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2017 ANNUAL SALARY & CAREER REPORT

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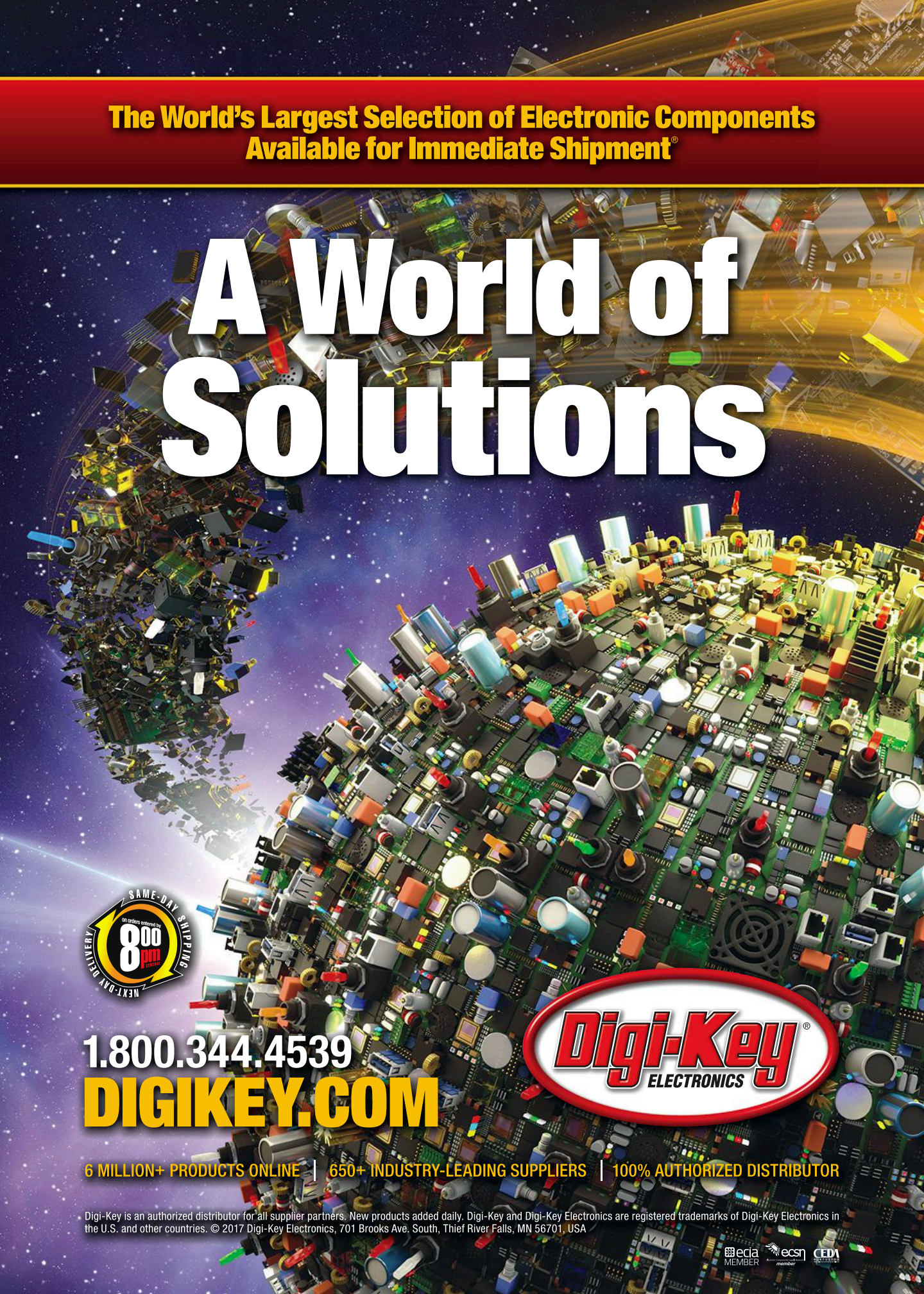

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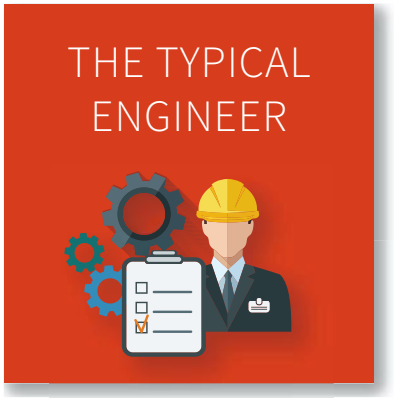

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To provide the most current, accurate, and in-depth technical coverage of the key emerging technologies that engineers need to design tomorrow's products today.

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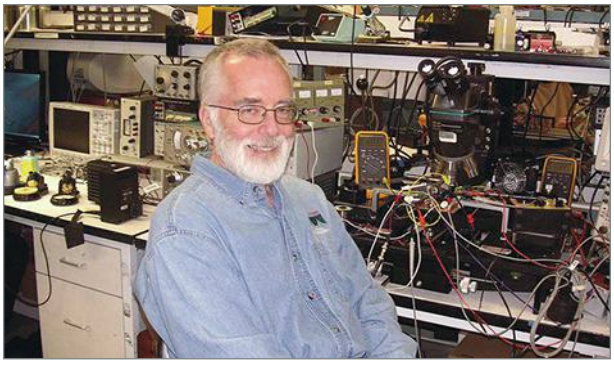
ON ELECTRONICDESIGN.COM

Ten Years of the iPhone and Counting…

With last month's introduction of the iPhone 8 and the unveiling of iPhone X, we take a look back at the iPhone's evolution, breaking down and comparing components and costs from the original to the iPhone 7.

http://www.electronicdesign.com/embedded-revolution/ten-years-iphone-and-counting



Q&A: "Analog Guru" Carl Nelson

In Paul Rako's cyber-interview with renowned engineer Carl Nelson, discussion ranges from his start in the industry, to his storied career that includes innovations like the LM35, to living in bear country.

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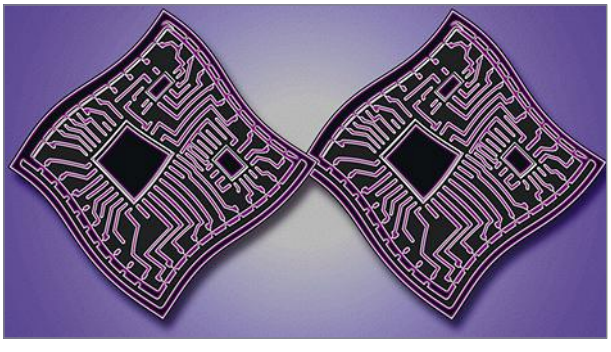
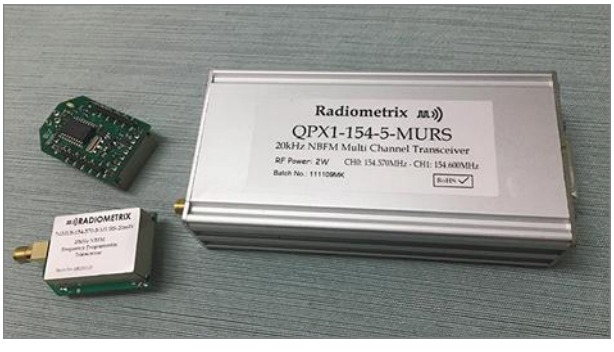


Designing with Ultra-Thin Printed Circuit Boards

Space savings, greater reliability, low mass, and high ductility are some of the advantages offered by flexible PCBs, but designers must also prepare for their complexity. This would also involve testing the ergonomics of the installation, any misalignments, and servicing. In addition, it necessitates that designers understand the different types of flex circuits available and the way they work.

http://www.electronicdesign.com/industrial-automation/designing-ultra-thin-flexible-printed-circuit-boards



MURS: Another Potential IoT Wireless Option

Most Internet of Things (IoT) projects are adopting the well-known wireless technologies like Wi-Fi, Bluetooth, Z-Wave, ZigBee, and other IEEE 802.15.4-based standards. But if longer range is needed, consider the often overlooked MURS (Multi-Use Radio Service).

http://www.electronicdesign.com/wireless/murs-another-potential-iot-wireless-option

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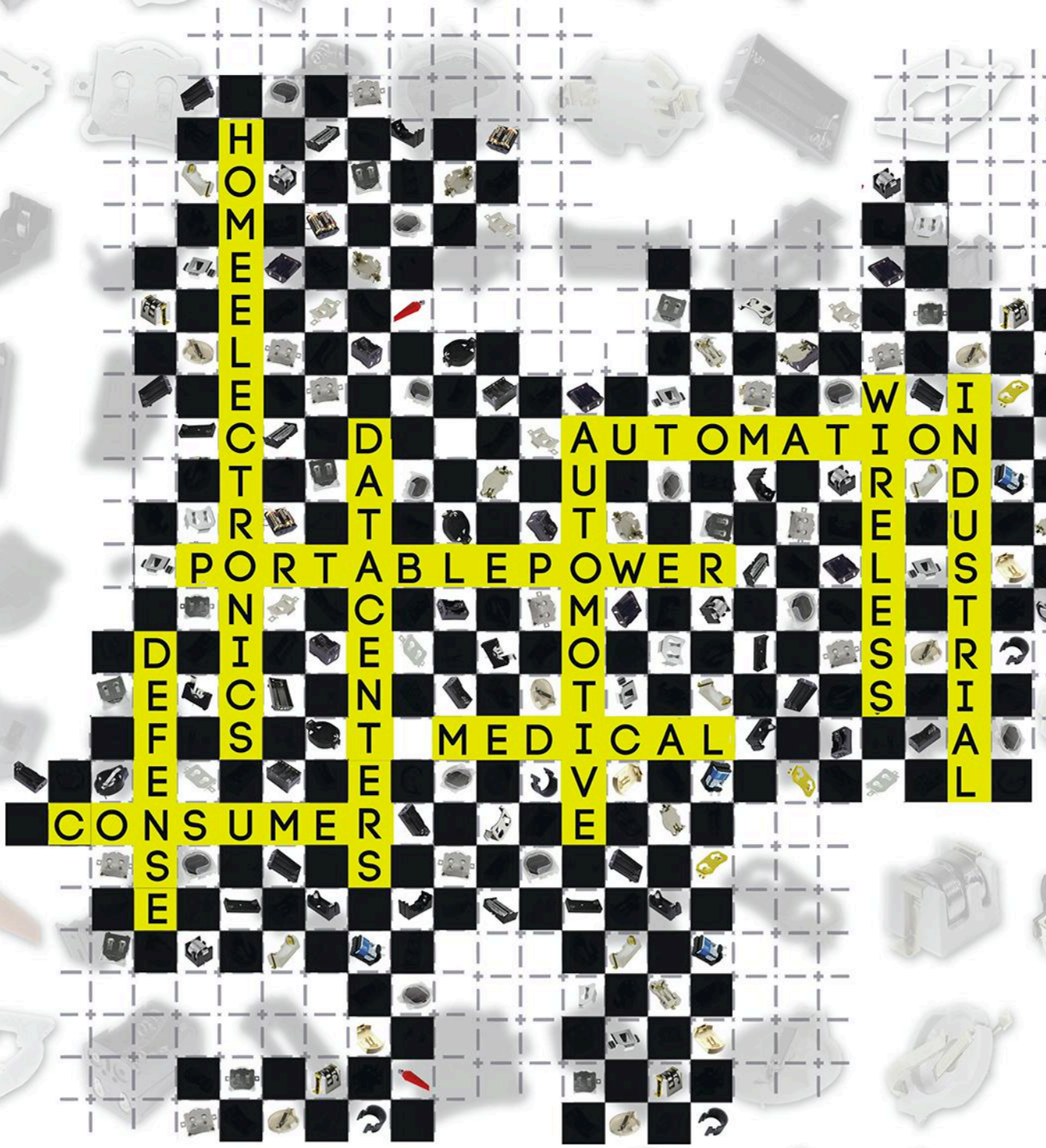

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EDITORIAL

CONTENT DIRECTOR: **NANCY K. FRIEDRICH** nancy.friedrich@penton.com
CONTENT PRODUCTION DIRECTOR: **MICHAEL BROWNE** michael.browne@penton.com
CONTENT PRODUCTION SPECIALIST: **ROGER ENGELKE** roger.engelke@penton.com
PRODUCTION EDITOR: **JEREMY COHEN** jeremy.cohen@penton.com
EMBEDDED/SYSTEMS/SOFTWARE: **WILLIAM WONG** bill.wong@penton.com
ANALOG/POWER: **MARIA GUERRA** maria.guerra@penton.com
CONTENT OPTIMIZATION SPECIALIST: **WES SHOCKLEY** wes.shockley@penton.com
ASSOCIATE CONTENT PRODUCER: **LEAH SCULLY** leah.scully@penton.com
ASSOCIATE CONTENT PRODUCER: **JAMES MORRA** james.morra@penton.com
CONTRIBUTING EDITOR: **LOUIS E. FRENZEL** lou.frenzel@penton.com

ART DEPARTMENT

GROUP DESIGN DIRECTOR: **ANTHONY VITOLO** tony.vitolo@penton.com
SENIOR ARTIST: **JIM MILLER** jim.miller@penton.com
CONTENT DESIGN SPECIALIST: **JOCELYN HARTZOG** jocelyn.hartzog@penton.com
CONTENT & DESIGN PRODUCTION MANAGER: **JULIE JANTZER-WARD** julie.jantzer-ward@penton.com

PRODUCTION

GROUP PRODUCTION MANAGER: **CAREY SWEETEN** carey.sweeten@penton.com
PRODUCTION MANAGER: **FRAN VAUGHN** fran.vaughn@penton.com

AUDIENCE MARKETING

USER MARKETING DIRECTOR: **BRENDA ROODE** brenda.roode@penton.com
USER MARKETING MANAGER: **DEBBIE BRADY** debbie.brady@penton.com
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SALES & MARKETING

MANAGING DIRECTOR: **TRACY SMITH** **T** | 913.967.1324 **F** | 913.514.6881 tracy.smith@penton.com

REGIONAL SALES REPRESENTATIVES:

AZ, NM, TX: **GREGORY MONTGOMERY** **T** | 480.254.5540 gregory.montgomery@penton.com

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SHANNON ALO-MENDOSA **T** | 978.501.9116 shannon.alo-mendosa@penton.com

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BELGIUM, NETHERLANDS, LUXEMBURG, UNITED KINGDOM, SCANDINAVIA, FRANCE, SPAIN, PORTUGAL:
JAMES RHOADES-BROWN **T** | +011 44 1932 564999 **M** | +011 44 1932 564998 james.rhoadesbrown@husonmedia.com

ITALY: **DIEGO CASIRAGHI** diego@casiraghi-adv.com

PAN-ASIA: **HELEN LAI** **T** | 886 2-2727 7799 helen@twoway-com.com

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SMARTREACH CLIENT SERVICES MANAGER: **JAMES ADDISON** **T** | 212.204.4318 james.addison@penton.com

ONLINE

PRODUCT DEVELOPMENT DIRECTOR **RYAN MALEC** ryan.malec@penton.com

DESIGN ENGINEERING & SOURCING GROUP

EXECUTIVE DIRECTOR OF CONTENT AND USER ENGAGEMENT: **NANCY K. FRIEDRICH**
GROUP DIRECTOR OF OPERATIONS: **CHRISTINA CAVANO**
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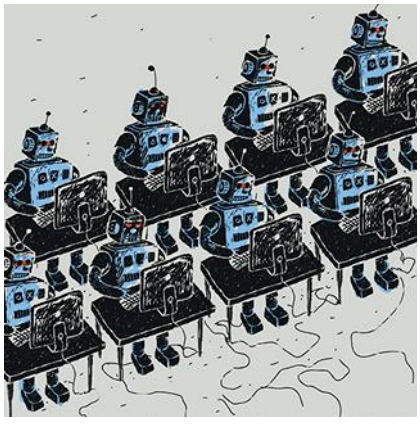
AI Means More Jobs, Not Less

Even as robots take over some manufacturing duties, new industries and fields will guarantee continuous opportunities—especially for engineers and other technical professionals.

