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## For Engineers, It's Not All About the Money

WITH SALARIES UP, WHERE DO YOU STAND?

KEEPING UP WITH TECHNOLOGY

THE IMPACT OF OUTSOURCING

TOP FACTORS IN JOB SATISFACTION

PREPARING FOR THE INTERNET OF THINGS

SALARY SURVEY
2015 • ELECTRONIC DESIGN



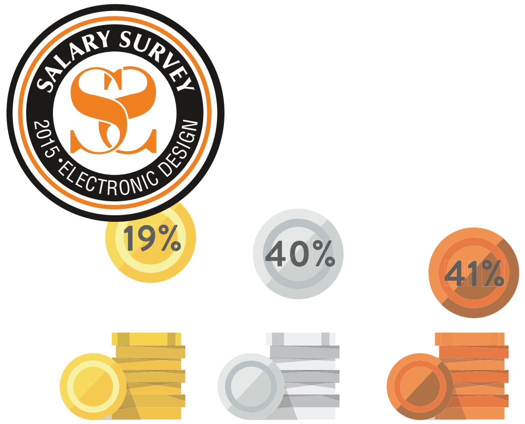
October 2015 VOLUME 63, ISSUE 10

electronic design

# InThisIssue

## FEATURES



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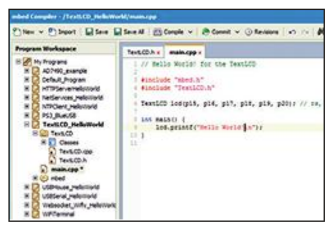

35

36

## NEWS & ANALYSIS



## IDEAS FOR DESIGN



## DISTRIBUTION RESOURCE



## COLUMNS & DEPARTMENTS





EDITORIAL MISSION:
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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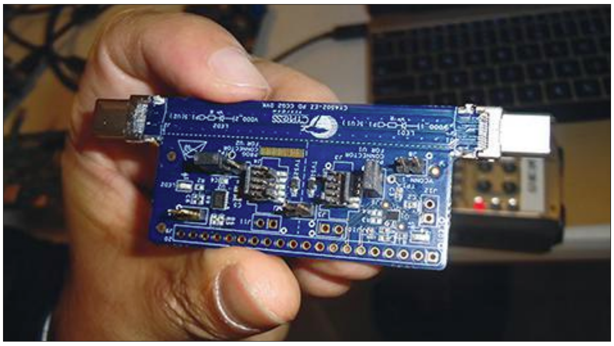


## WHAT'S UP WITH USB 3.1 TYPE-C?

There is a lot more to the USB 3.1 Type-C discussion than its reversible nature. Power management is a key differentiator, as is the ability to handle more than one interface through alternate mode operation. This will allow a single connector on a device like a laptop, smartphone, or tablet to link to devices other than those of the USB variety.

*http://electronicdesign.com/interconnects/what-s-usb-31-type-c*

## WHAT'S NEXT AFTER VPX?

First introduced in 2007, the VPX (VITA 46/48) board and backplane standard quickly became established as the next-generation replacement for the venerable VMEbus. More demanding emerging applications required support for serial fabrics, distributed, scalable compute architectures, and much greater data rates beyond VME's pin-based connector's capabilities. But today, technology and application requirements are accelerating at an even faster rate.

*http://electronicdesign.com/boards/what-s-next-after-vpx*

# blogs

**LOUIS FRENZEL**
COMMUNICATIONS
• What's Next for Smartphones?

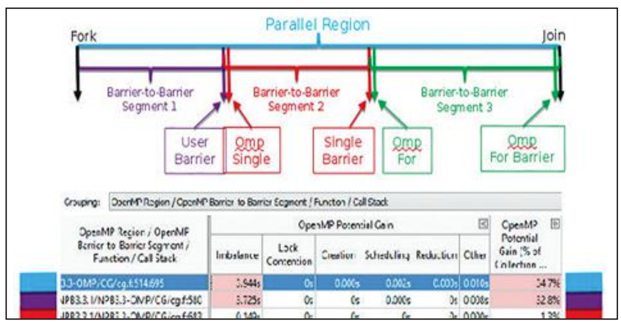
**BILL WONG**
EMBEDDED/SYSTEMS/SOFTWARE
• Write the FCC Now! Save Wi-Fi

**PATRICK MANNION**
TEST AND MEASUREMENT
• I Failed This "Please Help Me" Test. Would You?


## GALLERY: FOR DESIGNERS, A NEW SELECTION OF STORAGE CHOICES

All the latest memory technologies were at the Intel Developers Conference and the Flash Memory Summit, including 3D NAND, m.2 modules, and dual-port NVMe drives. The move to flash storage is clear, but there is no single solution that answers all environments.

*http://electronicdesign.com/memory/designers-new-selection-storage-choices*




## PARALLEL PROGRAMMING TOOLS GIVE TIPS TO PROGRAMMERS

Intel's Parallel Studio XE 2016 provides tools that deliver hints on how to improve parallelism so compilers can provide optimization. The compilers and libraries support the latest standards such as Java, C++14, C11, Fortran 2008, and the draft version of Fortran 2015 along with OpenMP 4.0 support.

*http://electronicdesign.com/dev-tools/parallel-programming-tools-give-tips-programmers*

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# The Developer's IoT Dilemma

Okay, it's time to develop something for the Internet of Things (IoT). Everyone's doing it, so it should be easy, right? Wrong. The dilemma for developers is that partners are needed to create a solution, since very few will develop an IoT solution from scratch. While getting tools and hardware from vendors is nothing new, buying or building IoT infrastructure is—and it tends to involve a larger number of cooperating parties. It also involves selling services, which is often a much different sales model for developers and their companies. This may also entail small payments or subscriptions with a range of additional services to separate customers from their money.

The problem is that once an infrastructure is chosen, it is unlikely that migration to another solution is possible (let alone easy, or practical). This means upfront research is critical, and long-term stability of partners will be key to overall success or failure. If you think migrating a website to a new platform is bad, even between versions of the same product, then the IoT equivalent could be a nightmare.

There is a plethora of IoT framework/stack solutions. It almost seems like every cloud provider, chip vendor, module vendor, and board vendor are working on, providing, or partnering to deliver a solution akin to the Matrix MXE-202i gateway, which works as part of ADLINK's SEMA Cloud platform *(see the figure)*.

All of these tend to be "standards based," but are typically APIs at the interface level. This is useful and, "in theory," makes it possible for components to be swapped out.



**The Intelligent IoT Gateway kit Matrix MXE-202i gateway runs the Intel IoT Gateway software, and it can be part of ADLINK's SEMA Cloud IoT solution.**

But an IoT framework is not—or at least, should not be—an isolated set of black-box components. Features like remote management and security need to span the system. Even minor differences in implementations will make testing changes a major task, and they could create performance-, security-, support-, or bug-related issues.

The IoT discussion makes all other technical discussions about languages, operating systems, or development environments seem like trivial exercises. IoT encompasses much more than just adding networking to embedded devices or linking networked devices to the cloud. It has more to do with integration than connectivity.

IoT comes in many flavors, from consumer to industrial, and each solution will have a different set of functional and IoT-related requirements. *Electronic Design* will continue to track emerging IoT technology and ask the hard questions that developers need answered. ed

# News

# CHARGE MANAGEMENT SYSTEM Extends Battery Life for Low-Power Wearables

**The MAX14676 attempts to extend the time between charges in low-power wearable devices by more efficiently managing system load.** *(Image courtesy of ThinkStock)*

The short battery life of low-power wearable devices has become a major concern for manufacturers, especially as wearable technology begins to emerge in the consumer electronics market and in the medical field for monitoring patients. The MAX14676, recently introduced by Maxim Integrated, attempts to extend the time between charges by more efficiently managing the flow of battery power in these devices. The integrated circuit (IC) includes a 1.8V buck regulator that exhibits a typical quiescent current of 900nA and 74% efficiency with 10 μA output.

Low-power wearable devices are integrated with embedded processors, light-emitting diode (LED) displays, and other components for transmitting data—all of which are a significant drain on its small battery. Not all these systems are in constant operation, however, so the MAX14676 is designed with a fixed-frequency pulse width modulation (PWM) and burst modes for increasing efficiency during both normal and light load operations.

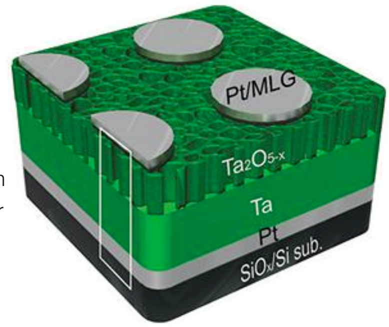
The MAX14676 is also equipped with a linear battery charger that is capable of operating on a dead battery and limits input current up to 28V based on a register setting. In the event that the charger power source is unable to support the full system load, a power control circuit will supplement the system load with current from the battery. In addition, the IC has an embedded fuel gauge that estimates the available capacity for rechargeable lithium batteries.

The MAX14676 is contained in a 0.5mm pitch wafer-level package (WLP). It features 3.2V 100mA low-dropout regulator (LDO), an always-on 2.0V 50 μA LDO, a +5V safe output LDO, and a 6.6V 120 μA charge pump. In terms of controlling power to LED displays, the IC comes with a 5V to 17V output boost converter and three-channel current sinks that can be programmed around LED configurations. The full data sheet is available from Maxim Integrated. ■

## NON-VOLATILE 3D RESISTIVE RAM Packs 162 Gbits

**A RESEARCH TEAM** from Rice University has produced a nonvolatile, resistive random access memory (RRAM) technology that provides high-density storage in crossbar memory arrays. Developed in the laboratory of Professor James Tour, the solid-state memory is based on tantalum oxide, a material commonly used in capacitors for mobile devices and computers.

Each 3D memory cell supports up to 162 gigabits or 20 gigabytes of information, using highly resistive materials to increase the density of the memory between each crossbar. The cells are built with layers of graphene, tantalum, and nanoporous tantalum oxide, all of which are pressed in between two platinum electrode crossbars. The research team found that applying a control voltage to the 250-nanometer-think stack creates addressable bits where the layers meet. The control voltage that writes and rewrites the cell is adjustable, although the crossbars are not dense enough to address individual bits.




**A schematic shows the layered structure of tantalum oxide, multilayer graphene, and platinum used for a new type of RRAM technology developed at Rice University.** *(Image courtesy of Rice University)*

The memory is based on a two-terminal material that requires only two electrodes per circuit, in contrast to the three electrodes used in current flash memories. The team, which published its research in the American Chemical Society journal *Nano Letters*, stated that the memory could be fabricated at room temperature and without using any diodes or selectors. Tour stressed that the memory is capable of running on 100 times less energy than present devices, resulting in higher endurance and durability.

The memory's switching ability is facilitated by the movement of oxygen ions and vacancies within the stack. The control voltage sent through the cell causes a boundary within the material to transform into a Schottky contact. This contact barrier changes its function based on the way oxygen vacancies shift within the cell, explained Gunuk Wang, the lead author of the research paper and assistant professor at Korea University.

Other authors of the research paper were assistant professor of mechanical and industrial engineering Jae-Hwang Lee, and Rice postdoctoral researchers Yang Yang, Gedeng Ruan, Nam Dong Kim, and Yongsung Ji. The full research paper can be downloaded at no charge by visiting *http://pubs.acs.org/journal/nalefd*. ■

## DESIGN COMPETITION TESTS Students While Exposing Them to Employers

**TEXAS INSTRUMENTS (TI) RECENTLY** honored student projects submitted to its 2015 North American Innovation Challenge, with entries judged primarily on their level of engineering analysis and their use of TI integrated circuits. The competition encouraged students to work through all levels of the design process, from the concept stage to sourcing components for their projects.

Troy Bryan and Sean Lyons, recent electrical engineering graduates from the University of Florida, were named the overall winners for their project—a synthesizer that can be played with hand movements rather than a keyboard. The project, 7 Deadly Synths, employed 12 infrared beams that detect hand movements and correspond to musical notes. The instrument, which was designed for musicians with limited mobility, is connected to both analog and digital synthesizers, making noise as the musician moves his hand through the infrared beams.

**The 7 Deadly Synths project, inspired by analog synthesizers of the 1960s and 1970s, was the first-place winning project of this year's TI Innovation Challenge.** *(Image courtesy of Texas Instruments)*

The Innovation Challenge, which is managed by Texas Instruments' University program, represents an ongoing initiative by chipmakers to interact with both students and potential job candidates through educational programs. These programs give students access to learning materials, components, and reference designs for teaching and research. In the process, students become more familiar with the company's products and design approach, which has the potential to ease their transition into an engineering position or internship.

Over the last year, the TI Innovation Challenge accepted submissions from almost 300 teams at accredited engineering colleges and universities in the United States, Canada, and Mexico for the North American competition. TI also runs design competitions in India, China, Europe, and the Middle East to extend its search area for potential engineers. The 2016 North American TI Innovation Challenge opened in September to eligible contestants. ■

# 2015 ENGINEERING SALARY SURVEY: It's Not All About the Money

According to the nearly 3,000 electrical engineers that participated in *Electronic Design*'s 2015 Salary and Opinion Survey, the engineering professions is in a period of transition. On the one hand, companies are still in the process of recovering from the economic recession and risk-averse corporate culture. On the other hand, the Internet of Things (IoT) is slowly maturing into a reality for technology companies and igniting demand—and competition—for engineering expertise.

With priorities shifting out of cost management and into developing new technologies for an IoT ecosystem, the employment outlook for engineers improved slightly over the last year. In general, companies are increasingly motivated to hire experienced engineers and provide slightly higher compensation to keep them. But at the same time, concerns about working conditions, job security, outsourcing, and continuing education have grown more entrenched in the psyche of the typical engineer.

The majority of engineers anticipate that their companies will either maintain or increase hiring next year. But approximately 51% of respondents—a percentage that has been steadily rising over the last five years—noted that their companies were having difficulty finding qualified candidates, especially in embedded and software design. "Extreme specialization in engineering makes job mobility difficult on the technical path," said one respondent, "and many employers seem to be unwilling to hire or train people who are merely close enough. The glut of engineers seeking work allows employers to be extremely choosy in hiring candidates."

According to this year's survey, almost two-thirds of engineers think a career in engineering and the potential for salary advancement is as promising as it was five years ago. In terms of total compensation, engineers reported an average compensation of $108,560, with bonuses and other incentives included, in 2015. (In contrast, the average compensation was $103,680 in 2010 and $106,482 in 2014).

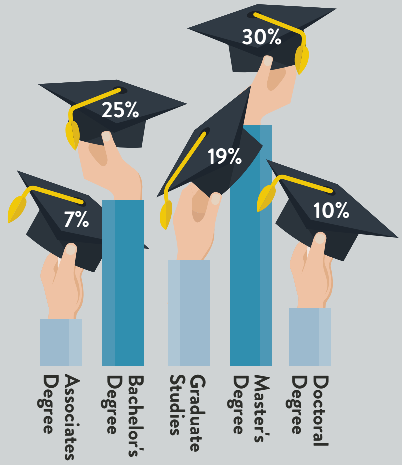
Even though many respondents are concerned that compensation is not keeping pace with workflow, almost two-thirds of engineers felt that they were adequately compensated for their work this year. At the same time, in contrast to questions about compensation, the vast majority of engineers reported that they feel satisfied and intellectually challenged in their current positions.

In general, the engineering profession appears to be moving in a positive direction. However, many engineers may have to adjust their opinions slightly to what constitutes a positive employment outlook, especially as the industry becomes more engrained in the global economy. The U.S. Labor Department Bureau of Labor Statistics (BLS) predicts that electrical and electronics engineers will have around 318,700 jobs in 2022—almost 50,000 more than in 2014, but also about 17,000 fewer jobs than the bureau recorded in 2013. Perhaps most importantly, many engineers remain satisfied with a profession that affords them the opportunity to get paid for indulging in their passions. ed

JAMES MORRA, associate content producer at *Electronic Design*, wrote this report. Data conducted and compiled by Jay McSherry.

