annual growth rate in excess of 6% through the year 2020, at which point some estimate the global market to be north of $300 billion. To me that's an astounding figure as it pegs electronics to be approximately 10% of the total cost of a vehicle. Regardless, it's a huge market that translates to a lot of bare printed circuit boards to be made by our industry.

Further, with the projected trajectory of electronics content in vehicles, it will definitely be a global growth driver for our industry. The immediate questions that must occur to a North American PCB manufacturer probably include the following:

- When can I get started in this market?
- How do I get a piece of the pie?

In my opinion, however, the very first question should be this: Do I want to even bother targeting the automotive market?"

I have two career experiences that show why it looks like I have a chip on my shoulder for the automotive industry.

First, prior to being in the PCB industry, I worked for a consulting group that focused on bankruptcy/turnaround/crisis management. Based on the outskirts of Detroit (where I also grew up) we naturally had a lot of automotive-related business. A LOT! More often than not, our group's conclusion as to the root cause of a supplier's financial issues was pricing pressure from the OEMs (Note: it was the OEMs that hired us to investigate the supplier in the first place). Then, instead of having us fix the issue that they helped to create, the OEM who hired us found it to be a cheaper solution to shut the supplier down and move production elsewhere.

"***This market forces you to maintain extremely high levels of quality, service, and performance, all while maintaining an extremely low cost basis. If you can make it in the automotive market, you will be a rock star to customers in other industries.***"

Needless to say, that job started to suck pretty bad after a few years, which led me to move into this industry in the banner year of 2001. That's where my second experience comes into play. My previous employer was also heavily into the automotive market, with automotive PCBs accounting for 90% of sales in 2000. In a further testament to the nature of the automotive industry, I saw more than half of our 2001 sales disappear within a three-week period—starting the week before Christmas—as customers moved their production to China. I worked the following 10 years to diversify as much as possible out of automotive markets and am happy to say that we were very successful in doing so.

OK, so now it's all on the table. There's very good reason for a fabricator to really ask himself if he even wants to bother targeting the automotive market. If the answer is yes, please read on, as your approach to this market will be critical. Approach it the wrong way, and you might be paid a visit by my former colleagues.

If the answer is no, you should also read on, as you can still benefit from implementing the systems and performance requirements of the automotive market. I believe that servicing the automotive market can be viewed as a boot camp to build a better company. This market forces you to maintain extremely high levels of quality, service, and performance, all while maintaining an extremely low cost basis. If you can make it in the automotive market, you will be a rock star to customers in other industries.

TS16949 Quality Management System: What is it?

While a strong ISO-9000 quality management system will sometimes suffice, to be a true player in the automotive supplier base, being certified to TS16949 is a must. TS16949 came about as a way to merge all U.S., European, and Asian automotive standards into a single technical specification. Prior to this, an automotive supplier had to hold the individual certifications required by each customer, making it very difficult to operate a single plant with multiple customers.

While many PCB fabricators hold an ISO-9000 certificate, only five PCB manufacturers in North America have achieved TS certification (we just passed our initial TS certification audit last month, making us the fifth). Now, before you call me a hypocrite, let's review the TS standard and compare it to the ISO-9000 standard.

The standard rule for ISO-9000 is do what you say, and say what you do, meaning as long as you are performing the task as you have documented that it should be performed, you are ISO-9000 compliant. I'll admit that this does oversimplify the standard; it is a fairly easy standard to pass. In contrast, the TS standard is much stricter as it is more process driven, dictates management involvement, and requires continuous improvement to be a documented part of the system. Below are the primary elements of TS16949:

0. Introduction
1. Scope
2. Normative reference
3. Terms and definitions
4. Quality management system
5. Management responsibility
6. Resource management
7. Product realization
8. Measurement, analysis and improvement

While the first three clauses do not contain QMS requirements, they do provide helpful background and summary information. Clauses 4–8 contain the guts of the standard and would really require an entire article dedicated to those alone to provide sufficient explanation. However, there are a host of helpful web resources should you wish to investigate further. Some of the sites I used include:

- www.askartsolutions.com
- thequalityportal.com
- 16949store.com

"In our opinion, the difference between ISO-9001 and TS16949 is 75 additional paragraphs which reinforce the concept that "you cannot only meet specification; but, you can do so efficiently and without interruption to guarantee viability of the entire supply chain to the TS customer."

From my perspective as a manager, regardless of which industry created the standard, it's really the right way to run your business. Focus on processes and systems to control product quality, involve management, and monitor customer satisfaction indices to verify effect.

We implemented TS16949 at our company not because we wanted to be a full-blown automotive supplier, but rather, we wanted to build a solid company using TS16949 as a foundation for quality and business management. As such, if the answer to the question that started this whole article (Do I want to even bother targeting the automotive market?) was no, automotive standards still may find a home in your business.

TS16949 Quality Management System—How do I get it?

Achieving TS certification involves a process similar to that required to achieve ISO-9000 certification, but work requirements are much more robust. Most registrars that support ISO-9000 also support TS16949 so a registrar change may not be required. However, plan on spending a lot of which most of us don't have—time!

In our opinion, the difference between ISO-9001 and TS16949 is 75 additional paragraphs which reinforce the concept that "you cannot only meet specification; but, you can do so efficiently and without interruption to guarantee viability of the entire supply chain to the TS customer." That means control of your suppliers, regulatory compliance, contingency plans, and a stable work force. The 75 additional paragraphs also expect improvement in both quality consistency and efficiency. All of this requires

documented proof.

Here is pretty neat checklist if you are converting from an ISO-9000 to a TS16949 system.

www.woodbridgegroup.com

It's important to have one person dedicated person to control of the program from an administrative standpoint, because there are a lot of moving parts. For our implementation, we approached the process by tackling the following primary areas:

1. Preventive maintenance
2. Work verification

We included the calibration, procedures, and document control from the existing ISO-9000, but beefed them up a bit.

There's no magic here—just hard work to create and implement production procedures for each major process step, a true calibration and preventive maintenance system, and an audit plan.

From a timing and cost perspective, if you currently have little automotive experience but a very qualified quality control manager, I would estimate an existing ISO-9000 system can be converted over to a TS system within 8–12 months with the full support of 1.5–2 employees.

Performance Requirements: Huh?

The Tests

When selling to the commercial market, the vast majority of performance requirements center on IPC standards such as IPC-6012 and IPC-A-600. While these standards are definitely helpful, they focus on acceptance criteria that are mostly visual. As you encounter automotive suppliers that you want to sell to, you will become exposed to performance and reliability requirements that make military requirements look easy. Global Tier 1 suppliers like Delphi and Continental even have their own PCB qualification specifications complete with test vehicle Gerbers, test methods, etc., striated, based on the end application of the PCB. For example, one such supplier's PCB certification breaks PCB requirements into five primary categories by application (Figure 3).

Automotive PCB Categories	
Class A	Interior Components
Class B	Under-Hood
Class C	On-Engine
Class D	In-Transmission
Class E	In-Engine

Figure 3: Automotive PCB categories.

The primary differentiating characteristic between meeting each of these specifications are the thermal cycling requirements (which I have used as a test method within past articles regarding PCB laminate quality).

- Standard cycle is room to minimum temperature within five minutes
- 25 minutes at minimum temperature
- Five minutes from minimum temperature to peak temperature
- 25 minutes at peak temperature
- Five minutes to lowest temperature

The PCB must pass through 1000 cycles with less than a 10% change in resistance as measured across a standardized daisy chain pattern. Figure 4 is a table that shows the changes in peak temperature between these classes of PCBs.

In comparison, the military requirements only call for 100 cycles between - 65°C and + 125°C. While the lowest temperature is lower than that used by automotive, the reduced number of cycles works in the fabricator's favor. In the last five years of testing I've rarely seen failures in even the first 336 cycles of the automotive thermal cycling tests we've performed. As such, if you can pass these requirements it will surely add to your rock star status.

What do I need to do to pass them?

Don't let the above performance requirements scare you. It is not absolutely necessary

Class	Min Temp	Peak Temp
A	- 40°C	+ 85°C
B	- 40°C	+ 125°C
C	- 40°C	+ 145°C
D	- 40°C	+ 155°C
E	- 40°C	+ 165°C

Figure 4: Changes in peak temperature between the five classes of automotive PCBs.

for you to meet them in order to build for the automotive market. There are plenty of lower risk and lower thermal exposure applications, but they typically involve lower technology and more commodity-like PCBs. Needless to say, there's plenty of competition in those segments of the market so it's going to be tough to earn a decent rate of return on the investment required to pursue the automotive market. There's a heck of a lot less competition in the high-performance segments of the market whose products include under-hood and on-engine applications.

Passing these testing requirements could really make you the Bon Jovi of the PCB world, as it requires discipline and process knowledge throughout the organization. I've written articles for *The PCB Magazine* that touch on these topics:

- Materials for High Reliability Applications (June 2011)

- Built Board Tough—Backbones of PCB Reliability (July 2012)

- Built Board Tough: Budget DC Copper Plating for High Reliability and Increased Capabilities (January 2013)

These articles go into the details surrounding key processes and materials so I'll just briefly summarize each here.

Raw Materials: The most critical component towards building a high reliability PCB, in my opinion, is the copper clad laminate. Unfortunately, since this is often the single largest cost component of a PCB, many fabricators treat it like a commodity and purchase from the cheapest source. As I detailed in Latest on Lead Free Capable Materials (February 2012), materials do perform differently than one another even when having the same data sheet characteristics. It's important to test out each resin system as it behaves with your processing parameters.

Multilayer Lamination: Continuing with the materials selection, it's important to thermally profile the lamination parameters with each resin system. You're not just looking to achieve cure, but also optimize resin flow, remove voids, and achieve flatness. Putting the extra process engineering time in at initial recipe setup along with continual monitoring is paramount to achieving optimal results.

Drilling: Here's another area that scares me at many shops. I've seen and heard of fabricators using multiple brands and geometries pretty much willy-nilly, based on price and sometimes even auction scores. My belief is that each brand and geometry has its own set of optimal drilling parameters (feed, speed, retract, number of hits, etc.) that should be dialed in for your process. Since via failures are the most common root cause for a PCB failure in a high-stress environment, it's critical to have smooth hole walls that allow for optimal copper plating to occur.

Plating: One of my favorite topics—copper plating for through-holes and vias. The key to achieving plating for high reliability applications is to reduce variation as much as possible, making sample thickness measurements more reliable. Other characteristics such as tensile strength and elongation are determined by both chemistry selection and plating line setup. As I described in January's article, it doesn't have to cost you an arm and a leg to convert a standard copper plating setup to an optimal one.

What's in it for ME?

The bulk of the $1–$2 billion PCB market is currently being supplied by overseas sources. Trying to compete head-on is likely a prescription for bankruptcy, and may not even be necessary since most fabricators remaining in North America likely don't have the throughput necessary to run a true automotive production program. However, there are programs I can think of off the top of my heard that remain ideal for North American suppliers.

Prototypes: Here's a given: Almost across the board, volume automotive suppliers hate doing low-volume projects. Since automotive protos are often used for more than just design validation (life cycle testing, performance testing, etc.), it's often critical that they be built to production standards. As such, they need production-qualified suppliers that are willing and eager to supply quick-turn prototypes.

Optional Equipment/Low Volume Programs: While overall volumes for a given car or truck line often exceed 200,000 units annually, many of the higher-end options are picked up on only a fraction of the total vehicles sold. Also, automakers remain keen on having trophy vehicles that are not expected to sell well just to bring attention to the rest of the product lineup (e.g., Chevy Volt, Dodge Viper, Ford GT). These programs would require production quality units at much lower than standard volume as well (~10k–30k units annually). Coupled with volatile market demand, these types of programs are perfect to be supplied by a North American supplier.

Service Parts: Federal law requires OEMs to make available to the market all parts required to service any given product for a set number of years after the end of life of the program. These volumes typically only run up to a few

thousand units a year, have extremely volatile demand, and sometimes require a quick turnaround. Again, a perfect fit for a North American supplier.

Conclusion

While PCBs for automotive electronics represent a huge market, it's important not to get wrapped up in targeting it for the wrong reasons. Revising your systems and processes to become a qualified automotive supplier is a great way to improve the overall quality of your products and business as a whole; accordingly, you can become a rock star supplier to other industry segments and not just for automotive customers. Should you choose to end up having a focus on automotive work, there's still a lot of work out there that you can turn a profit on—it just isn't the super sexy 750,000 units for the F-150 program. The gold may just lie in the 5,000 units per year seat massage option on a Ford Taurus. The main idea here is to target the work that's right for your business. Do so, and you'll run circles around your competition, or at least a few burnouts and donuts in the parking lot. **PCB**

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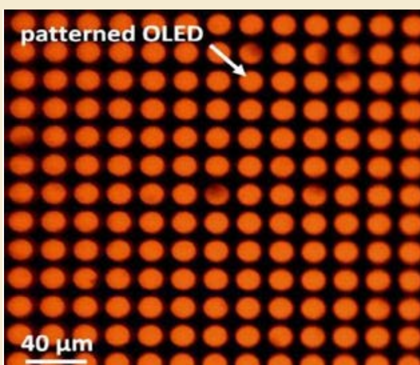
New Tech Improves Production of Organic Semiconductors

Due to their lightness, flexibility, and the possibility to manufacture them in a large area, research and development on organic semiconductors has intensified in recent years. Organic semiconductors can be used in various applications such as organic solar cells, flexible displays, organic photodetectors and various other types of sensors.

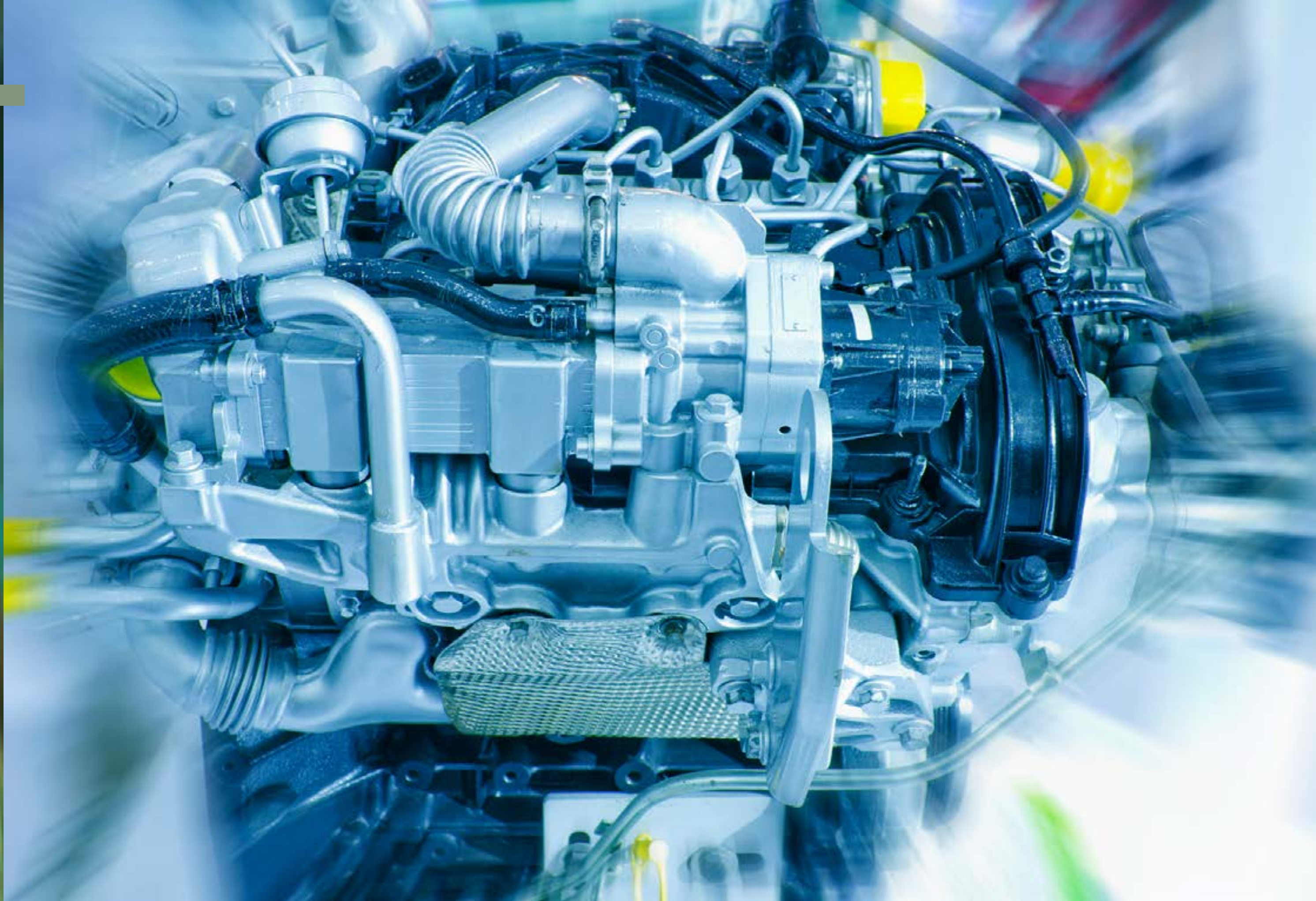
Current methods for patterning organic semiconductors include shadow masking and inkjet printing. However, these patterning methods are not suitable for high-resolution patterning on large-size substrates. Patterning based on photolithography would solve this issue. But photolithography is currently mainly adopted for patterning of silicon semiconductors. When applying it to organic semiconductors using standard photoresists, the photoresist dissolves the organic semiconductor material during processing.



Fujifilm and imec have developed a new photoresist technology that enables submicron patterning on large-size substrates without damaging the organic semiconductor materials. The new photoresist technology was developed by fusing the semiconductor processing technology of Fujifilm and imec, with Fujifilm's synthetic-organic chemistry material design technology. Since existing i-line photolithography equipment can be used, and investment for new equipment is unnecessary, the new technology contributes to a cost-effective production of high-resolution organic semiconductor devices.

For technical verification, Fujifilm and imec developed organic photo detectors (OPD) and organic light-emitting diodes (OLED) using the new photolithography technology, and tested their performance. Organic semiconductor materials were patterned to produce OPD composed of fine light receiving elements down to 200 µm x 200 µm size.

Generally, patterning of organic semiconductor materials degrades the property of converting light into electricity (photoelectric conversion property), but the OPD developed in this case were patterned without degradation. With respect to the OLED arrays that were produced using the newly-developed photolithography pattering method: 20 µm pitch OLEDs emitting uniform light were realized.



Selective MiB Thermal and Power Pathways for Automotive Applications

by William Burr
and Nick Pearne
BPA CONSULTING

Background

Industry forecasts continue to paint a bright picture for the growth of automotive electronics. Strategy Analytics estimates that the value of electronics in automotive systems is expected to reach US $314.4 billion by 2020, from a value of about $191 billion in 2013. This represents a CAGR over the next seven years of some 7.3%.

A top-of-the-line vehicle may contain up to 150 electronic control units. Many of these are sensors or processors in cockpit applications; however, as shown in Figure 1, about 65% of the electronics value is in powertrain/body/chassis, according to PCB Network/ZVEI. And most of this involves digital Power.

Early digital applications such as engine controllers and antiskid braking are either morphing into more intelligent and capable subsystems (e.g., the move from simple antiskid braking to enhanced stability control), or the advances in digital power are enabling the replacement of electromechanical or hydraulic systems by smaller, lighter, all-electric functions such as electric power steering. The growth of the hybrid/electric vehicle (H/EV) market is presenting a further set of opportunities and demands.