It's an oft-leveraged promise for politicians: "We'll bring jobs/manufacturing/etc. back." "Back" means to the U.S. mainland versus China, India, Mexico, etc. While making it more beneficial for manufacturers to invest in the U.S. would obviously be beneficial in many ways—including to the work force—this promise is an outdated one. Some jobs are going away—especially in manufacturing—and they are not coming back. The reason, of course, is automation.



But I'm not here to tell our engineering audience that automation is changing the employment landscape. You are the ones writing the software, developing the algorithms, deploying the sensors, and more. Engineers have a front-row seat to this tremendous leap in how people live, work, and function in myriad ways. As we roll out the results of our annual Salary & Career Report (see page 12), we are not yet seeing the impact of this change in your opinions about your career, salary, education, and more. The responses of our engineering audience are much in keeping with recent years.

These findings tell us that engineering jobs are not feeling much negative impact from the rise of automation. In fact, some say increased automation bodes well for engineers, who will see an increase in engineering jobs. Others predict that we will need more engineering, but with a mix of information-technology (IT) skills to manage automated approaches. It's probably pretty safe to predict that while we will still need engineers in large numbers, there will be a different mix of tasks for them to do. The prime example is more coding.

Last month, CNBC published an article on the topic of robots taking jobs featuring Lee Rainie, director of internet and technology research at the Pew Research Center. According to Rainie, "analysts see a trend in so-called STEM jobs involving science, technology, engineering, and math." In particular, Lee singled out algorithm writers and assessors as being in demand.

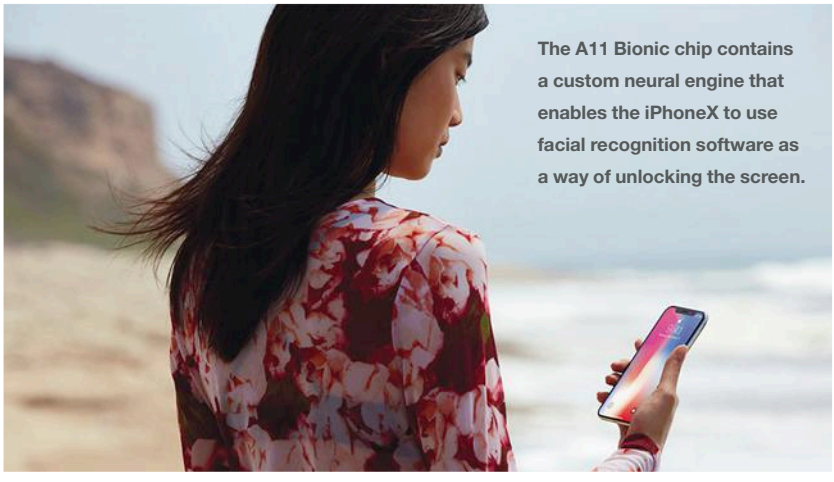
Beyond engineering, the outlook—even with AI in our midst—is certainly not all doom and gloom. As noted by research-based firm TechCast Global, "The tech revolution is creating a flood of new products, services, and industries that are taking off: e-commerce, alternative energy, green economy, IoT, high-tech homes, climate control, intelligent cars, etc. The field of energy, climate change, and environment alone is likely to create a $10- to $20-trillion global industry. TechCast estimates market saturation for about 50 technologies at an average of about $1 trillion each, for a total of about $50 trillion in new economic growth over the next few decades. That's as big as the present global economy. All these industries will create lots of new jobs, including routine jobs."

The key, it seems, is in re-training and re-educating our work force as we adapt. Gone will be many of the jobs of yesteryear, which would remain relatively the same throughout a person's work career. Going forward, more people may start off performing one role in one profession and then be prompted to change—either to a different profession or to fulfill a new or adapted role within their current field. People may have two, three, or four very different careers over their work lives. It may be that we rely on AI as a teacher and guide as we learn new required skills, making artificial intelligence a partner instead of a foe. ED

News

APPLE'S FINGERPRINTS ALL OVER
New iPhone Chips

The latest iPhone models contain lots of silicon that Apple developed by itself for itself. During its annual launch event last month, the company boasted about the capabilities of its newest chip—a tiny silicon slab called the A11 Bionic.



The A11 Bionic chip contains a custom neural engine that enables the iPhoneX to use facial recognition software as a way of unlocking the screen.

Etched with 4.3 billion transistors, the chip contains a six-core CPU and custom GPU that Apple built specifically for the new iPhone 8, the larger iPhone 8 Plus, as well as the premium iPhone X. The company unveiled it at Apple's new corporate headquarters in Cupertino, Calif.

Apple said that inside the CPU are two performance cores 25% faster and four efficiency cores 70% faster than the firm's previous generation chip, the A10 Fusion. It is also 70% faster at multithreading, in which a computer chip chews on small sets of code at different stages of execution.

The A11 also contains a custom neural engine that enables the iPhoneX to use facial recognition software as a way of unlocking the screen. Phil Schiller, Apple's senior vice president of worldwide marketing, said that it can perform 600 billion operations per second without burning through battery life.

The GPU runs around 30% faster than the A10, Apple said. The company said it also musters the same performance as the A10 while consuming half the battery power. It takes advantage of improved cameras and new motion sensors to better support augmented reality applications, which overlay digital images on scenes viewed through the smartphone.

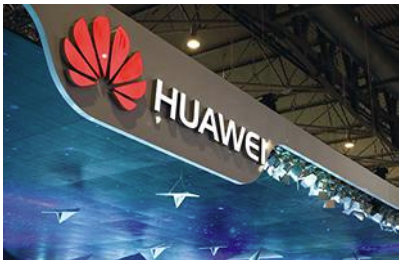
The new graphics chip can also accelerate applications using machine learning to recognize objects in images, improve photo composition, and other advanced software tasks that would normally require models to be trained in data centers and then recalled from the cloud.

The GPU announcement comes after Apple vowed in April to phase out graphics chips in its smartphones, watches, tablets, and televisions licensed from Imagination Technologies within the next two years. Imagination has been trying to curb the financial fallout by putting other business units up for sale. But since June, the company seems resigned to its fate.

Imagination is now trying to sell itself completely and Apple was viewed as an unlikely but possible destination. The company had used Imagination's graphics since the first iPhone came out a decade ago, and it poached engineers from the firm's ranks. But after Tuesday's announcement, an acquisition seems unlikely.

Apple's chip engineers also built an image signal processor (ISP) and video encoder from scratch. That way, the iPhone 8 camera can estimate lighting conditions and autofocus faster in low light, and provide real-time image and motion analysis to optimize video. The A11 handles world tracking and scene recognition for augmented reality.

Developing silicon is nothing new for Apple, one of the world's largest chipmakers thanks to its smartphone sales. It has also applied its semiconductor smarts—led by Johny Srouji, Apple's senior vice president for hardware technologies—to the W1 connectivity chip inside its wireless earbuds and the T1 touch bar chip for the MacBook Pro. ■



HUAWEI'S SMARTPHONE CHIP Eases Artificial Intelligence

HUAWEI REVEALED ITS latest smartphone chip, the Kirin 970, which contains a neural processing unit to sort images, translate text, and understand speech. The company said that the custom silicon lets smartphones do artificial intelligence tasks without using the cloud, where such software typically runs.

Many companies are trying to reap the benefits of this embedded artificial intelligence. In smartphones, personal assistants could relay faster insights to users without being connected to the internet and preserving privacy. In sensors, messages sent to the cloud could be condensed, saving battery life and network bandwidth.

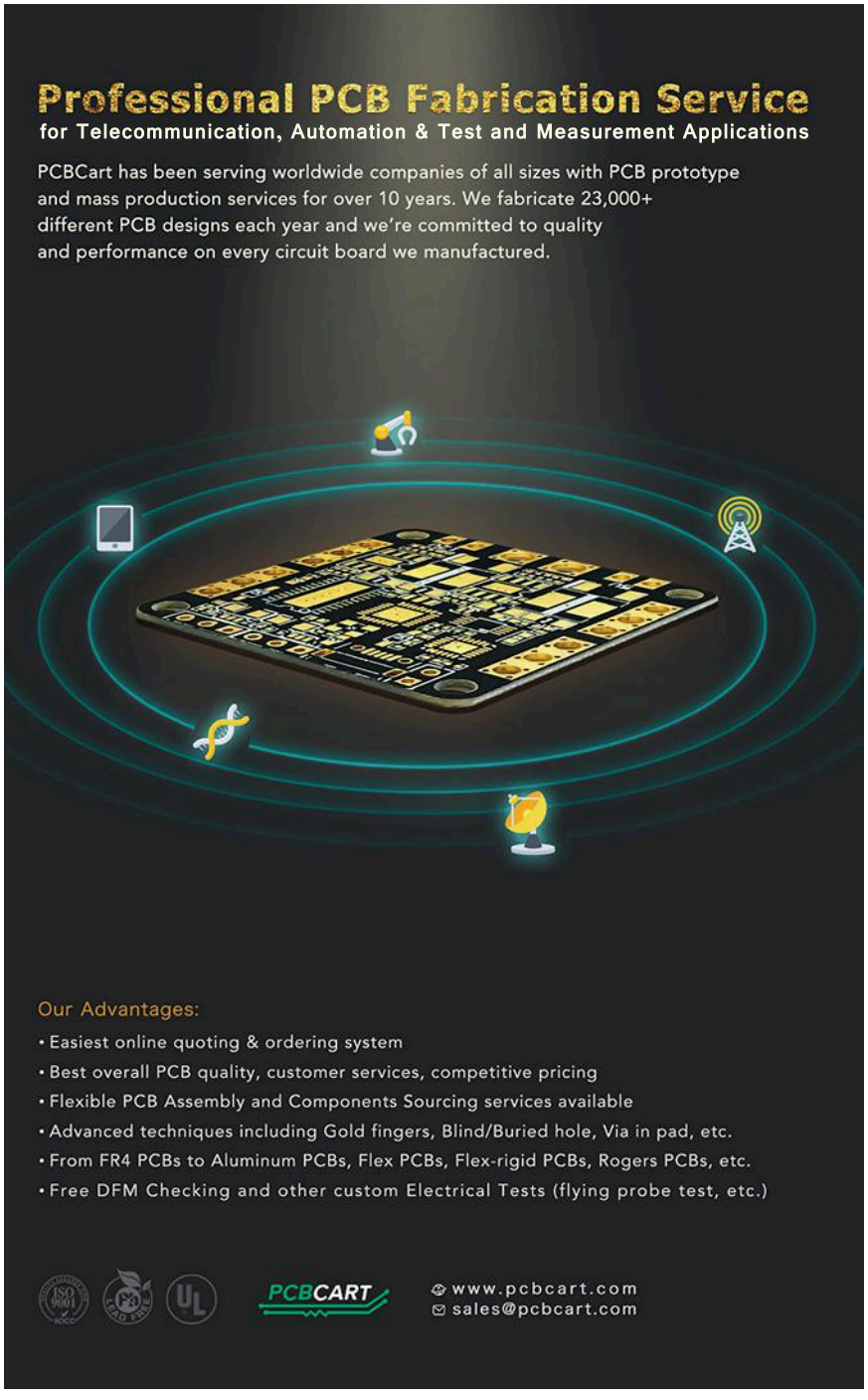
With the neural processing unit, Kirin can run image recognition and other artificial intelligence tasks around 25 times faster and 50 times more efficiently than quad-core Arm Cortex A-73 processors. Huawei's semiconductor unit HiSilicon also equipped the chip with an eight-core CPU and 12-core GPU.

Huawei's announcement comes amid other attempts to impart artificial intelligence to gadgets. Last month, Intel released a computer vision chip that enables drones to avoid obstacles and recognize gestures. Microsoft has planned a custom chip that could, for example, translate signs in a foreign language viewed through its HoloLens goggles.

Qualcomm, the world's largest smartphone chip maker, stopped short of selling chips with its own neural processing unit. Instead it released a software tool to cleverly portion out the existing processing power its chips, so that machine learning and augmented reality programs can run vastly more efficiently on smartphones.

Huawei did not mention which smartphones would have the Kirin 970 installed. But the company plans to release its new flagship phone this month. The chip—whose 5.5 billion transistors were manufactured in 10 nanometers—is only part of Huawei's strategy. It also sells telecommunications equipment and hardware for data centers.

"Huawei is committed to turning smart devices into intelligent devices by building end-to-end capabilities that support coordinated development of chips, devices, and the cloud," said Richard Yu, chief executive of Huawei's consumer business, in a statement. "The ultimate goal is to provide a significantly better user experience." ■



AIMING TO DIVORCE CLOUD, Qualcomm Buys Machine Learning Start-Up

LAST YEAR, QUALCOMM stopped short of including an accelerator core called the neural processing unit its Snapdragon silicon. Instead, it announced that it would publish software to bend its existing smartphone chips to the whims of machine learning.

The strategy shift shows Qualcomm's sense of urgency around machine learning, which has typically required powerful servers to understand speech and sensor readings. It also reflects the chipmaker's plans, which it elaborated on last month when it acquired Dutch machine-learning startup company Scyfer.

Scyfer's software has been used to classify manufacturing defects for Tata Steel and predict store revenues for Dutch supermarket chain Albert Heijh. It runs machine learning techniques on storehouses of data generated by factory sensors, online shoppers, cameras, bank transactions, and medical imaging machines.

Making sense of such information usually happens in data centers. Shelves of graphics chips train models on, for instance, the identifying features of images of cats. Then, algorithms apply that model to a particular cat in a smartphone video or photo. This is called inferencing, and it also typically occurs in the cloud.

Qualcomm wants to take inferencing out of the cloud, bringing it to individual gadgets. That would allow a smartphone to translate text written in a foreign language without calling back to the cloud, or a sensor to identify chemicals leaking from an oil refinery, instead of streaming raw data to the cloud for the final word.

Matt Grob, Qualcomm's executive vice president of technology, wrote in a blog post that "in many cases, inference running entirely in the cloud will have issues for real-time applications that are latency-sensitive and mission-critical like autonomous driving."

Grob added that such "applications cannot afford the roundtrip time or rely on critical functions to operate when in variable wireless coverage." The benefits, he said, include more privacy and lower latency when chatting with the cloud over the internet. Messages sent to the cloud would also be condensed, saving battery life and network bandwidth.

"The cloud remains of course very important and will complement on-device processing," Grob said. That strategy fits Qualcomm, which has been trying to plant roots in markets like robotics and sensors. Last year, it gave the clearest sign yet of its ambitions, agreeing to pay $47 billion for NXP Semiconductors, the world's largest maker of automotive chips. ■

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JAMES MORRA | Associate Editor

2017 *Electronic Design* SALARY & CAREER REPORT:

All About the Right Place, Right Time

For electrical engineers today, productivity is power. Asked to do more than ever with fewer resources, engineers with a broad range of expertise can command higher salaries, compete for limited jobs, and carve out a place in an industry interwoven with outsourcing.

That was a major takeaway from 2,000 electrical engineers surveyed by *Electronic Design*. In general, engineers are in high spirits even though employers continue to tighten their belts. They still take satisfaction from the technical challenges of the profession, where it is increasingly hard to plant professional roots.

Not everything, however, is staying the same. Around 37% of survey respondents said that their companies plan to hire more engineers in the next year, up from 29.5% from last year. Separately, many engineers are skeptical that new hires will stick around long.

"We can't get people to stay," said one respondent. Others added that employers are hiring young engineers who earn lower salaries but need additional training. At the same time, they are looking for those with broad expertise in fields like analog and systems engineering—a scarce commodity these days.

As electrical engineering companies continue to merge and trim headcounts, it is not clear that more jobs are available. The Bureau of Labor Statistics says that there were 315,900 jobs for electrical engineers in 2015, and that the profession would see zero growth in the United States in the next seven years.

Nonetheless, companies are willing to pay well for the right engineering talent. This year, the average base salary for electrical engineers dipped to $104,996 from $106,250 in 2016. That is still higher than the $99,514 that engineers earned on average in 2015.

Yet as salaries continue to rebound from the economic recession, engineers are grappling with lukewarm attitudes from employers. This year, only 31.3% of respondents feel that their company is more focused on employee retention than last year, down from around 55% of engineers in 2011.