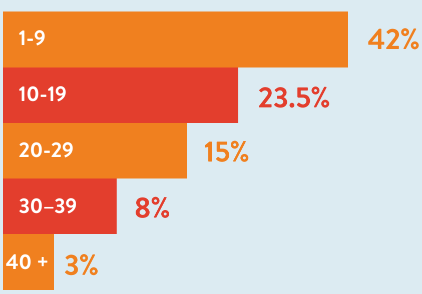
# THE TYPICAL ENGINEER

## Highest education level

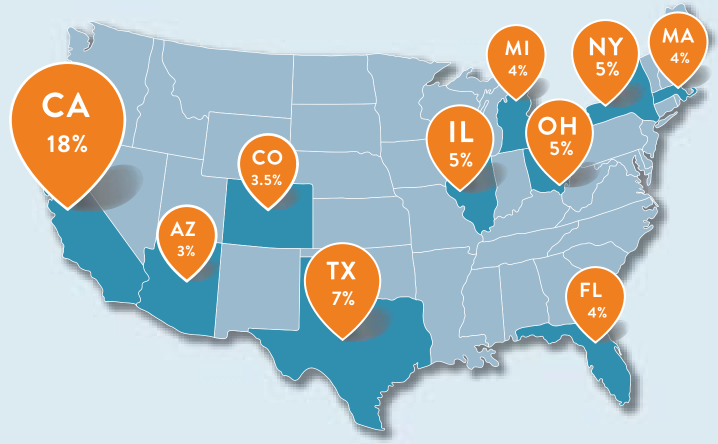



"To remain in the technical path, you have to be a life-long learner. Employers are looking for skills that a college education itself does not provide."

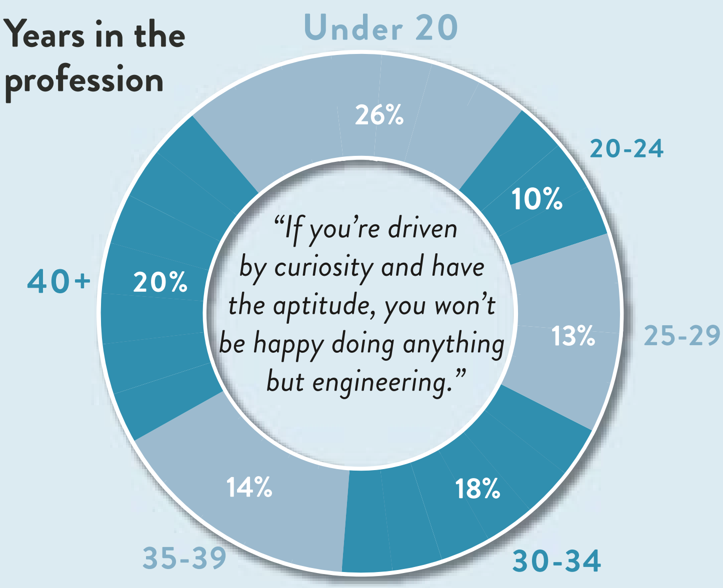
## Years at present company




## Work locations

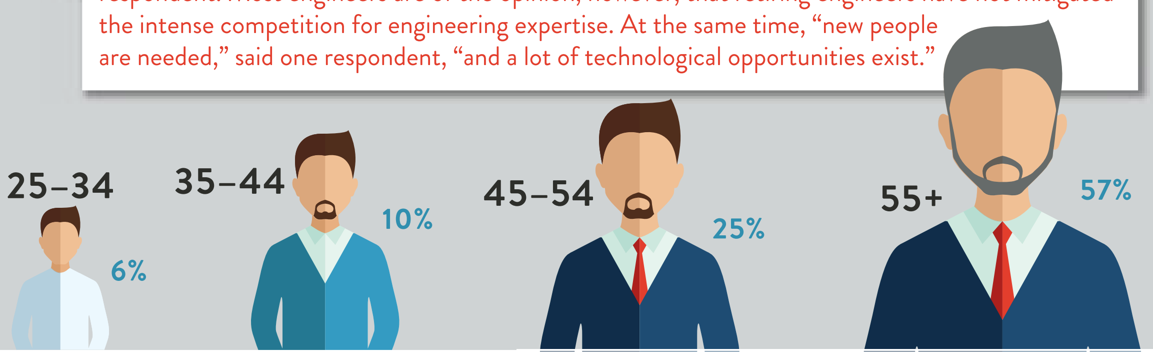



## Years in the profession




## Age

The typical engineer is growing older and edging closer to retirement age. "Engineers from the baby-boomer generation are retiring faster than engineers are graduating from college," lamented one respondent. Most engineers are of the opinion, however, that retiring engineers have not mitigated the intense competition for engineering expertise. At the same time, "new people are needed," said one respondent, "and a lot of technological opportunities exist."



## Average Compensation

# $108,503

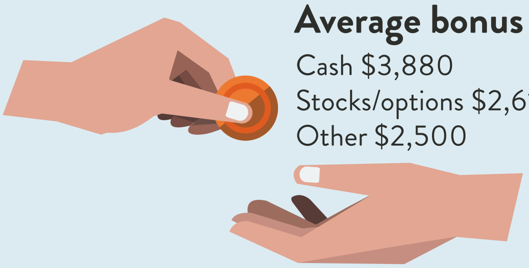
### Average compensation increase

**1.5%**

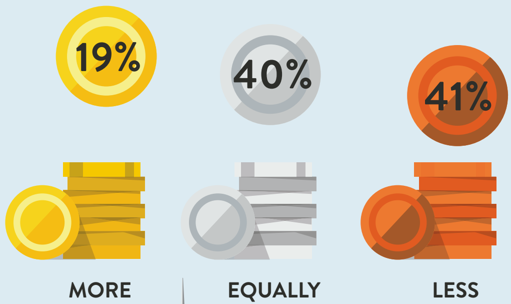
# COMPENSATION

### Average bonus

Cash $3,880
Stocks/options $2,616
Other $2,500



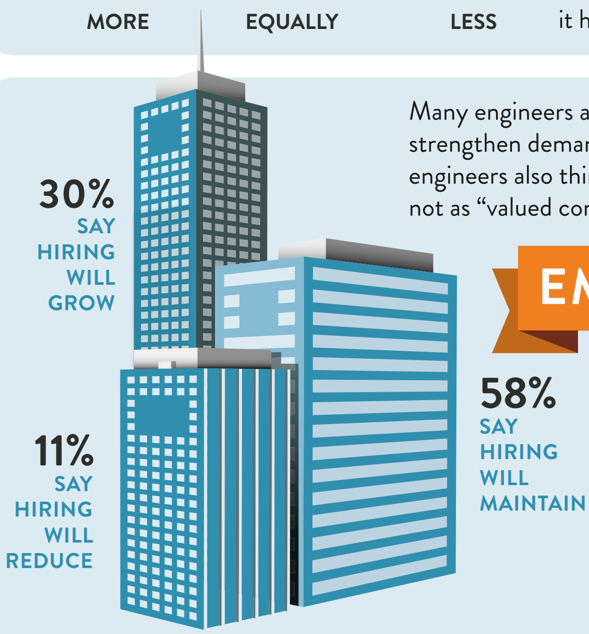
### How competitive is the average engineer's compensation?




In general, engineering salaries have not changed significantly in recent years, with many engineers referring to a "glass ceiling" on compensation rates and downward pressure from cost-averse corporations and H-1B workers. While compensation varies widely based on geographic location and job function, the average compensation rate grew more from last year than it has in almost five years.

Many engineers are optimistic that technological advancements will strengthen demand for their expertise going forward. But many of the same engineers also think that they are increasingly viewed as "commodities" and not as "valued contributors," as one respondent noted.

# EMPLOYMENT OUTLOOK

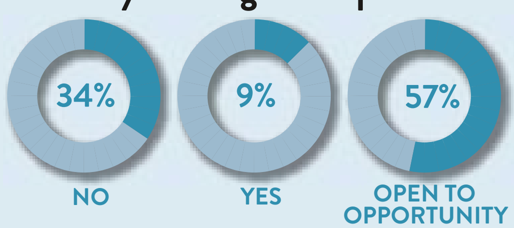



**Is an engineering career as promising today as it was five years ago?**

# 62% SAY YES

"Things are better now than five years ago with the recession, but overall engineering careers have been on a downward trend for a while, in my opinion."

### Actively seeking a new position




### Is your organization more focused on employee retention this year?

| | |
|---|---|
| YES | 30% |
| NO | 70% |
| % Contacted by a recruiter this year | 53% |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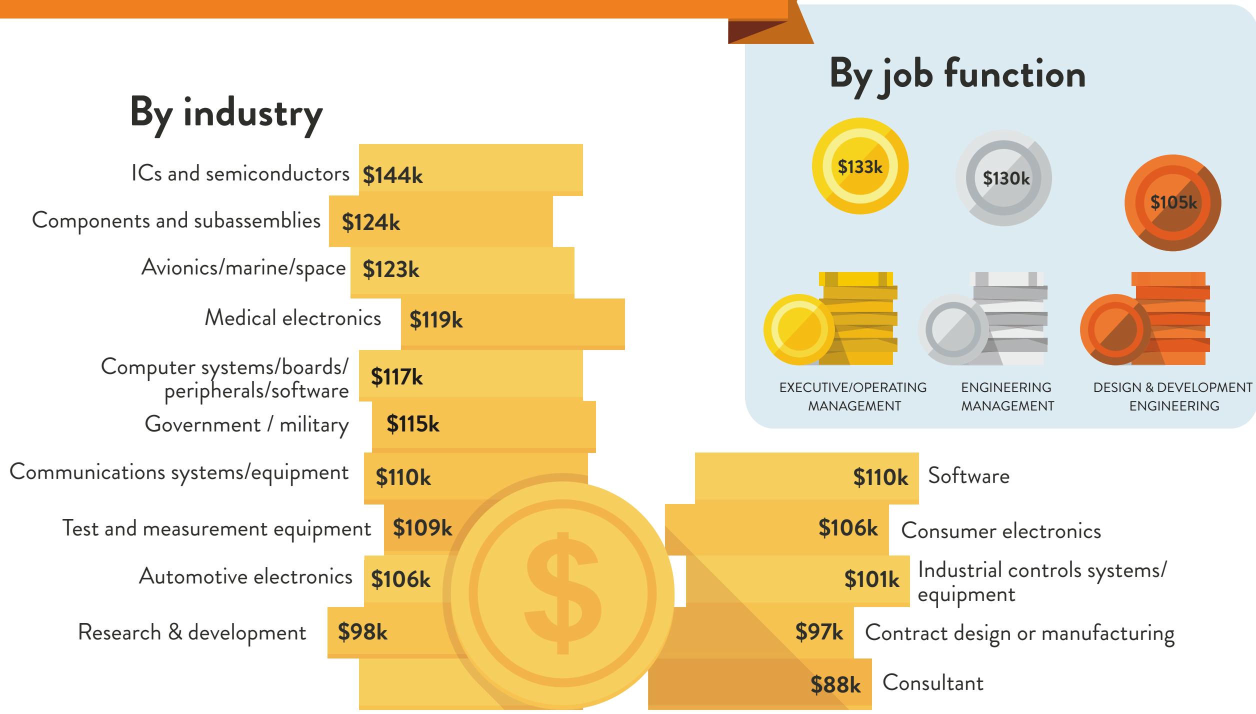
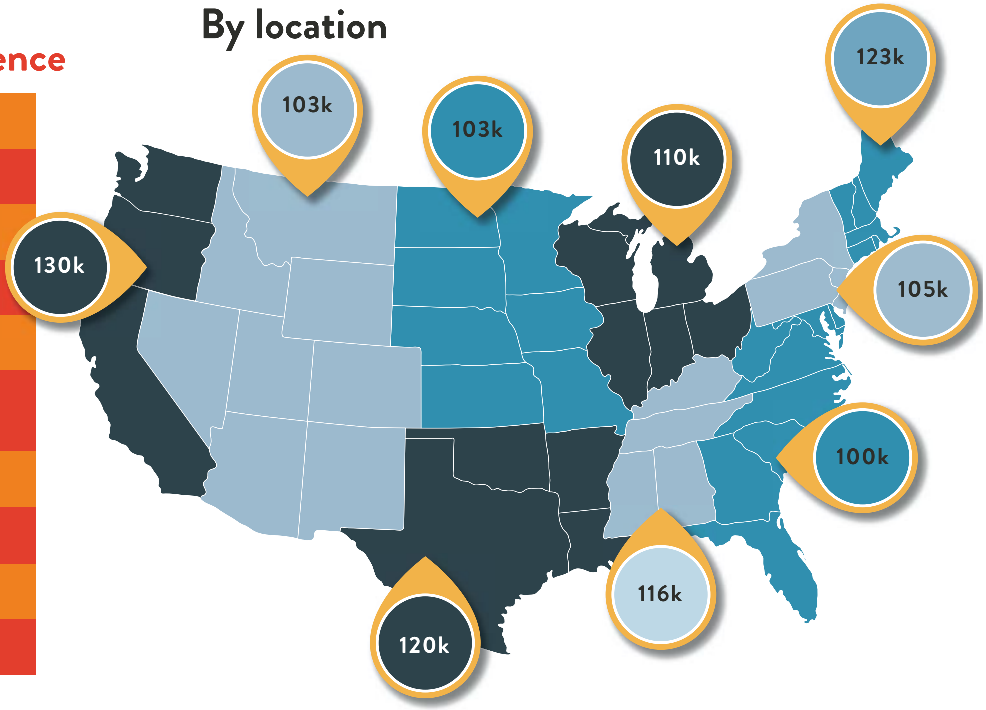
# COMPENSATION BREAKDOWN



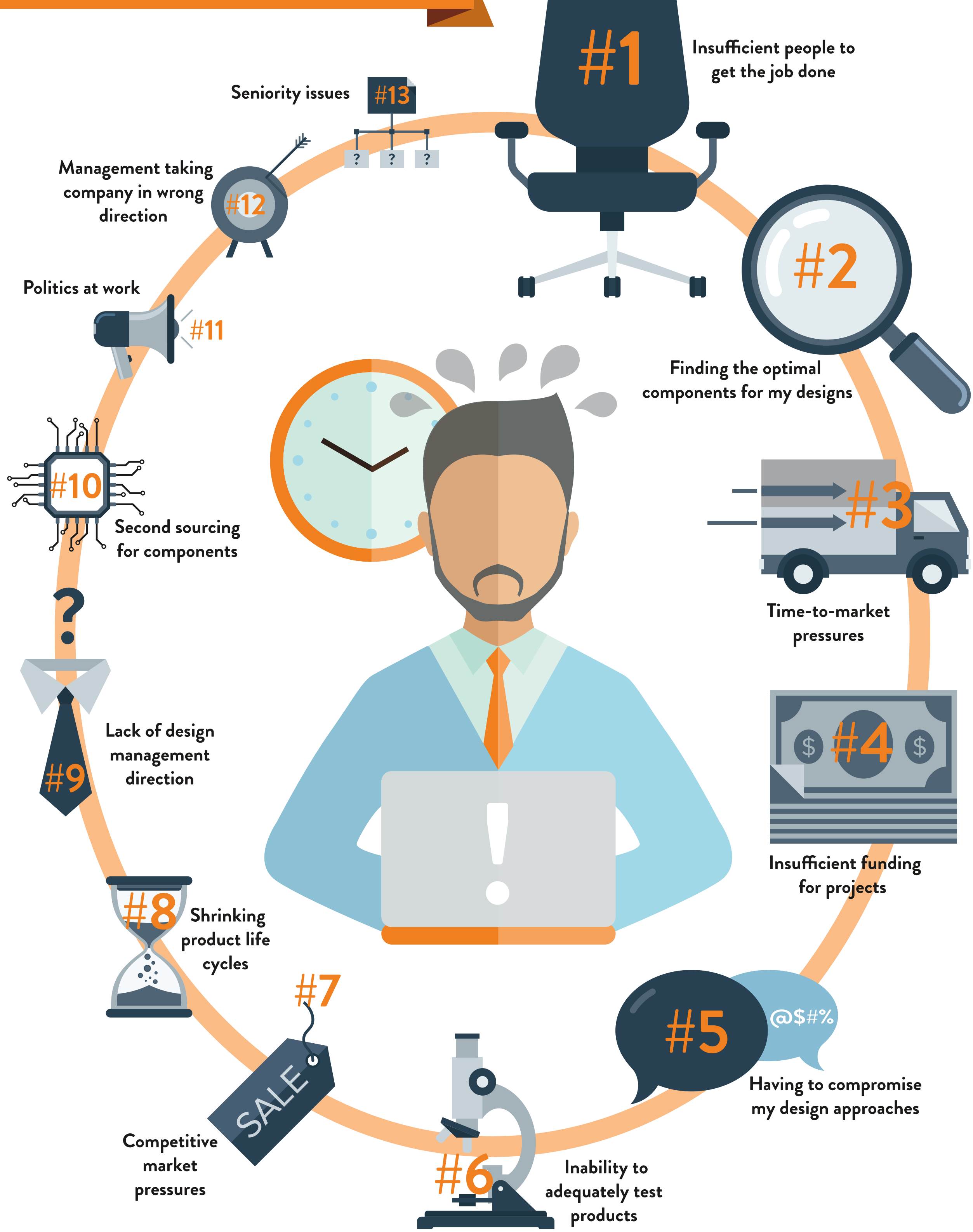
## By years of engineering experience

| | |
|---|---|
| 35-39 years | $123,212 |
| 25-29 years | $116,623 |
| 30-34 years | $115,780 |
| 20-24 years | $112,053 |
| 15-19 years | $105,917 |
| 40 years or more | $105,766 |
| 10-14 years | $90,093 |
| 5-9 years | $84,754 |
| 1-4 years | $68,100 |
| Less than 1 year | $60,389 |