Although one of the initial insights which led to the growth of the digital age and solid state devices was that the reliability of silicon was essentially the same as copper wire[1], the nano geometries of modern semiconductor processes and general complexity of electronic assemblies continue to support doubts that elec-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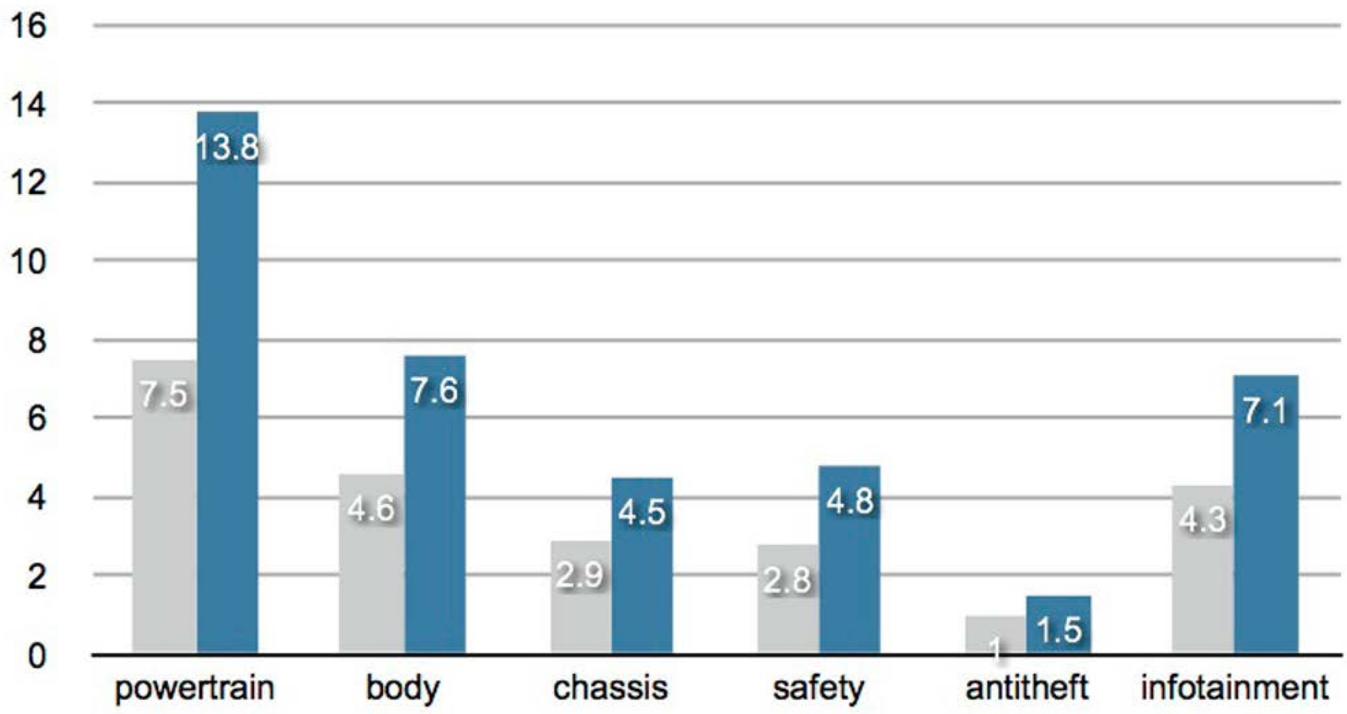


Figure 1: Electromobility drives microelectronics consumption, 2010 vs. 2015, in USD billions p.a. (source: PCB Network)

tronic systems reliability is sufficient to meet the demands of the automotive industry at competitive price points. While these concerns derive in part from the lack of field experience at the high voltages and currents of powertrain/body/chassis applications, the combination of miniaturisation and power density in digital power systems represent a further series of challenges.

Getting the Heat Out

Making things smaller has led to a proliferation of package types for power semiconductors, and in addition to the direct-drive capabilities provided by increasing voltage and current ratings, most of these bring lower assembly costs and improved assembly efficiencies through surface mounting. But since they are power devices, some fraction of that is transformed into thermal energy notwithstanding the improvements in junction efficiencies, and this has to go somewhere, or the device will overheat. This is bad news for lifetime and reliability, because semiconductor lifetimes and failure rates are directly connected to temperature of the semiconductor junction. Most predictive models base the relationship between temperature and failure rate on the Arrhenius equation, where temperature can be used as a proportional multiplier. A first-order solution of this relationship suggests that MTTF (mean time to failure) is reduced by half for every 10°C rise in junction temperature.

The combination of surface mount packaging and compact assembly volume means that in most cases the heat can no longer go out to ambient through a heatsink. Surface mounted devices are intended to be small, and they lay flat on the board. So at least for the first part of the journey, the only way out is down—into the board. This means that the board must now provide low-resistance thermal pathways in addition to the well-known mounting and interconnection functions.

The solutions that are emerging offer the potential for replacement of hardware and components formerly used to manage heat and power, and range from simply providing a metal base

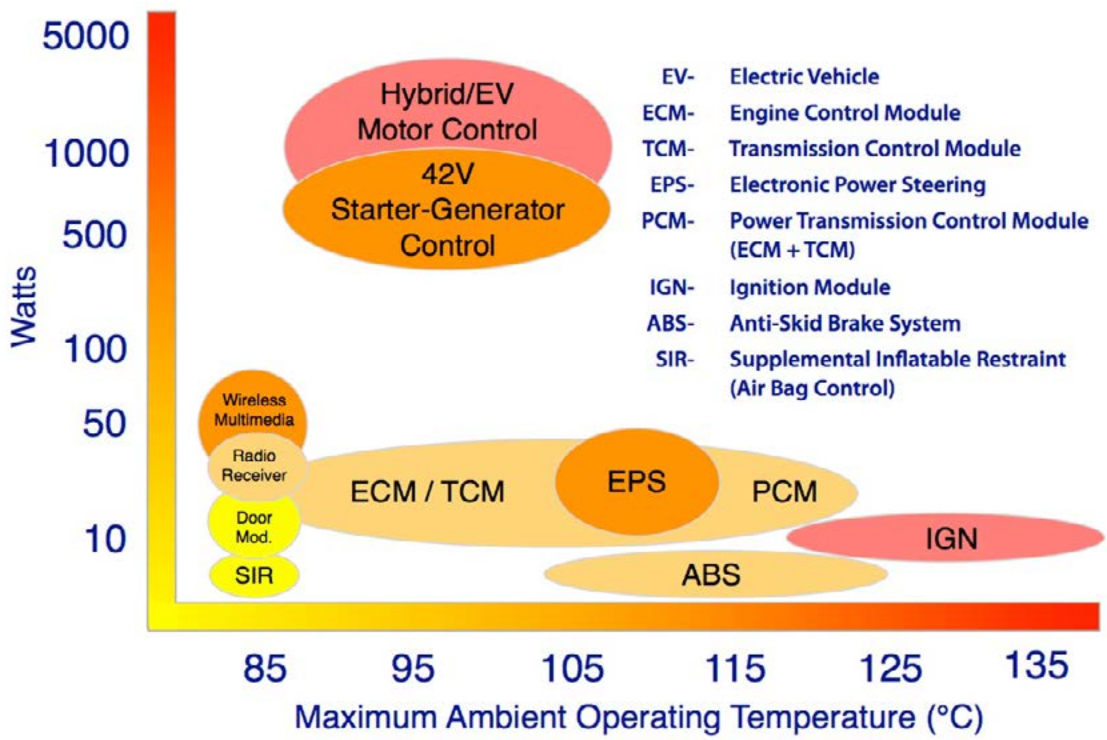


Figure 2: Operating temperature and power for automotive subsystems. (source: Delphi Electronics)

on the board for heat dissipation to sophisticated solutions combining thermal and power management with high density interconnect and formability. BPA uses the term "metal in the board,"or MiB, because these solutions are not metal core or metal base. They are metal in the board.

The manufacturing technologies and capabilities of MiB range from simple three layer buildups commonly known as Al-based or insulated metal substrate, to complex assemblies using a variety of techniques to provide low thermal and electrical resistance pathways in the board. In every case, the MiB component is providing additional functionality—thermal and/or power management.

While the potential volumes represented by the automotive industry pale in comparison to sectors such as mobile devices and other digital information processing, automotive challenges are one of the primary motivational forces driving the innovation occurring in the MiB space. The board has to provide a conductive heat path as well as electrically conductive interconnects not only for digital logic signals, but also high current. BPA's conversations with Tier 1 suppliers have shown that this is driving the use of MiB across an expanding range of automotive subsystems, where electronic control units are providing the smart power needed to drive solenoids or DC motors and actuators in an expanding range of automotive applications:

- Engine control
- Vehicle control
- Antiskid/stability control
- Transmission control
- Electrical power steering
- Active suspension
- Electro-motive primary (hybrid and electric vehicles)

The power dissipated by these subsystems varies with the application, and the overall thermal stress on the system is also dependent on ambient temperatures. Figure 2 gives an idea of the range of operating parameters for automotive electronic systems.

Depending on device junction temperature requirements, thermal management strategies are generally necessary when the subsystem power is over about 10 watts at an ambient temperature of about 85°C or above. At these levels the surface mounted devices providing power management and control operate in harsh environments, which require sealed enclosures. Therefore, all automotive electronic power control/smart power systems share a very similar thermal management strategy:

- Provision of a conductive heat path from the component thermal pad through the substrate for cooling of high-loss devices such as power transistors and supply components
- Heat dissipation via the housing case and base
- Heat dispersion mainly by free or forced convection depending on subsystem controller location

For example, an engine controller is mounted directly on the engine block and is in the airstream from the engine compartment cooling fan. In this case, the thermal path is conductive through the housing into the block and convective into the air stream, and the first stage of this path—out of the component—is provided by MiB.

Applications and MiB Technologies

MiB has been used for more than 20 years in automotive systems beginning with the first generations of engine control modules (ECM). Board types ranging from rigid flex to ceramic substrates were employed as the technology evolved. As power semiconductor performance improved with lower power losses due to source-drain resistance and surface mount packaging appeared, most designs migrated to the MLBTV type—a multilayer board with arrays of thermal vias (Figure 3). Heatsinking is provided by a direct connection between the thermal via array

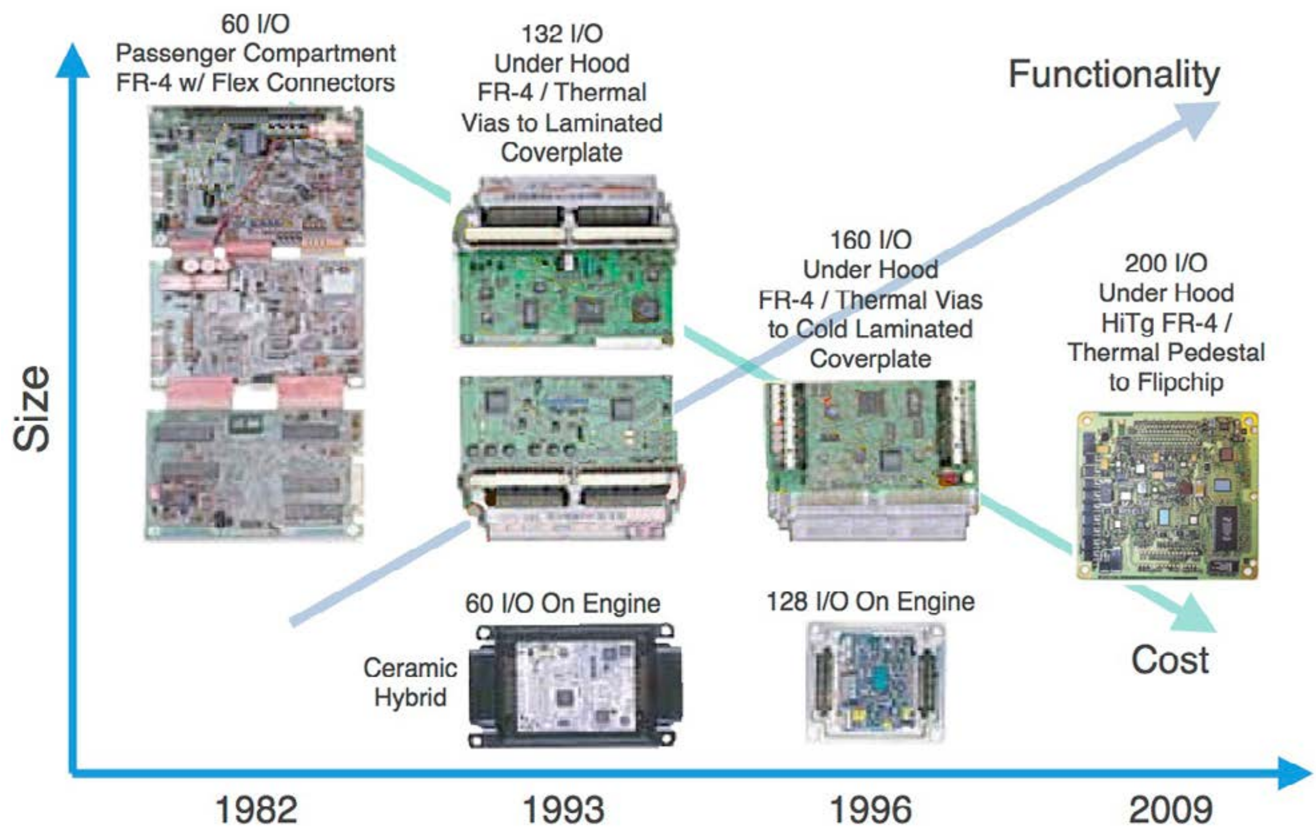
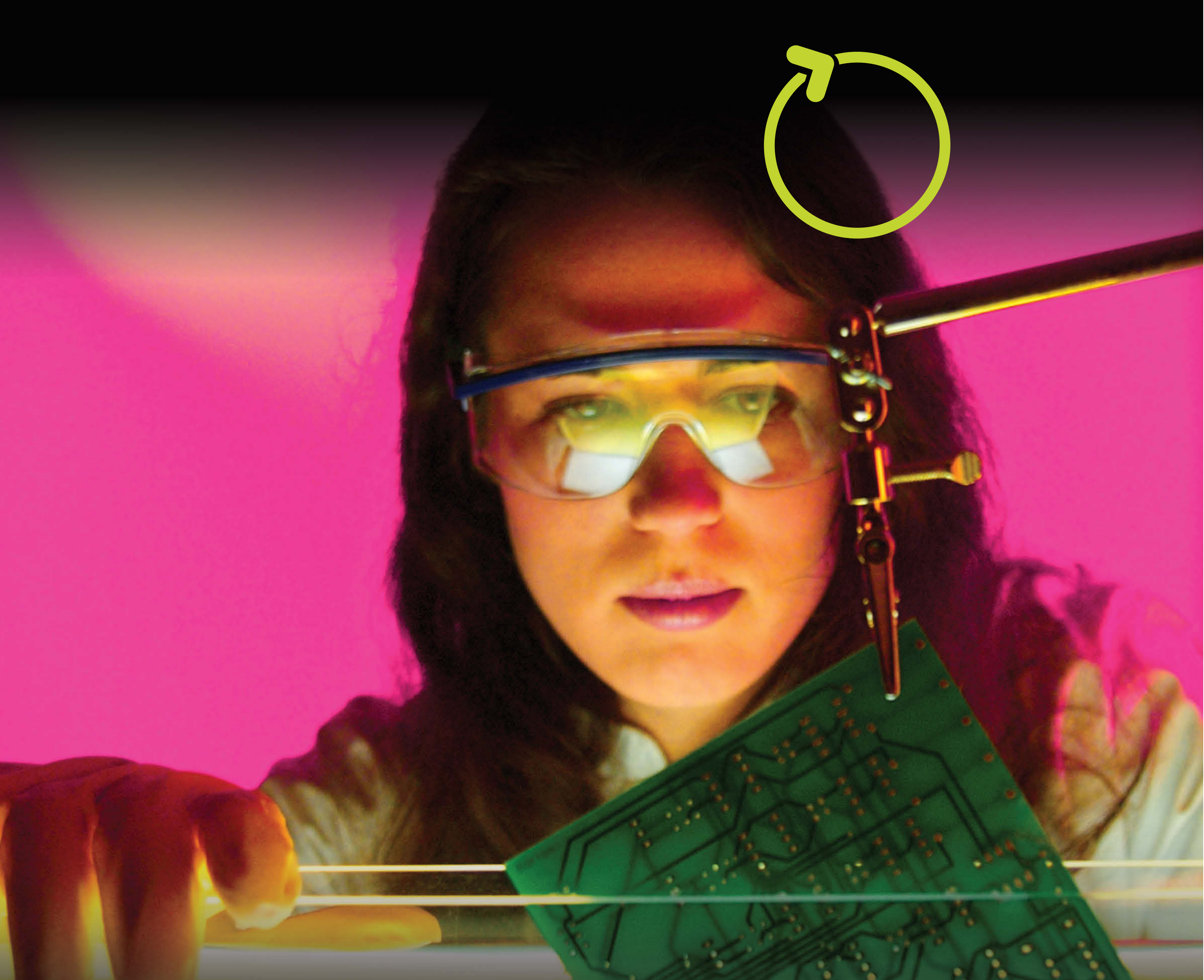


Figure 3: Engine control module evolution. (source: Delphi Electronics/LPC Ltd)



	Thermal	Power	Wiring	Cost
Via arrays	++	+	++	+++
Coins/inlays	+++	+	++	++
Embedded bus	+++	+++	+	+
Discrete wire/profile	+++	++ - +++	+++	++
Area selective Cu	++	++ - +++	+	+
Segmented	++	++ - +++	+++	++

Table 1: Comparative characteristics of selective technologies.

and the subsystem housing, and this continues to be the most commonly used solution for power devices dissipating from one to about 10 Watts. However, as electronics are taking over more and more vehicle functions with an expanding range of both voltage and current, the variety of configurations and thermal/power management requirements specific to each subsystem are driving the need for more variations in the substrate type.

These variations range from modifications to layout and fabrication techniques for creation of effective thermal pathways to development of new structural concepts. In all cases, the economics of the automotive market demand that application of MiB technologies is in the context of zero-sum costing (i.e., the added value provided by enhanced substrate thermal characteristics is either offset by reduction in other aspects of assembly cost, or represents an increment in the level of functionality of the subsystem).

Making this determination is next to impossible when using conventional costing models based on cost per square. By definition, MiB is adding processing and materials to what would otherwise be a conventional printed circuit, so it almost inevitably costs more. The key is to understand the overall subsystem-level cost compared to what it replaces. The metrics of this analysis would include additional functionality and the benefits of reduced weight and size, both of which contribute to improved vehicle efficiency in terms of range or energy consumed per kilometer.

Use Only Where Needed

In this context, the concept of selective enhancement by providing thermal and high current pathways only where needed is gaining traction. For example, metal core boards (MCPCB) were an early solution to the problem of hot spots under power components: The metal core spread the heat more efficiently than a conventional substrate. However, this meant that the core occupied the entire board, whereas the power components were limited in area. As a result, the needs of a few components drove an overall cost increase for the entire board. A similar situation is seen with thick copper inner and outer layers: The additional cost of the thick copper is everywhere even though the components and nets which require thermal dissipation or heavy current may be limited to a small percentage of total board area.

Selective MiB technologies are emerging that address this issue. These range from providing power lines and thermal pathways as discrete elements only where needed to actual segregation of the board outline into thick and conventional copper areas during the manufacturing process. Table 1 provides a relative comparison:

These technologies are covered in the following sections.