"My employer is hoping to improve their value proposition for young people," said one engineer who filled out the survey. "But they need to update their benefits to better align with the shift from one employer over a career to multiple employers over one's working life."

Something is wrong somewhere, though. Around 49% of respondents said that their companies are having difficulty filling open positions. The most elusive engineers are in analog and software, which 38.7% and 41.1% of engineers said that their companies were struggling to hire, respectively.

At the same time, almost nine out of every 10 engineers would recommend the profession to young people. They say that a fulfilling career await talented engineers who survive an education system not geared for them, as well as the side effects of an imperfect work visa program in the United States.

Around 51% of respondents believe an engineering shortage exists, but others contend that employers are being too picky. And engineers—who work around 54 hours per week in and out of the office—are still strapped for time to learn new technologies, which is still the top concern for most engineers.

One manager echoed a common—and almost contradictory—observation about the job market: "We need generalists with lots of experience in just the right specialties."

THE TYPICAL ENGINEER

Average Age	
Under 25	1.9%
25-29	3.4%
30-34	4.2%
35-39	4.3%
40-44	6.3%
45-49	9.5%
50-54	14.1%
55-59	20.3%
60 or older	36%

AVERAGE COMPENSATION

$114,796

AVG SALARY $104,996

AVG BONUS $4,249

AVG STOCK OPTIONS $2,809

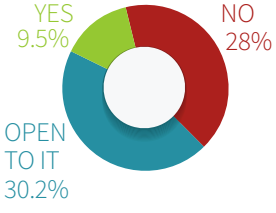
AVG OTHER SOURCES $2,742

ENGINEERS WHOSE SALARIES...

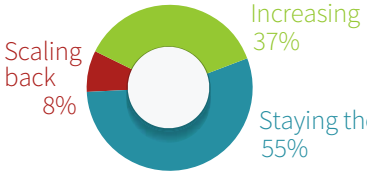
- Increased – 58.1%
- Decreased – 9.3%
- Equal – 32.6%

EMPLOYMENT OUTLOOK

Actively seeking a new position



Your company's hiring status



YEARS IN THE PROFESSION

Less than 1 year	2.2%
1-4 years	5.8%
5-9 years	5.9%
10-14 years	6.4%
15-19 years	8.7%
20-24 years	10.9%
25-29 years	13.5%
30-34 years	16.5%
35-39 years	12.6%
40 years or more	17.5%

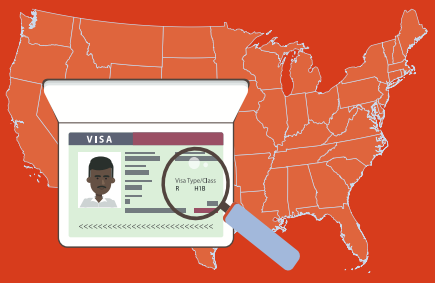
WORK LOCATION

California	19.0%
Massachusetts	6.1%
Illinois	5.1%
Texas	5.1%
Florida	4.8%
Michigan	4.2%
New York	3.7%
Maryland	3.2%
Ohio	3.1%
Arizona	3.1%

YEARS AT PRESENT COMPANY

Currently unemployed	2.0%
Less than 1 year	8.3%
1-4 years	28.5%
5-9 years	19.6%
10-14 years	11.3%
15-19 years	10.4%
20-24 years	5.8%
25-29 years	4.7%
30-34 years	3.9%
35-39 years	2.0%
40 years or more	3.5%

WORK VISAS



DOES YOUR COMPANY HIRE EMPLOYEES ON H1-B VISAS?

YES 34.2%

NO 65.8%

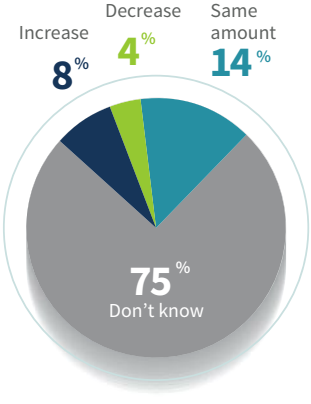
DOES H1-B HURT EMPLOYMENT OPPORTUNITES FOR ELECTRICAL ENGINEERS IN THE UNITED STATES?

YES 53.7% **NO 46.3%**

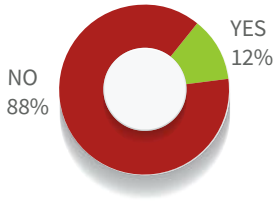
"It reduces the incentive for companies to hire fresh engineers out of school with little experience. These junior engineers may not get a chance for that first job experience for a long-term career in electrical engineering."

"It can be abused but I do not think it generally is, in electrical engineering at least. Lots of international companies have approached me for jobs, highlighting the fact that engineering is a global profession. There are little to no national borders that the field respects."

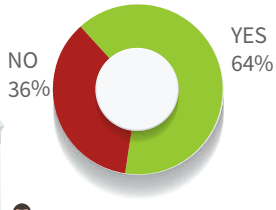
Will your company look to apply for more H1-B visas over the next year if the system remains the same?

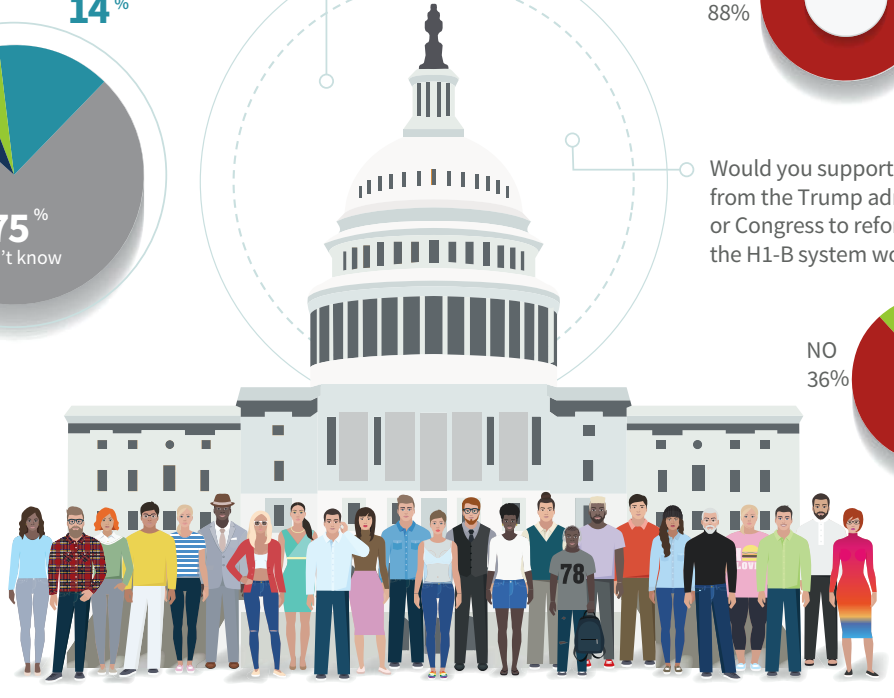


Do you personally feel threatened by H1-B visas?



Would you support measures from the Trump administration or Congress to reform how the H1-B system works?





Surface Mount High Voltage The Right Way

DTI'S SURFACE MOUNT HIGH VOLTAGE DIODES

The cost and quality advantages of surface mount manufacturing technology make it extremely popular in new electronic design. Limited availability of diodes has made the transition to utilize this technology hard for many in the high voltage space - until now!

High voltage surface mount diodes from Dean Technology cover a wide range of electrical performance, and with our new SL series in a longer package we can offer ratings up to 30 kV.

Custom versions are also available for customers that have specific needs not met by our standard product line. We will work with you to get the parts you need for your new designs now.

IN STOCK TODAY! Contact us for a quote or to place your order!

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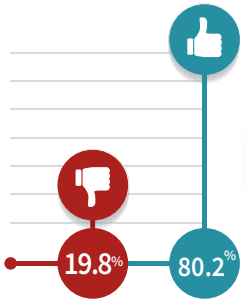
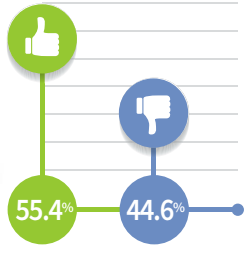
PRODUCTS BY: DEAN TECHNOLOGY

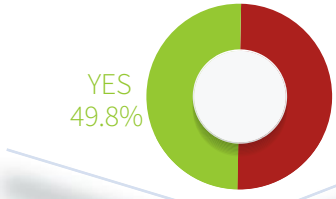
STEM AND EDUCATION



Should there be a stronger focus on STEM at an earlier age?



Are engineering students learning the right skills?

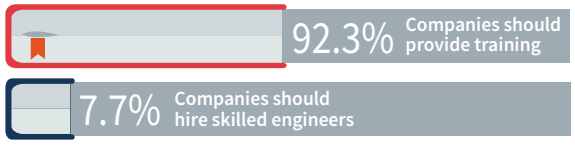


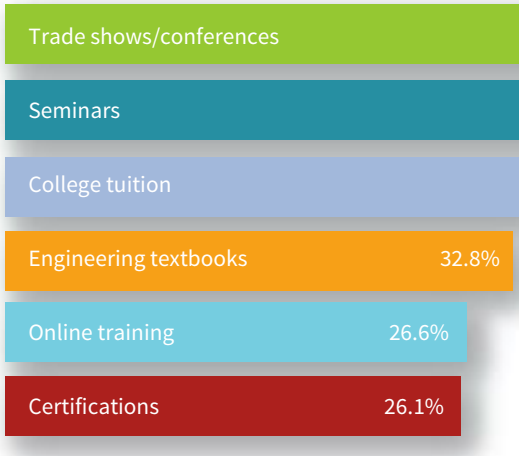
Do you find workers right out of school are bringing new skills to your company?

How do you continue your engineering education today?

Seminars	59.6%
Webcasts	69.1%
Engineering videos	59.5%
White papers	65.1%
Trade shows/conferences	46.3%
Engineering textbooks	49.7%
E-books	40.5%
Engineering/technology publications	66.4%
Engineering/technology publication websites	54.9%

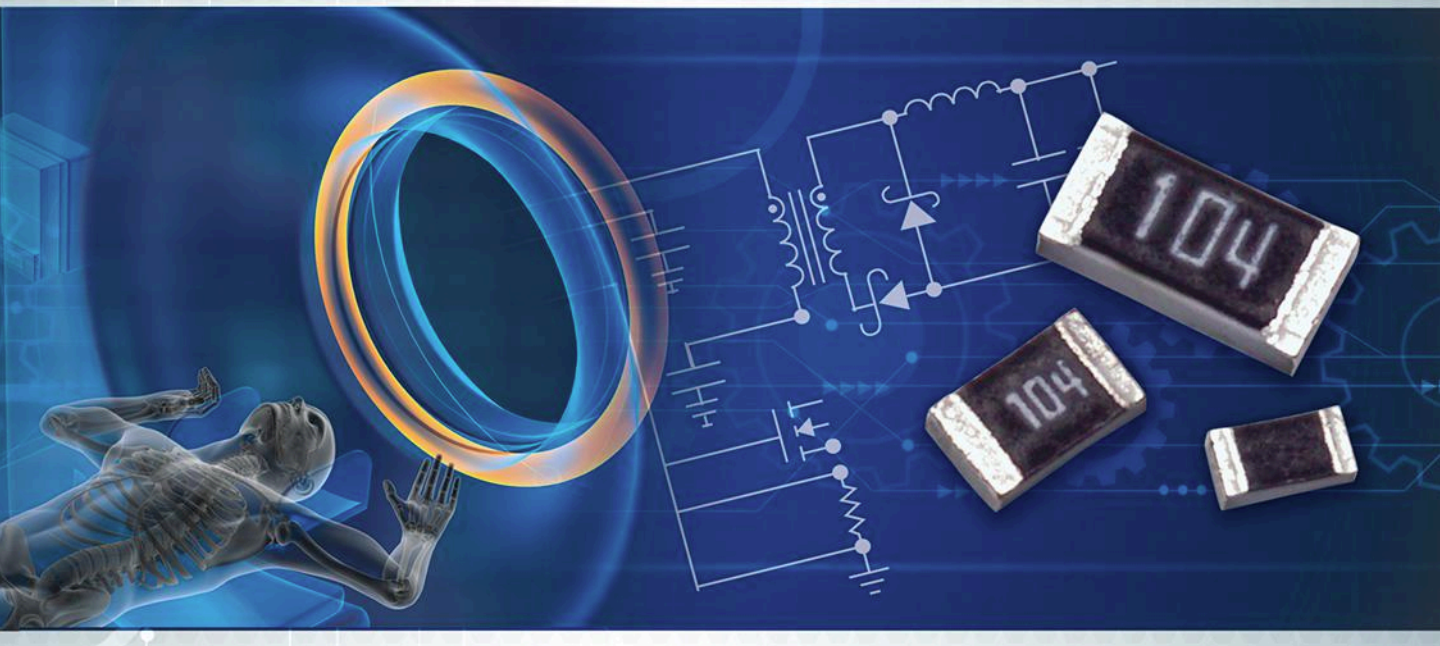
SHOULD COMPANIES PROVIDE MORE TRAINING TO ENTRY-LEVEL ENGINEERS, OR ONLY HIRE ENGINEERS THAT HAVE LEARNED NECESSARY SKILLS?





WHAT FORMS OF EDUCATION DOES YOUR COMPANY REIMBURSE YOU FOR?

From Concept to Reality



Our new passive component solutions will help you make the leap!

Whether you're designing the medical device of tomorrow or connecting the Internet of Things, you need cutting-edge product solutions to bring your design to fruition. At KOA Speer, we're the ideal partner to help you do just that. Our constantly expanding line of passive components will give you the solution to make your concept a reality!

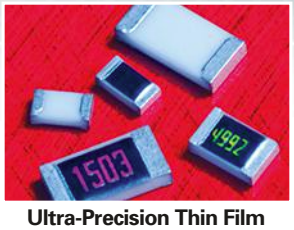
More than just Resistors - yes we're the world leader in thick film resistors, but our product line is broad and growing every day, including:

- Shunt/Current Sense Resistors
- Wide Terminal Resistors
- High Voltage Resistors
- Thin Film Chip Resistors
- Surge Resistors

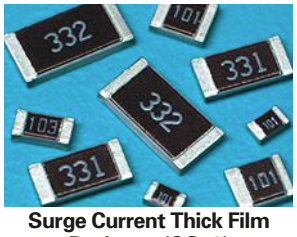
Passive Component Solutions - our engineering group will work with your design team to develop the passive component solution you need. Many of the hundreds of new products we've introduced in recent years are the result of such collaboration.

Award Winning Passive Supplier - we're the industry's most recognized and awarded supplier for achieving the highest product quality, on-time delivery and responsive customer service.

NEW! From KOA Speer



Ultra-Precision Thin Film Resistors (RN73)



Surge Current Thick Film Resistors (SG73)

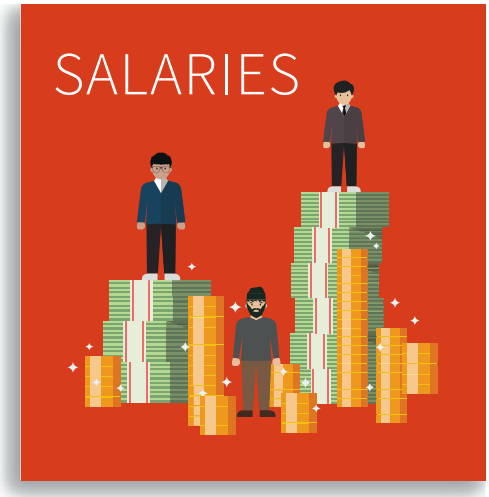
High Voltage Chip Resistors (HV73)

KOA SPEER ELECTRONICS, INC.