## By location



# CONCERNS AT WORK



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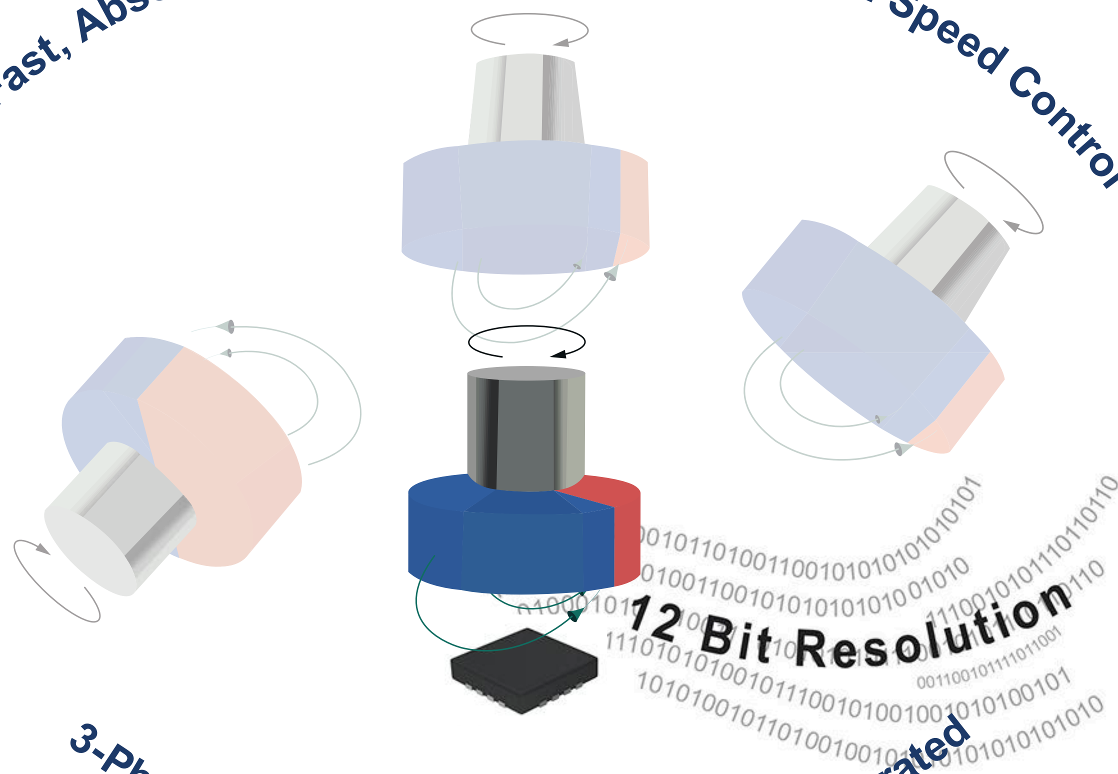


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# JOB SATISFACTION

The majority of engineers work for long hours under significant pressure from employers, but rarely view their compensation as the spoils of war. On the contrary, most engineers are satisfied with their personal circumstances, feel sufficiently challenged in their current position, and believe they are adequately compensated. "Engineering is a career where you get out of it exactly what you put into it," opined one respondent.

The average engineer works **54 hrs/week** at the office and at home and other locations

**64%** Feel adequately compensated

Feel compensation should increase on average by **21%**

| Reasons engineers would leave the profession | |
|---|---|
| No further chance for advancement | 16% |
| Do something less stressful | 22% |
| Do something more fulfilling | 23% |
| Curious about other opportunities | 31% |
| Start a business | 22% |
| Switch to teaching | 12% |
| Ready to retire | 19% |

| Job Satisfaction | |
|---|---|
| Extremely satisfied | 21% |
| Very satisfied | 32% |
| Satisfied | 35% |
| Not very satisfied | 10% |
| Not at all satisfied | 2% |
| Have considered leaving the profession | 34% |

"Engineering has lost a lot of its passion as evidenced by the lack of commitment engineers are making to their employers, due to the lack of commitment from the employers themselves."

## Most important factors in job satisfaction

1. Challenges that accompany the design of new products
2. Researching potential design solutions
3. Opportunity to design products that can benefit society
4. The compensation you receive for the work you do
5. Working in team situations with peers
6 .Working independently of others
7. The recognition you get from others for the work you do
8. The pressures associated with solving design problems

**58%** feel sufficiently challenged

**32%** feel somewhat challenged

**89%** would recommend the profession to a young person

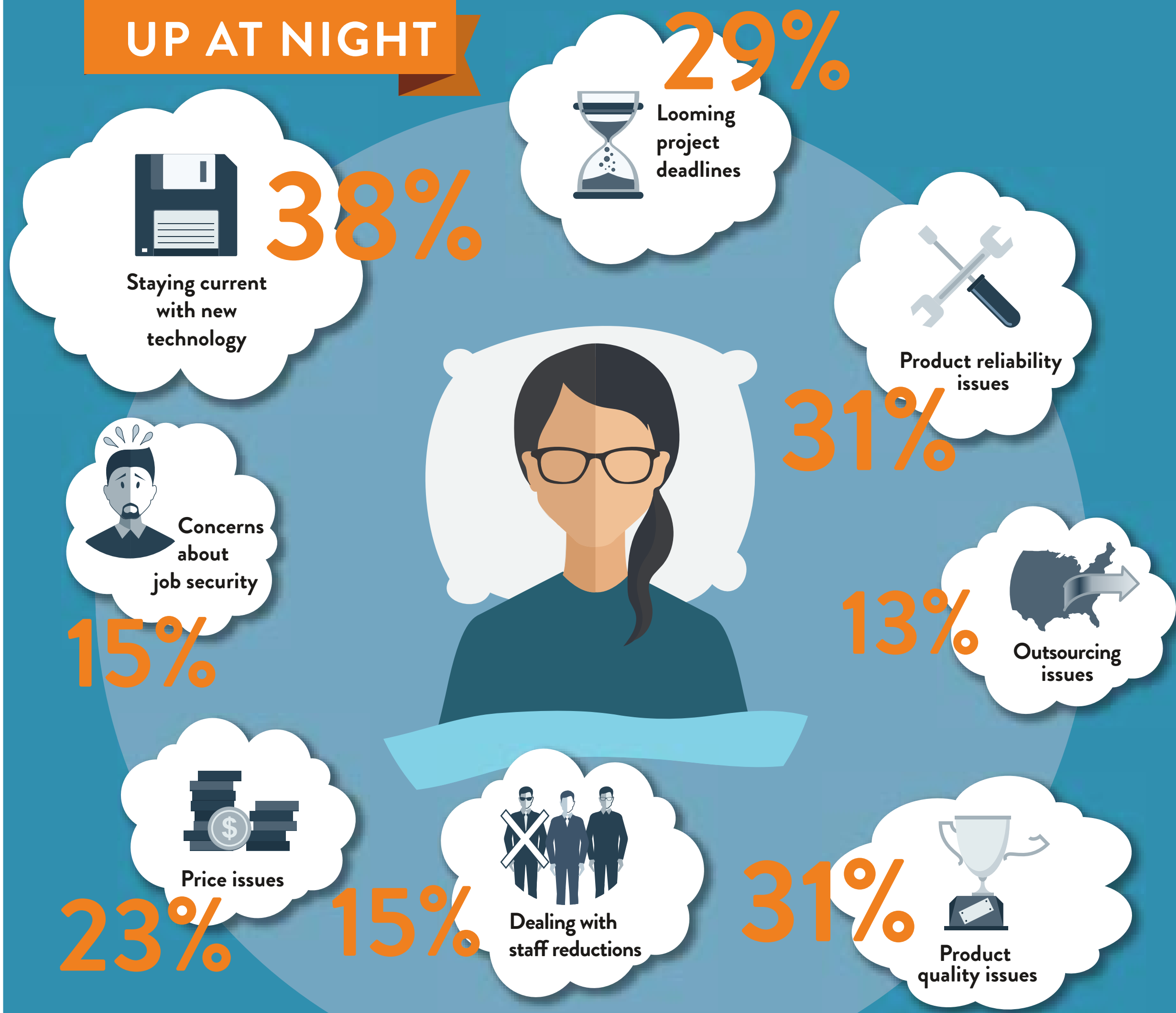

## ENGINEERS TALKING FROM THE PULPIT

"My career has offered me great flexibility personally and professionally—this is somewhat dependent on the company you work for, but the pay is good, and the challenge of solving tough problems is very rewarding."

"An engineering profession, if done properly, can keep you mentally sharp, diversifies your skills, and keeps you abreast of technological advancements. Engineers are likely to be well suited to move into many new professions, if their motivations drift in other directions."

# ISSUES KEEPING ENGINEERS UP AT NIGHT

The majority of engineers point to time constraints as the root of their professional concerns, especially as engineering jobs are reduced and the people left behind are forced to assume more responsibilities on shorter deadlines.




## ENGINEERS TALKING IN THEIR SLEEP

"It is impossible to stay current; there is too much information and not enough time. It is not possible to have any knowledge depth on new technologies."

"What worries me is the rapidly changing expectations of experience. Employers do not want to hire you for a position where you will have to learn new skills."

"It doesn't matter how efficient we become if we are not supported to test our products. Testing is an afterthought, and quality is long-gone."

"Unfortunately, the prevailing reason for outsourcing is purely economical, not technical, which jeopardizes the quality of products."

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|---|---|---|
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| Touch Screen | 8.5-inch Capacitive | No |
| Zone Touch Triggering | Yes | No |
| Sample Rate | 5 GSa/s | 2.5 GSa/s (>= 500 MHz)<br>5 GSa/s (1 GHz) |

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** Competitive oscilloscopes are from Tektronix publication 48W-30020-3

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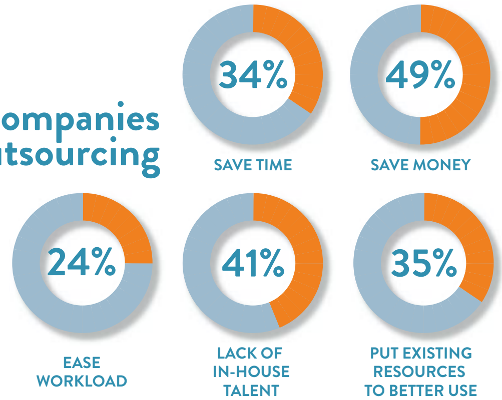
# THE NECESSARY EVIL OF OUTSOURCING

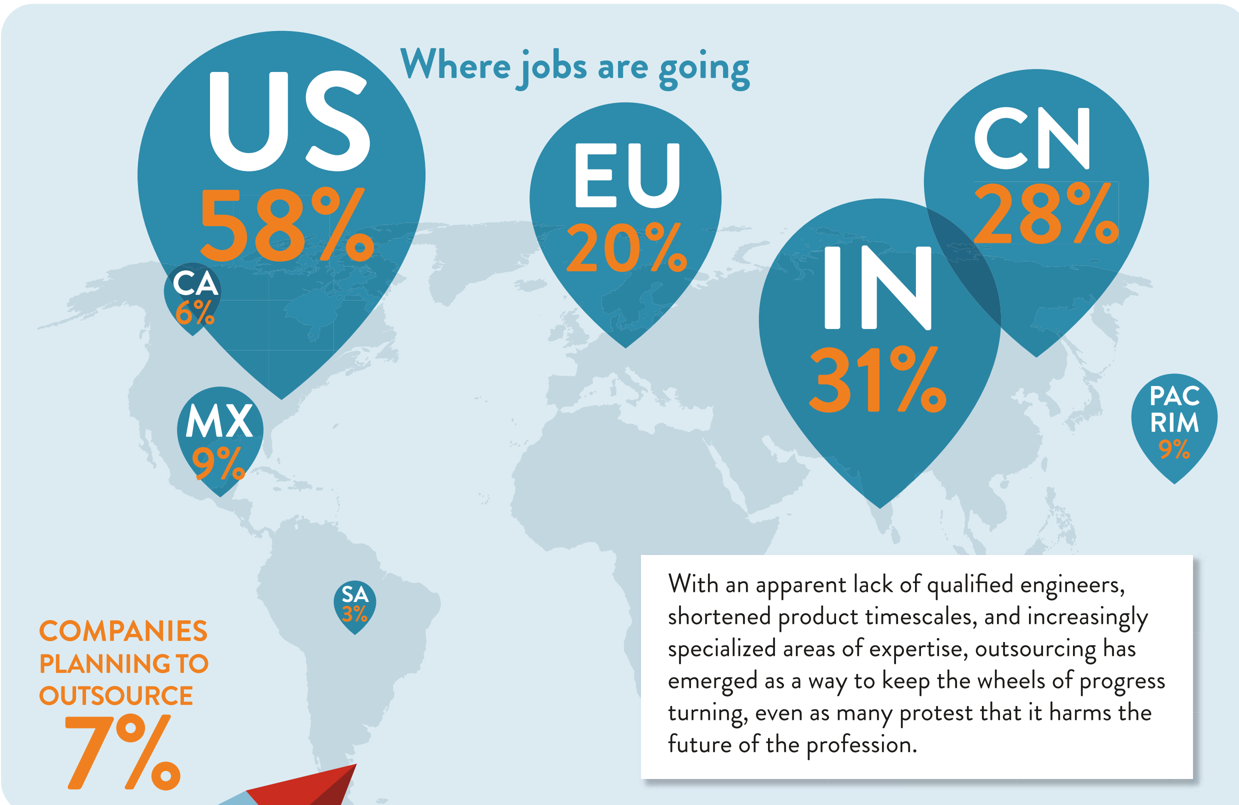
## OPINIONS ON OUTSOURCING

| | |
|---|---|
| FEWER ENGINEERING JOBS AVAILABLE | 42% |
| LOWER EMPLOYEE MORALE | 41% |
| FEWER OPPORTUNITIES FOR ADVANCEMENT | 35% |
| NEW HIRES AT REDUCED SALARIES | 34% |
| SKILLS VALUED LESS | 30% |
| SALARY REDUCTIONS FOR EMPLOYEES | 24% |
| OPPORTUNITY FOR MORE INNOVATIVE PROJECTS | 23% |
| IMPORTANT ASPECT TO BUSINESS GROWTH | 16% |
| SKILLS VALUED MORE | 14% |
| NEW HIRES TO SUPPORT OUTSOURCING EFFORTS | 12% |

## Reasons companies are outsourcing




## Where jobs are going




With an apparent lack of qualified engineers, shortened product timescales, and increasingly specialized areas of expertise, outsourcing has emerged as a way to keep the wheels of progress turning, even as many protest that it harms the future of the profession.