Via Arrays

Arrays of vias are often used to provide multiple parallel conductive pathways. The ohmic equivalent thermal resistance of a via array is inversely proportional to the number of vias as shown in the relationship

$$(1)\ R_{\theta\ array} = l/k \times (N_{vias} \times \{\pi \times [(D_1/2)^2 - (D_2/2)^2]\})$$

where:
- l = depth of via
- k = conductivity of copper (approx. 380 W/m-K)
- D_1 = drilled diameter
- D_2 = finished (plated) hole diameter
- N_{vias} = number of vias in the array

The thermal resistance provided by a via array in a typical thermal pad of 100 mm^2 may range from about 1.3°C/W for an array of 100 0.5 mm PTH vias to 0.01°C/Watt for 1290 microvias. As a consequence, microvias are increasingly seen in high power density applications where an embedded copper inlay is available just below the surface of the board. In automotive systems, thermal via arrays are used as the primary thermal management technique in engine and vehicle control modules, where the MiB requirement is derived primarily from the need to drive fuel injectors from MOSFETs mounted on the motherboard. A combination of duty cycle and drive current causes about 5–7 watts of power to be dissipated in the form of heat from each device, and ambient operating conditions as well as the overall thermal path enable thermal via arrays to be used.

Coins/Inlays

Copper coins, or inlays, provide a highly selective Z-axis thermal pathway. Rectangles and irregular shapes as seen in Figure 4 generally require manual assembly into prerouted and plated cutouts, but circular inlays of ≤10 mm diameter can be pressfit into drilled and plated holes using auto insertion equipment. As a result, this technique is frequently used as a substitute for via arrays when thermal vias cannot provide sufficient conductivity to meet the instantaneous and sustained thermal loads that occur in antiskid and vehicle stability systems. The conductive path may involve internal thermal dissipation planes, but most often simply carries the heat to the backside of the board, where chassis standoffs or bottomside heatsinks provide an onward pathway to the “infinite” heatsink. Although coins/inlays are available from a number of board suppliers and are basically a simple concept, their manufacture is non-trivial: The thermal pads of power semiconductors are usually soldered directly onto the coin, so co-planarity with the surface of the board is a critical tolerance. Other control points include pressout force and integrity at the glass/copper interface in the plated coin socket. The thermal resistance of a 10 mm diameter inlay through a 1.5 mm thick board is about 0.05°C/W, and it is used for power densities up through 50W/cm^2. The limiting factor therefore becomes the conductivity of the rest of the thermal path out towards ambient.

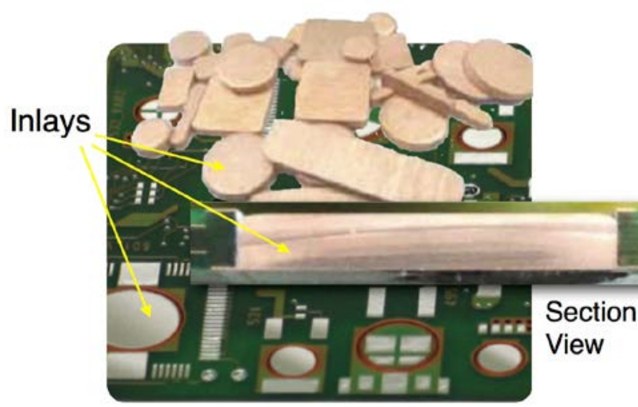


Figure 4: Inlays, inlay board, and cross-section.

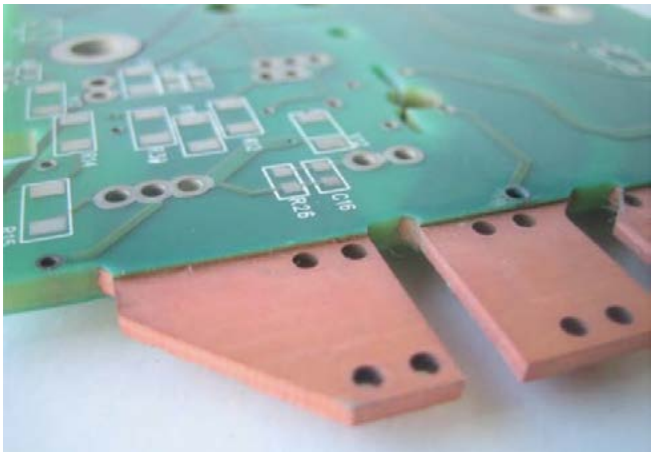


Figure 5: Embedded bus bars. (source: Andus Electronic GmbH)

Embedded Bus Bars

Embedded bus bars represent another selective technology. Thick copper (up to approx. 2 mm) embedded in the board provides high (400–600A, peaks over 1,000A) current capability. The embedded bus can be accessed from the surface using arrays of PTH or blind vias as long as the cross-sectional area of the array supports the required current density. Selective milling of the embedded bus can bring risers to the surface for direct power or thermal connections.

This versatile technique comes at a cost: The buried structure needs chemical or mechanical milling to form the required pattern, and the embedding process needs preformed prepregs and careful control of process parameters to ensure absence of cracking within the resin matrix. As a result, development is focusing on alternative manufacturing methods, with a general consensus that work is also needed in the materials area on resin systems which provide the operating temperatures required by automotive applications without the brittle characteristics of current phenolic formulations. This need is urgent in view of the forecast growth in hybrid/electric vehicles.

Discrete Wire/Profile

Discrete wire/profile technologies use embedded 0.5 mm wire or 0.5 mm copper strips bonded to copper tracks on innerlayers (Figure 6). This selectivity means that additional costs are confined primarily to those nets providing enhanced thermal and current pathways. Commercially available discrete wire technologies

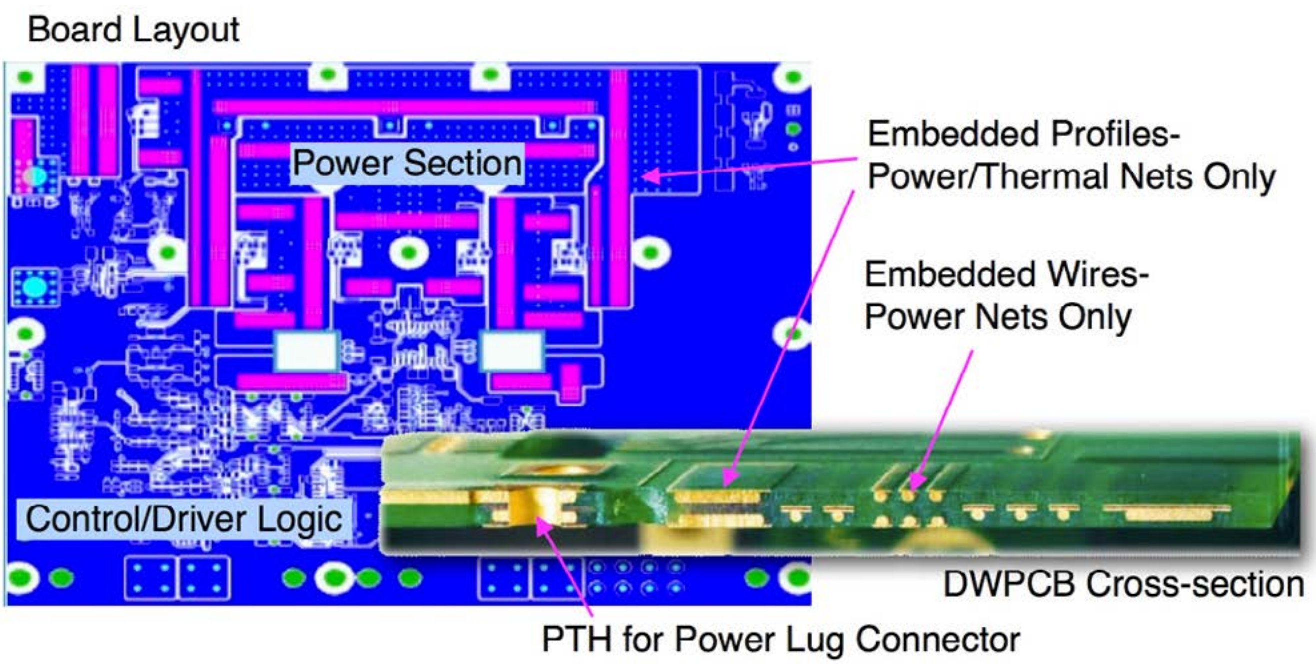


Figure 6: Discrete wire/profile layout and section[2]. (source: Häusermann GmbH)

are proprietary, but the supply base is expanding as inventors provide licensing or otherwise make the technology available to qualified suppliers. Thermal and electrical characteristics are strongly design dependent, as the embedded features permit a wide variety of design options in combination with blind and PTH access vias. For example, the additional cross-section can be increased by running several wires in parallel on a single bonding track, providing as much as a 4X reduction in the area necessary compared to a conventional layout. Form-to-assemble capabilities are also provided as the wire can be used together with depth milling to provide a bendable backbone in the board. Since discrete wire is a selective embedding technology, again the characteristics of available resin systems need care in processing to ensure void-free encapsulation and absence of cracking.

Area Selective Copper

Area selective copper describes selective etching techniques that provide copper of two different thicknesses in the board. The primary advantage of this approach is the ability to support digital logic and digital power design rules on the same substrate. Typical outerlayer design rules call out a minimum trackwidth of 250μ in 105μ copper for logic layouts, with 400μ tracking available on the same layer for power lines. While this technique confers definite advantages in layout compared to a thick copper board, eventual selective cost benefits derive primarily from the copper recovered from etch formation of the thinner tracks, and the multiple etching processes add cost to the entire panel.

Segmented

True selectivity in an etched copper process is provided by the segmented approach. This technique basically prefabricates multilayer subassemblies incorporating thin and thick copper. Since the sections are prefabricated separately, any copper foil thickness and layer count can be used provided that the prefabricated blocks are within a defined thickness tolerance (Figure 7). They are then laid up side by side to form a panel and bonded together in a foil lamination process. The final board can have high density wiring rules with linewidths to 100μ in the logic section and will contain buried thick copper (200–400μ) planes, which can support up to about 200A.

Metal in the Board: Recapturing Value

In each of these examples, metal has been added to the board to provide the thermal or power pathways required by the application. Without this capability, additional material would have been needed in the form of busbars, cabling, heatsinks, and the assorted mounting and fastening hardware. Elimination of all this also eliminates the associated BOM and assembly costs. One applications example involving a 125A motor control unit compared a conventional design using FR-4 with 105μ copper and

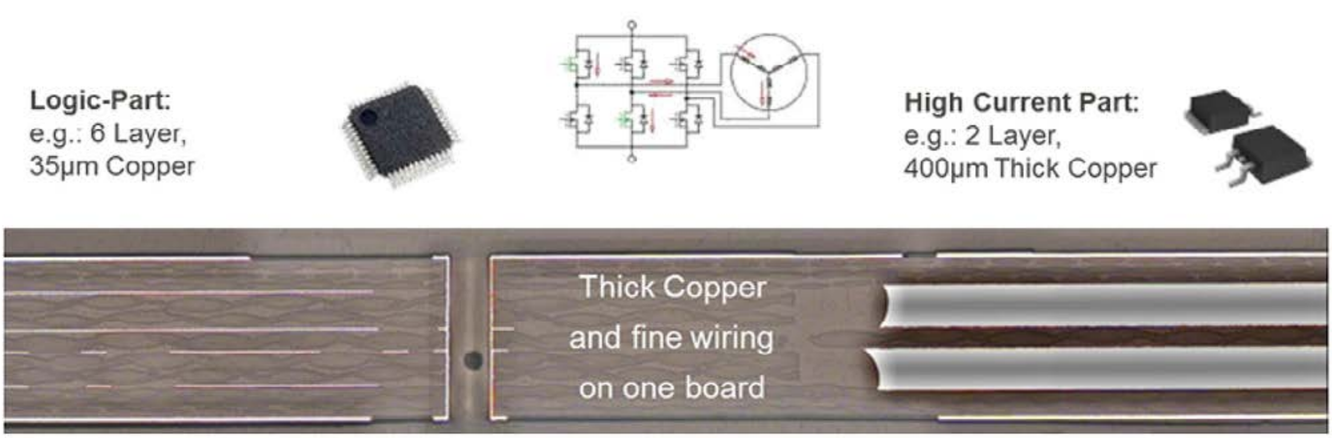


Figure 7: Segmented board cross-section[3]. (source: Schweizer Electronic AG)

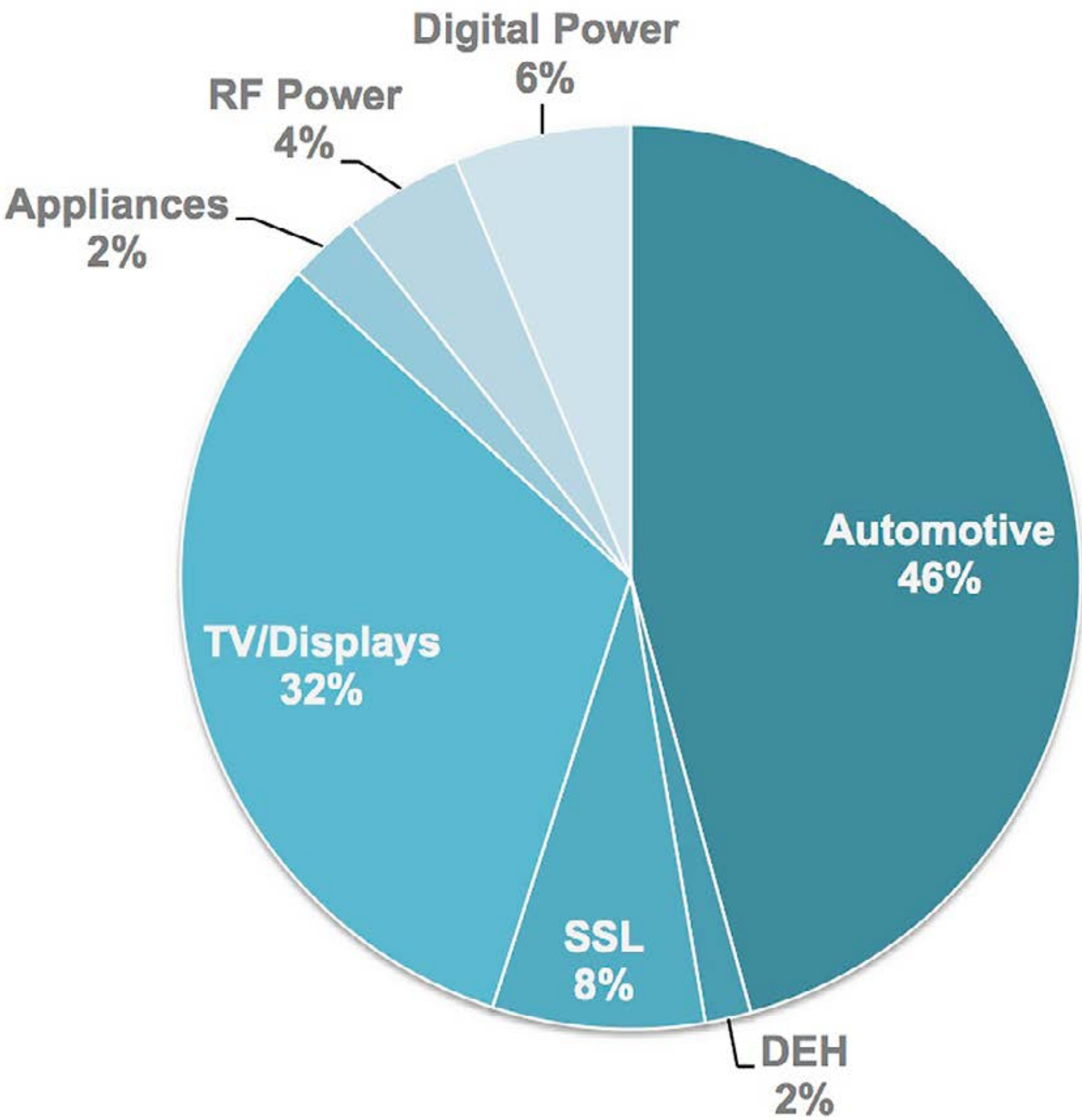


Figure 8: MiB applications split, 2012. (source: BPA[4])

external bus bars to a discrete wiring solution. Elimination of the external hardware and corresponding assembly resulted in a 10% reduction in overall subsystem costs, even though the discrete wiring board cost more per square than the FR-4 PCB. Considering that most automotive subsystems migrate from hydraulic or electromechanical to digital power solutions, the development of selective MiB technologies is a key advantage in terms of cost and design flexibility compared to using full core MCPCB or IMS-type boards. Comparing the bare board cost of a thick copper board to a selective approach in the 125A example given above, using a 4L thick copper board with 210µ outerlayers would cost about 13% more than a selective technology using embedded copper profiles only on the high current nets. Using a selective approach for another electromobility design requiring three 200A nets for MOSFET power devices with a maximum permissible temperature rise of 40°K resulted in a cost savings of about 18%, compared to the equivalent thick copper board.

Clearly, MiB is here to stay in the automotive arena as time-tested and proven conventional printed circuit processes and materials are combined into innovative solutions providing enhanced thermal and power management capabilities in the board. The demands of the automotive marketplace for reliability, reductions in weight and size, and improved performance efficiency—all at a zero sum cost—are not only driving innovation, but at some 46% of the total value of MiB shipped worldwide in 2012, represent an engine of growth for the MiB sector (Figure 8).

Although metal core and metal base boards have been around for a long time, the game changer in this space is the accelerating evolution and proliferation of surface mounted power semiconductors in response to the never-ending drive of the electronics industry towards higher performance, greater efficiency, and lower cost. Selective MiB technologies are evolving in response to these demands as the printed circuit industry rises to this latest series of challenges. **PCB**

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The Design Challenges of Complex Automotive Electronics

by Nikola Kontic
and Humair Mandavia
ZUKEN

Introduction

Increasing electronic content of automotive vehicles is creating a wide range of design challenges for electrical engineers in the automotive industry. The large number of electronic components in today's vehicles and the huge number of possible combinations of optional equipment make it more difficult than ever to meet physical constraints. Frequency and power consumption of automotive electronics are rising at a rapid pace, making it harder to maintain the signal and power integrity of the design. The increase in the number and complexity of electronic systems also creates challenges in managing and securing the vast amount of data involved in the automotive design process.

A new generation of system-level, multi-board design solutions is addressing these challenges by enabling automotive design teams to plan, design, analyze and manufacture their entire system within a single platform. Multi-board 3D design solutions with direct translation capabilities to leading mechanical computer-aided design (MCAD) systems open the door to improved electronic/mechanical collaboration to meet physical constraints. Integration of signal integrity, power integrity, analog, digital and multi-technology verification tools within the design platform helps identify errors that otherwise might not be detected until the prototype stage. Integrated design management tools help manage library and design data and guarantee transparency of all changes and interdependencies across all objects within a lifecycle.