Make the Leap from Concept to Reality, visit KOASpeer.com

BY INDUSTRY

$134,456	ICs and semiconductors
$118,714	Components and subassemblies
$118,714	Computer systems/boards/peripherals/software
$117,917	Avionics/marine/space
$117,889	Communications systems/equipment
$112,871	Government/military
$102,077	Research & development
$101,965	Power design
$101,135	Software
$100,220	Consumer products
$100,016	Test and measurement equipment
$94,130	Industrial controls systems/equipment



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Higher Reliability
smaller footprint

New Screw-Lok for tougher demands

- Metal back-shells for maximum strain relief and RF shielding
- Up to 45% smaller and up to 75% lighter than Micro-D
- Resists extremes of shock, vibration and temperature
- Excellent out-gassing properties

gecko SL

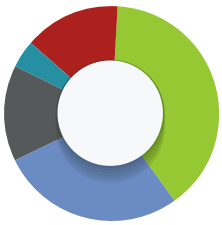
www.harwin.com/gecko-sl

BY LOCATION

BY EXPERIENCE

40 years or more	$102,629
35-39 years	$122,383
30-34 years	$111,786
25-29 years	$116,202
20-24 years	$105,741
15-19 years	$101,974
10-14 years	$91,439
5-9 years	$81,563
1-4 years	$75,479
Less than 1 year	$66,537

HOW DOES YOUR COMPENSATION PACKAGE COMPARE WITH OTHER ENGINEERING EMPLOYERS?

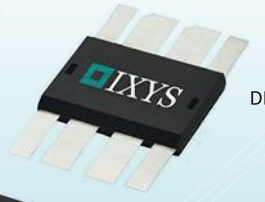


- MUCH MORE COMPETITIVE – 4.5%
- SOMEWHAT MORE COMPETITIVE – 14.4%
- EQUALLY COMPETITIVE – 39.1%
- SOMEWHAT LESS COMPETITIVE – 27.7%
- MUCH LESS COMPETITIVE – 14.2%

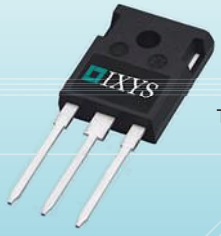
High Voltage High Frequency Power MOSFETs and Drivers

Optimized for high speed and high power applications

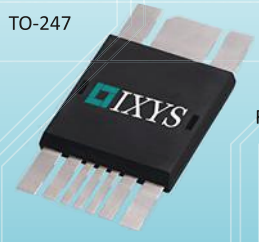
DE-Series



DE275X2-Series



TO-247



RF Power Modules

Power MOSFETs:

High Power 100V to 1200V devices
Low-Inductance DE-Series and industry-standard package styles
Optimized for:

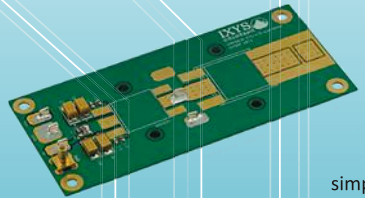
- ISM band RF generators and amplifiers
- High voltage pulse generators and pulsed laser diode drivers
- Switched-mode and resonant-mode HF power supplies

Gate Drivers:

Class D and E HF RF and other high speed switch applications
Up to 30A peak current, ultra-fast rise times

RF Power Modules:

Integrated gate driver and MOSFET in a low-inductance package
500V and 1000V configurations
Designed for Class D, E, HF, and RF applications at up to 27 MHz



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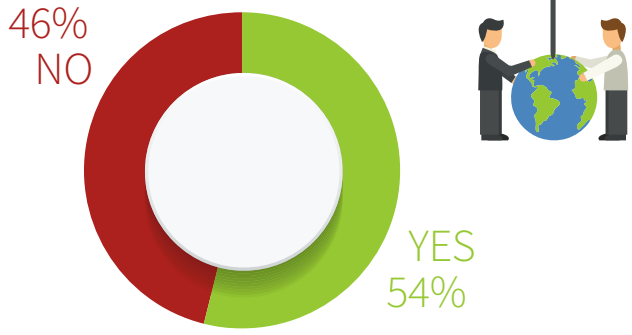
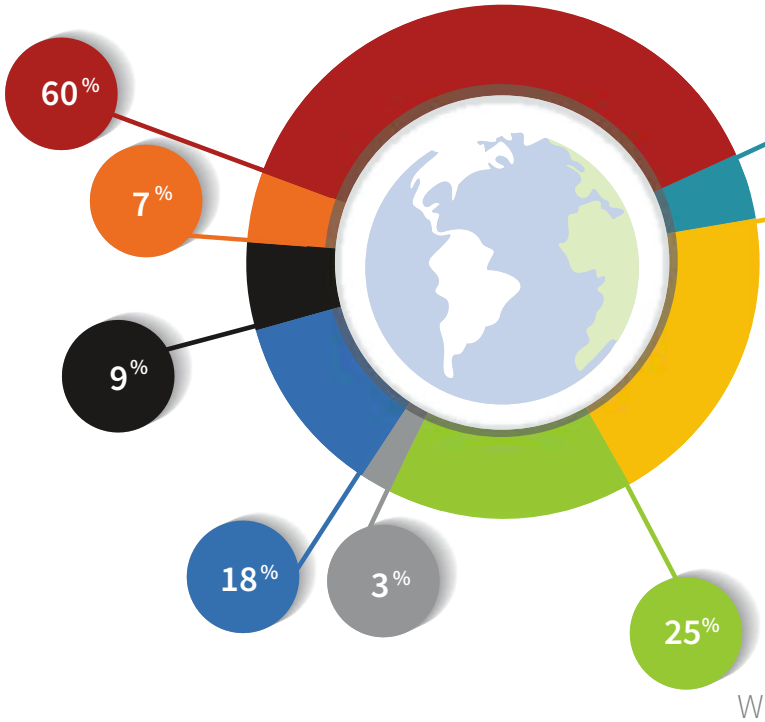
Evaluation boards to simplify your application design and development

DOES YOUR COMPANY OUTSOURCE?





WHERE ARE JOBS GOING?

- UNITED STATES
- CANADA
- PACIFIC RIM
- SOUTH AMERICA
- INDIA
- CHINA
- MEXICO
- EUROPE

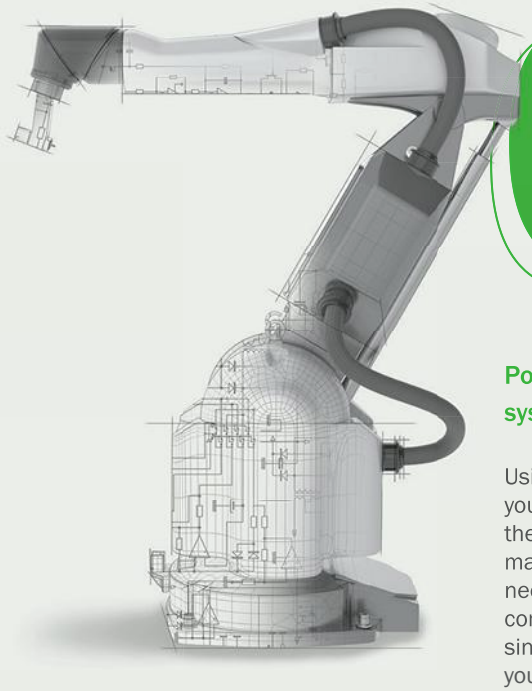
REASONS FOR OUTSOURCING

WORK BEING OUTSOURCED

Software engineering/development	49.4%
Design	37.5%
Manufacturing/assembly	35.1%
PCB layout	30.8%
CAD/CAE	22.6%
Software verification/test	21.4%
R&D	20.8%
Design verification	18.0%
Final test	13.6%
Drafting	10.3%
Incoming inspection	5.0%

EVERYTHING YOU NEED, ALL IN ONE PLACE.

THINK ON.



Powering your industrial automation system has never been easier.

Using ON Semiconductor solutions to power your industrial automation designs can make them more reliable, flexible, and affordable. No matter what package size or power levels you need, we offer a comprehensive portfolio of components that are built to work together as a single, end-to-end solution—helping you build your system faster and more efficiently. We design our solutions with a deep understanding of the power demands you face, so when you're looking for the smartest solutions to your complex challenges, Think ON.

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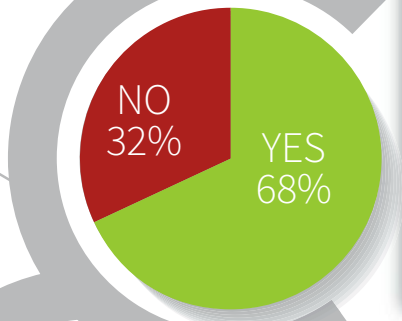
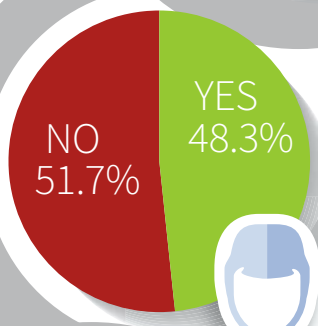
ON Semiconductor®

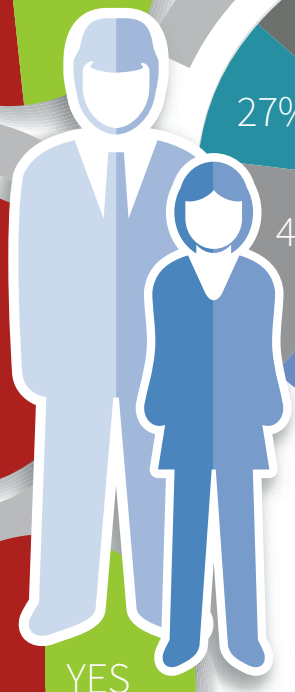
ENGINEERING LABOR FORCE

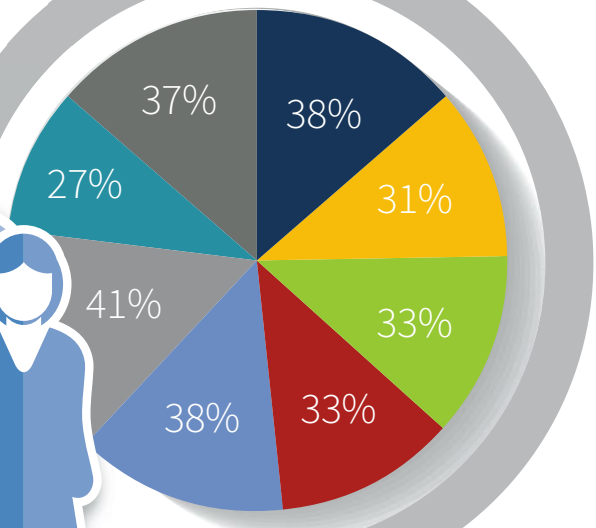
Is it important to have a diverse engineering workforce, with women and minority engineers?



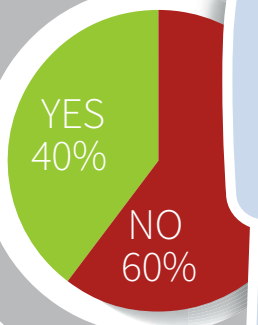
Is there an engineering shortage?

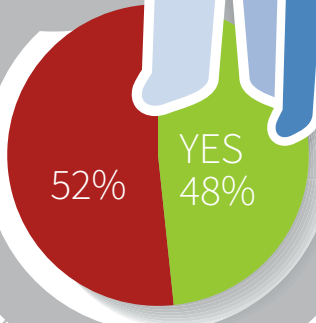






Does your company track employee diversity in either a public or internal report?





Is your organization having difficulty finding qualified candidates for open engineering positions?

For which engineering specialties are you having trouble hiring?

- ANALOG
- RF
- POWER
- DIGITAL
- EMBEDDED
- SOFTWARE
- MECHANICAL DESIGN
- SYSTEMS ENGINEERING

GPS disciplined ***10 MHz reference*** ...

... and so much more !

- GPS/GNSS disciplined 10 MHz
- TCXO, OCXO or Rb timebase
- Time tagging to GPS and UTC
- Frequency counter with 12 digits/s
- Source out: sine, square, triangle & IRIG-B
- Built-in distribution amplifiers
- Ethernet and RS-232 interfaces

The FS740 GPS disciplined10 MHz reference delivers cesium equivalent stability and phase noise at a fraction of the cost.

It's host of features includes a 12-digit/s frequency counter, a DDS synthesized source with adjustable frequency and amplitude, built-in distribution amplifiers, and event time-tagging with respect to UTC or GPS.

The optional OCXO or rubidium clock (PRS10) provide better than –130 dBc/Hz phase noise.

FS740 ... $2495 (U.S. list)

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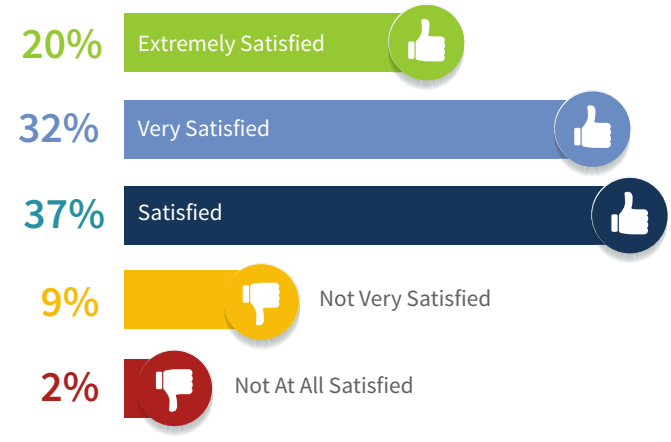
JOB SATISFACTION

HOW SATISFIED ARE YOU IN YOUR JOB?



MOST IMPORTANT FACTORS IN JOB SATISFACTION

8.15	8.12	7.68	7.55	6.86	6.69	6.67	6.64
Challenges that accompany the design of new products	Researching potential design solutions	Opportunity to design products that can benefit society	Compensation you receive for the work you do	Working in team situations with peers	The pressures associated with solving design problems	Working independently of others	The recognition you get from others for the work you do

[Based on a scale of 1 to 10]

Solid State Relays and Contactors

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5. Try something different	23%
6. Have more freedom/free time	21%
7. Start a business	19%
8. Do something more fulfilling or satisfying	19%
9. Do something less stressful	15%
10. Burnout	15%
11. Poor job outlook for engineers	10%
12. No further chance for advancement	8%
13. Switch to teaching	6%

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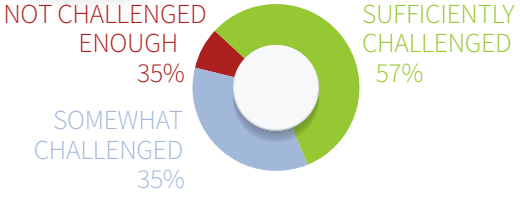

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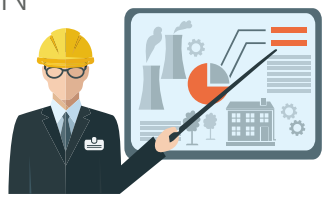