COMPANIES PLANNING TO OUTSOURCE **7%**

**52%** OF COMPANIES OUTSOURCE WORK

## JOBS BEING OUTSOURCED

| | |
|---|---|
| SOFTWARE ENGINEERING/DEVELOPMENT | 52% |
| MANUFACTURING/ASSEMBLY | 48% |
| DESIGN | 38% |
| SOFTWARE VERIFICATION/TEST | 22% |
| R&D | 21% |
| CAD/CAE | 21% |
| DESIGN VERIFICATION | 16% |
| DRAFTING | 12% |
| PCB LAYOUT | 12% |
| FINAL TEST | 17% |

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# CONTINUING EDUCATION


#1 obstacle to staying current with information:

## Finding the time.

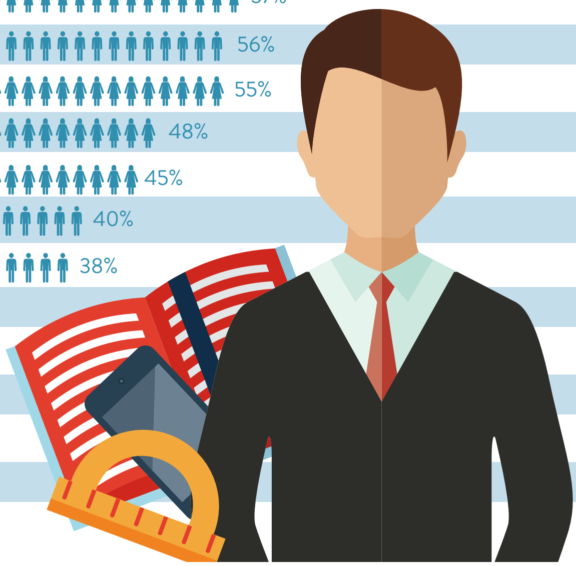
Staying current with new and emerging technologies remains a central issue among engineers, especially as it becomes more important in the eyes of employers. Heavy workloads, productivity pressures, and inadequate support from short-sighted management are among the main obstacles to continuing education, according to survey results. “The biggest challenge,” said one respondent, “is to convince the management that staying current is an investment in the future that might not pay off immediately.”

| For which of these forms of education does your company reimburse costs to engineers? | |
|---|---|
| Trade shows/conferences | 55% |
| Seminars | 54% |
| College tuition | 38% |
| Engineering textbooks | 35% |
| Engineering association dues | 27% |
| Certifications | 26% |
| Publication subscriptions | 26% |
| Online training | 25% |



## How engineers are keeping up

| | |
|---|---|
| White papers | 69% |
| Engineering/technology publications | 68% |
| Webcasts | 63% |
| Engineering videos | 57% |
| Engineering/technology websites | 56% |
| Seminars | 55% |
| Engineering textbooks | 48% |
| Vendor-sponsored education | 45% |
| Trade shows/conferences | 40% |
| E-books | 38% |
| Engineering association-sponsored meetings | 22% |
| Online discussion forums | 22% |
| Online college courses | 21% |
| User group meetings/Meetups | 19% |
| In-house educational programs | 18% |
| In-classroom college courses | 11% |



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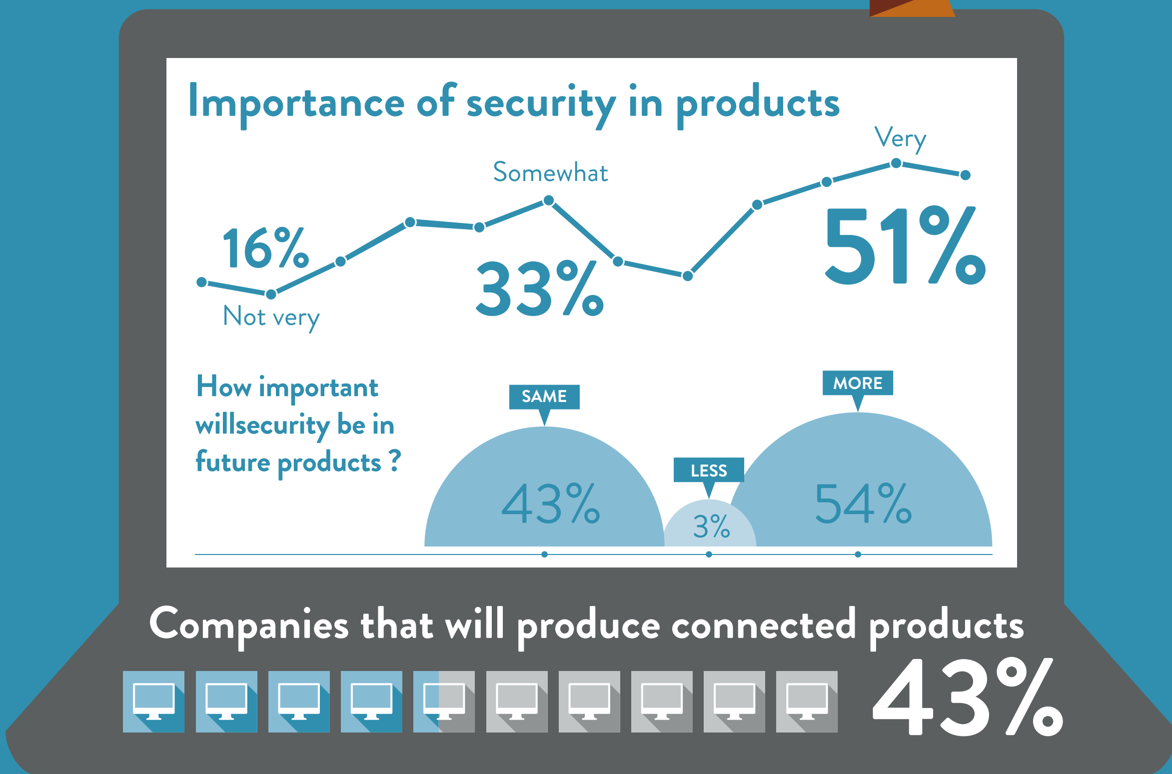
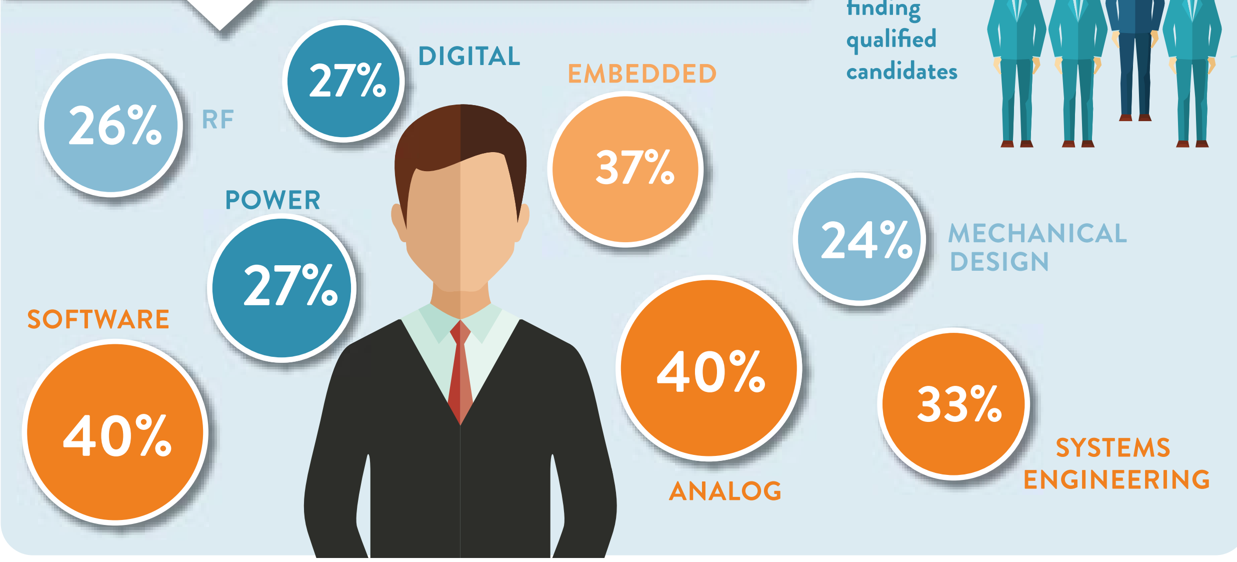
# PREPARING FOR THE INTERNET OF THINGS




**The Internet of Things** is expected to change the way in which individuals interact with technology and engineering companies design their products. Many companies are preparing for this paradigm shift with strategic acquisitions of analog and mixed-signal chipsets, in addition to Wi-Fi technologies. These maneuvers are being reflected in the engineering specialties that are currently in high demand. . . .

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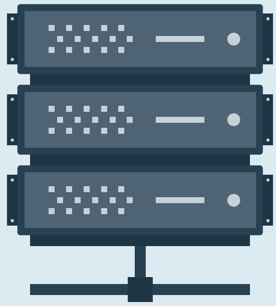
# TEST AND MEASUREMENT

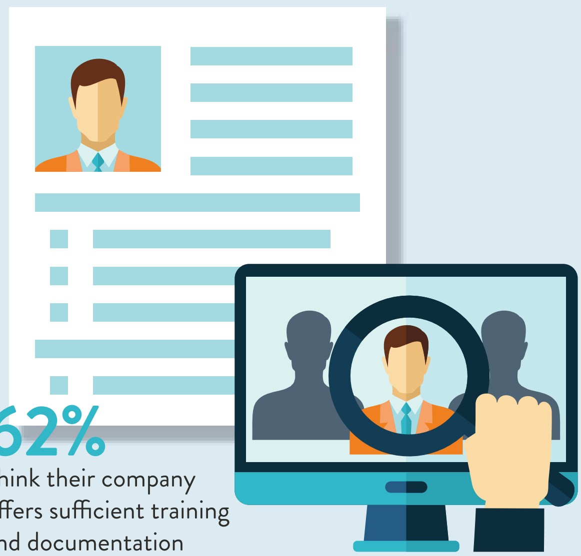
62%

**Think their company invests sufficiently in test equipment**



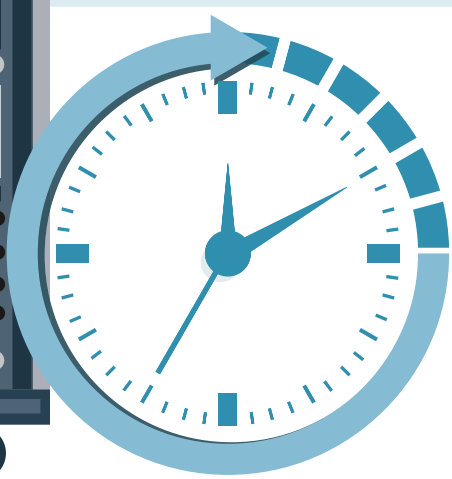
17%

Companies that have replaced box test instruments with modular solutions



62%

Think their company offers sufficient training and documentation



65%

Think testing is a significant challenge in terms of time consumption

BILL WONG | Embedded/Systems/Software Editor
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# SMART PERIPHERALS Make Low-Power IoT Possible

**Many IoT applications demand low-power solutions to provide long product lifetimes. Intelligent and linked peripherals are one way to make this work.**

How do you extend battery life in the Internet of Things (IoT)? Turning off everything you can, from the processor to peripherals, is a good approach. Since peripherals consume less power than the processor, it's a good idea to use them alone whenever possible.

This has led to more complex microcontrollers for IoT with more power modes. The advantage is lower power consumption, but the flip side is more complex applications. Peripheral controllers need to run without processor support, and cascading peripheral control can extend the complexity of the system to keep that very important CPU asleep.

The "smart peripheral" approach has many variants with different names, but the general idea is the same. For example, Renesas' RL78 has a "snooze mode" in which the analog-to-digital converter (ADC) operates while the processor is asleep. An $I^2C$ slave or CAN controller can watch for an address before it captures incoming data and then wakes up the CPU.

In a sense, Cypress Semiconductor's PSoC flexible family was out in front with configurable digital and analog peripherals. Part of the configuration is the ability to link peripherals together, so an ADC result could be dropped into a serial port to be sent to another device without the CPU being involved. The company's latest PSoC 4 BLE (Bluetooth Low Energy) can run the BLE radio while the CPU is asleep.

Microchip's Configurable Logic Cell (CLC) highlights the more conventional approach to configurable peripherals. A microcontroller may have one or more CLC blocks. Each block has a selectable set of inputs and outputs with limited logic capability so that the output of one peripheral can be fed to another. As with the PSoC, linked peripherals can often handle simple algorithms faster than the CPU can programmatically.


**Silicon Labs' energyAware Profiler tracks power utilization, in addition to power modes and peripheral status.**

STMicroelectronics' STM32 has "autonomous peripherals" that use a "peripheral interconnect matrix" to link peripherals together. Timers, DMA, ADCs, and DACs can be linked together.

The trend toward more functionality and complexity is highlighted by Microchip's PIC16F18877 family. It has a 10-bit ADC tied to a computational unit that can perform accumulation and averaging. It can even do low-pass filter calculations in hardware. The CPU can sleep until a filtered result exceeds programmed limits.

Intelligent hardware is useful, but taking advantage of it is more than just programming the peripherals. Advanced power trace tools like Silicon Labs' energyAware Profiler *(see the figure)* typically track power usage, as well as active and sleeping device status. This information is more complex because the CPU and peripherals are often operating independently. Part of the challenge for developers is understanding the ways in which different power modes interact with the CPU and peripherals as well as the power cost of using various configurations. The startup time for the CPU from different modes will be an additional factor.

Even volatile memory comes into play, with some microcontrollers being able to preserve segments of memory while in various sleep modes. Of course, some microcontrollers only contain FRAM that is a non-volatile memory, so it's not necessary to be as selective about what data to save between power modes.

Intelligent peripherals, distributed power management, and energy trace tools are here to stay. Developers can often get better battery life an order of magnitude or more of that available with basic CPU sleep mode over the life of a product for many applications (and not just IoT applications). Doing so requires some research, because microcontroller and peripheral solutions that have this type of facility vary widely in functionality. ed

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# IoT Development Tools Run on the Cloud

**Development tools are no longer rooted on your PC. Today, IoT development often means using the cloud to access your IDE.**

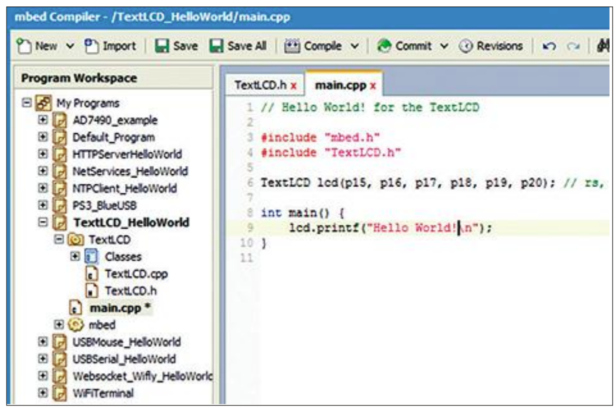
Running conventional development tools on the cloud is easy using virtual machines, but creating web-based tools becomes a major undertaking. They usually take the form of Infrastructure as a Service (IaaS) or Platform as a Service (PaaS). On the other hand, vendors see significant advantages to providing tools in the cloud. It also minimizes setup and configuration time for new users. Furthermore, developers can access the latest versions and possibly companion products.

For developers, a cloud-based solution allows the cloud to do the (often considerable) heavy lifting for large applications—especially for tasks like unit or regression testing. Development platforms can be lightweight hardware, such as Chromebooks.

Of course, there are potential downsides: Fast, reliable Internet connections are a must. Security is also a major issue, and some environments may not allow code to be located offsite. Customization and updates can be problematic as well. For example, a production environment may require a fixed version of the IDE and toolset. Many systems do automatic updates, and setting up multiple users on the same version—if it is not the latest one—can be a challenge.

Cloud-based development has been common for apps that target smartphones, but more platforms targeting embedded solutions have appeared. ARM mbed includes a cloud-based IDE (see the figure), although that's just one aspect of the mbed environment. The mbed environment includes an IoT framework and its own operating system, mbed OS. It targets ARM platforms and supports partners like IBM that provide IoT services.

The mbed targets embedded applications that run on ARM Cortex-M microcontrollers, so it is a more focused development environment. It can be used for standalone applications running on devices without communication links, as well as connected IoT applications. ARM has announced the mbed Client, a set of libraries allowing mbed OS programs to be ported to Cortex-A platforms running Linux. IoT communication support includes standard protocols like MQTT, CoAP, and LWM2M. These run on top of interfaces like Bluetooth, 6LoWPAN, IPv4, and IPv6.




**The mbed IDE runs on the cloud. It can download applications to local hardware for debugging.**

Wind River's Helix is another portfolio of software and services similar to mbed, but targeting a wider range of devices (including x86 architectures). The Helix Device Cloud is the cloud-based portion of Wind River's IoT support providing device management. Wind River was showing new additions to Helix at the 2015 Intel Developers Forum, including a cloud-based IDE integrated with remote hardware and debug tools.

Cloud-based collaboration using existing desktop IDEs is another way to take advantage of the cloud. A number of platforms use this approach, such as Microsoft's Visual Studio Online. Of course, this works with Microsoft's Visual Studio, but it's a team project system that works with projects written in any language using any IDE. For example, Visual Studio Online also supports Eclipse, a popular open-source IDE.

Visual Studio Online provides everything except the IDE from version control to agile development collaboration support. It's extensible using REST APIs and OAuth 2.0. Visual Studio Online also provides services like load testing. This feature can help make sure an application scales properly.