The share of value-add in current generation automobiles contributed by electronic technology is expected to reach 40% for traditional internal combustion engine vehicles by the 2015 model year. Electronic content of automobiles has been rising at a rate of 6% per year to the point that the current value of electronics is in the neighborhood of $2,000 for a luxury vehi-

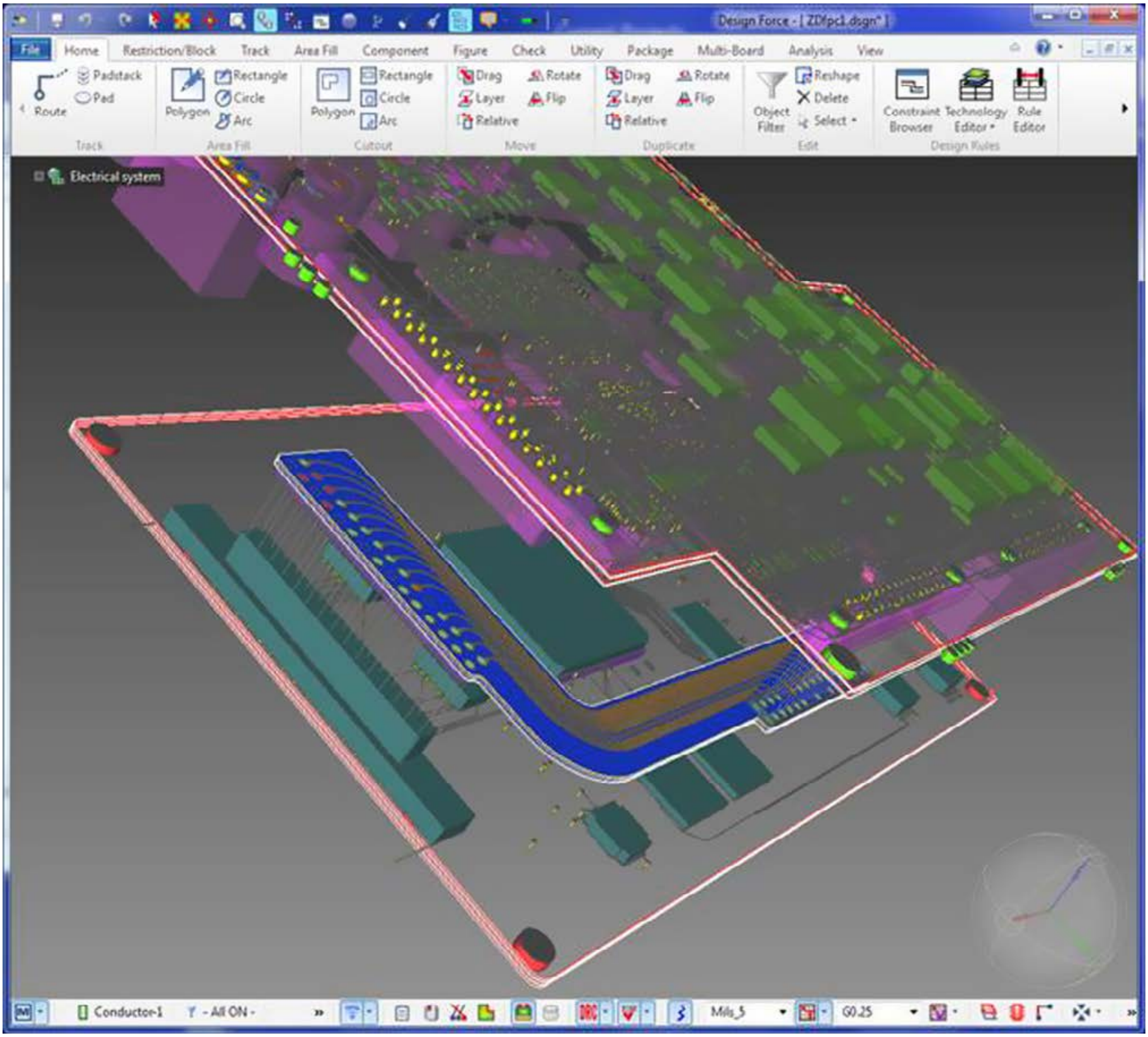

Figure 1: Multiboard physical circuit design manages and optimizes system-level interconnects.

cle. The demand for electrical energy has grown from roughly 500 watts in 1970 to about 2000 watts for current year model vehicles. The typical mid-range vehicle produced today has between 25 and 55 electronic control units (ECUs) while the typical luxury car has about 80 ECUs. The increased functionality and complexity of automotive electronics systems has greatly increased the challenges involved in automotive electronic design[1].

Meeting Physical Constraints

The continuing increase in the number of electronic components makes it more difficult than ever to meet the physical constraints of the electronic design process. Automotive electronics engineers are increasingly using multi-board designs to handle increasing functionality and embedding components inside the PCB to ensure reliability while operating in harsh environments. The trend towards increasing design complexity frequently bumps up against space limitations, creating the need for closer design collaboration between the electronic and mechanical design processes. The greatest obstacle to effective communication of design data is that nearly all MCAD systems today are 3D, while most electronic computer-aided design (ECAD) systems are 2D with some type of 3D viewing capability. The need to convert from 2D to 3D and back, each design turn, and the inability of electrical designers to define 3D geometry slows down the design process. The challenge is increased by the fact that enclosures are increasingly migrating from orthogonal to more complex curved shapes that cannot be accurately depicted in a 2D system.

Multi-board designs make ECAD-to-MCAD translation more difficult because of the need to communicate the position of connectors and other common points between the boards. Using a spreadsheet or some other disconnected document to manage the large number of interconnects between the PCBs in the system is time-consuming and prone to error. With mechanical engineers and board designers working with disconnected systems it's difficult if not impossible to intelligently manage connectivity and changes between boards. When mechanical engineers have inaccurate information on the electrical design or electrical engineers have inaccurate information on the mechanical design the result in many cases is that batteries don't fit, mounting screws create shorts against PCBs and connectors don't mate with packaging openings.

The new generation of ECAD systems offers a full multi-board 3D design environment, giving PCB designers the ability to import the mechanical enclosure directly into the layout so they can get single or multi-board design right the first time. 3D parametric libraries are shared between the ECAD and MCAD systems. Electrical engineers can design to the true native 3D constraints as defined by mechanical engineers while mechanical engineers in turn have access to the true 3D board design so they can accurately place and conduct interference checks during board layout. Electrical engineers can design multiple boards within a single model to ensure precise positioning of angles, shapes and cuts needed to avoid interference. Working with the exact product shape makes it possible to, for example, fit more functionality into a package that is curved to conform to interior styling than could be accomplished with an orthogonal approximation. 3D ECAD design enables more accurate alignment of connectors so that they precisely fit openings on the enclosures.

“*When mechanical engineers have inaccurate information on the electrical design or electrical engineers have inaccurate information on the mechanical design, the result in many cases is that batteries don't fit, mounting screws create shorts against PCBs and connectors don't mate with packaging openings.*”

Maintaining Signal Integrity

The ever-increasing number of electronic components in today's automobiles creates a vast number of additional potential failure modes that require attention before bringing the product to market. For example, electronics generate large volumes of stray electromagnetic emissions that can interfere with other components in the product. Other products that happen to be in the area, such as the driver's smartphone, also generate emissions and are subject to interference. The increasing number of electronics components and the vast number of potential combinations of optional equipment create a huge number of possible scenarios which should be evaluated before bringing a new model to market. Running physical tests on each of these possible scenarios would be very expensive and when physical testing is used it often fails to explain why or how the failure occurred so the next product iteration may very well also fail. The challenge goes well beyond signal integrity in that structural mechanics, heat transfer, fluid

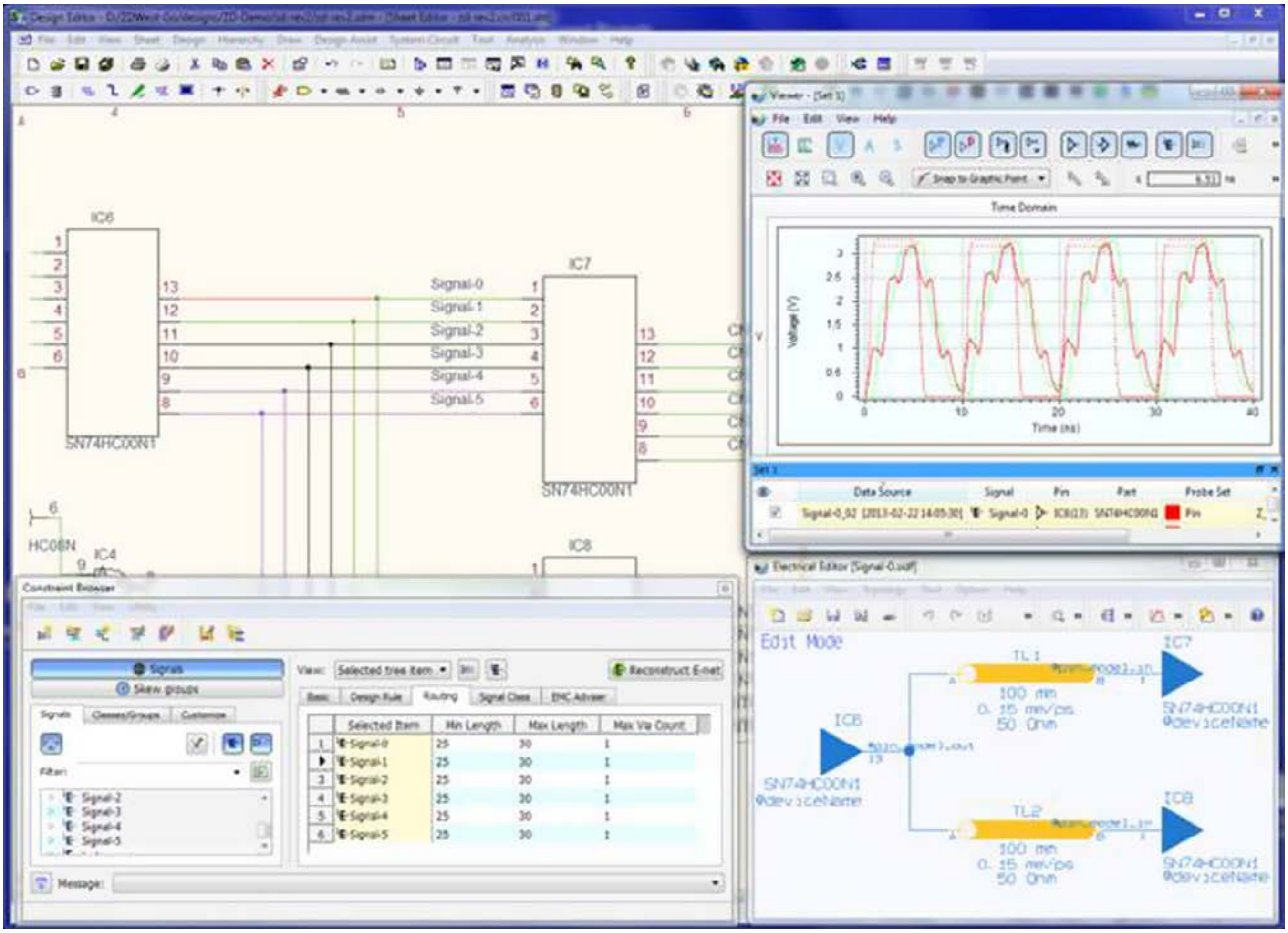

Figure 2: Concurrent high-speed design and simulation addresses signal performance issues earlier in the design process.

flow, hydraulics, and pneumatics each offer their own potential failure modes.

The latest generation of ECAD tools enables users to drive electromagnetic (EM) simulation directly from the familiar ECAD interface. Materials properties, port setup and boundary conditions can be set up from the ECAD interface. The model is then transferred to the EM software for solving the electromagnetic fields. The EM field solution can be used to calculate electric potentials, current densities, impedances and scattering parameters (s-parameters) in order to determine signal integrity, power integrity and electromagnetic interference (EMI). S-parameters describe how a signal on a given port scatters and exits on other ports, including reflection on the same port, transmission to connected ports and coupling to other ports. S-parameters are complex numbers that affect magnitude and phase. Circuit simulators read s-parameters to produce time-domain simulations that can be used to evaluate the quality of a digital channel. By leveraging cloud-based computer architectures, designers can achieve fast run-times while performing exhaustive analysis at the same time they are minimizing hardware and software expenditures.

System-Level Design

Meanwhile, ever-increasing global competition in the automotive industry has spurred auto manufacturers to reduce typical design time from concept to manufacture from 54 months in the past to between 24 and 36 months today.

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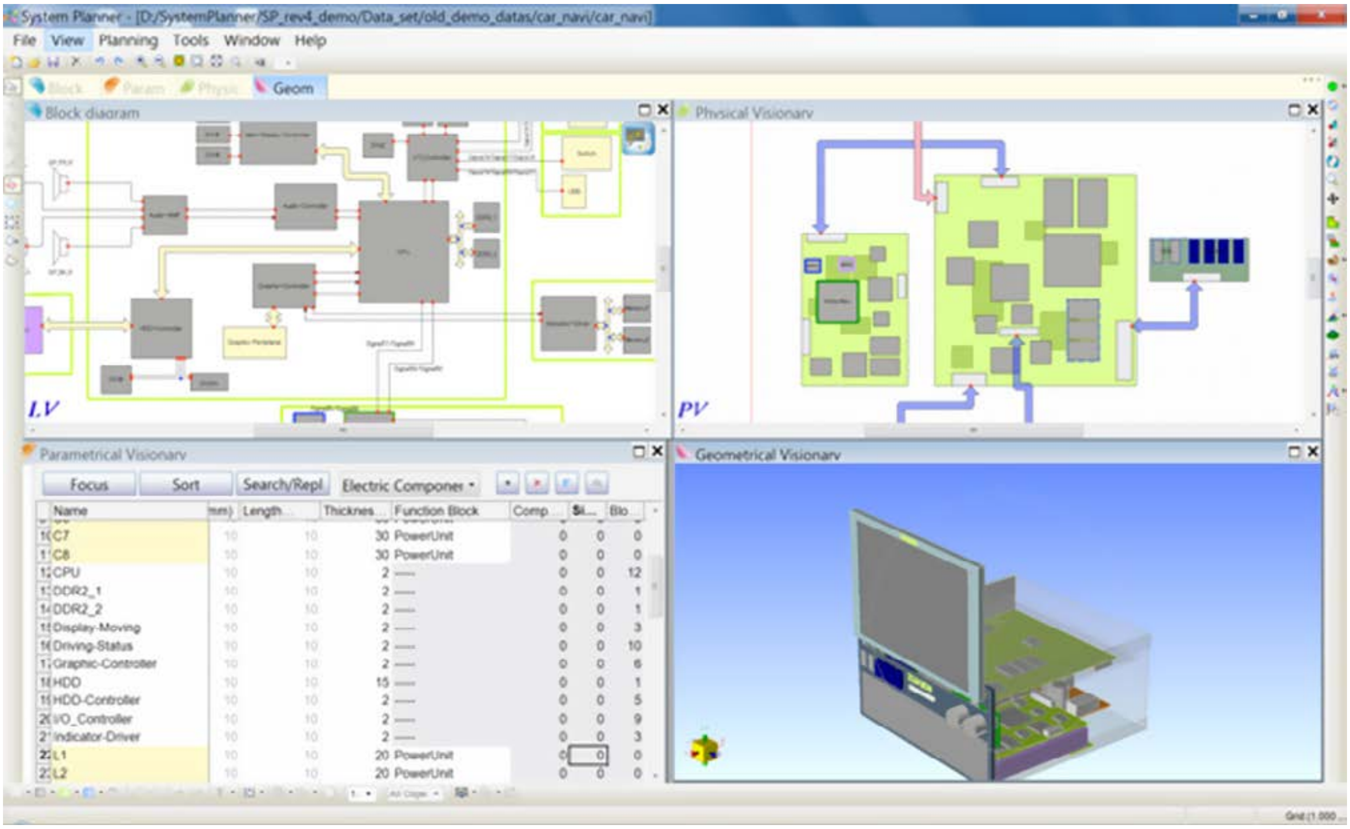

Figure 3: Multiboard system planning for automotive navigation system.

To achieve this goal, automotive manufacturers are creating platforms and sharing their designs among model series on a global basis. This creates the need to easily reuse the design information captured at the concept stage within the detail design process in order to achieve further time savings and reduce errors.

A system-level design environment for upfront planning and partitioning of electronics systems provides the starting point for concept development and design creation. This approach offers the capability to consider the platform with the 3D design aspects, partitioning of the functional modules across multi-board systems, and allowing early cost, weight and power analysis before the idea is prototyped in hardware. It intelligently brings together steps that were disconnected in one view. Engineers and designers can flow through the design process optimizing form, fit and function of single and multi-board systems, maximizing design reuse, without reentering upfront planning data into the design tools during detailed design. Product planning tasks—such as bill of materials (BOM) creation, logical function block diagrams, and 2D physical and 3D geometrical planning—can be accomplished in one environment. This eliminates the need to jump between non-intelligent tools such as Excel, Visio and AutoCAD.

Managing Design Data

With the number of components, partners and suppliers increasing at an exponential rate, electronic design data management presents increasing challenges in the automotive design process. Automotive electronics engineers face the need to design ever more complex products at the same time their design process is becoming more complex. Even the smallest design teams rely on specialists who must collaborate closely with one another for the project to succeed. The design process must also take into account the views and concerns of stakeholders, which means engineers must communicate the

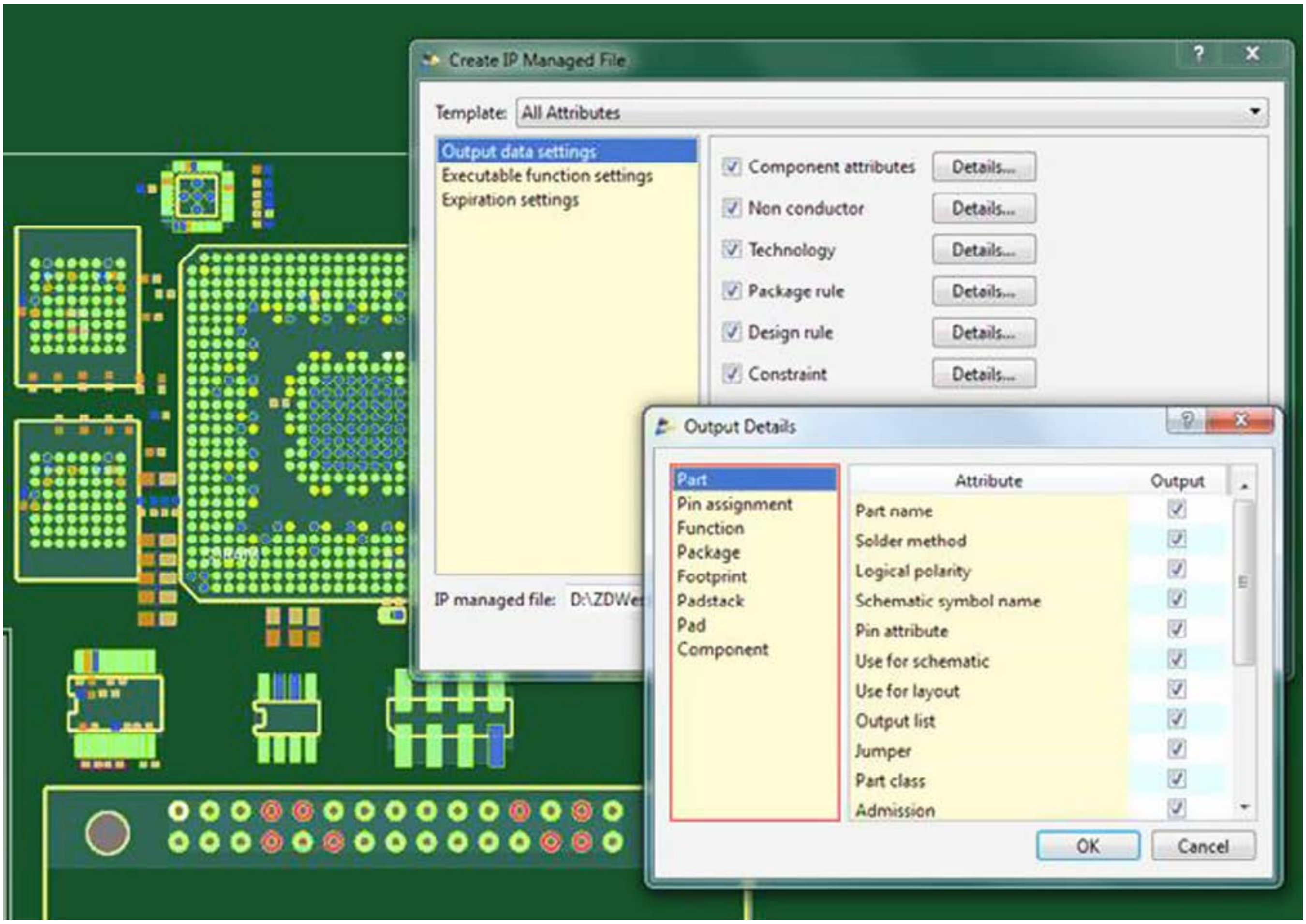

Figure 4: Integrated IP management enables secured data exchange with downstream partners.

design intent to these stakeholders and accept their feedback as input into the design process. Small design teams are also subject to regulatory and legal risks that may require documentation of the product development process, proof of design due diligence and detailed reports on product composition.