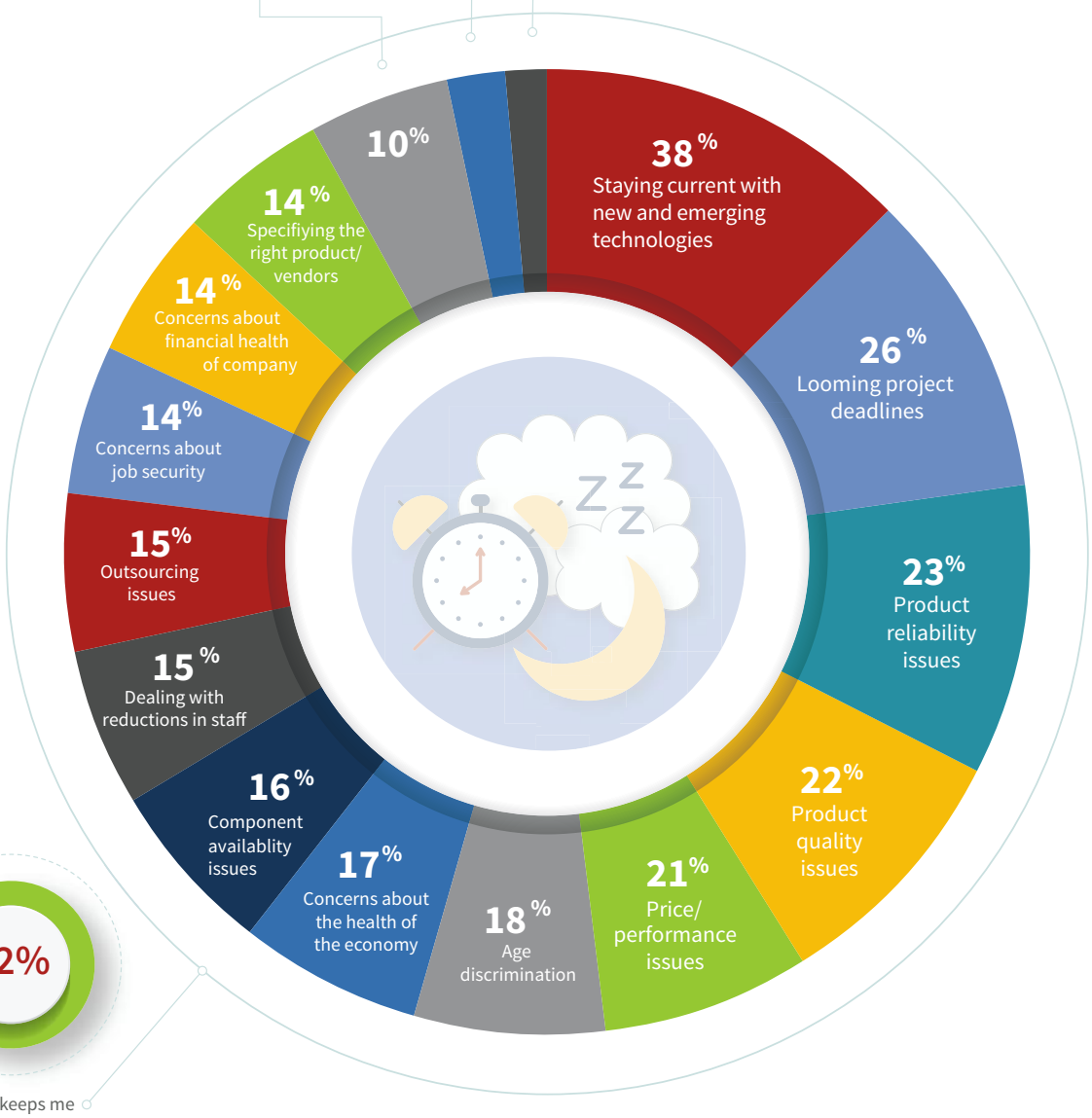

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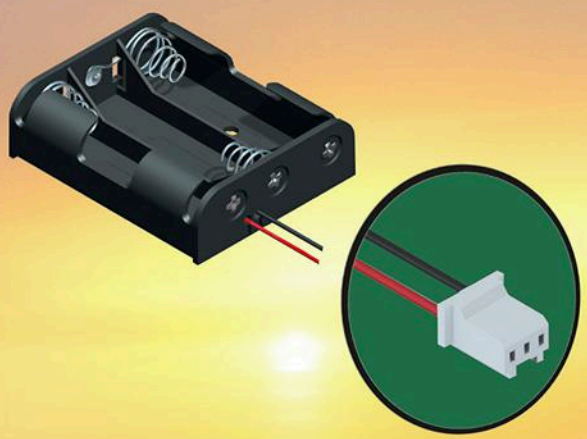

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Bumping into COBOTS

Beware, cooperative robots—more commonly referred to as cobots—are gaining popularity and could very well be coming to a street near you.

1. Marble's robot, controlled by an Nvidia Jetson TX1, delivers food in San Francisco that was ordered using a Yelp Eat24 app.

Robots have become ubiquitous in assembly lines, doing everything from manhandling a car to assembling a smartphone. They are fast, accurate, and do not require breaks or overtime pay. They have been unfeeling, literally, which often makes them hazardous to us humans.

Robots have killed and injured their human counterparts, but this usually occurs because safety mechanisms have allowed them to continue to operate after a person has moved into the space reserved for robotic operation. These types of production robots are typically caged, either physically with barriers or electronically with optical or ultrasonic "curtains."

These restrictions have changed, though. So beware, cobots, the truncated word for cooperative robots, may be coming to a street near you *(Fig. 1)*. For example, Marble's robot is controlled by an Nvidia Jetson TX1, delivering food in San Francisco's Mission and Potrero Hill districts that was ordered using a Yelp Eat24 app. These autonomous ground delivery vehicles (ok, they are tiny self-driving cars) roll along the sidewalk with their tasty treats, avoiding people, cars, and pets while cruising at walking speeds to the intended diners.

Programs running on the Jetson TX1 take advantage of the latest deep-neural-network (DNN) machine-learning technology *(see "What's the Difference Between Machine Learning Techniques?"on electronicdesign.com)* to analyze information from an array of sensors that surround the cobot with a virtual sensor map. "Through Jetson's AI and deep-learning capabilities, our robots can better perceive the world around them," says Matt Delaney, CEO and co-founder of Marble. "Together we're working to make urban transportation of goods more accessible."

Cobots in the wild "outdoors" are just an extension of cobots in more controlled spaces like hospitals. Aethon's Tug *(Fig. 2)* has been trundling around medical facilities for years *(see "Robotics Moves To The Mainstream" on electronicdesign.com)*. The Tug's LiDAR and other sensors are similar to what's used by Marble. However, the Tug has a couple of advantages, such as Wi-Fi communication with doors and eleva-

2. Aethon's family of Tug cobots have found a home in controlled environments like hospitals, delivering everything from medicines to food.

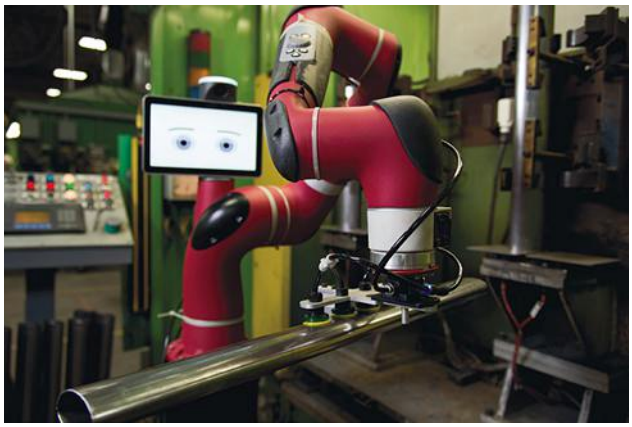
tors, that have been thoughtfully configured to interact with these almost silent robot couriers. This allows a Tug to move throughout the hospital without human intervention except for the exchange of materials.

Exchanges are similar to the Marble Robots system. The robot has one or more electronically locked compartments that are opened in response to a code entered by a user. These days, this could be done using a panel on the robot or with another device like a smartphone. A person is still required to open the door and add or remove items. The robot can then continue along with subsequent deliveries, or it may return to a control point or charging station, since most of these robots are electrically motivated.

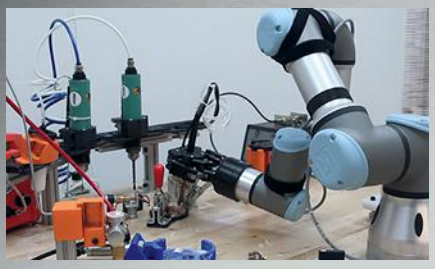
Generally speaking, Marble Robots looks to change urban logistics, while Aethon has already done so in hospitals. More articulate delivery robots are already being employed in controlled spaces such as warehouses. These range from smart forklifts to inventory pickers.

ARMED AND NOT DANGEROUS

Putting a robot behind a physical or virtual barrier is handy within an assembly environment if the robot can operate in isolation as materials move through the system. This has been very successful to date, but there are advantages to robots that can operate in close proximity to humans. Examples of this include Rethink Robotic's one-armed Sawyer *(Fig. 3)* or its two armed counterpart, Baxter *(see "Interview With The Creators Of Baxter - Rethink Robotics" on electronicdesign.com)*.



3. Rethink Robotic's Sawyer is a one-armed cobot designed to operate in close proximity with humans.



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4. Festo's BionicCobot is a pneumatic lightweight robot that can work in close quarters with humans.

Like many cobots, Sawyer is designed to detect humans through sight, sensors, and touch. However, it also has limbs that are designed to minimize their power. Furthermore, it's designed for low impact operation with a counterweighted arm.

In fact, the easy movement of the arm by a person is one way of programming Sawyer and Baxter. Enable its training program, move the arm around and adjust the grippers, show an object to be manipulated to the camera in the hand, and so on. Then stand back and allow it to repeat the process without fear of getting knocked off your feet by that robotic arm.

Festo's BionicCobot *(Fig. 4)* is a pneumatic lightweight robot that can work in close quarters with humans. It has seven joints with a drive approach that makes it possible to exactly determine the force potential and rigidity level of the robot arm. The pneumatic arm automatically eases off in the event of a collision to protect nearby humans or objects, including other cobots.

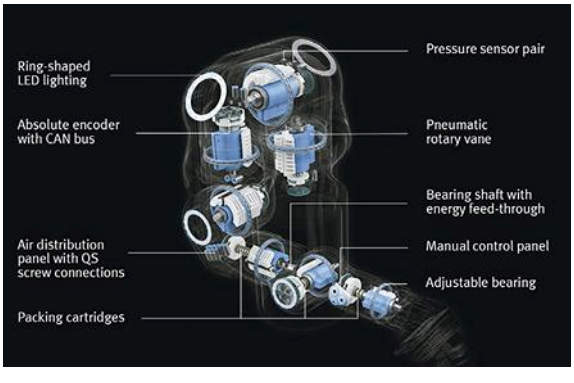
The arm has three axes of freedom in its shoulder area, one each in the elbow and lower arm, plus two axes in the wrist. At each point, there is a rotary vane with two air chambers. This pneumatic motor can be infinitely adjusted like a mechanical spring by filling the chambers with compressed air *(Fig. 5)*.

Of course, these cobots will not be lifting cars, anvils, or other large and heavy objects in close proximity to humans because the objects are dangerous. Designers and users need to keep this in mind, since the cobots aren't the only part of the equation. A beaker of acid may not weigh much, but it can have severe consequences if spilled.

LOOK AND DO TOUCH

The range of sensors employed by cobots continues to grow as the cost drops for these devices. Low-cost video cameras combined with machine learning and DNNs are just one way cobots, self-driving cars, and other robots are gaining more information from their surroundings.

Bebop Sensors' smart-fabric technology *(Fig. 6)* applications range from shoes to smart baseball bats. The washable fabric can measure XYZ location in addition to bending, twisting, rotation, and force being applied. The BeBop materials are available in woven and non-woven base cloth, and multiple sensors can be placed on same piece of fabric in sizes up to 60 in. wide. Thickness ranges from 0.25 mm to 0.50 mm. The printed layers can include dielectric, resistive, and controlled conductive structures, along with USB, BLE, CAN, or Wi-Fi electronics. This can give a cobot real feelings, so to speak.



5. The BionicCobot mixes pneumatics with electronics to provide precise control.

6. Bebop Sensors' materials have been used in a range of smart-fabric applications, from shoes to smart baseball bats.

7. TriLumina's VCSEL array emitters are paired with Analog Devices' high-speed laser drivers to produce 3D LiDAR illumination.

In another area, TriLumina's vertical cavity surface-emitting laser (VCSEL) array emitters are paired with Analog Devices' high-speed laser drivers *(Fig. 7)* to deliver 3D LiDAR illumination that will radically change the LiDAR landscape. LeddarTech and TriLumina demonstrated a 256-pixel LiDAR solution at the 2017 Consumer Electronics Show.

Conventional LiDAR relies on mechanical means for laser scanning; many LiDAR systems are, in fact, 2D. They're not cheap or low power, compared to the emerging solid-state alternatives. Systems with a resolution up to 512 by 64 pixels on a field-of-view of 120 by 20 degrees, and detection ranges that exceeds 200 m for pedestrians and well over 300 m for vehicles, should be available in 2017.

LeddarTech and TriLumina aren't alone in the race for 3D LiDAR dominance that, at this point, is targeting automotive applications. Quanergy's S3 has a 150-m range, an accuracy of ±5 cm at 100 m, and a 120-degree horizontal and vertical field-of-view. The forthcoming S3-Qi is even smaller and lower power, with a range over 100 m.

Velodyne's Velarray, which leverages the company's proprietary ASICs, comes in a 125- × 50- × 55-mm package. It offers a field-of-view of 120degree horizontal and 35degree vertical with a 200-m range. It will have an ASIL B safety rating. Multiple units can provide a 360-degree view to provide safe operation in L4 and L5 autonomous vehicles.

These technologies will revolutionize other application areas like self-driving cars, and most likely will do the same for cobots. ed

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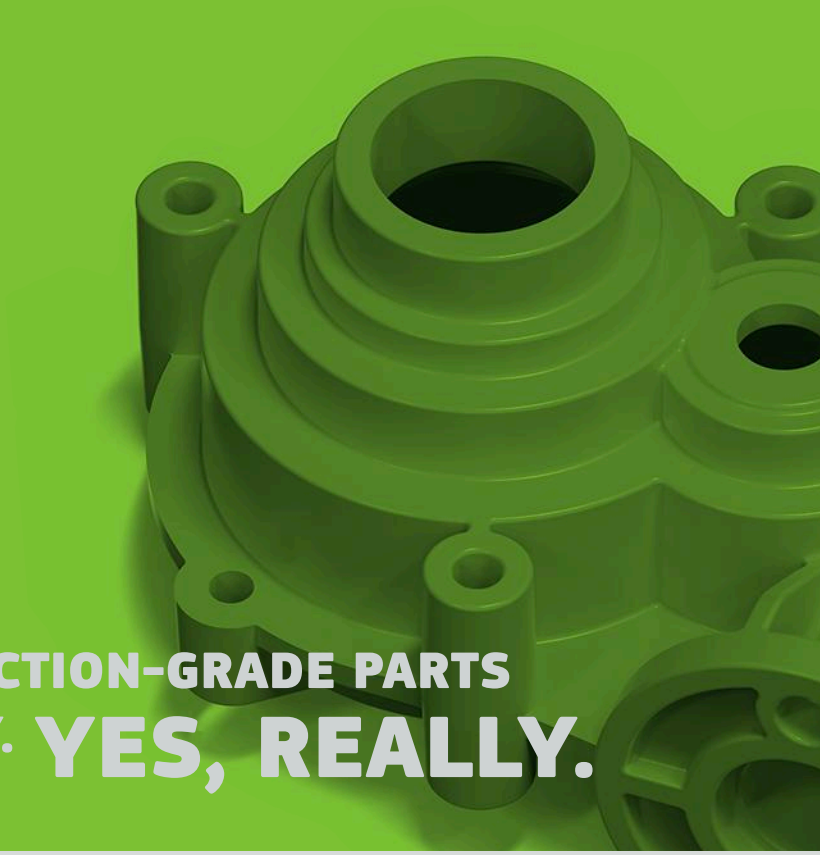

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DESIGN NOTES

60V 2MHz Buck-Boost Controllers Regulate High Power Voltage and Current with High Efficiency and Low EMI

Design Note 567

Keith Szolusha

Synchronous buck-boost controllers are versatile and highly efficient. They can produce high power as both a boost and a buck with a single inductor, keeping power supply design simple. Normally, a buck-boost controller in a high power application is operated at a standard or low switching frequency, this maximizes efficiency and avoids complications related to shoot-through and switch blanking time, which can arise in synchronous rectification at high frequencies. Nevertheless, a high frequency 2MHz buck-boost controller with a smaller inductor ensures that the EMI content resides above the AM frequency band.

The LT8390A and LT8391A buck-boost controllers are unique in that they operate at 2MHz. The high switching speed enables use of a small inductor for a compact solution size, even in high power applications.

Unlike monolithic converters, which save space with power switches inside the IC package, controllers can drive external power switches with much higher peak currents, such as 10A. Such high peak currents would burn up the small IC packages of typical integrated converters, but external 3mm × 3mm synchronous MOSFETs can handle this power. The MOSFETs can be arranged in tight quarters with hot-loop capacitors for very low EMI. The unique peak switch current sense amplifier architecture places the sense resistor next to the power inductor, outside the critical input and output hot loops, also reducing EMI.