Desktop IDEs are not going away, but they are no longer the only alternative—even for embedded development.

LOU FRENZEL | Contributing Editor

# Serial I/O Interfaces Dominate Data Communications

**Electronic devices crave speed, speed, and more speed, which has triggered the creation and implementation of an array of serial interfaces across many markets.**


**The Tektronix MDO 3104 oscilloscope uses its I²C software to test and troubleshoot the interface.**

Practically every electronic product made today uses one or more serial data interfaces. A serial interface is the fastest and easiest way to get data into or out of a device. With so many different types of devices populating an enormous range of applications, it should come as no surprise that literally dozens of different interfaces are available for every occasion. USB, HDMI, and RS-232 are perhaps the most common interfaces, but many others also occupy this space.

## RATIONALE FOR SERIAL I/O

Digital data flows into or out of a circuit or device using two basic methods. The first way is via parallel data interfaces, which transfer multiple bits over parallel data paths. Parallel interfaces require one path, printed-circuit-board (PCB) trace or wire per bit plus a ground. If using balanced differential lines, two paths are required per bit. While this is the fastest way to trans-

**TABLE 1: AUTOMOTIVE INTERFACES**

| Interface | Speed | Medium | Application |
|---|---|---|---|
| Controller area network (CAN) | 5 kb/s to 1 Mb/s | Twisted pair | Most automotive uses |
| Ethernet | 100 Mb/s, 1 Gb/s | Shielded twisted pair | Most automotive uses |
| FlexRay | 10 Mb/s max. | Twisted pair | Sensor, actuator to controller |
| Local Interconnect Network (LIN) | 19.2 kb/s max. | Single wire | Switches, doors, windows, seats, controls, etc. |
| Media Oriented System Transport (MOST) | 25, 50, 150 Mb/s | Plastic optical fiber (POF) or twisted pair | Infotainment and navigation systems |
| On-Board Diagnostics II (OBD II) | 10.4, 41.6 kb/s | Multi-wire cable | Diagnostics and performance monitoring |
| Single Edge Nibble Transmission (SENT) | Clock tick interval 1.5 to 90 µs (11 to 667 kb/s) | Any wire | Sensor to controller only |

| TABLE 2: CONSUMER AND VIDEO INTERFACES | | | | |
|---|---|---|---|---|
| **Interface** | **Speed** | **Range** | **Medium** | **Application** |
| DisplayPort | 1.296, 2.16, 4.32 Gb/s | 2 m for max rate | 20-wire cable, 4 diff. pairs | PC to video monitor, projector |
| High-Definition Multimedia Interface (HDMI) | 6 Gb/s max. (Version 2.0) | 5 m for max rate | 19-wire cable, 4 shielded twisted pairs | TV set, DVR, cable box, other video |
| Lightning | 480 Mb/s | Several feet | 8-wire cable, 2 differential pairs | Apple iPhone, iPad data and charging |
| Thunderbolt | 10 Gb/s, dual channel | 3 m (copper) 50 m (fiber) | 20-wire cable, optional fiber optical cable | PC, Apple Mac peripherals |
| Universal Serial Bus (USB) | 480 Mb/s (Ver. 2) 5 or 10 Gb/s (Ver. 3) | 5 m (Ver. 2.) 3 m (Ver. 3.1) | 4- wire cable, shielded twisted pair (Ver. 2.0), 10-wire cable with 3 twisted pairs (Ver.3.1) | All purpose: PC peripherals, video, solid state drives, charging, etc. |

fer data, it's expensive and hardware-intensive because a driver and receiver are needed for each path. And cables for long distances become large and expensive.

The primary limitation of a parallel interface is speed over distance. As data-transfer rates accelerate, the path characteristics dictate an upper limit. Parallel PCB traces or wires in a cable act as filters and transmission lines. Path inductance, capacitance, and resistance introduce attenuation and rounding, thereby limiting the data rate. Furthermore, crosstalk between lines creates mutual noise, and different path lengths introduce bit skew that may affect timing at higher speeds. On top of that, parallel buses generate a significant amount of electromagnetic interference (EMI). All of this reduces the data-transfer range.

Such limitations not only restrict range, but data rate as well. The upper limits depend on specific cases, but the upper data rate is generally in the hundreds of megabits per second over no more than about several feet. That's why parallel transmissions are usually limited to interconnections between chips on PCBs or over short differential ribbon cables between PCBs or chassis.

Serial data interfaces, obviously the second digital-data-flow method, eliminate or at least minimize this problem. While data transfers are theoretically slower because of the bit-by-bit transfer, today's data rates range from a few bits per second to 100 Gb/s over long distances.

Serial connections require only a single path, either unbalanced or differential. Data can travel over PCB traces, single wires, twisted pair, coax cable, or fiber-optical cable. Range can be inches to hundreds of meters, or even more. Special

| TABLE 3: INDUSTRIAL INTERFACES | | | | |
|---|---|---|---|---|
| **Interface** | **Data rate** | **Range** | **Medium** | **Application** |
| Ethernet | 100 Mb/s, 1 and 10 Gb/s | 100 m | Shielded or unshielded twisted pair; fiber cable option | Connecting field buses to existing business networks or the Internet |
| Foundation Field Bus | H1: 31.5 kb/s, HSE: 100 Mb/s, 1 Gb/s | 1900 m max. | Shielded or unshielded twisted pair | Connect sensors, actuators, etc., in process control |
| Highway-Addressable Remote Transducer (HART) | 1200 and 3600 b/s | < 10,000 ft.. | Shielded twisted pair | Analog and digital sensor and actuator connections in process control |
| Modbus | 9.6 & 19.2 kb/s | < 1000 ft. | Shielded or unshielded twisted pair | Monitor and control with PLCs |
| Profibus | 9.6 and 31.25 kb/s, to 12 Mb/s | 1200 m | Shielded or unshielded twisted pair | Monitor and control in process automation |
| RS-232 | 1.2 to 115.2 kb/s | < 50 ft.. | Multiwire cable | Connections to PC peripheral and industrial devices |
| RS-485 | 100 kb/s to 10 Mb/s | 40 to 4000 ft. | Shielded or unshielded twisted pair | Industrial and commercial networks |

| TABLE 4: CHIP, PCB, AND BACKPLANE INTERFACES | | | | |
|---|---|---|---|---|
| **Interface** | **Data rate** | **Range** | **Medium** | **Application** |
| 100 Gigabit Ethernet Attachment Unit Interface (CAUI) | Ten 10-Gb/s links for max. 100 Gb/s | 50 cm | PCB and backplane traces | Chip and module connections on Ethernet equipment |
| HyperTransport | 3.2 Gb/s per serial link | <12 in. | PCB and backplane traces | Chip and module connections |
| Inter-Integrated Circuit ($I^2C$) | 100, 400 kb/s, 1, 3.4 Mb/s | <12 in. (PCB),< several feet (cable) | PCB traces or 4-wire cable | Chip and module connections |
| PCI Express (PCIe) | 2.5, 5, 8, 16 Gb/s per link. | <12 in. | PCB and backplane traces | Connections between processor and peripherals, backplanes |
| RapidIO | 1.25, 2.5, 3.125, 5, 6.25, 10 Gb/s per link. | <1 m | PCB and backplane traces | Connections between processor and peripherals, backplanes |
| Serial peripheral interface (SPI) | 20 Mb/s up to 100 Mb/s | <1 m | PCB traces or short 4-wire cable. | Connections between processor and peripherals, chip to chip |
| 10/40 Gigabit Attachment Unit Interface (XAUI/XLAUI) | 40 or 100 Mb/s | <50 cm | PCB and backplane traces | Chip and module connections on Ethernet equipment |

line drivers and receivers with equalization deal with the various path distortions. In summary, serial interfaces make it possible to go faster over longer distances with less hardware at lower cost.

One other note: Wireless interfaces are also serial—with only a single free-space path, serial transfer is the only practical method. The most popular short-range wireless interfaces are included in this article.

machines, robots, sensors, actuators, and other devices such as the widely deployed programmable logic controller (PLC). Some industrial interfaces define only the basic physical layer, while others define specific networking configurations and protocols. Several of these interfaces are referred to a fieldbuses.

The old and reliable RS-232 and RS-485 interfaces still dominate in the industrial sector, but Ethernet has made

## CATEGORIZING SERIAL INTERFACES

Typically, the two best ways to characterize serial interfaces is by speed and application. This article, however, categorizes interfaces as wired baseband, wired broadband, and wireless. Data provided includes speed, range, media, application, and standard designations. Applications targeted by these interfaces include automotive, consumer, industrial, and PCB interconnects and backplanes. Wireless interfaces are treated separately.

*Wired-Baseband Interfaces*

Interfaces discussed in this article are grouped by application. Maximum data rates and ranges are provided; data rate depends on range or medium length. Due to space limitations, only the most popular interfaces are listed.

- Automotive interfaces: With so much electronic equipment in cars and trucks, it was a natural evolution to connect things with buses or interfaces. Table 1 shows the most common interfaces that are used today.
- Consumer/video interfaces: Everyone uses these interfaces just about every day *(Table 2)*. For the most part, they deal with video connectivity or PC peripheral connections. The best example is the USB interface, which is by far the most widely utilized interface in the world (except for, perhaps, the RS-232 interface).
- Industrial interfaces: Factories, plants, process control, automation centers, and other manufacturing facilities all take advantage of industrial interfaces. They connect computers to one another and to a huge variety of

| TABLE 5: MOST POPULAR BROADBAND INTERFACES | | | | | |
|---|---|---|---|---|---|
| Interface | Standard | Speed | Medium | Modulation | Application |
| Data Over Cable Service Interface Specifications (DOCSIS) | CableLabs, ITU | 42.88 Mb/s max. per 6-MHz channel | Optical fiber and coax cable | QPSK, m-QAM | Cable TV, Internet access, VoIP |
| Digital subscriber line (DSL) | ANSI, ITU | Depends on version, from 8 Mb/s to 1 Gb/s | Twisted-pair telephone cable | Discrete multitone (DMT) with BPSK, QPSK, m-QAM | Internet access, VoIP |
| G3-PLC | IEEE, ITU | 46 kb/s, 300 kb/s | LV or MV ac power line | OFDM with DBPSK, DQPSK or D8PSK | Utility metering, smart grid, lighting, alternative energy monitoring |
| G.hn | ITU | Up to 1 Gb/s | Twisted pair, coax, or ac power line | OFDM with QAM | Home networking, video, Internet access |
| HomePlug | HomePlug Alliance, IEEE | Depends on version: 10 Mb/s, 200 Mb/s to 1 Gb/s | Home ac power line | OFDM with QAM | Home networking, video, Internet access |
| Multimedia over Cable Alliance (MoCA) | MoCA | 700 Mb/s to 1 Gb/s | Home cable TV coax | OFDM with QAM | Home networking, video, Internet access |
| PoweRline Intelligent, Metering Evolution (PRIME) | PRIME Alliance, IEEE, ITU | 5.4 kb/s, 128.6 kb/s, up to 1 Mb/s | LV or MV ac power line | OFDM with DBPSK, DQPSK, D8PSK | Utility metering, smart grid |
| X10 | Authinx | 120 b/s | Home ac power line | ASK/OOK | Home lighting and appliance control |

massive progress in this space due to widespread network connectivity and the subsequent need for higher data rates. Table 3 summarizes the most widely used interfaces in industry, but a number of special interfaces are in play, too.

- PCB/backplane interfaces: These interfaces are designed to connect chip to chip or PCB to PCB *(Table 4)*. The faster interfaces are used on backplanes in routers, switches, and other high-speed equipment. $I^2C$ and SPI interfaces dominate the chip-to-chip and PCB interconnections. PCI Express (PCIe) is the most widely used fast interface, but there's competition from HyperTransport and RapidIO. The faster interfaces all use two or more parallel serial links to produce higher throughput.

*Wired-Broadband Interfaces*

Broadband interfaces use modulation to transmit data—serial baseband data bits modulate a carrier or carriers, which are put on a cable. This is done primarily because data can be transmitted faster over longer distances. The downside, of course, is the greater complexity and cost, since both ends of a link require modulation and demodulation. The connecting device is a modem. Table 5 runs down the most widely used broadband interfaces and their main characteristics.

*Wireless Interfaces*

Various wireless interfaces have emerged over the years for specific applications, with a range of success in terms of popularity. Some are employed as a cable eliminator, while

| TABLE 6: MOST POPULAR SHORT-RANGE WIRELESS INTERFACES | | | | | | |
|---|---|---|---|---|---|---|
| Interface | Standard | Frequency | Speed (max) | Modulation | Range (max) | Application |
| 802.15.4 | IEEE | 868, 902-928 MHz, 2.4-2.835 GHz | 20, 40, 250 kb/s | DSSS with BPSK, or O-QPSK | 10-100 m | Industrial, consumer, IoT, utility |
| Bluetooth | Bluetooth SIG | 2.4-2.4835 GHz | 1 Mb/s, 2.1 Mb/s, and 3 Mb/s | FHSS with GFSK, π/4-DQPSK and 8DPSK | 1-100 m | Speakers, headsets, , medical, fitness, smartphones and watches |
| Digital Enhanced Cordless Telecommunications | ETSI | 1880-1930 MHz | Up to 2 Mb/s | GFSK, π/2 -DBPSK, π/4-DQPSK, π/8-D8PSK | 200 m | Cordless phones, home automation |
| EnOcean | ISO/IEC | 315, 868, 902-928 MHz | 125 kb/s | ASK | 30 m | Building or home automation, industrial |
| ISA100-11a | ISA, IEC, IEEE, WCI/ASCI | 2.4-2.4835 GHz | 250 kb/s | DSSS with O-QPSK | 10-100 m | Process automation, industrial, IoT |
| Near-field communications | ISO/IEC, ECMA, GSMA | 13.56 MHz | 106 - 424 kb/s | ASK | < 20 cm | Payments, access, pairing |
| Ultra Wideband (UWB) | IEEE, WiMedia Alliance | 3.1-10.6 GHz | 480 Mb/s, 1.3 Gb/s | OFDM, BPSK, pulse | < 10 m | Video, docking, military |
| Wi-Fi (802.11) | IEEE | 2.4 - 2.4835 GHz, 5.725-5.875 GHz, 60 GHz | 11 Mb/s to 7 Gb/s | DSSS, mostly OFDM | 100 m | LAN, Internet access, IoT, industrial |
| WirelessHART | HART Comm. Foundation, IEEE | 2.4-2.4835 GHz | 250 kb/s | DSSS with O-QPSK | 10-100 m | Process and building automation, sensor nets |
| ZigBee | IEEE, ZigBee Alliance | 868, 902-928 MHz, 2.4-2.4835 GHz | 20, 40, 250 kb/s | DSSS with O-QPSK | 10-100 m | Industrial, home automation, IoT |
| Z-Wave | Z-Wave Alliance | 908.42 MHz | 9.6 and 40 kb/s | GFSK | 30 m | Home automation, IoT |

others just simplify remote connections without the expense of laying cable. The majority of these interfaces are designed to cover short ranges, spanning from a few inches up to about 100 meters. Table 6 offers a summary of the most prominent among this group.

All of these interfaces use the unlicensed frequency spectrum specified in the FCC rules and regulations Parts 15 and 18. Several interfaces are based on the IEEE 802.15.4 standard, including ISA100, WirelessHART, and ZigBee. Applications are across the board, ranging from industrial monitoring and control, home networking, and the Internet of Things (IoT) to consumer, smart-grid and utility metering, and general networking.

### TESTING SERIAL INTERFACES

Before testing any serial interface, you should be aware of the particular standard's details. It's best to acquire the documentation from the standards organization. Such documentation spells out the specifications and, in many cases, recommended testing procedures.

The key testing requirements are usually data speed and bit error rate (BER). BER, typically used in high-speed interface testing, is simply the percentage of bit errors per quantity of bits transmitted. BER values range from roughly $10^{-5}$ to $10^{-15}$, depending on the interface.

Some high-speed interfaces also require eye-pattern testing and jitter measurements. Certain complex interfaces may also need protocol analysis equipment or software.

When it comes time to perform the tests, the instrument of choice is a digital oscilloscope with the appropriate software. Most scope manufacturers offer special testing software for the popular serial interfaces. It's a superior investment, as it greatly speeds up and simplifies testing. Manufacturers such as Keysight Technologies, National Instruments, Rohde & Schwarz, Tektronix, and Teledyne Lecroy offer appropriate equipment and software. In one example, a modern oscilloscope delivers the waveforms and code for an $I^2C$ interface *(see the figure on page 36).*

FOOTNOTE: This article is abstracted from the new book *Handbook of Serial Communication Interfaces, A comprehensive compendium of serial digital input/output (I/O) standards* to be published by Newnes/Elsevier in the fourth quarter of 2015.