The new generation of ECAD systems addresses these challenges by providing domain-level management with metadata-based data handling at the file level including explicit definition and tracking of object versions together with the controlled progression of changes through the development lifecycle. This approach ensures that relevant changes are consistently highlighted and then distributed to other models that require the change. Change management support across the engineering process enables users to communicate individually with related teams, projects, designs, components or even across disciplines. It closes the loop on workflows by automatically notifying the relevant people, technologists or change groups and providing them with acknowledgement and confirmation of the receipt of changes. History management capabilities perform concurrent changes to components throughout the product lifecycle, with full tracking and transparency.

Securing Intellectual Property

Innovation in the automotive industry is increasingly carried out in the field of electronics design. Meanwhile, automobile manufacturers are increasing subcontracting production to electronic manufacturing service (EMS) providers. The result is the rising risk of intellectual property (IP) theft. In a recent example, a search of the laptop of an engineer for Beijing Automotive Company who had previously worked for Ford Motor Company revealed 41 trade secrets that had been stolen from Ford. Included in those documents were system design specifications for the engine/transmission mounting subsystem, electrical distribution system, electric power supply, electrical subsystem and generic body module, among others. The engineer, Xiang Dong Yu, pleaded guilty to stealing trade secrets and admitted he caused $50 million to $100 million of damages to Ford[2]. Many news stories detail how direct copies have gone to market shortly after or even, in some cases, before the owner of the intellectual property released the product.

The risk of IP theft largely arises from the common practice of providing design information in a form conducive to reverse-engineering to employees, EMS companies and partners. ECAD systems are typically set up by default to export complete information as output. Many OEMs have recognized that most employees and subcontractors actually do not need much of the information normally included in output files for manufacturing and by removing this information they can substantially reduce the danger of their product being reverse engineered. So OEMs have in many cases assigned engineers to the task of manually manipulating their designs and output files to reduce the amount of information that is exposed to the EMS. A new generation of ECAD software saves the time involved in this approach by providing permission controls that enable users to define, with a high level of granularity, the design information that will be included and excluded from the published data set. Permission controls make this process quick and straightforward, allowing for secure and controlled data exchanges during the design process. Design information is encrypted or filtered prior to publication to engineers in other departments, the EMS or a third-party design team.

"Many OEMs have recognized that most employees and subcontractors actually do not need much of the information normally included in output files for manufacturing and by removing this information they can substantially reduce the danger of their product being reverse engineered."

Conclusion

The increasing electronic content in today's automobiles has led to a number of new design challenges such as difficulty in meeting physical constraints, maintaining signal integrity and avoiding EMI and maintaining and securing vast amounts of electronic design data. The latest generation of ECAD systems helps address these challenges by offering a 3D, multi-board design environment that seamlessly integrates with MCAD, integration with EM and other simulation tools that can validate the design prior to the prototype stage and data management tools that ensure the integrity of design information and protect IP. **PCB**

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1. www.sae.org (scroll down below 404 message) and e2af.com
2. www.justice.gov

Nikola Kontic is a technical marketing manager for Zuken and contributes to the strategic direction of electronic product design solutions within Zuken and works closely with customer's engineering communities.

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PCB Technology and Automotive Power Distribution System Design

by Christopher Brandon
DELPHI ELECTRICAL CENTERS

Summary: PCB-based bussed electrical centers technology are just one of the many steps in the evolution of automotive electrical architecture, enabling vehicle safety improvement, the reduction of product over-design and waste, and more.

The application of PCB-based bussed electrical centers (BECs) technology is just one of many steps in the evolution of automotive electrical architecture. It enables improvement in vehicle safety, reduces product over-design and waste and enables the diversity of electrical system connectivity while maintaining cost. BECs are the "fuse blocks" or "relay centers" where the electrical circuit switching, control and protection devices for the automotive electrical system are centrally located for ease of installation and service. The BEC concept provides a number of electrical system designs and electrical harness segmentation advantages over the hardwired or "on-harness" electrical centers. In the last 10 years, the BEC itself has evolved into a stand-alone device, which uses heavy copper (thicker than 70 microns), multilayer printed circuit boards with press-fit and soldered terminals and electromechanical power control devices that interconnect the various subsystems within the vehicle's electrical system. The relative ease in the design of the BEC PCBs, with available computer-aided design and engineering tools, has shortened design lead times and made engineering changes faster and easier to implement. The PCB itself and its structure provide a foundation for PCB-mounted devices that rarely, if ever, require servicing. This removes the relays from the wiring harness, or separate custom pluggable devices, thereby reducing system complexity and cost.

Early Architecture

A major leap in the vehicle wiring architecture was made with the Saturn vehicle in the early 1980s. The wiring harness design changed drastically from a common circuit wire methodology with in-line connectors and devices incorporated into the harness with individual and some localized relay and fuse connections structures, to a segregated harness structure where several compartmentalized harnesses plug into a central device. This device allows

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connectivity to the harnesses while providing a central location for pluggable devices: relays, fuses, circuit breakers and electrical transient suppression devices. The result was the creation of the BEC. The architecture provided a single-point attachment for the segmented, forward lamp harness, engine harness, body harness and instrument panel harness that greatly improved the buildability of the vehicle. Major subassemblies of the vehicle could be easily prewired offline, tested and brought to the vehicle assembly line and mated to the rest of the vehicle's electric system with one or two interconnections within the BEC. The interconnecting of several leads within a single harness, such as grounds, could be done in the BEC, thereby eliminating the complex fabrications of splices within the wiring harness. Now, all of the leads in the wiring harness could be single leads with point-to-point connections that are simple to fabricate automatically.

"After six months of qualitative and quantitative analysis of hundreds of concepts, their finding was that printed circuit technology would be the most cost-effective and flexible design concept to use. However, during that time, the supply base for heavy, multilayer PCBs was not yet developed to support a BEC program."

Generation to Generation

The first generation of BECs was constructed with arrays of stamped conductors, or buss bars, layered in isolative plastic trays. Female-to-female terminals are placed on the ends of the buss stampings, creating the interface to the male blades of the pluggable devices. Circuitry changes in this first-generation technology were costly and time consuming because it often required the redesign of multiple stamped metal parts and the associated change in tooling. Material utilization with stamped buss bars is poor with significant amount of waste from the individual stampings.

A second generation was created in the late 1980s that replaced the stamped metal buss bars with programmable routings of bare copper wire automatically placed in a predefined grid pattern molded into plastic isolation trays. The molded grid pattern allowed for multiple routed wired circuit patterns to be generated; insulation displacement type terminations connected the routed wire and the terminals electrically. Several plates of the routed wires were stacked together and the terminals pressed into through holes in the plastic isolation plates.

The 1990s was a third generation of electrical centers with the development of the "tuning fork" terminal. This forked terminal "pinches" a male blade inserted between two cantilevered beams of the female terminal.

The Dawn of the PCB BEC

But why not use a PCB for the internal routing and bussing of the electrical center circuits? As early as the start of production of the first electrical centers, a multi-disciplined group of experts were charged to determine the best methodology for creating the internal bussing layers of a BEC. After six months of qualitative and quantitative analysis of hundreds of concepts, their finding was that printed circuit technology would be the most cost-effective and flexible design concept to use. However, during that time, the supply base for heavy, multilayer PCBs was not yet developed to support a BEC program. In the early 2000s, advancements in heavy copper PCBs for the power supply industry and the development of solder reflow technology with no-clean solder pastes, allowed the fourth generation of electrical centers to emerge: PCB-based bussed electrical centers (PCB BECs). Terminal designs were created to interface automotive connectors to the PCB with press-fit terminals and soldering. The tuning fork terminal was also redesigned to be inserted into the other side of the PCB to provide electrical and mechanical interfaces to the plug-in devices. Package the terminals and printed circuit board assembly into plastic housings with lead-in and attachment support of the

connectors on one side and pluggable devices on the other, and the PCB BEC is realized.

Still more improvements and cost reductions continue as a result of the move to PCB technology. Mounted directly to the PCB and within the plastic housing cavity are PCB-mounted relays. For many of the low to moderate current loads in the vehicle, these PCB-mounted relays replaced the larger and more expensive pluggable relays. Electrical transient suppression devices, such as diodes, were also placed on the PCB; this resulted in further simplifications of the wiring harness.

The flexibility inherent in the PCB design has resulted in higher device counts packaged in the same vehicle volume. Reduced center lines in the mating connection systems with terminals as small as 0.64 mm² in the same connector as blade terminals of 9.5 mm wide, can be implemented with careful design for manufacturing considerations. The change to lead-free soldering in the mid-2000s required PCBs with higher temperature capability (resin glass transition temperature: T_g) to be used for processing considerations in addition to the application requirements. The high number of large terminals, combined with the weight of the copper, makes the PCB assembly relatively heavy. This requires special considerations for handling of the PCB with conveyors, assembly machines and solder reflow equipment. While the electronics industry continuously drives smaller components for consumer electronics, the technology of the heavy copper and the modified pin-in-paste solder printing and reflow methods limits the smallest size of the components that can be used on the BEC PCB. The amount of solder paste printed onto the power BEC PCBs for the modified pin-in-paste applications, combined with the narrowing center lines between adjacent terminals, requires a thick stencil to deposit the required solder paste volume in the allotted space provided. The required thick (up to 0.015" or 0.38 mm) solder paste deposits and the associated stencil makes reliable printing of smaller apertures, (required for devices smaller than 0805 size chip and 50 mil pitch SOIC) which is not cost effective. The minimum spacing between pads and traces, and the minimum width of traces required for the heavy copper PCB fabrication (in the range of 0.38 mm or 15 mils), marries well with the needs of the BEC designs to deter circuit isolation failures (leakage currents) among the continuously powered, battery circuit traces. Differences in thermal masses of the relays, the inserted terminals and surface-mounted devices create a challenge for the solder paste reflow profile and oven capability.

"The minimum spacing between pads and traces, and the minimum width of traces required for the heavy copper PCB fabrication (in the range of 0.38 mm or 15 mils), marries well with the needs of the BEC designs to deter circuit isolation failures (leakage currents) among the continuously powered, battery circuit traces"

Electrical testing of the PCB assembly is fairly simple, but comes with some mechanical complications. All of the terminals need to be probed from the top and the bottom simultaneously; simple electrical continuity checks are made; relays are cycled and contacts are checked with moderate current loads; and high-voltage isolation resistance measurements are made among the independent circuits—a parasitic leakage current on a battery circuit is a concern. Although the manufacturing challenges are difficult, yet manageable, the design implementations are straight forward. The PCB BEC design enables the change of circuit sizes and/or locations with relative ease and eliminates the tooling-intensive, low-design flexibility of a conventional stamped buss bar BEC. The flexibility to place electrical and mechanical devices as necessary to fit circuit routing patterns and plastic housing constraints allows for a higher device packaging density than with BECs based on a pre-defined matrix of circuit patterns.

The Future of PCB BEC

PCB BEC designs and technology will continue to evolve. Designs are being developed to move away from electromechanical power switching devices (relays) to solid state power switching devices (MOSFETs). The PCB technology enables this change to occur, but not without new challenges for the product design and manufacturing processes. The use of solid state power switching and its ability to be controlled with multiplexed serial communications standards (LIN and CAN busses) in the vehicle reduces wire content and possibly the total cost of the electrical system. The self-protection and monitor functions built into the new smart power MOSFET devices for current and temperature overload conditions can replace not only the relay but also the associated fuse element. Semiconductor devices are more predictable and reliable than electromechanical relays and melt-fuses, and with the feedback signal capability from these new smart power MOSFET devices, an inherent diagnostics mode is easily realized.

PCB construction technology with heavy copper, higher resin temperature, tighter hole positioning and smaller plated through-hole diameter tolerances has allowed the PCB to become the standard for automotive electrical system power distribution and control centers. The PCB BEC has changed vehicle electrical architectures to enable improvements in vehicle assembly and wiring harness assembly costs. With the explosion of electrical systems within the automotive industry and with electric vehicles themselves, the heavy copper, PCB-based, automotive electrical center will continue to evolve to address the increased content and changes in the vehicle's electrical power distribution, control and monitoring requirements. **PCB**

Christopher Brandon is senior technical advisor at Delphi Electrical Centers.

VIDEO INTERVIEW

Unexpected Results in Intermetallic Growth Study

by Real Time with...IPC APEX EXPO 2013

Senior Materials Research Engineer Jose Servin, CIT of Continental, reviews the high points of a study on intermetallic growth that he reported on at IPC APEX EXPO 2013.

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productronica 2013

innovation all along the line

Interview with Christian Rocke, Exhibition Director, productronica

In six weeks, productronica 2013 celebrates its 20th anniversary in Munich, Germany. Recently, Exhibition Director Christian Rocke shared his thoughts on the upcoming show, and the history of productronica.

In about six weeks, productronica 2013 gets underway. What awaits this year's visitors?

CR: productronica's visitors may look forward to a diverse trade fair: In seven exhibition halls, approximately 1,200 exhibitors from more than 35 countries including the industry's key players will present their latest product developments and pioneering innovations representing the entire value chain in electronics production in live operation! Exhibits will be rounded out by a first-rate program of related events—exceptional special shows, a wide-ranging forum program, live demonstrations at the stands (hands-on sessions) and an international CEO roundtable with executives from leading companies. Once again, the fair will include a gathering for the international circuit-board and EMS industry, the PCB & EMS Marketplace, which celebrated its highly acclaimed premiere at last year's fair. In other words, the fair will be like a fireworks display of possibilities for our visitors, so we are also having an actual fireworks display at the lake in front of the main entrance on Tuesday and Wednesday of the fair.

What topics will be the focus of this year's show?

CR: As the most important international platform for electronics production, productronica promotes the industry's vital elements. As a result, the fair focuses on future-oriented topics as well as established segments. This year, for example, there is "Manufacturing Technologies for Cables and Plug Connectors" and "Coilware and LED Manufacturing," which deal with sustainable and reliable production—particularly important with regard to energy turnaround or electromobility. Reliability and quality are also key themes of the special show on automotive electronics in Hall B2.

Outsourcing production in an effort to cut costs and concentrate more on developing new products, marketing and sales is still a key theme in the industry. That is why electronic manufacturing services (EMS) is a highlight topic again at this year's fair.

Everyone is talking about Industry 4.0. Is it also one of productronica's themes?

CR: productronica has always been a pioneer: Industry 4.0 was one of the fair's central themes back in 2009. At that time, the fair featured a special on "Self-organizing Production (SOPRO)"—a precursor project to Industry 4.0. To move the entire production process forward and make it more transparent, this project and production-related systems such as MES (manufacturing execution system) and ERP (enterprise resource planning) are key factors for the industry. In addition to the exhibitors, we will examine this topic in a series of presentations that are part of the Highlight Forum. And on the first day of the fair, the industry's leading executives will discuss "Industry 4.0: Opportunities and Challenges for a Competitive Production of Tomorrow" at the CEO Roundtable.

What other highlights await visitors?

CR: The special shows at productronica are definitely highlights of the exhibition. Vivid demonstrations and a diverse range of lectures and discussions will give visitors a unique look at various hot topics.

Particularly when it comes to electromobility or energy-storage technologies, innovative solutions are needed, and these will be presented and discussed. For example, the special show on coilware production will depict the entire value chain, from refineries, materials and distributors to machines and final applications. It is being organized by the Electrical Winding & Insulation Systems (EWIS) Division of the ZVEI (German Electrical and Electronic Manufacturers Association).

The special show on automotive electronics deals with the high demands placed on that sector, and thus, on their production. The special show is being organized by the Productronics Society in the VDMA in conjunction with the Fraunhofer Institute for Reliability and Microintegration (FhG-IZM). It will shed light on topics such as reliability, sensor technology, power electronics, interiors and LEDs and examine how machine manufacturers are dealing with the industry's growing demands.

The PCB & EMS Marketplace celebrated its premiere in 2011. The gathering in Hall B1 was very well received among members of the international circuit-board and EMS industry, and we are looking forward to a lively exchange at

the industry platform and a number of innovations again this year.

The Cleanroom event stage in Hall B2 will feature several demonstrations and panel discussions on the "Modern Art of Cleanliness," and the Cleaning and Contamination Testing Center will deal with solutions for cleaning, contamination monitoring and overcoming common reliability failures.

Hands-on sessions such as live demonstrations, shows, product and service demonstrations, etc., are particularly popular among visitors and are held at the exhibitors' stands during the entire fair.

Finally, a personal question: What will be your highlight at productronica 2013?

CR: One of my personal highlights is the CEO Roundtable on the first day of the fair. Leading international executives introduce themselves and discuss one of the most popular topics: the Opportunities and Challenges of Industry 4.0. We will welcome representatives of Beckhoff Automation, DFKI, IG Metall, NXP Semiconductors Germany and the SDD Division of Mentor Graphics on stage. I also attach a great deal of importance to Student Day on the last day of the fair. It gives future engineers a chance to gather information about embarking on careers and to make contact with companies. Who knows, one of them may even turn out to be a future CEO for our roundtable event!

For a complete guide to productronica 2013, click here.

3D Printing: Tales from the Road

by Steve Williams

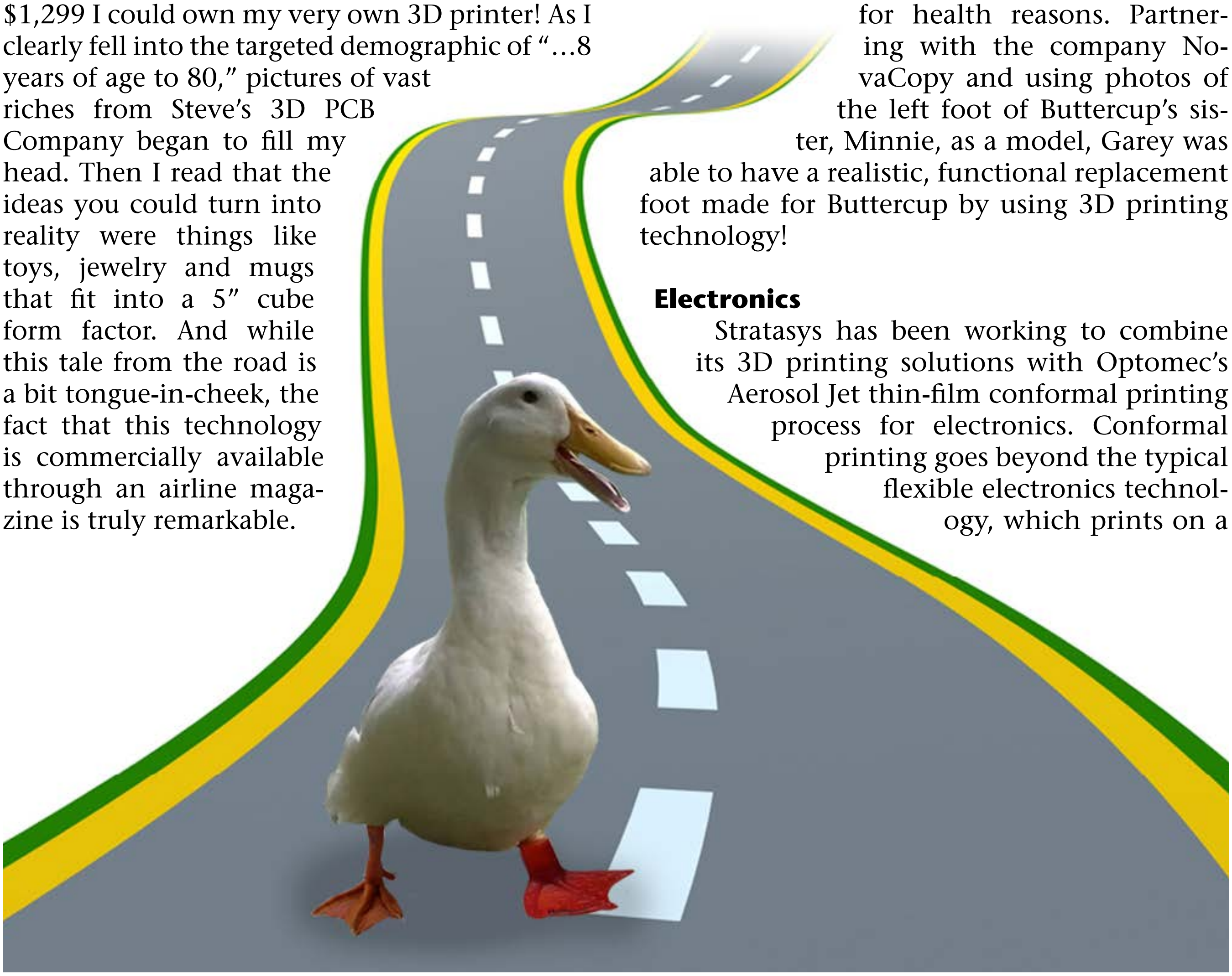
In September of last year, I wrote about the potential of 3D printing to "save" American manufacturing, as it was quickly becoming the new industry buzzword. Fast forward a year and it is clear that 3D printing may be here to stay and not just another passing fad.