2MHz, 95% Efficiency, 12V, 4A Buck-Boost

The 2MHz, 12V, 4A buck-boost regulator in Figure 1 boasts efficiency to 95%. This relatively compact design uses 3mm × 3mm MOSFETs and a single high power inductor. The temperature rise for this converter is low, even at 48W. At 12V input, no component rises more than 45°C above room temperature. At 7V input, the hottest component rises less than 55°C with a

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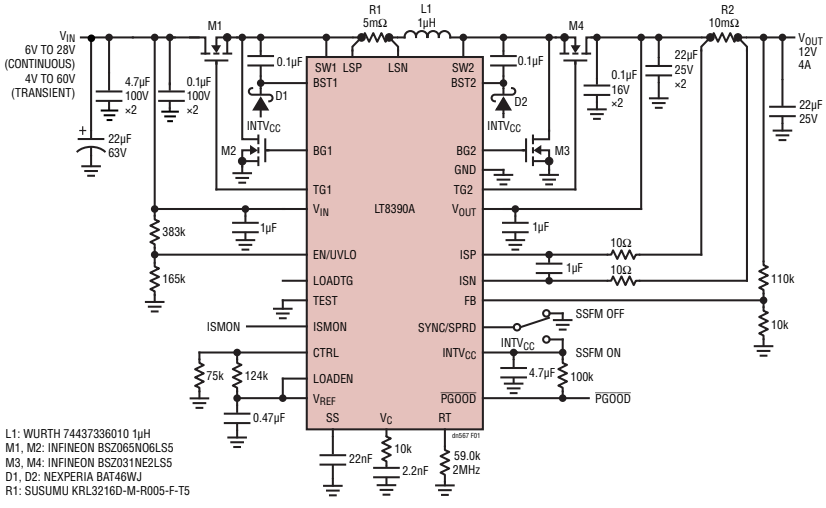

Figure 1. 2MHz 12V, 4A Buck-Boost Voltage Regulator with High Efficiency

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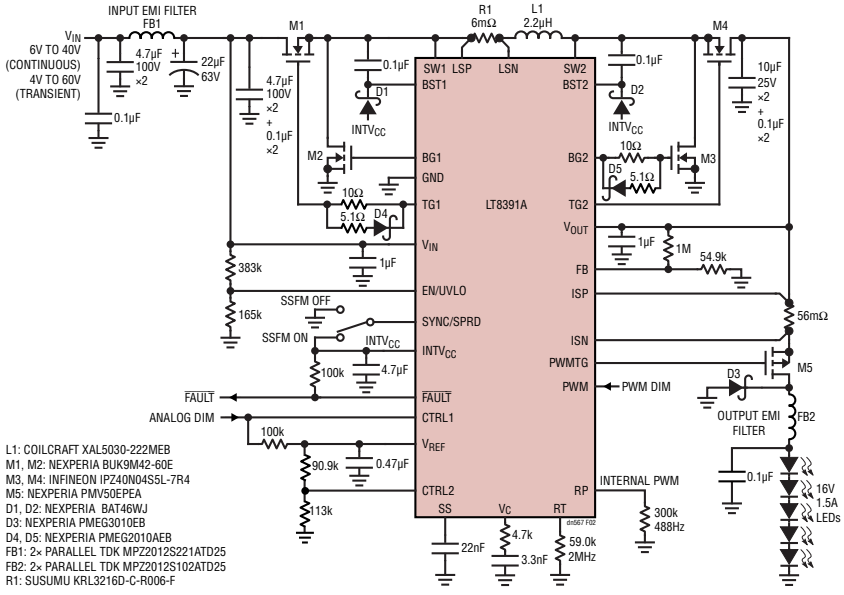

Figure 2. Low EMI 16V, 1.5A Automotive Buck-Boost LED Driver Passes CISPR 25 Class 5 EMI

standard 4-layer PCB and no heat sink or airflow. This converter handles short input transients down to 4V at 4A load, or runs continuously at 4V input with 2A of load (~25W).

The LT8390A's high switching frequency (600kHz to 2MHz) distinguishes it from the field of 4-switch controllers. It also has a variety of notable features like its lower frequency cousin, the LT8390. It has a PGOOD flag, short-circuit protection, and a flexible current-limiting sense resistor for output or inrush current restrictions. Its spread spectrum frequency modulation (SSFM) for low EMI makes it ideal for automotive applications.

2MHz Low EMI Automotive Buck-Boost LED Driver

The LT8391A is a 2MHz LED driver counterpart of the LT8390A. The main difference is that LT8391A includes LED driver PWM dimming features and open LED fault protection. The output sense resistor controls current through a string of LEDs whose voltage may lie within the input voltage range, such as the 9V to 16V car battery. It can run down to 4V cold crank and can withstand up to 60V input transients. LT8391A provides up to 2000:1 PWM dimming ratio at 120Hz and it can use its internal PWM dimming generator (no external clock required) for up to 128:1 accurate dimming.

The 2MHz LT8391A LED driver shown in Figure 1 is optimized for automotive headlights. It uses AEC-Q100 components and meets CISPR 25 Class 5 radiated EMI standards. SSFM reduces EMI, and also runs flicker-free simultaneously with PWM dimming.

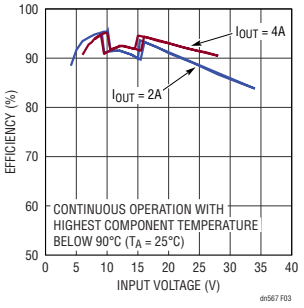

Figure 3. LT8390A Efficiency of Figure 1

This compact design features a small inductor and especially small input and output EMI filters. It can run down to 4V and up to 60V. The four synchronous MOSFETs shown can be replaced with two dual MOSFETs for reduced component count when needed. It reaches 93% efficiency. The FAULT flag reports short-circuit and open LED conditions, which are handled with ease.

Conclusion

The LT8390A and LT8391A 2MHz 60V buck-boost controllers can regulate high power voltage and current in compact spaces. The low EMI architecture and SSFM feature make these ideal for low EMI applications.

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WILLIAM WONG | Embedded/Systems/Software Editor

VM, Containers, and Serverless Programming for Embedded Developers

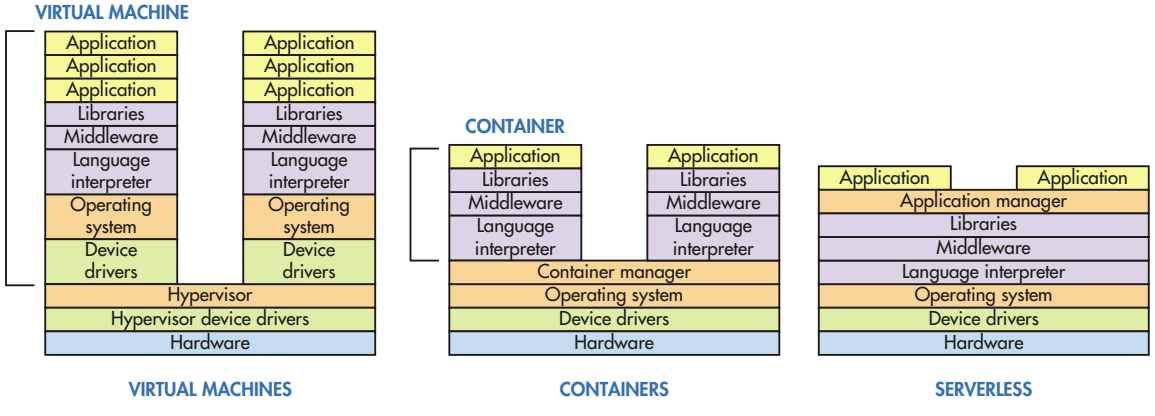
Enterprise computing has delivered virtual machines, containers and now serverless programming. Find out where it fits for embedded developers.

Having already provided developers with virtual machines (VM) and containers, enterprise computing has now rolled out serverless programming *(Fig. 1)*. This migration takes advantage of the growth in cores and processors within the cloud and enterprise systems. The number of cores involved is staggering compared to a typical embedded system that employs a virtual memory operating system like Linux. I mention this to partition out lower-end embedded systems that may lack even a memory management unit.

Enterprise computing tends to be way ahead of embedded development technology for a variety of reasons, including the need to push the envelope in terms of size, performance, management, and capacity. Embedded systems rarely push the same limits, and designs tend to be more conservative since they often need to run for years or decades. Still, many of the technologies that have been refined at the enterprise level are finding their way into embedded systems development depending upon how applicable and how robust the solutions are. VMs are one example where the technology has been commonplace in the enterprise and is becoming more common in embedded systems.

One reason for the enterprise focus application modularity is the way services can be sold to developers and companies as more computing gets moved to the public or private cloud. This has led to a range of systems include System as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS), Containers as a Service (CaaS) and now FaaS (Function as a Service). FaaS is also known as serverless computing. It isn't really serverless, but from a user/developer perspective there is no server to manage.

IaaS is implemented using VMs. The others can be implemented within a VM but the underlying software is hidden from application developers. VMs take advantage of VM hardware that lets a VM to think it has a complete machine to itself. It does mean that an operating system is part of the package although it is possible to do a bare-metal application that is essentially its own operating system with built-in device drivers.



1. Virtual machines, containers, and serverless programming run applications, but how they are supported differs.Virtual machines incorporate everything including the operating system. Containers provide access to a common operating system while serverless systems provide a standard application interface.

A hypervisor manages multiple VMs and typically the hypervisor can support many different operating systems. For example, Linux's KVM and Microsoft's Hyper-V can run a range of operating systems from Solaris to BSD. Of course, Linux, Microsoft Windows, and Microsoft Server are in the mix as well.

VIRTUAL MACHINES

VMs can be isolated by the hypervisor providing a hardware-based security environment. Communication between the VMs can be achieved by using a network or virtual network interface, but some hypervisors allow shared peripherals and shared memory.

The downside to VMs is their size and complexity. They need to be large to include all the components that multiple applications will need. The advantage is that multiple instances of systems running on computers can be moved to a single computer running multiple VMs. The multicore processors make this practical and help provide a scalable environment, since high-end CPU core performance has essentially flattened.

It is possible to run VMs that use more cores and memory than the underlying hardware provides. Cores are time shared and swapped disk storage is used to provide more memory. This overprovisioning is practical for some systems, but it can significantly slow down systems that would regularly use more cores and memory than are actually available.

A number of techniques are used to reduce overhead in running and managing VMs. For example, file formats like QCOW2 can be configured in a hierarchical fashion *(Fig. 2)*, where top-level files contain a VM but are referenced by other files that are used for individual VMs. These files only contain changes for a running an instance of the VM. Starting a new VM is a matter of creating a new QCOW2 file based on an existing file.

A typical creation process would be installing an operating system on the root file as the VM boot disk. New VMs can be based on this VM disk. In the next step, a new QCOW2 file is set up for a new VM where a database server is installed. The process is repeated to create a VM database that will be used to store data. The upper level files will be read-only, and a running VM will use that data if it has not been changed. This is usually space-efficient since most data does not change. For example, program code would not change unless software is upgraded. Creating new VMs is fast because they are based on existing files and the new files only contain a small amount of metadata.

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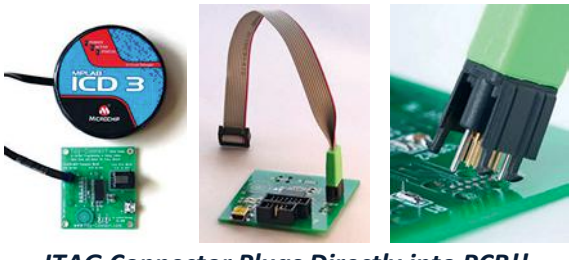

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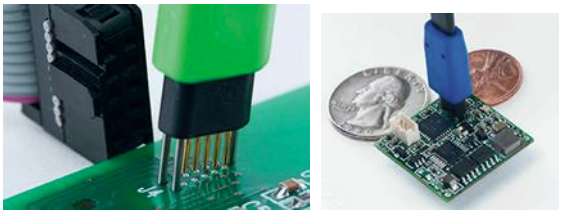
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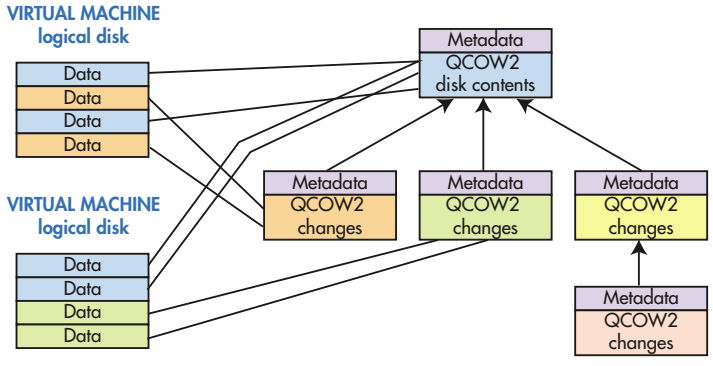

2. The root and upper level QCOW2 files are read-only. The leaf files can be used with a single virtual machine that can make changes that will be reflected in the leaf file.

VM hypervisors sometimes perform similar optimizations by tracking the memory blocks that are mirrored in a virtual disk. In many cases it is possible to determine that a read-only memory block from a virtual disk is the same for two or more active VMs. In this case, a single memory block can be shared among the VMs in a read-only fashion. The memory management system can provide this protection. A hypervisor can support changes to these blocks if it can remap the block or if one of the VMs makes a change. The remaining VMs can still share the original block, but the other VM will need to have its own block. This support will be transparent to the VMs.

CONTAINERS

Container systems, like Docker, require virtual memory hardware but not virtual machine support to host multiple applications. A Docker instance can run in a VM, but it can also run alone. It runs on top of an operating system like Linux and can run one or more containers.

Containers use services provided by the underlying container manager that in turn gets its support from the host operating system. Containers are isolated from each other and the underlying system using security features like Linux chroot, control groups (cgroups), and namespaces. These are typically implemented using the operating system's virtual memory system and security support. The security features tend to be more varied than a VM, where systems tend to be isolated by default and resources include memory and peripherals.

Containers do have an advantage because they can often take advantage of the container system's security support, which is based on the operating system's security. For example, this allows a Linux-based container system to employ security systems like TOMOYO, AppArmor, SELinux, and GRSEC. These have advanced policy-based features that are typically not found in a VM environment.

Containers have other advantages over VMs besides just a more customizable security environment. There is more commonality among containers, since they are all based on the same framework that is built on a common operating system. Developers do not have to manage or worry about the underlying operating system from a container perspective. The containers include less code and data and tend to be easier to configure because there is no need to address operating system functionality.

On the downside, containers are specific to the operating and container environment. It is possible to migrate between platforms in the same way that it is possible to migrate VM virtual disk files between different host VMs, but

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both of these tend to be exceptions associated with moving existing applications to a new host environment.

A server can typically support many more containers than VMs using the same resources because containers inherently have less overhead compared to applications running in a VM. They also tend to be easier to configure and upgrade since there are fewer items involved. For example, there is no operating system to worry about upgrading.

Not all container systems are created equal. Some allow containers to have a single application while others allow multiple applications to reside within a container. The latter would allow an SSH server to be included in a container for remote access to the container. Likewise, a single container could include a web server and a database server. The other approach would require two containers, one for the database server and one for the web server. There are advantages to both approaches including differences in configuration, upgradeability, support and so on.

Container management systems usually allow groups of containers to be configured and deployed. This is very necessary where containers are restricted to a single application. Container applications are linked via network connections so related applications can be on the same virtual network or on another server. Container migration between servers is normally available for load leveling and redundancy.

Containers tend to be run in a similar fashion as VMs. They tend to run for a long period of time and are normally started by a user when a system starts up, or in response to a limited number of events.