**IN CASE YOU FORGOT** or just didn't know, the telegraph (1845) was the first wired serial interface. Instead of 1s and 0s, the code was dots and dashes of the Morse code. The range was miles over a single wire and ground. The concept behind this 19th century technology still goes strong today.

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# The IoT and the Supply Chain

Harnessing the power of the Internet of Things means identifying the hottest potential markets for design engineers and getting the right products to engineering and production in a timely manner, as well as laying the groundwork for better connectivity in manufacturing environments.

VICTORIA FRAZA KICKHAM | DISTRIBUTION EDITOR

**THE INTERNET OF THINGS** market is set to have a considerable impact on the electronics supply chain, affecting everything from purchasing to design to the plant floor. It will play out in different ways for each party, but industry watchers agree that the potential for 50 billion connected devices by 2020 (according to technology company Cisco Systems and others) means increased business opportunities across the board.

"The statistics don't lie. The number of connected devices [in the future] is going to be massive," said Dianne Kibbey, global head of community for electronics distributor and online community element14, which surveyed 3,500 customers on the potential of the technology earlier this year. "And there is so much development going on. If you think of everything in your life that is going to be connected—and also all the industrial and manufacturing applications that can benefit from this—every aspect of engineering is going to be affected by this technology."

That includes design engineers, purchasing professionals, and employees on the plant floor. The element14 study, titled "Engineering a Connected World," identified some of the hottest markets for IoT technology today and in the years ahead. Other industry researchers have pointed to key factors driving the potential of the industrial Internet of Things—a subset of the IoT that will have an impact on the plant floor. Here's a look at how IoT trends may play out across the electronics supply chain.

Image courtesy of Thinkstock

### TARGET MARKETS FOR ENGINEERS

The "Engineering a Connected World" report found that two-thirds of consumers want to see more "green" IoT technology; 68% think healthcare is one of the most important industries for IoT innovation; and 64% are worried about security implications, particularly for wearable electronic devices. This translates to key potential opportunities for design engineers working on energy- and environmental-related projects, health and wellness, and security applications. The automotive industry checked in as another top area for IoT development.

"There is a lot of development in automotive—and not just in entertainment systems, but in developing different efficiencies, reduced emissions [and so forth]," explained Kibbey. "The healthcare industry, renewable energy, and the environment are the top focus areas."

Kibbey added that the focus largely depends on geographic region, with healthcare ranking top in the United States and the United Kingdom, and transportation-related industries ranking highest in France, for example. The data helps point engineers and entrepreneurs in the direction of the industries that will be most important going forward. Kibbey also noted the potential for larger IoT-related projects, including city-wide water, lighting, and other energy- and transportation-related projects.

What's more, the survey data is helping element14 shape its online design challenges—contests in which engineers and hobbyists develop products and solutions for a range of real-world applications. In its newest iteration, the design challenges are shaped around the Engineering a Connected World theme, with environmental and health-related issues ranking high on the list.

"The design challenges we have coming up are very much centered around IoT," said Kibbey, emphasizing the importance of the technology not only to the design engineering community, but to society at large.

**"... If you think of everything in your life that is going to be connected—and also all the industrial and manufacturing applications that can benefit from this—every aspect of engineering is going to be affected by this technology."**

**—Dianne Kibbey, element14**

### IN THE PURCHASING DEPARTMENT

The proliferation of connected devices will affect the purchasing department, too. Buyers will be busy accommodating a growing need for the pieces and parts to make IoT projects work, as original equipment manufacturers and contract manufacturers keep up with new applications. Buyers will likely see an increased need for sensors and wireless technology, in particular.

"As a purchasing agent, you'll see an influx of purchases of electronic components for the pieces that make IoT work," explained Kibbey. "[There will be] a lot of pressure and demand to get these solutions to the design engineers fast."

Technological advances in and of themselves will also have an effect on buyers.

"Their world will change, too," added Kibbey, pointing to the inevitable streamlining of the profession due to increased connectivity. As one example, she points to HP smart printers that can detect when toner is low in the printer and automatically order more. "So the purchasing agent is freed up to do other things."

"You can see the impact of where this is going," said Kibbey, noting the potential to grow beyond the anticipated 50 billion connected devices in just the next few years. "The possibilities are endless."

### ON THE PLANT FLOOR

The challenge for manufacturing operations is a bit more fundamental. Production facilities nationwide will need to focus on developing a platform that will allow existing systems to talk to each other, enabling greater connectivity.

The industrial IoT (IIoT) refers to "smart connected operations" within a plant or production facility to create products and services, according to LNS Research, a manufacturing industry research organization. There is much work to be done to create these "smart" systems, LNS explained in a report earlier this year. It referred to a legacy of information and automation technology solutions that exist in manufacturing facilities nationwide that "do not easily interoperate with one another" today.

"... this communication sticking point is a major roadblock to actually realizing industrial IoT capabilities, and why the creation of an IIoT Platform that can integrate the information from these legacy systems is necessary," the firm said.

As technology improves and hardware becomes less expensive, more and more objects within a plant will become part of this connected network. LNS noted that by 2020, the network is expected to include devices, sensors, instrumentation, materials, mobile and fixed assets, products, and people. What's more, the researcher said manufacturers will have to focus on four main areas to develop the IIoT platform that will create the smart, connected factory of the future:

**Connectivity:** This includes all necessary hardware and software to network within the plant and the enterprise; standards for integrating machines, clouds, and applications; and the technology for quickly and efficiently managing devices, moving data, and triggering events.

**Cloud:** This includes all of the various clouds across an enterprise to implement computing and storage capabilities wherever they are most needed—at the edge, within the plant, at the enterprise, or outside the firewall.

**Big Data Analytics:** This includes the use of a broad set of statistical and optimization tools to cleanse, monitor, and analyze both structured and unstructured data for enabling unprecedented insights.

**Application Development:** This includes the needed tools for quickly and easily creating new mashup software applications that leverage all other areas of the IIoT platform, as well as quickly and easily moving existing legacy applications on top of the platform. ■

# Half-Bridge Flyback Converters Outperform Conventional Types

MLADEN IVANKOVIC and FRED SAWYER | INFINEON TECHNOLOGIES

**A CLASSIC FLYBACK** converter stores energy as a magnetic field in a transformer's air gap—as long as the converter switching element is conducting (*Fig. 1*). When the switch turns off, the stored field collapses, and the energy transfers to the circuit's output as current. Generally, the topology includes a transient voltage suppressor (TVS) to limit voltage on the low-side switch.

In a half-bridge flyback converter with serially connected MOSFETs, the upper switch pair shares the total voltage in the same way that the low-side switch interrupts input voltage (i.e., the bus voltage) (*Fig 2*). Meanwhile, the high-side switch interrupts transformer-reflected voltage, along with the voltage spike caused by the transformer's leakage inductance.

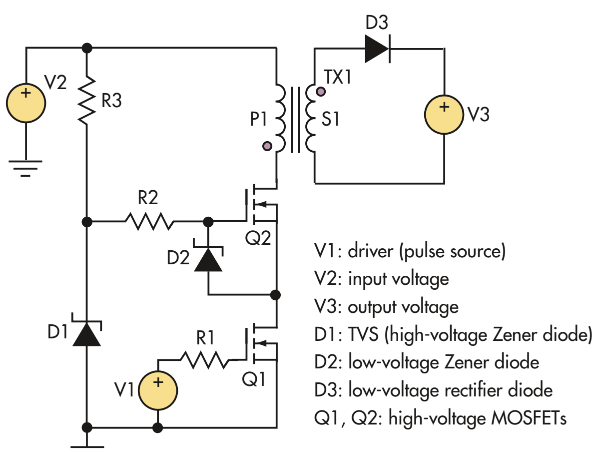
Integrating serially connected switches into the half-bridge flyback helps enhance efficiency because they minimize turn-off losses. This comes in handy for applications dealing with wide input-voltage ranges.

Delving further into this arena, Infineon developed a prototype to study half-bridge flybacks with these serially connected switches. The prototype features an 800-V input/24-V output capable of driving up to 0.33 A.

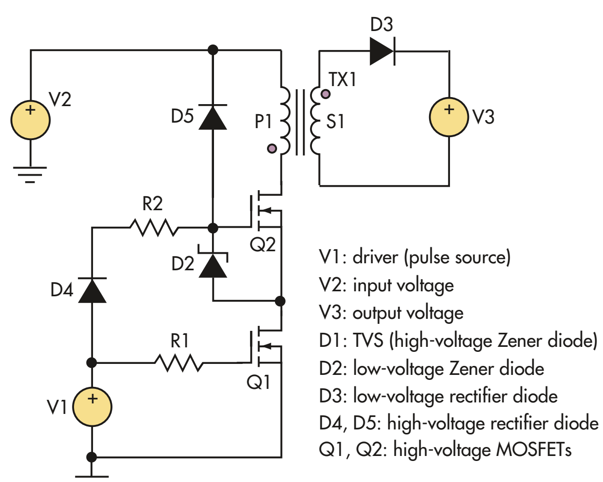
In looking at applications, the company pinpointed a smart-meter power supply, which requires a converter with low power demands (~8 W) and a wide input-voltage range. A typical flyback topology used in such an application faces limitations arising from MOSFET technology. Foremost among those is the MOSFET's breakdown voltage, which is on the order of 900 V. As a result, it can't provide sufficient voltage margin to accommodate transformer-reflected voltage (~200 V) and the peak voltage (~100 V) caused by the transformer's leakage inductance.

The conventional approach toward designing a reliable switch (i.e., one rated for a $V_{DS}$ of at least 1300 V) demands two MOSFETs connected in series. Such an approach also must incorporate transient voltage suppression (TVS) using a high voltage Zener diode to limit the voltage on low-side switch. That is, when the low-side MOSFET isn't conducting, transformer current would be directed through the source-gate capacitance of the high-side MOSFET and the TVS diode.

In that situation, two parallel processes are in operation: discharge of the $C_{GS}$ capacitor until the high side MOSFET turns off; and voltage-limiting on the low-side MOSFET, accomplished by turning on the TVS diode. In that situation, the losses in the TVS equal the product of transformer current and TVS voltage.




**1. A conventional flyback topology experiences significant switching losses.**

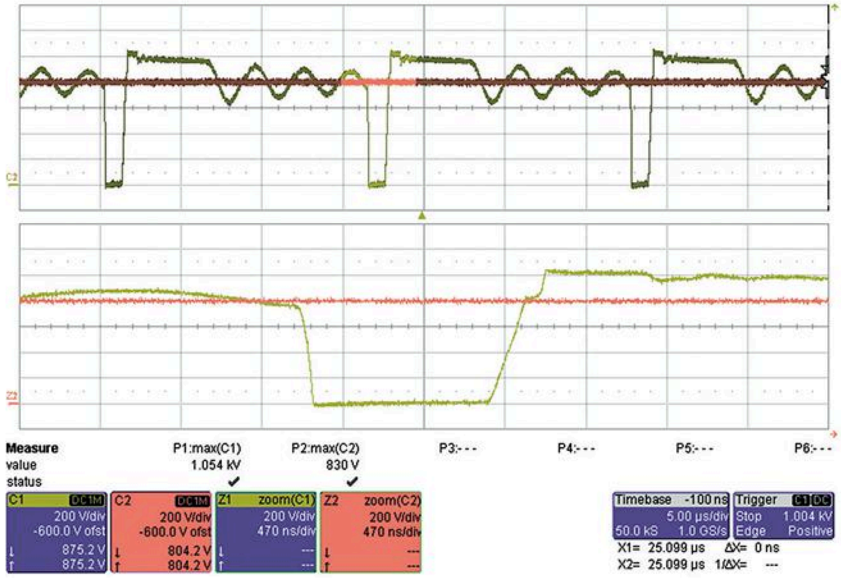



**2. To minimize losses, connect the high-side diode to the bus with a rectifier diode.**

A half-bridge flyback topology, using a rectifier diode that connects the gate of the high-side MOSFET to the bus (*Fig. 2, again*), offers a better alternative to the conventional approach. Although the turn-off current discharges the $C_{GS}$ capacitance of the high-side MOSFET, the circuit doesn't experience any additional losses.

Advantages of the half-bridge flyback include:

- Better efficiency as turn-off switching losses are minimized
- Simple low-voltage drive for high-side MOSFET
- Rectifier diodes can be used instead of a high-voltage TVS Zener diode (D1)




**3. In a test of the half-bridge flyback, the MOSFET switching at bus voltage (red trace) is 830 V. Note the knee at the start of high-side MOSFET turn-off (yellow trace).**

In the conventional solution, prior to turning ON, the MOSFET's parasitic capacitance would be charged to its breakdown voltage. Taking events in sequence, the switching cycle starts when MOSFET Q1 is turned on by driver V1 (a pulse source).

The next step is to charge the $C_{GS}$ capacitor of the high-side MOSFET using charge from the parasitic capacitance of D1. Once $C_{GS}$ is charged, the high-side MOSFET will turn ON. At that point, the input voltage is applied to the primary side of the transformer, and magnetizing current increases until the low-side MOSFET (Q2) turns off.

In the turn-off sequence, while Q1 is off, the $V_{DS}$ voltage increases until it reaches the breakdown voltage of D1. D1 then starts to conduct, and the low-side MOSFET current ($I_{DS}$) reroutes to D1 through the $C_{GS}$ capacitance of the high-side MOSFET Q2. The $I_{DS}$ current then discharges $C_{GS}$ and the high-side MOSFET turns OFF. When $V_{DS}$ on Q2 reaches the value of the reflected voltage, diode D3 turns ON, triggering transformer secondary current.

A coarse estimate for driving switching losses ($P_{SW\_conv}$) in this scenario is established with:

$$P_{SW\_conv} = V_{BR\_tvs} \times (Q_G) \times f_S$$

where $V_{BR\_tvs}$ = breakdown voltage of the TVS Zener diode; $Q_G$ = gate charge of the high-side MOSFET; and $f_S$ = switching frequency.

The half-bridge topology's basic characteristic is that neither one of the two MOSFETs "sees" any voltage larger than bus voltage. That's why the authors termed this topology the "half-bridge flyback."

The switching cycle starts when driver V1 (pulse source) turns on Q1. The next step is to charge the $C_{GS}$ capacitor of the high-side MOSFET using the same pulse source V1 and diode D4. When $C_{GS}$ is charged, the HS MOSFET will be turned ON. Input voltage is applied to the primary side of the transformer, and magnetizing current increases until the low-side MOSFET (Q2) is turned off.

In the turn-off sequence, when Q1 is off, $V_{DS}$ voltage increases until it reaches bus voltage V2. The rectifier diode

**CONVERTER TOPOLOGY EFFICIENCY COMPARISON**

| | | | | |
|---|---|---|---|---|
| **Half-bridge flyback** | | | | |
| Input voltage | 450 | 450 | 450 | 450 |
| Input power | 3.78 | 5.85 | 8.14 | 10.43 |
| Output power | 2.07 | 3.97 | 5.83 | 7.8 |
| Efficiency | 0.55 | 0.68 | 0.72 | 0.75 |
| **Conventional flyback with TVS limiter** | | | | |
| Input voltage | 450 | 450 | 450 | 450 |
| Input power | 4.11 | 6.76 | 8.92 | 10.84 |
| Output power | 2.07 | 3.97 | 5.87 | 7.78 |
| Efficiency | 0.50 | 0.59 | 0.66 | 0.72 |
| **Efficiency ratio = half bridge / conventional** | | | | |
| Topology efficiency ratio | 1.09 | 1.16 | 1.09 | 1.04 |

(D5) starts to conduct and the low-side MOSFET current ($I_{DS}$) then gets rerouted to D5 through the $C_{GS}$ capacitance of Q2. $I_{DS}$ current will discharge the $C_{GS}$ capacitance and the high-side MOSFET will turn OFF. When Q2's $V_{DS}$ reaches the value of reflected voltage, diode D3 will turn ON and transformer current will start transfer from the primary to secondary side. Losses occur via conduction at D5, in addition to the MOSFET losses.

A coarse estimate of this topology's switching losses is calculated by:

$$P_{SW\_hbf} = V_F \times (Q_G) \times f_S$$

Comparison of the two approaches reveals much smaller losses for the half-bridge flyback topology *(see the table and Fig. 3)*.

The half-bridge flyback converter employs a rectifier diode to limit the low-side MOSFET voltage to bus voltage. This improves efficiency by reducing turn-off loss when the high side MOSFET is turning off.