Rockets & Choo-Choos & Dinos, Oh My!

On a recent vacation, I was perusing the current SkyMall catalog of overpriced gadgets that seem cool at the time, but generally result in buyer's remorse, and I couldn't believe what I saw on page 17. For the very reasonable price of $1,299 I could own my very own 3D printer! As I clearly fell into the targeted demographic of "...8 years of age to 80," pictures of vast riches from Steve's 3D PCB Company began to fill my head. Then I read that the ideas you could turn into reality were things like toys, jewelry and mugs that fit into a 5" cube form factor. And while this tale from the road is a bit tongue-in-cheek, the fact that this technology is commercially available through an airline magazine is truly remarkable.

Buttercup

Buttercup the duckling was born in a high school lab with a deformity that threatened his ability to survive on his own; Buttercup's left foot was turned backwards. For the first few months of his life, Buttercup limped around on his side, enduring severe pain and constant foot infections. Little Buttercup's future changed when he was rescued by Feathered Angels Waterfowl Sanctuary, in Arlington, Tennessee, which happened to be owned by software engineer Mike Garey, who was intent on helping the baby duck after his foot was amputated for health reasons. Partnering with the company NovaCopy and using photos of the left foot of Buttercup's sister, Minnie, as a model, Garey was able to have a realistic, functional replacement foot made for Buttercup by using 3D printing technology!



Electronics

Stratasys has been working to combine its 3D printing solutions with Optomec's Aerosol Jet thin-film conformal printing process for electronics. Conformal printing goes beyond the typical flexible electronics technology, which prints on a

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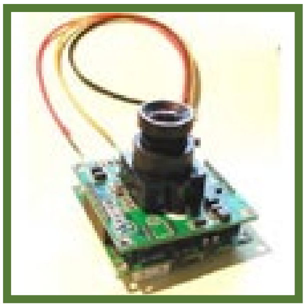

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2D flexible strip. This process matches whatever varied, three-dimensional surface on which it's printed, with all of its miniature mountains and valleys. Optomec has utilized this process to develop a method of printing 3D antennas on the standard plastic enclosures and inserts of smartphones and other mobile devices. This process will allow different placement of the antennas, thereby reducing mobile device thickness.

Beam Me Up Scotty

NASA is introducing its newest toy, a 3D printer built to make replacement parts in real time in space. According to astronaut Timothy Creamer, "3D printing provides us the ability to do our own Star Trek replication right there on the spot to help us replace things we've lost, replace things we've broken, or maybe make things that we've thought of that could be useful." In the upcoming months a 3D printer labeled Made in Space will be launched aboard the International Space Station. This 3D printer will allow astronauts to print either pre-loaded models or new designs uploaded to the printer from mission control.

> ***"3D printing provides us the ability to do our own Star Trek replication right there on the spot to help us replace things we've lost, replace things we've broken, or maybe make things that we've thought of that could be useful."***

Medical

Peking University's Dr. Liu Zhongjun has been using EBM 3D printing for the past four years to develop new spinal implants. During that time he's created dozens of orthopedic implants that have been custom engineered to fit each patient's body. Dr. Zhongjun currently has more than 50 patients in clinical trials with 3D printed implants and has used dozens of such implants in more than 50 other patients. He explains: "In the past, we used clinical titanium mesh, but with the growth of bone, titanium mesh could easily stick into the bone and cause collapse. 3D printed implants fit the bone completely. And as a result, not only the pressure on the bone is reduced, but it also allows the bone to grow into the implants." Zhongjun continued, "In this aspect, 3-D printed implants are more reliable than traditional ones."

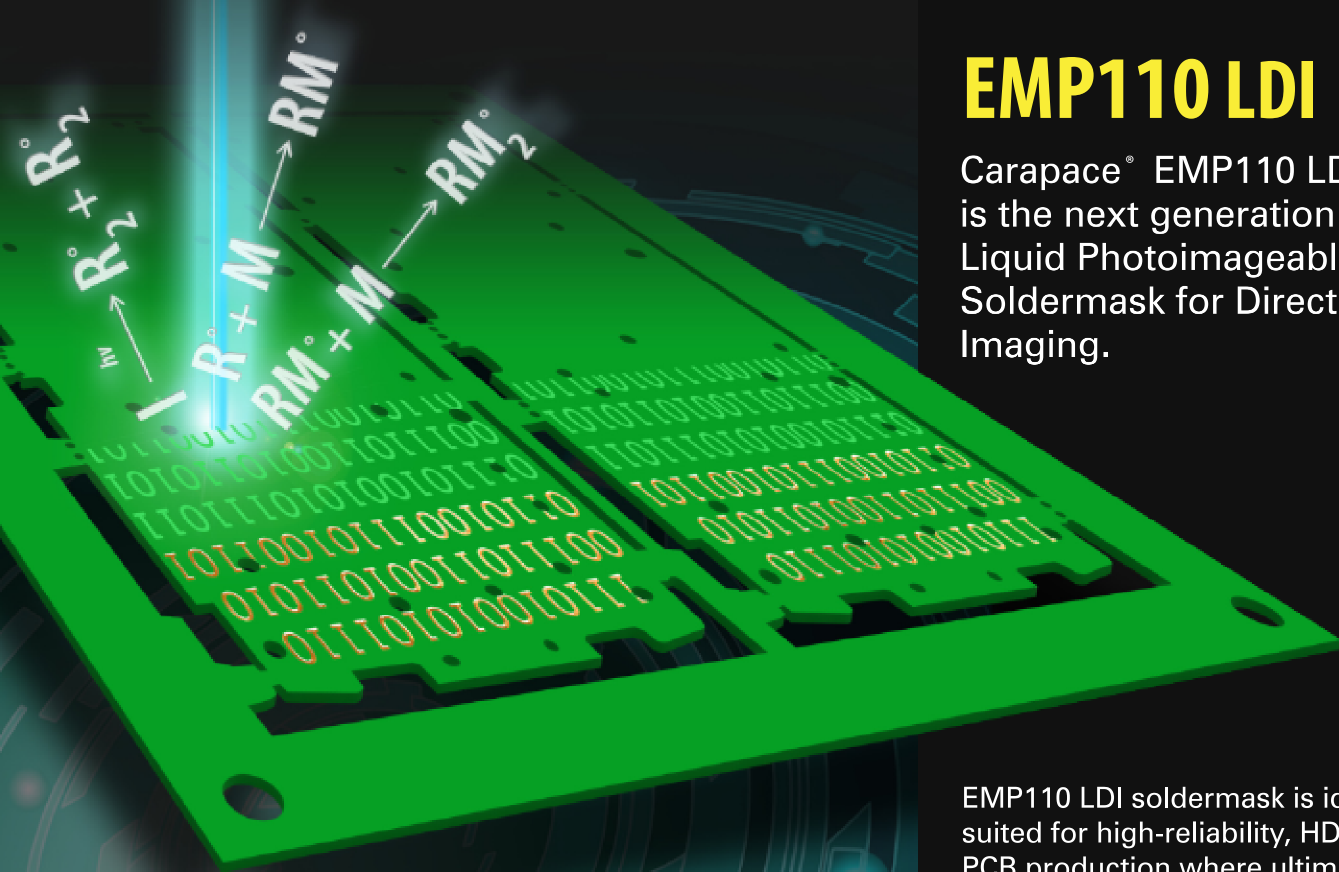
The Grizzly

While this may concern my friends that are a bit left of center, the technology is the focus of this tale. A Canadian 3D printing enthusiast known only as "Matthew" has created the world's first reliable 3D printed rifle! Created on a Stratasys Dimension industrial 3D printer, the Grizzly is a .22 caliber ABS plastic rifle made through 3D-printing technology, with the only exception being its firing pin. While not quite ready for prime time, the Grizzly 2.0 version can fire 14 bullets before breaking—a remarkable feat considering the complexity of a firearm and the combination of gun powder, heat and plastic. Can't wait to see what Grizzly 3.0 will bring!

A recent infographic published by MyCorporation & Visual.ly shows that 3D printing was the sixth fastest growing industry in the first half of 2013. With the explosion of both consumer (thank you, SkyMall) and corporate-level printers, this does not surprise me. As this current edition of Tales from the Road highlights, 3D printing is gaining steam and seems to be positioned to be a major change agent during the next five years. **PCB**

Steven Williams is the commodity manager for a large global EMS provider, and author of the book [Survival Is Not Mandatory: 10 Things Every CEO Should Know About Lean](). To read past columns, or to contact the Williams, [click here]().

Direct Image Solder Mask



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PCB007 Market News Highlights

LED Lighting System Market to Reach $55B by 2020

The LED lighting system market is expected to kick into high gear in 2013 and grow rapidly from 2015. In terms of revenue, the market is expected to reach $55 billion by 2020, from a mere $93 million (2012), with a high growth rate of 92.4% CAGR.

Health Care: New Tech Focused on Quality Improvement

Soaring healthcare costs, accompanied by growing demand from aging populations and emerging economies, are fueling technological and business innovation to address an emerging need in an industry worth trillions of dollars, according to Lux Research. "New technologies focused on improving the quality of healthcare are emerging across the medical spectrum," said Milos Todorovic, analyst.

Apple Faces New Challenge After Latest iPhone Release

The new 5S has dazzled onlookers with its fingerprint reader, while adding a better camera and a faster processor, but Dr. Klingebiel, Assistant Professor of Strategy at Warwick Business School, believes that Apple should go beyond product innovation and develop its strategy further as well.

Power Semiconductors in Automotive Industry to Witness Significant Growth

Environmental regulations, the electrification of the powertrain, the need for efficient power management, and the availability of new safety features are driving the global power semiconductor market in the automotive industry. The popularity of electric vehicles, which have a larger content for power semiconductors, is fueling installations.

Printed Electronics Market Continues to Grow

The global printed electronics market has become a widely growing sector in recent years due to the many benefits it offers, including long switching times, simple fabrication, and low fabrication cost. The Asia Pacific market holds majority of the market share closely followed by North America.

Solid State Lighting Market to Reach $56.79 Billion by 2018

Global solid state lighting market is expected to reach $56.79 billion by 2018, at an estimated CAGR of 18.7%, from 2013 to 2018. Backlighting and general lighting applications are contributing to the global solid state lighting applications market with a share of 87% in 2012 and is expected to record high growth in coming years.

Wearable Electronics Market to Reach $8.3 Billion in 2018

The market was worth $2.7 billion in revenue in 2012. In terms of product, wrist-wear accounted for the largest market revenue at $876.70 million, while neck-wear enjoyed the least market share, all as of 2012.

IPC's Costlow: N.A. Economy Slow, But Steady

A couple national manufacturing studies out this week highlight the continuing resurgence of American manufacturing. The economy may not be roaring back with any real speed, but it's seeing steady growth.

Global Semiconductor Market to Grow 3% in 2013

The worldwide semiconductor market is expected to grow 3% from 2012 to 2013. There has been sequential market growth from 1Q13 to 2Q13 and the vast majority of the top 20 vendors are expecting 3Q13 to grow revenues again.

U.S. CFO Economic Optimism Improves Entering 2H13

Top financial decision makers in the U.S. share an optimistic outlook towards the sustained economic recovery and opportunities for their businesses, according to findings from the most recent survey of chief financial officers conducted by Financial Executives International (FEI) and Baruch College's Zicklin School of Business.

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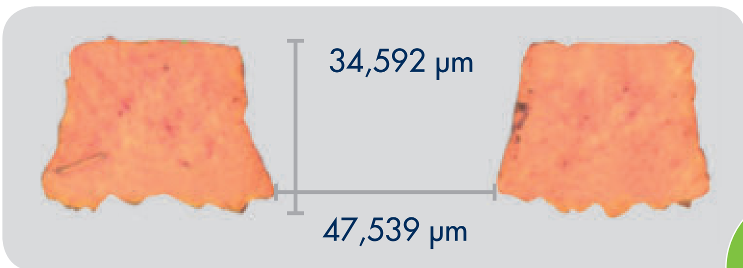

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Optimizing the Soldermask Process, Part 3

by Michael Carano
OMG ELECTRONIC CHEMICALS

Introduction

In previous columns (May and June, 2013) related to the soldermask process, I presented critical information on ink properties, methods of soldermask application, tack drying, etc. In this column, the exposure process is detailed. This includes exposure units, UV lamps, the phototool, and the overall exposure energy.

Exposure Process

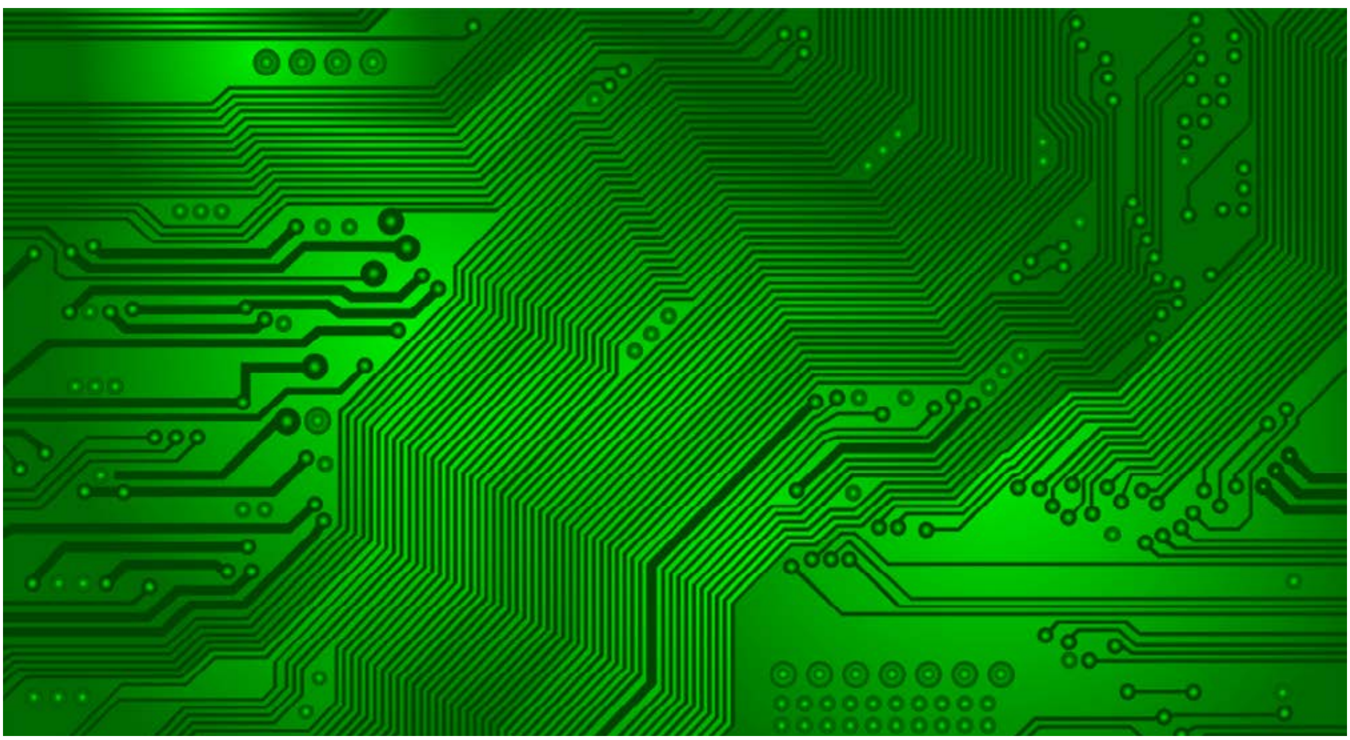
Once the soldermask ink is applied and properly tack dried, it is now necessary to expose the soldermask. Optimum exposure is critical in attaining a quality image. Essentially, exposure works hand-in-hand with development to maintain fine features and tight soldermask dams. Make no mistake: Proper exposure is the first step in the proper definition of the soldermask image. In order to achieve optimum exposure results the operator must consider the following:

- Exposure units
- UV lamps
- The photo tool or photographic template
- Exposure energy

All of these factors or critical aspects are important in order to optimize the exposure process. Each will now be presented in some detail.

Exposure Units

When specifying or purchasing an exposure unit for the soldermask operation, a unit with a minimum of a 5kW UV lamp and preferably a 7kW, is needed. The higher wattage will allow for shorter exposure times and minimize light scattering.



Equipping the unit with a sufficient vacuum will enable close contact of the phototool to the circuit board.

UV lamps

Liquid photoimageable soldermask (LPI) like primary photoresist are designed to respond (i.e., polymerize) when exposed to a particular wavelength of light. This is also known as the spectral response. For LPI, this is in the range of 350–375 nanometers. Over time and repeated number of exposures, the UV lamps will undergo a shift in the emission spectrum toward longer wavelengths. This situation in turn reduces the optimum exposure wavelength that the LPI ink is exposed to. When this occurs, longer exposure times and loss of resolution are the results. As a rule of thumb, UV lamps should be replaced after 1000–1500 hours of actual exposure use.

Phototool

The phototool, also known as the photographic template, is used to produce the image. Both diazo and silver halide films serve as the phototool. Here are the advantages and disadvantages of both:

• Intimate contact between the phototool and the ink-coated circuit board is necessary to produce an image of high resolution. Diazo films are more pliable than silver halide and thus conform more easily to the circuit board's conductors. However, the former is also thicker than silver halide, thus somewhat negating this advantage.

• Diazo films are better suited for optical registration since it possible to see through the opaque areas to register the tool.

Exposure energy

Ultimately, it is the actual exposure energy that affects the activation of photoinitiators leading to polymerization of the LPI ink. Exposure energy is measured in mJ/cm^2 (millijoules centimeter squared). Exposure energy is determined by the exposure intensity times the time of the exposure. Optimum exposure energy is beneficial in achieving vertical sidewalls on the exposed mask and preventing undercut (Figure 1).