SERVERLESS COMPUTING

Serverless computing services like Amazon's AWS Lambda or platforms like the open-source Apache OpenWhisk take the idea of containers to their extreme. Serverless computing is based on functions that are essentially small applications often designed to run on demand for short periods of time. Some systems even limit the time and resources a function can utilize. Containers and VMs can also have limitations, but they tend to be higher since they incorporate more services.

One reasons for serverless computing is to provide a system that is easy to track for billing purposes. A serverless system may simply track the amount of time a function runs while limiting the resources it can use.

Another reason is to support event-driven workloads that often arise with the Internet of things (IoT). A function

can be started on the reception of an IoT message. It is easy to scale the response based on demand with the underlying system handling this management instead of building it into the application.

Serverless functions can be written in languages like Javascript or Python, although it is possible to write them in almost any language, including C and C++. The approach does allow the functions to be written in a more generic fashion that is not dependent upon the underlying implementation or operating system.

Security in serverless environments is similar to containers in that the operating system and management environment provide mechanisms to allow the serverless functions to only access their provided resources. The potential for problems exists simply because of the number of functions normally involved in a solution and the need to implement policies properly.

Another issue with serverless solutions as well as containers is vendor or platform lock-in, since the application is now dependent on the underlying framework. This is less of an issue for embedded solutions that maintain their own platform but, in this IoT age, part of a solution may reside in the cloud on a public service like AWS Lambda.

System solutions may incorporate a range of platforms from VMs to containers to serverless functions. Some functionality may be more applicable to one approach over another.

Some enterprise solutions will be overkill for many embedded applications, but often solutions can be scaled to fit embedded needs. There also tend to be a wide range of options for all these approaches, and some may be more amenable to embedded developers.

At this point, VM support tends to be readily available and the same is true for container systems. It is possible to use the serverless approach in embedded applications. It may be a good fit for event-based applications, but developers will have to keep its advantages and limitations in mind when creating functions, since it tends to be a bit different than writing applications for VMs or containers. ed

System solutions may incorporate a range of platforms from VMs to containers to serverless functions. Some functionality may be more applicable to one approach over another.

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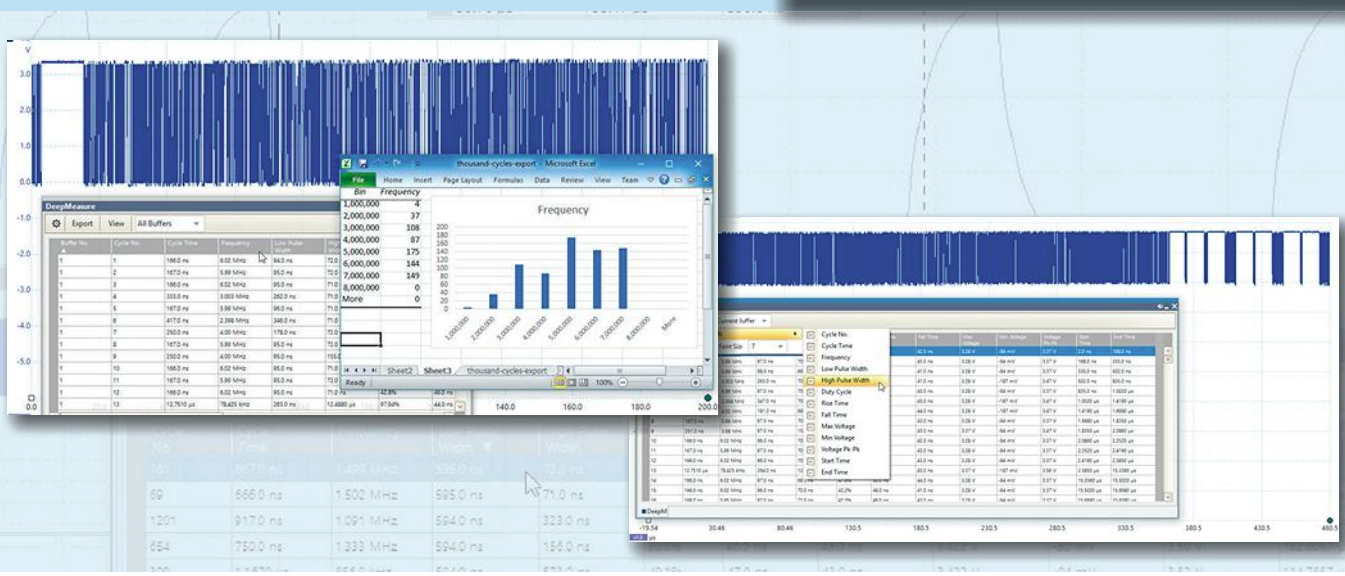

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MARIA GUERRA | Technical Editor

Wide-Bandgap Developments: What You Need To Know

The market adoption of SiC and GaN power devices is accelerating because many semiconductor companies are incorporating these materials into a wide range of trending applications as power packaging technologies improve.

Advances in wide bandgap (WBG) power devices are enabling silicon-carbide (SiC) and gallium-nitride (GaN) devices that can operate at higher voltages and temperatures than conventional semiconductor devices. Also, they can switch at faster speeds with lower switching losses. New SiC and GaN solutions and developments are especially taking hold in three fields: data centers, wireless charging, and energy harvesting. Each of these application areas are driving the development of WBG power devices in different ways, resulting in various product evolutions:

Data centers. The overall power consumption for data centers over the period covering 2010 to 2020 is expected to exceed 70 billion kW. Datacenter designers are always looking for better solutions to help them improve the efficiency of their designs for energy saving purposes. In response, semiconductor companies like Transphorm Inc., Texas Instruments, and Wolfspeed had developed WBG-based power-supply solutions. An example is a 2kW totem pole PFC topology developed by Wolfspeed for a power supply utilizing SiC MOSFETs capable of reaching 80+ titanium standards in data centers while keeping cost under control.

The totem pole PFC topology chosen by Wolfspeed for this reference design has a low component count with high efficiency because it doesn't have a bridge rectifier feeding it. With fewer components, it has a high power density and can be operated at relatively high switching frequencies. The design contains a pair of silicon diodes that help to achieve a low cost approach while still reaching the desired efficiency. The design, which contains two 900-V SiC MOSFETs, is claimed to reach a peak efficiency of 98.5% at 50% load at 230V. The breakdown of the losses with the estimated efficiency at 230V is as follows:

Components	Watts 100% Load	Watts 50% Load
MOSFET (conduction loss)	6.01	1.57
MOSFET (switching loss – Rg = 10)	7.0	6.03
Diode	8	3.4
Main inductor (300 uh)	7	3.9
Differential mode inductor	1.1	0.856
Common mode inductor	1	0.8
Sense resistor	0.74	0.185
Total (losses)	30.85	16.741
Efficiency	98.48%	98.35
Target	94.8%	98.5%

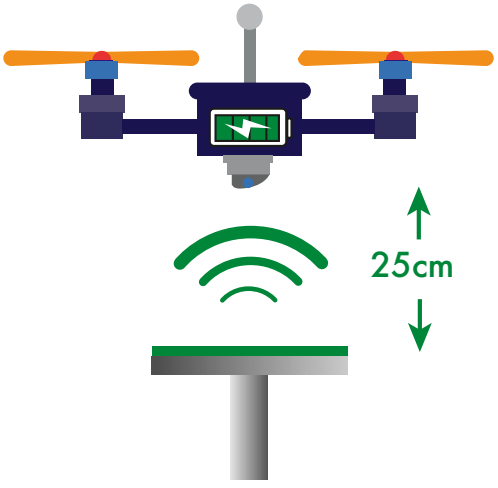
Wireless charging. GaN allow designers to use wireless charging in a wider range of products without having to redesign the antennas. Energous, the developer of WattUp, just announced a new GaN based, high-power Near Field WattUp transmitter reference design. It is capable of charging devices with up to 10 watts of energy. In doing so, it increases the amount of power delivered to receiving devices, while also eliminating connectors and charging contacts

> "These first GaN-based solutions for our WattUp wire-free charging technology support higher power and improved charging flexibility." —Michael Leabman, founder & CTO of Energous

for a much wider variety of devices. The solution includes a GaN-based 5-10W RF receiver IC and a GaN-based 10-15W RF power amplifier (PA).

"These first GaN-based solutions for our WattUp wire-free charging technology support higher power and improved charging flexibility," said Michael Leabman, founder & CTO of Energous. "Our ability to develop multiple components within the WattUp ecosystem allows us to innovate based on our customer needs."

Another company leveraging GaN technology is Solace Power. It uses a technology called Resonant Capacitive Coupling (RC^2). In fact, the firm has developed a demo that uses capacitive resonance to deliver power to flying drones *(Fig. 1)* that can be charged several inches above the charging pad on moving automobiles, increasing total time in the air and reducing human interaction. The demo uses EPC's GaN FETs working at 13.56 MHz. Compared to silicon devices that can handle the same power levels, these FETs are five to 10 times smaller.



1. The unmanned aerial vehicle (UAV) charging demo fully charges a 7.4 volt/ 450mAh battery in less than nine minutes while hovering. *(Courtesy of Solace)*

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Energy harvesting. The energy and semiconductor sectors are also aware of the many benefits of GaN and SiC, along with the growth opportunities to maximize solar harvesting technology with better switching loss performance. Infineon, for example, has expanded its portfolio of SiC power module solutions by developing additional module platforms and topologies for the 1200 V CoolSiC MOSFET family, including a full-SiC module and two half-bridge topology modules *(Fig. 2)*.

2. The 62 mm module in half-bridge topology is featuring even higher power with an RDS (ON) of 6 mΩ per switching function. *(Courtesy of Infineon)*

Due to extended robustness, Infineon is taking advantages of the lower failure in time (FIT) and short-circuit capability. Initially, this product will support applications such as photovoltaic inverters, battery charging, and charging/storage systems.

GaN and SiC devices are already being adopted in these and other markets. Yet we will see a bigger shift from silicon wafers to WBG substrates in the future, thanks to research and development. For example, The U.S. Department of Energy (DOE) advanced $32 million in funding for 16 projects as part of two new Advanced Research Projects Agency-Energy (ARPA-E) programs: ENergy-efficient Light-wave Integrated Technology Enabling Networks that Enhance Datacenters (ENLITENED) and Power Nitride Doping Innovation Offers Devices Enabling SWITCHES (PNDIODES).

With $25 Million, the ENLITENED program will seek to double datacenter energy efficiency by deploying new network designs enabled by integrated photonics technologies. Similarly, the ARPA-E's PNDIODES program will take its approximate $6.9 million to develop transformational advances in the process of selective area doping in the wide-bandgap (WBG) semiconductor, gallium nitride (GaN), and its alloys. ed

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DESIGNATORS	DESCRIPTION	SYMBOL	DESCRIPTION
①	Module Configuration	1	Two Isolated Gate Drivers
②③	Isolation Voltage	40	4.0 kV
④	Gate Current	1	10 A
⑤⑥	Positive Gate Voltage	15	15 V
⑦⑧	Negative Gate Voltage	05	-5 V
⑦⑧	Negative Gate Voltage	15	-15 V
⑨	Package Information		O – Open Frame, M - Molded

PART NUMBERS AND ORDERING OPTIONS:

IXIDM1401_1505_O - two isolated gate drivers with 10 A gate current , 15 V positive and -5 V negative gate voltage, open frame version.
IXIDM1401_1505_M - two isolated gate drivers with 10 A gate current , 15 V positive and -5 V negative gate voltage, molded version.
IXIDM1401_1515_O - two isolated gate drivers with 10 A gate current , 15 V positive and -15 V negative gate voltage, open frame version.
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WILLIAM WONG | Embedded/Systems/Software Editor

TESTING TYPE-C Power Management

Type-C has many advantages, including flexible power management, but this requires more advanced test tools to make sure things work properly.

The USB Implementers Forum (IF) brought the high-speed USB Type-C connector to the world. It has many advantages, including being reversible and sporting advanced power management that allows cables to deliver more power in addition to managing the power source. The new Fast Role Swap feature makes it possible to switch power sources in a multiple-device configuration that might include a combination like a docking station/hub, display, smartphone, keyboard, and mouse. The first three could be a power source.

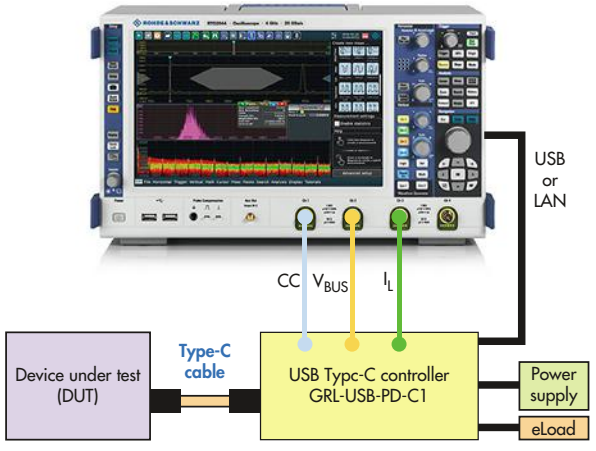
Likewise, USB Type-C cables are a bit smarter than the current run of USB 2.x compatible cables that is just a set of wires and connectors. Embedded in a Type-C cable can be a controller that lets the source and drain know what the cable is capable of handling since the specification goes up to 100 W. Most cables will likely support much less. The USB 3 standard upped the power from 2.5 W to 4.5 W (900 mA at 5 V). That is well short of the 100 W possible with Type-C.

Of course, making sure a source or cable does not allow other devices to be fried is a good idea, so advanced test tools and reference designs help developers make sure things work properly.

Kevin M. Jones, director of marketing and applications at Texas Instruments (TI), notes, "Compliance testing is a key requirement for many of our customers to ensure interoperability and a great user experience. TI has created the required infrastructure to allow customers to quickly set up and run USB-C/PD compliance testing. TI has also created reference designs to aid customers in testing complex interoperability and power design."

Granite River Labs developed the Compliance Test Software and the USB Type-C Test Controller Hardware *(see figure)*. These are available from Keysight, Tektronix, Rohde & Schwarz, and Teledyne LeCroy with the software running on digital oscilloscopes that can analyze the Type-C protocols.

The channel configuration (CC) pins are used to manage the power distribution. The CC is independent of the data channel that supports the USB 2.x and USB 3.x as well as alternate protocols like DisplayPort and MHL. The CC support manages the latter as well.



Granite River Labs developed the Compliance Test Software that runs on oscilloscopes from Keysight, Tektronix, Rohde & Schwarz, and Teledyne LeCroy. The USB Type-C Test Controller Hardware ties everything together.

Type-C test fixtures like Keysight Technologies' N7015A are needed to expose all the Type-C pins including power, CC and data. Jit Lim, product manager at Keysight Technologies, says, "The Type-C connector in conjunction with USB-PD (Power Delivery) brings wonderful capabilities to the USB ecosystem. In addition to electrical testing, it is very important to consider Safety Testing of Type-C power management. This is because USB-PD provides up to 100W capabilities."

A low-cost option for just checking the CC protocol is Cirrus Logic's CY4500 EZ-PD Protocol Analyzer. The device is a pass-through for the high-speed communication, but it monitors the CC lines. The PC application analyzes the capture data and developers can view it in trace mode.

The Type-C connector and cables promise a more flexible wired-device connectivity than the popular USB connections have delivered. The added solution complexity is matched by the increased control complexity that has been added to the mix. Proper operation will only be had with compliant and compatible cables and devices. Developers will be able to deliver that with the proper tools. ed

DANNY ROCKETT | VP of Manufacturing and Technology, Global Technology Systems Inc.

A Fundamental Approach to Mobile-Device Battery Selection

Effective battery-pack design can give you an important competitive advantage in the mobile-device marketplace.

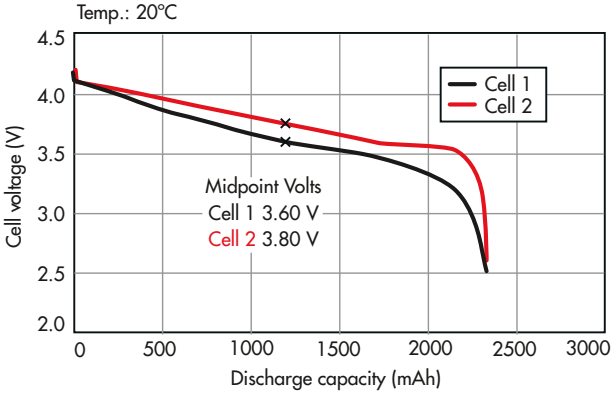
When trying to decide on the right battery cell for a mobile-device application, designers must sift through the differentiating features between these cells—as well as be keenly aware of their shortcomings. Another issue that's carrying more weight these days is the continuance of cell supplies to the industry.