To simplify the driver stage of converter designs, the half-bridge flyback approach can be extended to forward topologies. A half-bridge forward topology, which will handle the magnetizing current much in the same way as the half-bridge flyback, will require demagnetizing in order to turn on the forward transformer.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**FRED SAWYER** is a Senior Sr. Field Application Engineer at Infineon Technologies.


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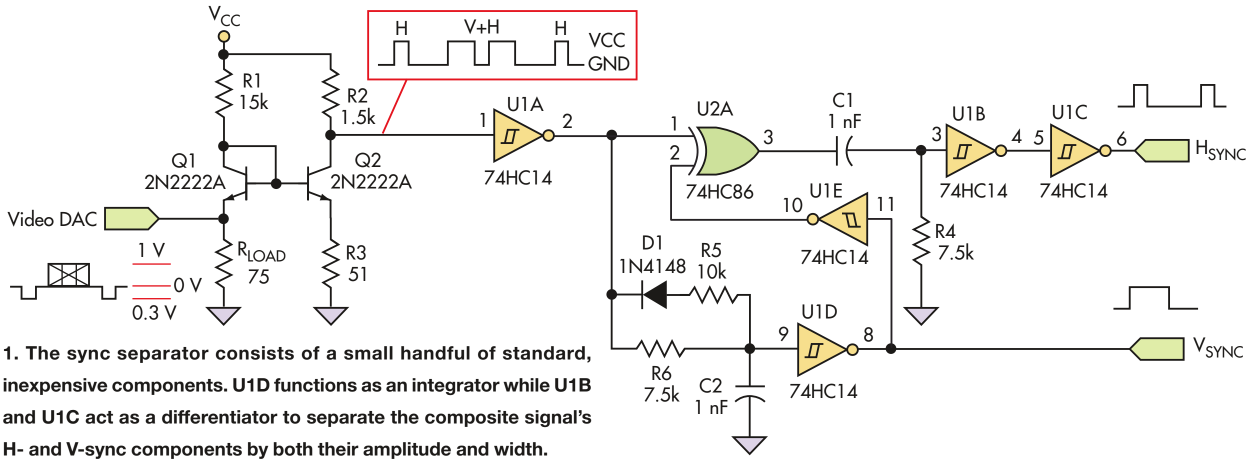
# RGB Video-Sync Separator Interfaces With VGA Monitor Using Basic Components

DAVE CONRAD | dconrad99@yahoo.com

**THIS CIRCUIT SOLVES** a problem where RGB video outputs existed, but there weren't enough unused general-purpose I/O (GPIO) pins on the DSP to directly provide individual horizontal (H) and vertical (V) sync signals to support RGB video output to a typical VGA-interfaced (video graphics adapter) computer monitor. However, simultaneous output




**1. The sync separator consists of a small handful of standard, inexpensive components. U1D functions as an integrator while U1B and U1C act as a differentiator to separate the composite signal's H- and V-sync components by both their amplitude and width.**

# DESIGN NOTES

# Robust 140V $V_{IN}$, 400mA Step-Down Regulator for Industrial, Telecom and Automotive Environments

Design Note 543

Mike Shriver

The LTC®7138 is a 400mA step-down regulator that can operate over an input voltage range of 4V to 140V, ideal for industrial, telecom, automotive and other applications subject to harsh line transients. Due to the regulator's hysteretic architecture, no external compensation is required. The output voltage is pin-programmable to 1.8V, 3.3V or 5.0V, or if an external divider is used, the output can be adjusted from 0.8V to $V_{IN}$. 100% duty cycle operation is possible because of the internal P-channel FET. The LTC7138 is offered in a thermally enhanced high voltage (skipped pins) MSOP package.

## Simple 5V/400mA Buck with Wide $V_{IN}$ Range

Figure 1 shows a 5V buck converter with a maximum input voltage of 140V using only four external components. Its output is set to 5V by tying the $V_{PRG1}$ pin to the SS pin and the $V_{PRG2}$ pin to ground. It does not require any external compensation.

Efficiency remains high over a broad range of loads due in part to the LTC7138's Burst Mode® operation and 12µA no load $I_Q$ current. For a 12V input, efficiency peaks at 87% for a load of 10mA and stays above 80% for loads down to 0.4mA. This level of energy conservation makes it ideal for always-on battery operated systems.

## 24V/800mA Buck Using Two LTC7138s in Parallel

Figure 3 shows two LTC7138s paralleled to provide an output of 24V at 800mA. Parallel operation is implemented by tying the feedback comparator output pin (FBO) of the master to the $V_{FB}$ pin of the slave. In this setup, the slave follows the master as it enters and exits the burst cycles (see Figure 4). The output of the 24V buck is set with an external feedback divider. The full load efficiency for this regulator is 93.6% for a 48V input (Figure 5).

## 32V/400mA Surge Stopper

Figure 6 shows another use for the LTC7138. For inputs of 32V or below, this regulator operates in dropout, where the internal power FET is on continuously. When the input exceeds 32V, the LTC7138 switches to keep the output voltage in regulation, as shown in Figure 7. For further protection, an overvoltage lockout can be implemented by tying the OVLO pin to a divider across the input supply. This circuit is suitable for protecting downstream converters or loads in industrial, automotive or avionics systems.



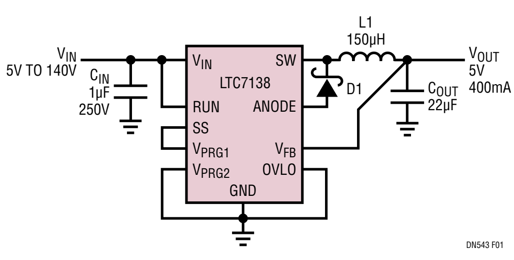



Figure 1. High Efficiency 5V, 400mA Buck Regulator

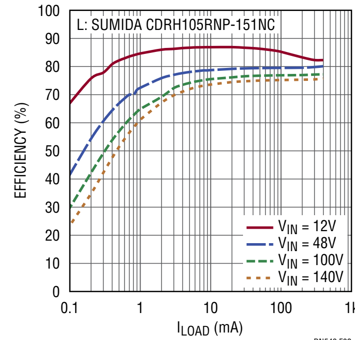


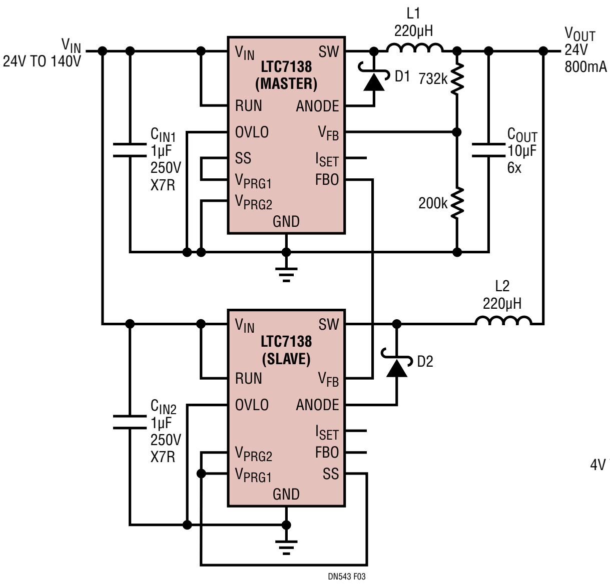

Figure 2. Efficiency of the Regulator in Figure 1

## More Features

The LTC7138 provides additional features which makes it suitable for a wide array of applications. These include a RUN pin for an external UVLO, an ILIM pin for programming the current limit or setting up an input side current limit, and soft-start—either internal or external.

## Conclusion

The LTC7138 yields low parts count, rugged solutions for wide input voltage applications. It features a 140V maximum input voltage rating, thermally enhanced high voltage MSOP package, Burst Mode operation, low $I_Q$ current, pin adjustable output voltage, no external compensation and operation at 100% duty cycle.




L1/L2: COILCRAFT MSS1278-224KLB
D1/D2: DIODES INC SBR1U200P1-7
$C_{OUT}$ : TAIYO YUDEN UMK325BJ106MMHT

**Figure 3. High Efficiency 24V, 800mA Buck Using Two LTC7138s in Parallel**

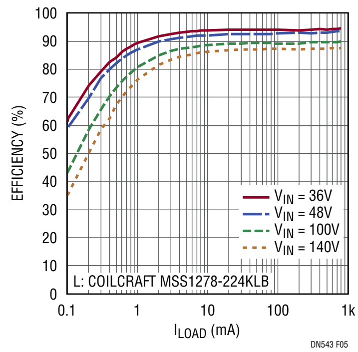
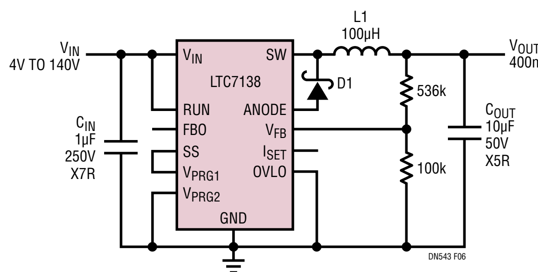



**Figure 5. Efficiency of the Regulator in Figure 3**




L1: SUMIDA CDRH104RNP-101NC
$C_{OUT}$: TAIYO YUDEN UMK325BJ106MMHT
D1: DIODES INC SBR1U200P1-7

* WHEN $V_{IN}$ > 32V, LTC7138 SWITCHES AND $V_{OUT}$ IS REGULATED TO 32V; WHEN $V_{IN}$ ≤ 32V, LTC7138 OPERATES IN DROPOUT AND $V_{OUT}$ FOLLOWS $V_{IN}$.

**Figure 6. 32V, 400mA Surge Stopper**

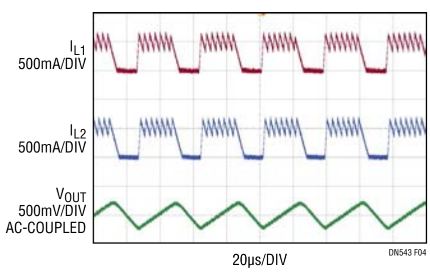



**Figure 4. Parallel Operation of the 24V, 800mA Buck at $V_{IN}$ = 140V, $I_{OUT}$ = 600mA**

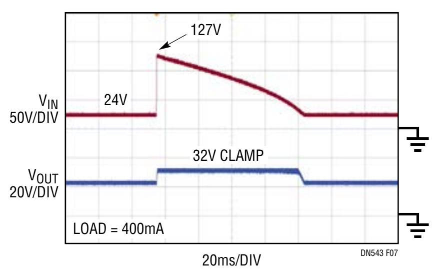



**Figure 7. Output of the Surge Stopper (Figure 6) Is Clamped to 32V During 127V Input Transient**

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of composite video was available, leading to a solution that achieves the same result but at far less cost than commercial off-the-shelf ICs (*Fig. 1*).

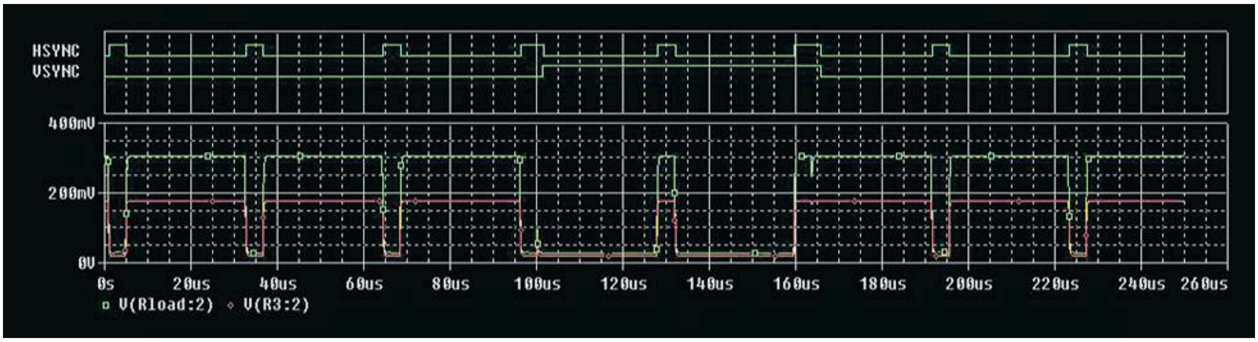
Most video digital-to-analog converters (DACs) provide a current-output signal that creates the video voltage across a nominal load resistance (typically 75 Ω) to ground. In this case, the sync-signal tips are at 0 V, the video black (blanking level) is at 0.3 V, and the maximum (white level) of the video signal is at 1 V *(left side of Fig. 1)*. The signal chart shows the composite video-sync signal input, the comparator reference level at the emitter of Q2, and the resulting $H_{SYNC}$ and $V_{SYNC}$ TTL-level (transistor-transistor logic) outputs *(Fig. 2)*.

Q1 and Q2 implement a temperature-compensated comparator, capable of resolving voltage levels in the millivolt range referenced to ground. R1 provides base bias for Q2 and should be sized such that the current in $R_{LOAD}$ does not excessively offset the black level. The value shown creates only +2-mV offset in $R_{LOAD}$. Q1's $V_{be}$ matches the value of Q2. So if Q1's emitter goes below Q2's emitter voltage, Q2's base current is shunted to $R_{LOAD}$, turning Q2 off and providing a positive-going signal in response to the negative-going composite sync signals. Signal levels above the comparator trip-point level, which is 160 mV in this implementation, saturate Q2.

The output at the Q2 collector swings from near-ground to $V_{CC}$, which is sufficient to drive the inputs of most TTL and CMOS logic families. U1A inverts and buffers the signal for driving the differentiator and integrator stages that follow. U1D and associated components R5, C2, and D1 form an integrator, whose time constant results in a 64-µs positive-going sync-pulse output, which meets the VGA specification for $V_{SYNC}$. The integrator ignores the inverted $H_{SYNC}$ pulse in the middle of the composite video $V_{SYNC}$ pulse. This is visible in an amplified and inverted form at the collector of Q2 in the schematic diagram and the signal chart.

U1B and U1C form a differentiator that also acts a positive edge-triggered pulse generator. The output pulse width is nominally 4 µs to comply with the VGA standard. Without U2A and U1E, the $H_{SYNC}$ pulse at the falling edge of the $V_{SYNC}$ pulse would be missing. Including these two circuit elements restores this $H_{SYNC}$ pulse with minimal timing errors.

The $H_{SYNC}$ pulse width at the leading and trailing edges of the $V_{SYNC}$ pulse are approximately 1 µs wider than the other



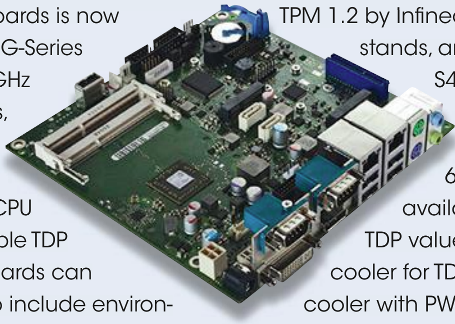

**2. The lower green trace is the composite sync input from the video DAC. (Video signals from 0.3 to 1 V are not included for clarity.) The red trace is the voltage reference level set by the on-current through Q2 into R3. The top two traces show the resulting TTL logic-level H- and V-sync output.**

pulses. Otherwise, the leading-edge timing is the same as that of the input composite-video signal. The delay from input to output in the $H_{SYNC}$ path is about 124 ns, which is well within the ability of most monitors to compensate and provide properly centered video on the screen.

This design will operate at either 3.3 V or 5 V, although R1, R2, and R3 values may need adjustment to provide the proper comparator level when operating at 3.3 V. The values shown are optimized for 5-V operation. Note that 100-Ω damping resistors are commonly placed between the $H_{SYNC}$ and $V_{SYNC}$ outputs and the connections to the VGA connector. Logic types are not critical, and substitution of the active components should not materially affect operation.

**DAVE CONRAD** is a retired electronics engineer. He creates innovative light-show systems using LED or video displays and also does some contract consultation.

## Mini-ITX Industrial Mainboards Equipped with AMD Embedded SoCs



**THE FUJITSU D3313-S SERIES** of mini-ITX boards is now available in two new AMD Embedded G-Series SoC versions, the D3313-S4 with a 2,2 GHz dual core and a cTDP of 10 to 15 watts, and the D3313-S5 with a 1,2 GHz quad core and a cTDP of 5 to 7 watts. The boards boast an improved CPU and graphics performance, configurable TDP values and a new boost mode. The boards can increase the SoC's frequency and also include environment variables such as temperature and adjusted TDP.