There are two important tools one should use to quantify the exposure process. One such tool measures the intensity of the UV light that actually passes through the phototool. Essentially, exposure intensity and exposure energy are intertwined. For LPI it is recommended that a minimum light intensity of $7mW/cm^2$ through the phototool be required to effect ideal image reproducibility. A UV radiometer will provide an accurate measure of the UV light intensity through the phototool. This is an important point to remember. In addition to measuring the light intensity through the phototool, a step tablet should be used to further qualify

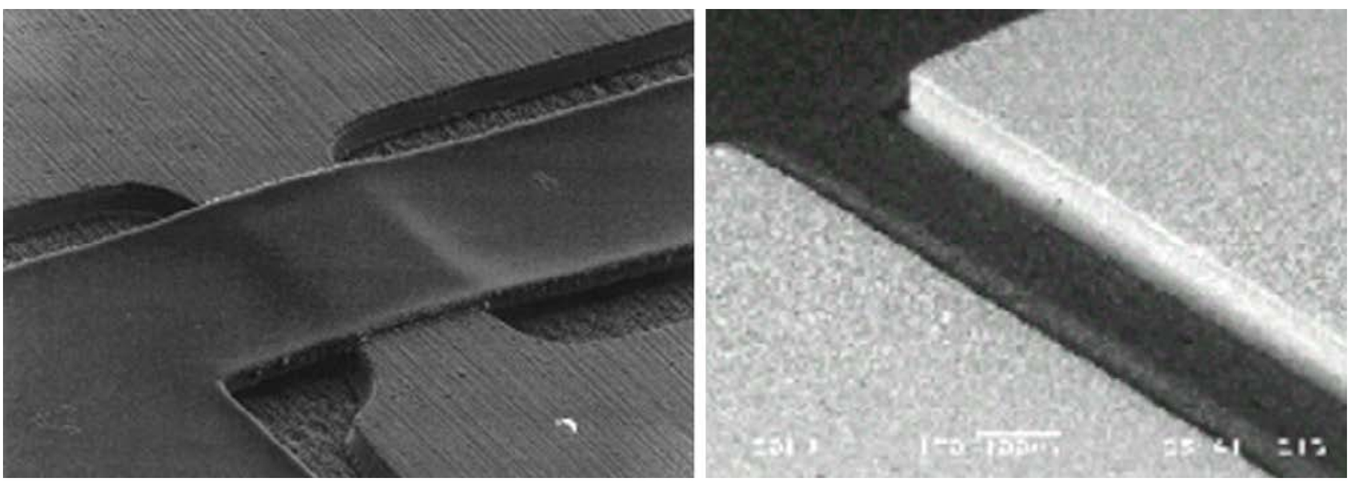
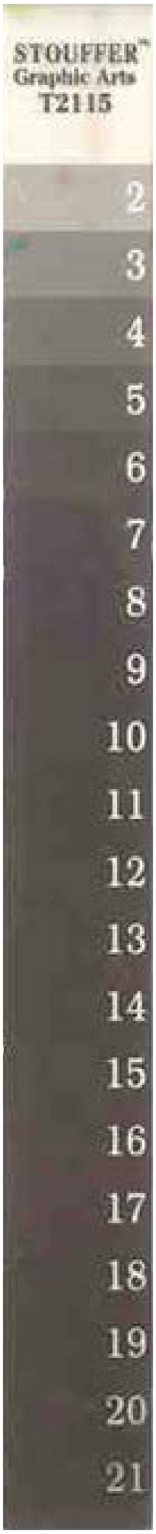


Figure 1: Exposed and developed soldermask; note straight sidewalls and absence of undercut.



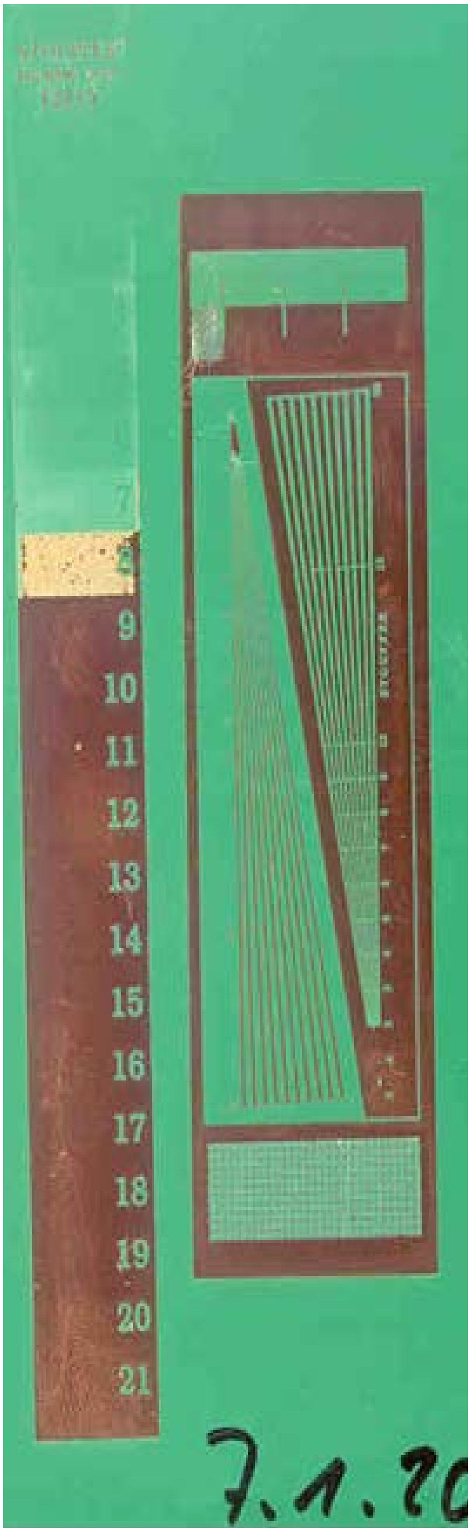


Figure 2: Actual step tablet (left) next to an actual circuit board with step wedge used to show the degree of exposure and development. As shown, the step that was held was 7 (where the green polymerized ink remains).

the performance of the LPI process. The step tablet or step wedge (Figure 2) is a film strip that is divided into various degrees of opaqueness. The darker the step the more impervious that step is to the UV light (21 steps in total). The step wedge is placed on the solder resist (perhaps a boarder of the circuit board) prior to exposure. The idea here is that the engineer will be able to quantify the entire process (exposure and developing) by inspecting to what step was actually held (after the developing process in the LPI process). If for example, after the developing, the first eight or so steps show solid polymerized ink that withstood the developing process, and steps 9–21 show no polymerized ink, one can state that the exposure energy and developing process were together capable of holding to a step 8. Now it may be that engineering decides that a step of 8 is not sufficient. Then one can increase exposure time and/or intensity to achieve a higher step if that is what is required. As is often the case with different solderable finishes, the requirement for the exposed soldermask to withstand these chemical solutions is to achieve a higher step (i.e., 10–12). Regardless, consult with the soldermask ink supplier about increasing exposure intensity and time.

There are concerns with overexposure and under developing as well. Underexposure will lead to poor resolution as well as undercut. Overexposure will lead to poor resolution as well and the possibility of partial polymerization of the ink in the vias and on the pads. Finally, there is a possibility that higher exposure energy will lead to polymerization of the ink on the unexposed side of the circuit board. This is commonly called shoot-through.

In a future column, the developing and curing process steps will be presented in detail. **PCB**

Michael Carano is with OMG Electronic Chemicals, a developer and provider of processes and materials for the electronics industry supply chain. To read past columns, or to contact the author, click here.

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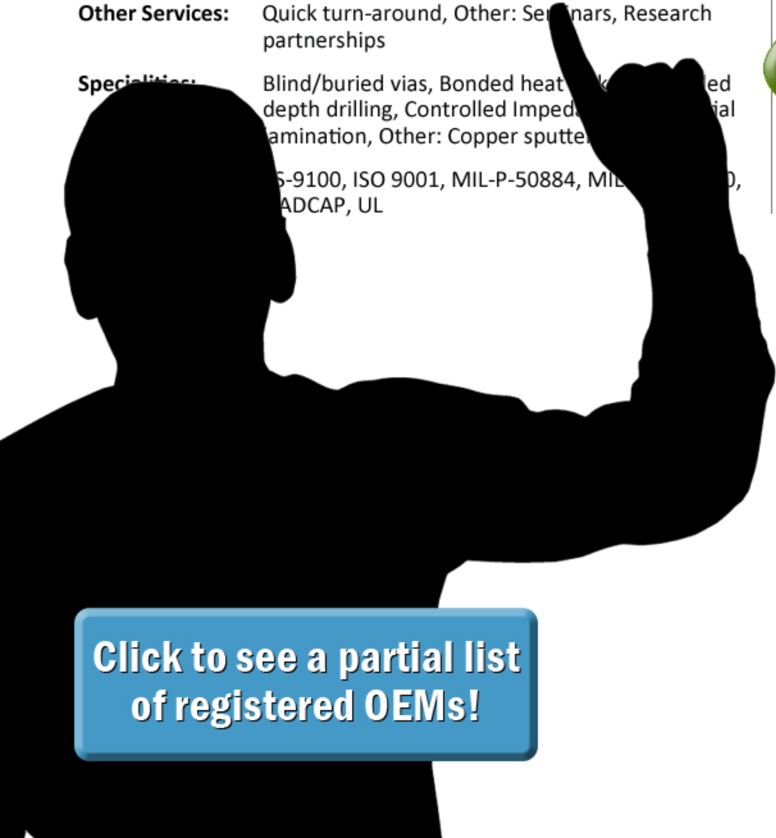

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Mil/Aero007 News Highlights

Hallmark Circuits USA Achieves Nadcap Certification

With this accreditation, all manufacturing sites of the SOMACIS Group—in Italy, China, and now in the U.S.—are Nadcap certified, as a further proof of the dedication of the company in assuring the highest possible standard of quality and reliability for advanced PCBs utilized in demanding industries such as aerospace.

Teknoflex Earns AS9100 rev C Certification

David Knight, director of quality and process engineering, commented, "It is good to finally reach the goal we set out to achieve; this was a company-wide effort and is a mark not only of the compliance of our QMS, but to the diligence and dedication of all of our staff."

Russia to Overtake West in Defence, Growth, Electronics

Steen Lomholt-Thomsen, IHS senior vice president, EMEA, said, "Russia is an exceptional opportunity. While leaders globally are concerned and cautious about geopolitical instability and economic volatility, business sentiment is rising in Russia."

Unmanned Surface Vessels Set to Conquer the Seas

Unmanned surface vessels still lag far behind their aerial equivalents in terms of technical capabilities, technology, and deployment. However, new threats, cost-benefit calculations, operational experiences in the past decade, and new technological developments are driving rapid growth in the market.

China's Aero & Defense Industry Seeing Rapid Growth

With a rapidly growing government budget for the defense sector, the Chinese aerospace and defense industry is witnessing the growth of many multinational companies who are setting up in the country and also actively indulging in joint ventures with Chinese companies.

SOMACIS Named Meggit's Preferred Supplier Partner

Meggitt PLC, a global engineering group specializing in extreme environment components and smart sub-systems for aerospace, defence, and energy markets, has selected SOMACIS as preferred supplier on PCBs.

Maritime Satellite Markets on Cusp of Bandwidth Revolution

"With the launch of GEO-HTS maritime services just on the horizon and MEO-HTS not far behind, maritime markets are on the cusp of a bandwidth revolution, yet, more data can also come in small bytes," explains Senior Analyst and report author, Brad Grady.

Interlocking Composite Components Create Big Structures

Researchers have developed a lightweight structure whose tiny blocks can be snapped together much like the bricks of a child's construction toy. The new material could revolutionize the assembly of airplanes, spacecraft, and even larger structures, such as dikes and levees. The new approach is described in a paper co-authored by postdoc Kenneth Cheung and Neil Gershenfeld, director of MIT's Center for Bits and Atoms.

Report: South East Asia Defense Market Opportunity Analysis

"South East Asia Defense Market Opportunity Analysis" research report gives comprehensive insight on following aspects related to booming Defense market opportunity in the South East Asian region.

Non-lethal Weapons Market on the Rise

The United States is a matured market with most of the market leaders situated in this region. The United States' non-lethal weapons market is estimated to be $183.0 million in 2013 and is expected to register a CAGR of 5.05%, to reach $234.2 million by 2018.

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Phototools—Part A

by Karl Dietz
KARL DIETZ CONSULTING LLC

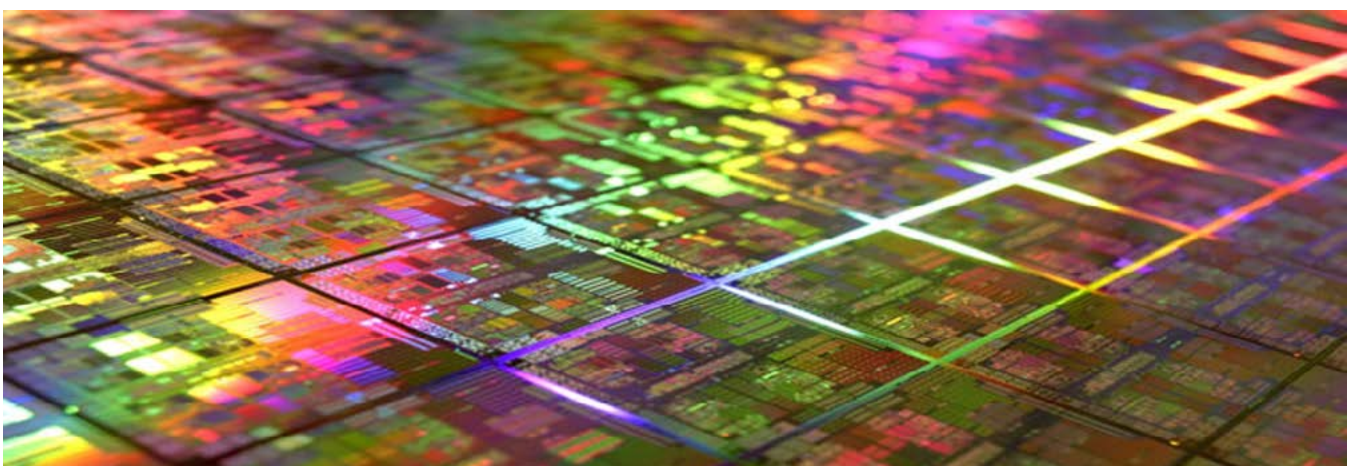
The objective of this column is to familiarize you with artwork generation, the film types and properties of silver and diazo films. Some technologies, no longer practiced, are mentioned to illustrate innovation and change over several decades.

It may be useful to explain the terms artwork and phototool. Historically, a "master artwork" was generated manually or by photolithographic means, or a combination thereof. This artwork was not used in the PWB exposure process to avoid damage to the artwork through handling and abrasion, but it was used to create copies, called phototools, which were used during exposure. Phototools may be called templates of the circuit pattern, with opaque and transparent areas through which UV radiation is transmitted in the transparent areas to form the resist pattern in the photoresist. Today, the phototool is directly formed from digital data in the photoplotter, so that "artwork" is a term used for the "data." The initial data are CAD data coming from the designer. The fabricator adds and modifies information in the CAM station. The CAM data encompass more information than just the circuit pattern: They include drill patterns, AOI data, legend pattern information, and soldermask pattern information. The circuit pattern information drives the photoplotter to generate the phototool. In the case of LDI (laser direct imaging), it drives the laser, omitting the generation of a phototool. Likewise, if legend print is inkjetted, the CAM data drive the inkjet, bypassing the generation of a screen for screenprinting.

The designer provides the circuit pattern for a "one-up" or single pattern. The CAM front-end engineer then steps, or repeats, the pattern for optimal use of a given laminate size. Additional features are then added (e.g., fiducials or registration targets, or non-functional copper areas for improved dimensional stability or better current distribution during plating, or copper areas around registration holes).

Phototools are either silver or diazo phototools. Less common, and more expensive, are chrome-on-glass phototools. Diazo phototools are transparent even in the darker unexposed areas and they come with a characteristic amber color.

Today's phototool plotters use the raster scanning method. Earlier models often used the vector plotting method. Figure 1 illustrates the difference in these methods. Raster scanning works pretty much like the formation of a picture on a TV screen. Raster scanning is faster than vector plotting and is independent of the complexity of the image.



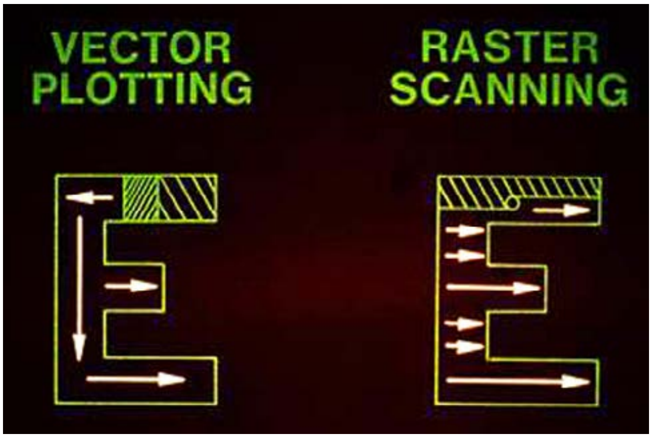


Figure 1: Vector plotting vs. raster scanning.

Figure 2 contrasts the earlier phototool generation methods with today's laser plotting.

The key characteristics of films are the speed class, spectral sensitivity, the reproduction mode, (i.e., positive vs. negative working, the processing chemistry), and the film type (e.g., silver vs. diazo, which basically determines the other characteristics listed here). Laser plotter films have a relatively high photospeed. By contrast, diazo films which are exposed by contact printing using a silver film to define the pattern, are much slower.

Films come with different "spectral sensitivities" (i.e., they are sensitive to different wavelengths of the electromagnetic spectrum). Most phototooling films do not see colors in the same way that we do. If they did, one would have to handle them in total darkness! The way films respond to different colors of light affects the room light conditions in which they can be handled in addition to how well they will work with different exposing lights. The following are the primary spectral sensitivity classes we use in PWB applications:

- Ultraviolet sensitive films respond only to UV radiation. They can be handled under yellow fluorescent lights for extended periods of time. UV sensitive photopolymer dry film photoresists and diazo films fall into this class
- Blue sensitive films are sensitive in the

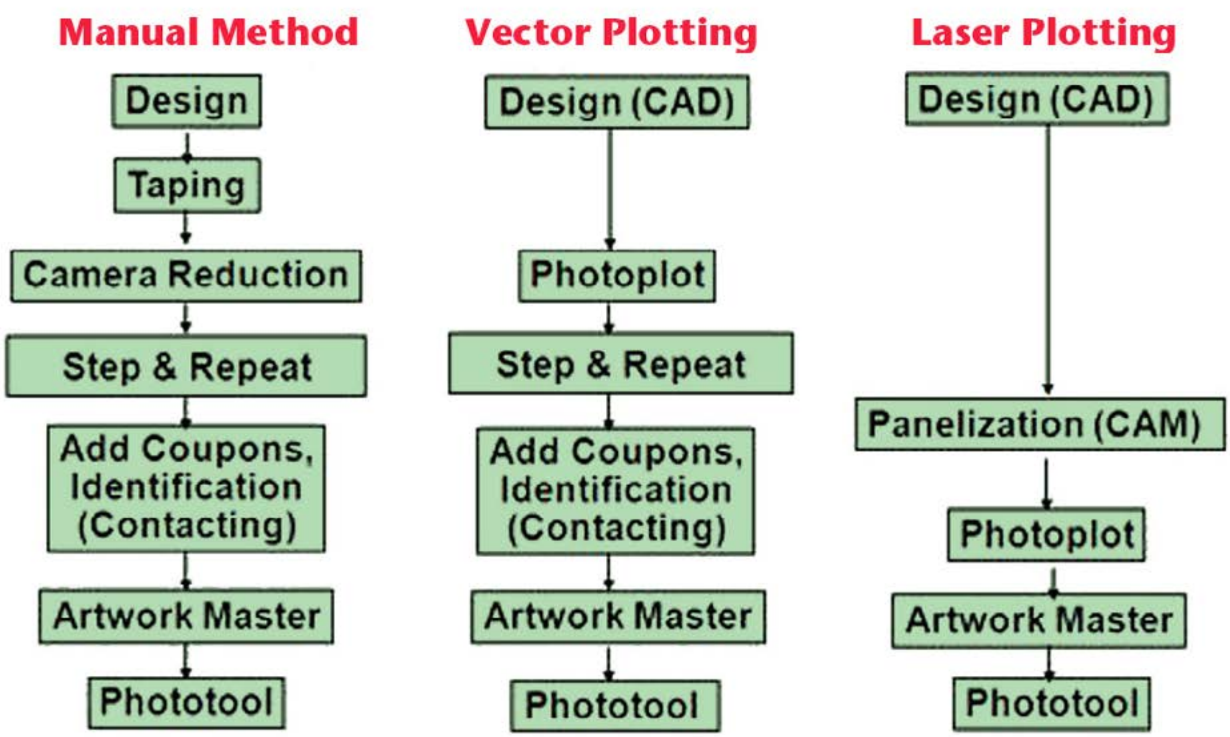


Figure 2: An overview of artwork generation methods.

blue light region and typically have some sensitivity in the near UV region as well. Most of these films exhibit the native color sensitivity of the silver halide grains, though filter dyes sometimes are added to depress their sensitivity in the blue and enhance their UV sensitivity. These films can be handled under amber safelights that are somewhat darker than the yellow fluorescent lamps used for UV sensitive films

- Orthochromatic films are sensitized to respond to green light as well as blue light. Most high speed films used in industrial applications are orthochromatic. Because they are sensitive to both blue and green light, the only color we can see that they cannot is red. Therefore, these films must be handled under red safelights.