For instance, due to the predicted growth in electric vehicles (EVs), cell manufacturers are dedicating much of their production to this emerging new market and are allocating fewer cells to the mobile-device markets. A recent article in the *Wall Street Journal* stated that more than 40 Tesla-sized "Gigafactories" would be required to meet the anticipated demand of the EV market. This puts new pressures on mobile-device and battery-pack designers—especially on smaller volume projects.

To gain a competitive edge in this mobile-device battery space, it's important to thoroughly consider the *entire* battery design and apply proper techniques during the development process. Just making minute tweaks in cells used, battery-assembly components, and assembly techniques can enhance overall device performance and end-user productivity.

Also, be sure that the battery cell you choose will be available during the estimated service life of your device. Keep in mind that you will likely be providing replacement battery packs and chargers for many years.

A high-performance—yet safe—battery has become paramount, especially in light of today's high-energy lithium chemistries. Thus, its design should be predicated on four main building blocks:



Cell 2 is better suited to provide more capacity to applications with higher voltage.

- A safe cell with optimal price/performance balance.
- A cell that will be available for the life of the mobile device it powers—now more important than ever.
- A properly designed battery-management system (BMS) or safety circuitry electronics.
- Battery-pack construction and internal materials.

FOLLOW THESE STEPS

Match Up the Specs

Perhaps the most critical consideration is to select a cell that properly matches the application. Choosing the *correct* cell is more than just about its overall form factor and cost. Differences in device run time and reliability under various operating conditions must also be carefully analyzed. Temperature extremes of the usage environment, charge and discharge

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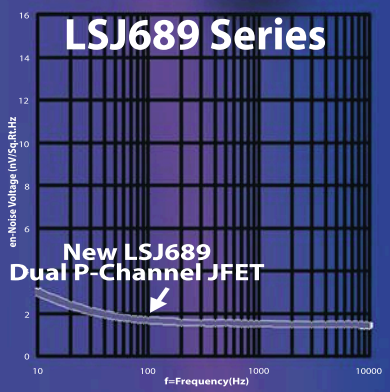

- A Low-Noise Alternative to IC-Only Solutions
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Perhaps the most critical consideration is to select a cell that properly matches the application. Choosing the *correct* cell is more than just about its overall form factor and cost.

regimes required by the device, internal cell impedance, and operating voltage profile of the cell also must be reviewed carefully to match device and user specifications.

Consider a Top-Tier Manufacturer

With the vast array of cell manufacturers and cell models out there, it can become quite the challenge to find a cell that correctly matches your device application. Often, the most pragmatic approach is to start with a top-tier cell manufacturer. Then get the following information:

- The cell safety certification per UL 1642/UL62133.
- The "UL yellow card" indicating that the cell was properly tested.
- A certificate showing that testing was performed for safe shipping of the product per UN 38.3.

If this documentation isn't available, steer away quickly. Top-tier cell manufacturers should be able to readily supply these documents.

Safety First

Cell performance should always be considered secondary to safety. Careful review of the cell specifications may highlight deficiency areas within some products that don't match the application.

Ask questions to sort out differences in cell-performance characteristics:

- How is the mobile device charged, and what are the temperature extremes during charge?
- Can the cell sustain discharge at the lower temperature extremes?
- How does cell life factor into the overall usage regime?
- How does the internal impedance affect overall discharge efficiencies?
- Does the cell's discharge voltage profile match the device's operating-voltage levels for maximum capacity and runtime gains?

Li-ion or Li Polymer?

Another important question regarding the cell is whether to use traditional lithium-ion (enclosed in metal cans) or the newer generation lithium-polymer (enclosed in a foil pouch) products. Each product has its own benefits and shortcomings in performance, durability, safety, and choice of sizes. Although either is acceptable from a power standpoint, there are many tradeoffs. Advantages of Li-ion include:

- Traditional Li-ion cells are the most rugged and have the highest "acceptance of abuse" from the user. High-end, ruggedized applications are best served with these types of cells.
- Their metal-can construction provides the greatest protection against impact and shock resistance, as well as puncture by foreign objects. It unitizes the cell construction within the battery assembly while having the highest power density to weight and volume.

Lithium-polymer cells come with important advantages, and one main disadvantage:

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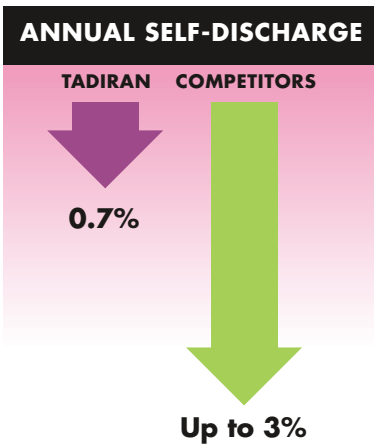

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- *Advantage:* Lighter weight.
- *Advantage:* More easily configurable for specific pack sizes and can fit into irregular shapes.
- *Disadvantage:* Due to their foil-pouch configuration, these cells aren't as ruggedized, and they can't pass some of the UL 1642 safety testing. Therefore, pack designs must be modified to adapt.

Consider carefully the proper cell-construction differences, whether traditional lithium-ion or lithium polymer, to assure your end product meets the intended usage.

Capacity and Lifetime

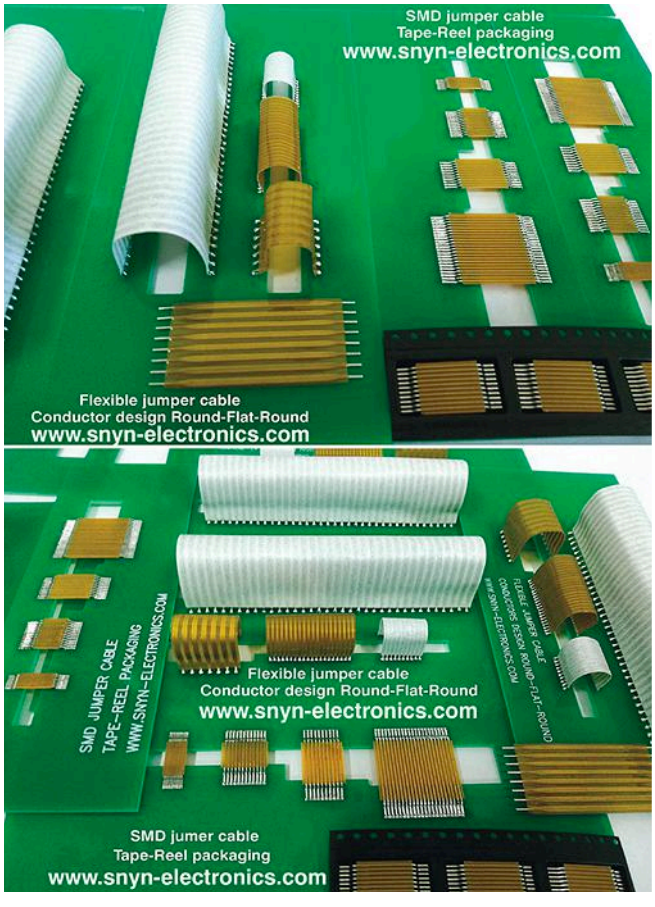
Overall cell-capacity differences must be reviewed to assure it meets the device needs in terms of capacity, voltage, and current delivery. Although usually specified to the same ANSI rating and overall testing, vast differences emerge under operating conditions. It's important to review the manufacturer's data, but also perform lab testing with various cell models to fully understand discharge differences.

Confirming that the cell you choose will be available during the estimated service life of your device is important. Proper cell selection will limit the design changes you may face down the road as that particular product goes end of life (EOL).

Consider carefully the proper cell-construction differences, whether traditional lithium-ion or lithium polymer, to assure your end product meets the intended usage.

Understanding all these possible scenarios may help avoid costly design changes later, and make your mobile device available for its intended lifetime. And addressing all of these issues will help protect against premature cell EOL and provide important sustainable competitive advantages.

DANNY ROCKETT leads the GTS technical and manufacturing teams as Vice President of Manufacturing and Technology. He has more than 35 years of battery experience in a variety of assignments and responsibilities with General Electric, Gates Energy, Energizer, Nexergy/ICC and GTS. His expertise in batteries covers OEM and aftermarket products for consumer, industrial, enterprise, and public-safety markets. Danny holds three U.S. patents and has published a variety of articles within the battery industry for trade magazines.



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18. Debbie Brady, Manager, User Marketing — Date 9/6/17

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Charged Up

MARIA GUERRA | Technology Editor
maria.guerra@penton.com

Taking Lithium-Ion Batteries to the Extreme

Rice University scientists went on a mission to discover ways to extend lithium-ion battery life in extreme temperatures.

Demand for lithium-ion battery technologies is higher than ever; in particular, the demand for harsh-environment-graded batteries is on the rise. We're seeing greater use of these in military and space applications, which typically have temperature ranges of between –40 to 80°C. Electric vehicles represent another popular application—battery systems must be able to perform well in both cold and hot conditions.

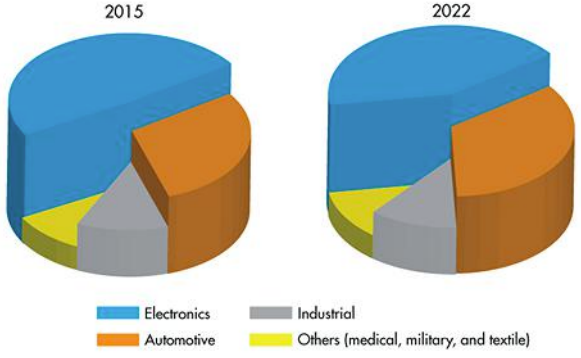
According to Allied Market Research *(see chart)*, electronics is the highest revenue-generating industry vertical for the Li-ion battery market, owing to the increase in their adoption in smartphones, tablets, laptops, and personal computers. However, the automotive segment is expected to be the most lucrative industry for these batteries, thanks to greater demand for electric vehicles and hybrid vehicles in China, the U.S., and Japan, among others.

Despite all of the advantages offered by Li-ion batteries, they suffer from aging and are prone to thermal runaway. Potential events similar to the Samsung Note7 and Boeing Dreamliner incidents are increasing the pressure to find better materials and designs for these batteries. Also, Li-ion performance drops as the temperature dips, due to the impact of the temperature on the mobility of electrons through the battery. Clearly, the technology still needs to mature.

LIFE MANAGEMENT

On this front, a team at Rice University is researching new ways to extend the life of lithium-ion batteries in extreme heat or cold temperatures. According to a published paper of their findings, they focused on the thermal tolerance of Li-ion batteries from a materials perspective in harsh environments. More specifically, they investigated how batteries perform in temperatures from –60 to 150°C (–76 to 302°F), knowing that current batteries are designed to operate near room temperature and within a narrow temperature range.

"Most research involving batteries and temperatures involves management systems. For instance, if a phone is used in cold temperatures, they slow it down a little bit to preserve the battery," says Hemtej Gullapalli, a postdoctoral researcher at Rice and co-author of the paper. "But we found in our review that the perspective is changing slightly. To make batteries that work from low to high temperatures, scientists have to take the materials perspective to see what temperature is specifically doing to the materials."



In this chart comparing the global lithium-ion battery market in 2015 and what's forecast for 2022, the electronics industry is the dominant consumer. *(Courtesy of Allied Market Research)*

The paper reports on the prospective materials for each of the three basic battery components: negative anode, positive cathode, and conducting electrolyte. The authors emphasized how critical it is to understand the limits of the materials being used. For example, water-based electrolytes like lead-acid and nickel-metal hydride operate only between –50 and 50°C, while molten salt batteries work fine only at temperatures above 90°C. Batteries with lithium thionyl chloride operate between –60 and 150°C, but only at peak between 20 and 55°C.

As battery researchers overcome challenges through the study of better components (cathodes and anodes), materials, and improved power-management and cooling techniques, it will lead to batteries with larger capacity and faster charging capabilities.

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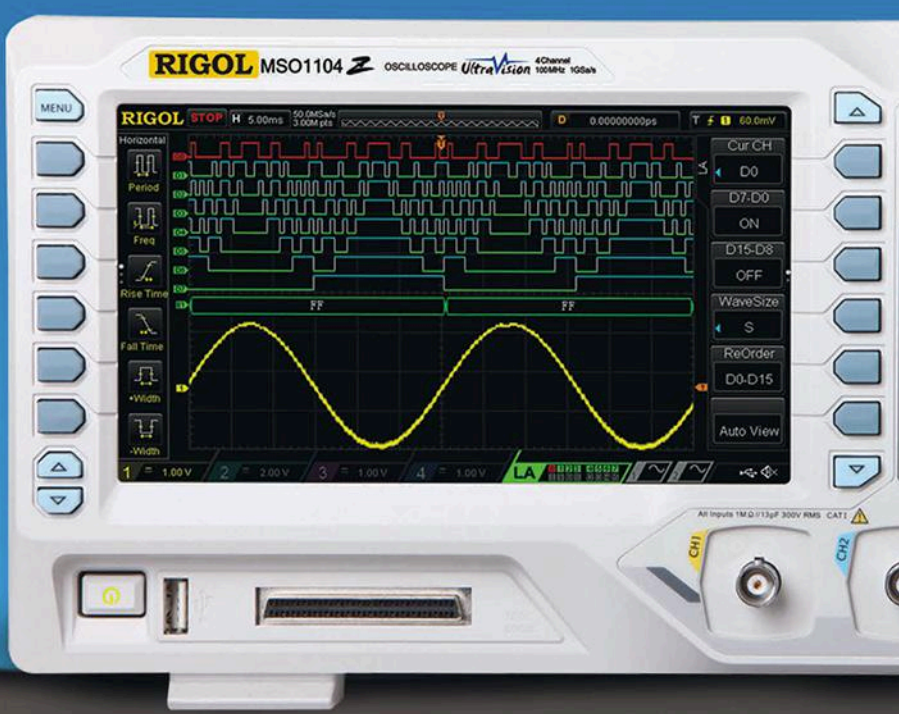

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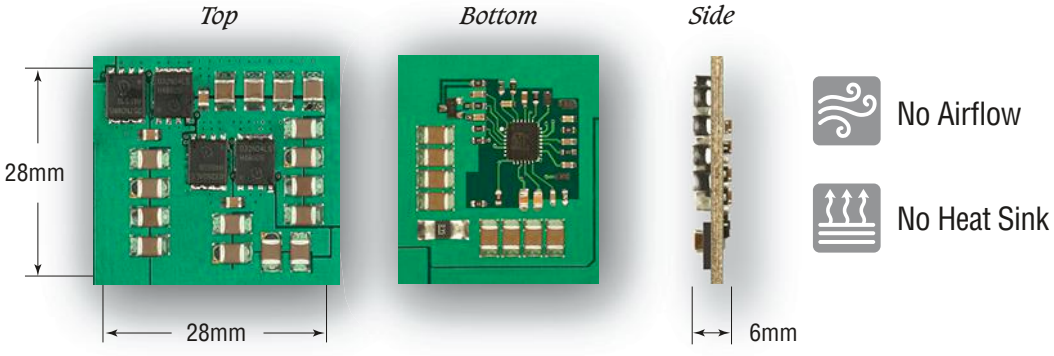

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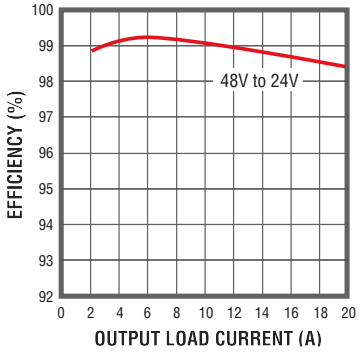
Efficiency vs Load Current



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