Films which are sensitized to respond to blue, green, and red light are called panchromatic films. These films must be handled in total darkness because they see all of the light that humans see. The films used in 35 mm cameras are examples of panchromatic films. True panchromatic films are not often used in phototool applications.

A variation of the panchromatic film which is used with red laser plotters is the red sensitive film. This film is actually sensitive in the blue light as well as the red but has very little sensitivity in the green. This allows the film to be handled under very dim green safelights.

A comment about safelights: No safelight is 100% safe. Most safelights are intended to provide reasonable illumination without seeing a noticeable effect on the film for about10 to 15 minutes. Longer handling times will cause quality problems, as will faded or cracked safelight filters. One should test the safelights in the safelight area to determine how long you can safely handle your films.

Silver halide films are available as either negative working or positive working. A negative working film reproduces a black line on a clear background as a clear line on a black background. A positive working or duplicating film reproduces a black line as a black line (Figure 3).

Diazo films are usually positive working, while plotter films are negative working films. Contacting films could be either, depending on the desired appearance of the reproduction and the appearance of the original. Usually, a positive appearing image (black lines on clear background) is used for outerlayers, and a negative appearing image (clear lines on black background) is used for innerlayers.

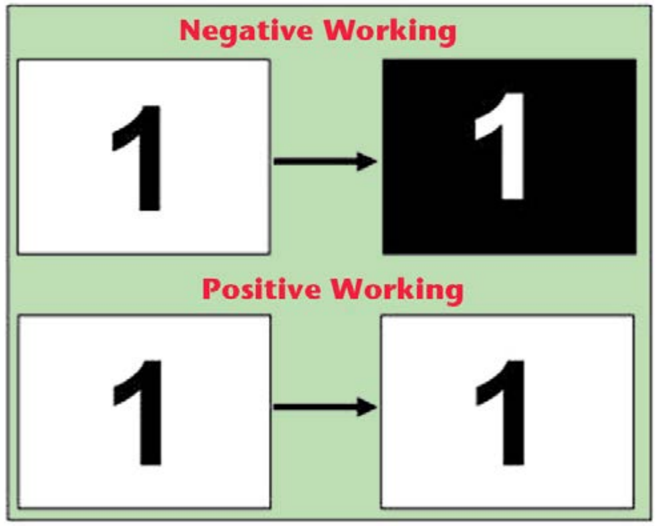


Figure 3: Negative vs. positive working films.

Not all silver halide films can be processed through any developer. Most films can be processed through either litho or rapid access developers. Few films are optimized for best performance through one kind of developer and do not work well when developed in another developer. The newer hybrid films and a few of the traditional litho and rapid access films exhibit this characteristic. When choosing a film for a particular application, the processing system to be used must be taken into consideration.

Acknowledgment

Information provided by my friend and former colleague, Robert Seyfert, is gratefully acknowledged. **PCB**

Karl Dietz is president of Karl Dietz Consulting, LLC, offering consulting services and tutorials in the field of circuit board & substrate fabrication technology. To view past columns or to reach Dietz, click here. Dietz may also be reached by phone at (001) 919-870-6230.

PCB007 Supplier/New Product News Highlights

Zuken Expands in Switzerland; Names New Operations Mgr

The company recently announced plans to expand its presence in Switzerland with the appointment of Tobias Martin as operations manager. Martin will lead a Swiss-based team focused on offering increased support and training to users of E3.series, Zuken's market-leading solution for electrical wiring and fluid design.

Insulectro Names James Kenny Technical Account Manager

Insulectro Vice President of North America Sales Kevin Miller commented, "We are very pleased to welcome Jim to our team. Jim is a respected industry veteran with a very strong engineering background. This technical knowledge, and his relationships with OEMs in the Northwestern United States, makes Jim an ideal fit for Insulectro.

Semblant's SPF & ProVIA System Selected by Tripod Tech

Semblant has announced global leading PCB fabricator Tripod Technology Corporation has selected the Semblant Plasma Finish (SPF) and ProVIA system to meet customer demands for high-volume PCB surface finish advancements.

Zuken's E3.eCheck Identifies Errors at Development Stage

"E3.eCheck represents an advancement in the tools available for electrical engineering of harnesses and control systems," says Steve Chidester, head of international marketing.

Longreach Group Acquires Shares of Hitachi Via Mechanics

Hitachi, Ltd. and The Longreach Group have announced that the two companies have concluded a share transfer agreement after agreeing that Hitachi will sell all the shares it owns of Hitachi Via Mechanics, Ltd. to the Longreach Group.

LTX-Credence to Acquire Dover's Multitest and ECT

The combination of LTX-Credence, Multitest, and Everett Charles Technologies will provide LTX-Credence with the opportunity to serve a greater share of the market, while increasing access to the electronics manufacturing industry. The combined company will be the only provider of comprehensive test solutions and services for the semiconductor and PCB markets.

Enthone Offers New OSP Performance Guide

Enthone recently published an organic solderability preservative (OSP) performance guide that enables OEMs, EMS, and PCB fabricators to easily determine how yields, quality, and reliability can be significantly increased throughout the supply chain, while dramatically reducing rework and rejects.

In-House PCB Prototyping at Eptech Mississauga & Ottawa

In-house PCB prototyping specialist LPKF Laser & Electronics has announced it will exhibit at both Eptech Mississauga and Eptech Ottawa. At both shows, LPKF will provide educational information about its rapid PCB prototyping equipment, including mechanical milling and laser etching systems.

OM Group Nets New $350 Million Credit Facility

"We are pleased to have the support of our banks for our growth strategy, including synergistic acquisitions," said Christopher M. Hix, CFO of OM Group, Inc. "This new credit facility includes attractive pricing and flexibility, recognizing our strong financial condition and more predictable business profile following the recent divestitures of our commodity businesses."


Why did you choose THAT fabricator?

Is Social Media Marketing Relevant?

by Judy Warner
TRANSLINE TECHNOLOGY

My column Does Marketing Matter? was so well received, I thought it worthwhile to plumb a bit deeper into the adoption of social media marketing and its relevance for the PCB industry. This subject matter is anything but simple. The best I can offer is to share a few tools from my toolbox and hopefully help you navigate your way through these murky waters.

For clarity's sake, here is how I would define social media marketing:

A set of online, socially interactive platforms and tools that help increase website traffic, connect with prospective customers, establish a company as an industry thought-leader, build a brand, create sources of inbound lead generation, and increase the amount of meaningful exchanges with current customers.

For businesses, these tools may include, but are not limited to: LinkedIn, Twitter, Facebook, YouTube, WordPress, Blogs, Google+, and content creation.

Bottom-Line Thinkers

Most of us in the PCB industry think in terms of the bottom line because we are always struggling to gain (or keep) precious market share. Therefore, we ask ourselves this question: Will social media increase my sales...right now? The obvious answer some people conclude is no, and therefore social media is not relevant; end of story. Another factor that comes into play is our age. At this year's IPC APEX EXPO, Alpha Circuits President Yash Sutariya made the interesting observation that at 40 years old, he feels like a youngster among our industry peers. So what does that mean? Well, I suspect it means that because of our age, we typically tend to be resistant to change and adopting new tools—such as social media. We have an attachment to what has worked in the past, even though the world has changed dramatically. We also watch our kids spend endless hours on social media, which seems frivolous to us. I mean, who really cares what I had for lunch? Our knowledge is complex and belongs in white papers—not on Facebook, right? Lastly, even if we are open to using social media, we are not sure how to effectively use it for our industry.

Paradigm Shifts That Rattle Us

It wasn't until I watched this brief, but impactful video that I fully understood the social media revolution. The demographics shown in the video are hard to grasp, aren't they? Along with individuals, small and large businesses alike are using social media as a key part of their overall marketing mix.

We have been brainstorming and experimenting, globally, about how to effectively use these tools to help our businesses to grow and prosper. Until recently, marketers have compartmentalized social media into segments such as B2B or B2C or C2C, etc. (business to business; business to consumer; consumer to consumer). In 2013, these segments are breaking down and dissolving as we see social media as more of an integrated whole that is called simply P2P and B2P (people to people or business to people). Here's another short but informative video that explains the shift in the P2P/B2P culture and how social media is gaining depth.

In other words, not only are IT people going to be using these tools, but so are sales and marketing people, CEOs, and supply chain folks. Even employees at the same company are engaging more frequently in multi-divison companies, using these tools to brainstorm and create innovative solutions at all levels of business. Here is one last, brief video further explaining this current trend.

The world is changing, and so must we—regardless of our past or prejudice. I have been using social media marketing for nearly three years to help our company grow. It hasn't been a vertical line of growth. It's been more of a bumpy roller-coaster ride, with a mixed bag of results. However, growth is occurring slowly and steadily, and it is picking up momentum as I become more skilled. What we have been able to create is everything on the following list:

Our website traffic has dramatically increased. We routinely connect with new prospects, and we have established ourselves as thought leaders. We have built a brand that went from complete anonymity to nationally recognizable, particularly in the RF/microwave market. We have multiple sources of inbound lead generation, and we have increased the amount of meaningful exchanges we have with our current customers. Most importantly, our sales have grown.

What tools have we used? Let me list them in order of importance (for us) along with links that I hope might help shorten your learning curve and provide an example of actual social media tools in action:

- LinkedIn (Personal and Company profiles)
- Content Creation
  - Articles: *The PCB Magazine*
  - Videos: Marketing in Today's PCB Climate and Real Time with IPC
  - Blog: Microwave Journal
  - Slideshare Slides
- Twitter
- Facebook
- YouTube
- Google+ (my newest platform—in progress)

> **"*Not only are IT people going to be using these tools, but so are sales and marketing people, CEOs, and supply chain folks.*"**

Just say no to being overwhelmed!

Okay, now take a breath. Everything I shared has taken almost three years to create and develop. I'm a big believer in baby-steps. If I could tell you just one thing to get started on immediately (if you aren't already) it would be to get really good at LinkedIn. Take some time each week to make connections and build your connection list—both with people you already know, and prospects you want to work with. Join a handful of groups and take 10 minutes a day to check the discussions in your groups and participate and offer insights along the way. Give sincere compliments to others that are doing the same. Over time, your connection list will grow and you will become recognized as an active and generous participant in your groups and relationships will begin to emerge naturally—just like in face-to-face interactions.

LinkedIn has been far and away the best social media platform we have engaged in for business-to-business interactions. It has also become an active source of inbound leads and quotes. The key is to not sell, but instead to be giving and resourceful. This is by no means a quick way to boost your bottom line, but the more consistent and authentic you are, the deeper and richer the opportunities will become.

You are not Alone

Let's face it, not everyone has the time or desire to do what I have done—but the great thing is that you don't have to! Outsourcing is a great way to tackle this task. There are two gentlemen that I have gotten to know (through LinkedIn, of course!) that can help you with both your social media marketing and your sales and marketing efforts. I'm sure there are others out there, but these two have been in the PCB industry for more than 30 years (each) and understand its nuances. Both men are regular contributors to www.pcb007.com. For social media marketing, check out Bruce Johnston's column, Getting Connected with Social Media. For sales, marketing and management, check out Dan Beaulieu's column, It's Only Common Sense.

The Brave New World

Those of us who have spent our careers in the PCB industry are slow-adopters of social media marketing and much of what the Internet has unleashed upon our society. Sometimes, like my parents before me, I want life to go backward and make it all slow down and get simpler.

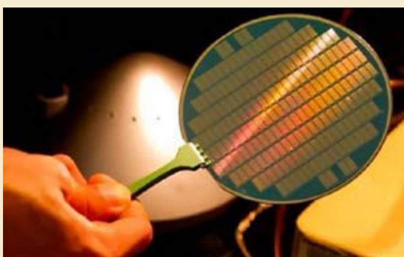
Yet, I know that other companies, industries, and even countries are embracing this technology to successfully grow their businesses and advance their causes.

Is social media marketing relevant? I think so, and I believe we must use it to remain equally relevant in the way we do business in this brave new world! **PCB**

Judy Warner is the director of sales and marketing for Transline Technology, a PCB manufacturer specializing in RF and microwave applications in Anaheim, California. To contact Warner, or to read past columns, click here.

Tiny Computer with Transistors Made from Carbon Nanotubes

With support from the National Science Foundation (NSF), a team of Stanford University engineers has built a tiny computer with 178 transistors made from carbon nanotubes, a semiconductor material that may replace silicon in computer chips. This change could launch a new generation of electronic devices that are smaller, cheaper, faster and more energy-efficient than those of today.



"This is greater than a promise; in the years ahead, it is a probability," said Mihail Roco, senior advisor for Nanotechnology at NSF, and a key architect of the National Nanotechnology Initiative.

The achievement, which culminates years of effort by scientists around the world, is detailed today in the cover story of the journal Nature. The research is led by Stanford professors Subhasish Mitra and H.S. Philip Wong.

"People have been talking about a new era of carbon nanotube electronics moving beyond silicon," said Mitra, an electrical engineer and computer scientist at Stanford. "But there have been few demonstrations of complete digital systems using this exciting technology. Here is the proof."

"This paper details a most significant nano-enabled integrated system with nanotubes that can perform a general set of computer programs proposed to replace the current transistor technology," said Roco.

"They have designed what is called a 'Turing complete' computer," explained NSF Computer Information Science and Engineering program manager Sankar Basu, who managed the funding for this project.

The Nature paper describes a two-pronged approach that enabled these Stanford engineers to create an «imperfection-immune design» for a basic computer.

TOP TEN

PCB007 News Highlights This Month

1 TTM Technologies Closes China MAS Plant

The company will cease operations and lay off approximately 600 employees at its Suzhou, China facility at or near the end of September 2013. TTM intends to transfer PCB production at MAS to one or more of its other facilities in China, providing an uninterrupted supply of PCBs to customers.

2 IPC: N.A. PCB Sales & Orders Trending Upward

Although still not quite in positive territory, YoY sales growth has been improving steadily over the past three months, bolstered by solid growth in orders since the beginning of 2013. Most of the improvements in July's results are due to the strong performance of the rigid PCB segment.

3 MFLEX Reports 20% Q3 Decline in Net Sales

"We believe our third quarter results will serve as an inflection point as we anticipate a meaningful sequential improvement in revenue in the fourth quarter with continued momentum into fiscal 2014…we expect to return to profitability in the first quarter of fiscal 2014, as well as on a full year basis in fiscal 2014," said Reza Meshgin, CEO.

4 Global PCB Market's CAGR to Grow 7.8% in 2012-2016

The analysts forecast the global PCB market to grow at a CAGR of 7.8% over the period 2012–2016. One of the key factors contributing to this market growth is the increasing adoption of smartphones and tablet PCs.

5 EMS & PCB Marketplace the Highlight of productronica 2013

ZVEI is organizing a series of technical lectures as part of a Highlight Day on November 13. Experts from the EMS sector will discuss "Silver Bullet: Development, Engineering, Manufacturing and Mechatronics from a Single Source: Are (Successful) EMS Providers becoming System Integrators?"

6 Wurth Elektronik Expands in China; Opens New Office

The company has been in Asia for over 13 years, where it has established several local businesses, manufacturing facilities, and its own quality and design center. With this move, the company is not only expanding its business area, but minimizing customer risk because it remains a partner throughout a product's life cycle.

7 Sunstone Circuits Upgrades PCB123; Launches New Version

The company has launched the newest version of their PCB design tool, PCB123, which includes two major upgrades to functionality: tools to create slots and cutouts and file-specific hole sizes. With the new version 5, PCB123 users can now create plated slots as small as 0.025" and as large as 0.250".

8 PCB Solutions Completes Complex Build for Nokia

Nokia contacted PCB Solutions in the early spring of 2013 by requesting a quote for the manufacturing and assembly of a very difficult PCB assembly requiring, but not limited to, controlled impedance, "crossed" or "surface controlled" blind and buried vias, copper filled vias under BGA pads for multiple layers and very tight trace and space requirements.

9 GUH: PCB Shipments Increase as Global Demand Rises

GUH Holdings Bhd managing director Datuk Kenneth H'ng said the group was seeing orders coming in for the third quarter of 2013, compared to a sluggish first and second quarter.

10 Cicor Reports 11.7% Sales Increase in 1H

The group's business volume grew by 12% compared with the first, weaker half of 2012 and by 3% compared with the good second half of 2012. While this growth is evidence of the growing demand for outsourcing services and high-tech manufacturing technologies, it is also the result of investments Cicor made in 2012.

EVENTS

For the IPC Calendar of Events, click here.

For the SMTA Calendar of Events, click here.

For the iNEMI Calendar of Events, click here.

For a complete listing, check out *The PCB Magazine's* full events calendar.

Long Island SMTA Expo and Technical Forum
October 9, 2013
Islandia, New York, USA

IEEE SMC 2013
October 13–16, 2013
Manchester, UK

electronicAsia
October 13–16, 2013
Hong Kong

SMTA International
October 13–17, 2013
Fort Worth, Texas, USA

SMTA Harsh Environments Symposium
October 15, 2013
Fort Worth, Texas, USA

SMC 2013
October 16—17, 2013
Santa Clara, California USA

2013 CEA Industry Forum
October 20–23, 2013
Los Angeles, California, USA

IMPACT-IAAC 2013
October 22–25, 2013
Taipei, Taiwan

TPCA Show 2013
October 23–25, 2013
Taipei, Taiwan

IEEE-SA Symposium on EDA Interoperability
October 24, 2013
Santa Clara, California, USA

Conformal Coating Reliability Seminar
October 24, 2013
Greater London, UK

MRO ASIA
October 29–31, 2013
Singapore

International Wafer-Level Packaging Conference
November 4–7, 2013
San Jose, California, USA

LA/Orange County Expo & Tech Forum
November 5, 2013
Long Beach, California, USA

productronica 2013
November 12–15
Munich, Germany

SMTA/iNEMI Medical Electronics Symposium—Tabletop Exhibition
November 12, 2013
Milipitas, California, USA

Aerospace & Defence Programs
November 13–14, 2013
Phoenix, Arizona, USA

MILCOM'13
November 18–20, 2013
San Diego California, USA

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Next Month in *The PCB Magazine:* Mil/Aero

The global military electronics market is presently worth about $77B, military avionics about $14B, and aerospace and commercial avionics about $50B. What do these market sectors expect and demand of their PCB suppliers, what approvals and qualifications are necessary, and how is PCB quality measured and certified? How does the US government control the import and export of defence related articles, services and technology? The November issue of *The PCB Magazine* explores the issues.