Kit versions are also available with extensive accessories such as housing, riser cards for expansion cards, TPM 1.2 by Infineon, a wall-mounting kit, desk stands, and diverse cables. The D3313-S4 and D3313-S5 mini-ITX boards are deployable in an extended temperature range from 0°C to 60°C. Three cooling solutions are available, including a passive cooler for TDP values up to 10 W, a passive heat pipe cooler for TDP values up to 15 W, and an active cooler with PWM fan control and monitoring for TDP values up to 25 W.

FUJITSU

*www.fujitsu.com/us*

## Hot-Swap VPX Ejector Handles and Panels Feature Rounded Base

**DESIGNED IN EUROPE** by Pixus Technologies, the Type IV IEEE hot-swap VPX ejector handles and panels for 3U and 6U VPX boards feature a rounded base that allow the handle to rock back, providing leverage when inserting/removing VPX boards, and enabling the board to withstand higher insertion forces. The handles can engage over 1000 N or 225 pounds of force per slot. Front panels in 0.8-in., 1.0-in., and custom widths are available in 3U/6U heights and in flat or U-channel versions for EMC. The 2.5-mm aluminum panels come in anodized or clear chromate finishes. Filler panels are also available in various widths. Customized front panels, including silkscreening, powder coating, cutouts/milling, and other specialty requirements are also offered. Providing a full line of VPX system platforms and backplanes in standard and rugged configurations, Pixus also offers handles and panels in telecom, VME (IEC), and other styles.

PIXUS TECHNOLOGIES

*www.pixustechnologies.com*

## Set-Top-Box Wi-Fi SoC Supports High Dynamic Range

**THE CANNES WI-FI** STiH390 SoC from STMicroelectronics is targeting HD HEVC Wi-Fi IP client and interactive set-top-box markets. Addressing the need for economical high-quality HD video within the whole home, ST has joined forces with Quantenna to create the new Cannes Wi-Fi SoC. The chipset integrates Quantenna's proven Wi-Fi 802.11 IP with ST's latest-generation HD HEVC SoC. The Cannes Wi-Fi's compatibility with ST's Cannes SoC family enables OEMs to leverage the existing large ecosystem to readily design innovative client boxes on multiple middleware products. Key features include a multi-core ARM CPU capable of delivering 6K DMIPS, Wi-Fi 802.11.ac 4x4, support for HDR content decode and display, Mali 400 GPU, a Faroudja post-processing Video Transcode Engine, HEVC 10-bit performance, a set of future-proof connectivity options including USB3 and HDMI, and 28 nm FD-SOI silicon technology providing RF and analog integration.

STMICROELECTRONICS

*www.st.com*

## XMC Form Factor SATA SSD Addresses High-End Embedded Demands

**MICROSEMI'S MXMCM256 AND MXMCM512** PCIe interface XMC form factor serial advanced technology attachment SATA SSDs are ideally suited for industrial and defense applications where ultimate security for data-at-rest is required. Plugging directly into the host card and eliminating the need for an external enclosure, the devices are part of the advanced TRRUST-Stor family of secure self-encrypting SSDs that include advanced security features such as hardware-based AES-256 XTS encryption and advanced key management systems. The XMC SSDs have a layered security protocol allowing a hardware or software command to erase the encryption key in less than 30 ms and erase full flash storage media in less than 10 seconds with no trace of recoverable data. In the most advanced method, no encryption key is stored in the SSD, leaving data forensically unrecoverable. Optionally offered as air-cooled or conduction-cooled, the platform incorporates an Armor II proprietary flash processor providing 256 GB (MXMCM256) or 512 GB (MXMCM512) of reliable SLC NAND flash. Up to 185 MB/second read/write speeds are reachable at industrial temperatures. The ANSI/VITA 42.3-compliant TRRUST-Stor family boards offer a x2-lane PCIe bus interface, plus a configurable SATA 2.6 interface supporting ATA-7 and ATA-8.

MICROSEMI CORP

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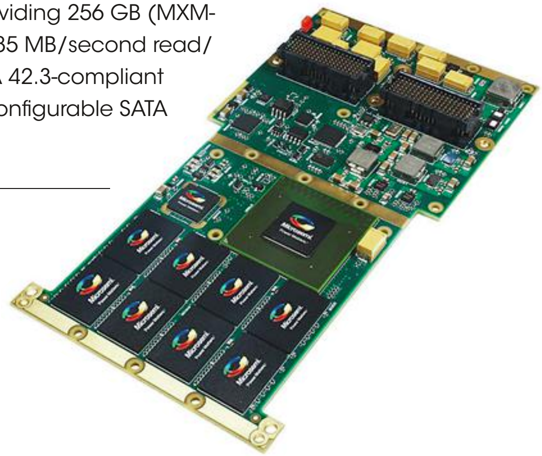


## Low Power PIC MCUs Double Flash Memory and Add Security

**MICROCHIP TECHNOLOGY'S EXTREME LOW-POWER** PIC24F GB4 MCU family features an integrated hardware crypto engine with both OTP and Key RAM options for secure key storage. Suited for designers of industrial, computer, medical/fitness, and portable applications that require secure data transfer and storage, and a long battery life, the family provides up to 256 KB of Flash memory and a direct drive for segmented LCD displays in 64-, 100- or 121-pin packages. Dual-partition Flash with live update capability allows the devices to hold two independent software applications, and permits the simultaneous programming of one partition while executing application code from the other.


The fully featured hardware crypto engine, which includes support for the AES, DES and 3DES standards, reduces software overhead, lowers power consumption and enables faster throughput. Two crypto-key storage options are available with the PIC24F GB4 MCU family, OTP to prevent overwriting keys or Key RAM that erases keys if power is lost. A segmented LCD display driver provides the ability to directly drive up to 512 segments, enabling more informative and flexible displays that include descriptive icons and scrolling.

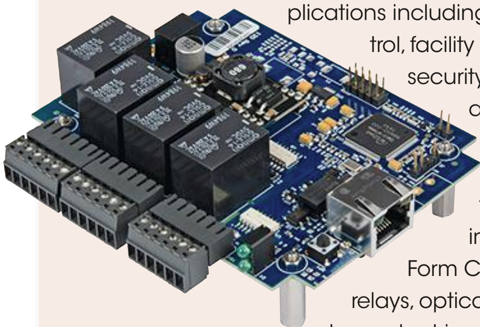
MICROCHIP TECHNOLOGY

*www.microchip.com*



## Embedded Ethernet Digital I/O Module Series Offers Six Configurations

**SEALEVEL SYSTEMS' EI/O FAMILY** of Ethernet digital I/O solutions for embedded OEM applications are suited for commercial and industrial computing applications requiring an embedded Ethernet I/O solution. The OEM modules provide a compact monitor and control alternative for applications including process control, facility management, security, and broadcast automation.



Available in six I/O configurations, the series includes Reed, Form C, or solid-state relays, optically isolated or dry-contact inputs, and A/D functionality. I/O connections are via removable 3.5-mm terminal blocks compatible with 16-30 AWG field wiring, with optional spring-clamp terminal blocks also available.

SEALEVEL SYSTEMS

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## 120 W Planar Transformers Optimized for Active Clamp Forward Topology

**COILCRAFT'S POE120PL SERIES** of high-efficiency planar transformers are optimized for active clamp forward converters, including use in PoE PSE and pre-standard powered devices. The series is suited for 60 W-120 W applications such as thin clients, monitors, industrial Ethernet, IPTV, building management, nurse call systems, point-of-sale terminals, and information kiosks, and is ideally suited for 90 W PoE++ powered devices. The transformers are optimized for 200 kHz, with a 36 V - 72 V input, and boast excellent DCR for high efficiency and very low leakage inductance. They also provide 1,500 Vrms primary-to-secondary isolation, 0.229 mm clearance above the seating plane and include a 12 V auxiliary winding. The planar transformers have a 20.83 x 23.37 mm footprint with a maximum height of 10.34 mm, requiring less board space and overall volume than a standard EFD20 wire wound package. The PoE120PL Series transformers are RoHS compliant, feature matte tin over nickel over brass terminations, and have an ambient temperature range of -40°C to +125°C.

COILCRAFT

*www.coilcraft.com*

## Medical BF Power Supply Offers 225 W Continuous at Natural Convection

**THE MEDLINE 225 OFM225 SERIES** from Powerbox offers ac/dc single output open frame converters for medical type BF applications. The new converters with their 3-in. x 5-in. footprint and 1.5-in. height are designed for a continuous output power of 225 W at natural convection and 40°C ambient temperature, increasing to 325 W continuous at 12 CFM forced air cooling. Several units can be operated in parallel with load sharing. Intended for type BF applications, the units can withstand 4000 Vac from input to both output and ground.

Utilizing a one-step conversion topology, where power factor correction, isolation, and regulation are combined in one conversion step, the component count stays below 120. This contributes to an efficiency of 93%, zero load power of 500,000 h. Over voltage protection, as well as over current and short circuit protection with auto recovery, adds to operational reliability that is further enhanced by intelligent over temperature protection regulating output power. With a nominal input voltage of 100-240 V 50/60 Hz and available output voltages of 12, 15, and 24 Vdc, the Medline 225 OFM225 power supplies are suited for a range of medical applications.

POWERBOX

*www.powerboxinc.com*

## 177-Ball BGA Sockets onto Any PCB with No Solder or Screws

**IRONWOOD'S SG-BGA-6434** high performance BGA socket for 0.8 mm pitch 177 pin devices is designed for a 13 x 13 mm package size and operates at bandwidths up to 27 GHz with less than 1 dB of insertion loss. The socket can dissipate up to several watts due to its aluminum structure. Contact resistance is typically 20 mΩ per pin and all pins are connected with 27 GHz bandwidth on all connections. A patented technology allows for mounting with no holes in the target PCB, no soldering, and minimal footprint. Constructed with high performance and low inductance elastomer contactor, the socket can be mounted on any existing PCB with an exclusive placement/epoxy system. The temperature range of the SG-BGA-6434 high performance BGA socket for 0.8 mm pitch 177 pin devices is -35°C to +100°C. Other features include 0.11 nH pin self-inductance, 0.028 nH mutual inductance, 0.028 pF capacitance to ground, and a 2 A per-pin current capacity.

IRONWOOD

*www.ironwoodelectronics.com*

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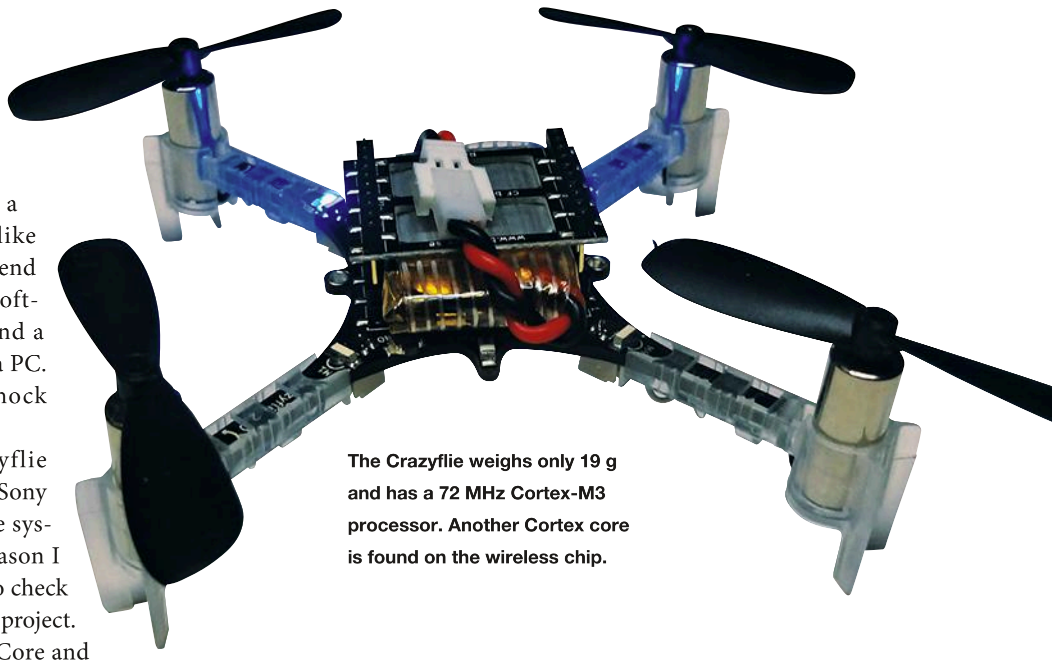
# Ada/SPARK Fixes Crazyflie Nano Quadrotor

**Crazyflie quadrotor is an open-source project, including the hardware. I tried out a project where the control software was rewritten in SPARK, a subset of Ada.**



The Crazyflie weighs only 19 g and has a 72 MHz Cortex-M3 processor. Another Cortex core is found on the wireless chip.

I just got my hands on the Crazyflie quadrotor from Bitcraze. The aircraft is an open-source project, including the open-source hardware. It is designed as a development platform, unlike most other quadrotors that tend to be closed systems. The software can be downloaded and a control application runs on a PC. It supports a Sony Dual Shock controller.

I ran through the Crazyflie checklist and pulled out my Sony controller from my PS3. The system works nicely, but the reason I really got the Crazyflie was to check out Anthony Gracio's SPARK project. Anthony is an intern at AdaCore and he rewrote the control software in SPARK, a subset of Ada.

The control software and library is written in C++. That is not surprising given that C and C++ tend to be the languages used for most deeply embedded projects like this. They are also part of the typical toolset available from chip vendors like ST Microelectronics that build the Cortex-M3 chip used in the Crazyflie.

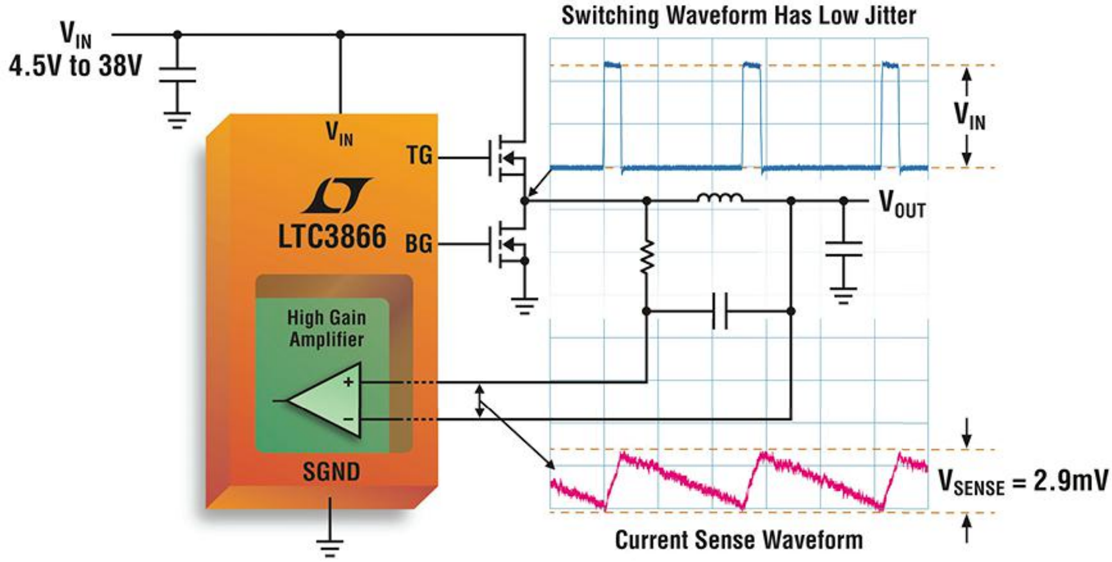
Anthony used Adacore's standard tool chain that is available as an open-source project. SPARK is designed for high-integrity software and it provides a platform that is much better than most for employing static and dynamic verification. Adacore also has a SPARK Pro version available.

One new feature of Ada and SPARK is the concept of contracts (see "Ada 2012: The Joy of Contracts" on electronicdesign.com). It was part of Ada 2012 and formalized the implementation that originally started with SPARK using a preprocessor. It allows "contract-based programming." This is where the procedures or methods are annotated with contracts that specify inputs and outputs. This is in addition to the range-checking already inherent in Ada.

Swapping out the C++ code for the SPARK code is a relatively trivial exercise. It is essentially the same as dropping in a new version of the C++ code. The difference is the quality. Anthony found and corrected a number of bugs due to the use of SPARK. Functionally the SPARK code is identical with the bug fixes.

I would really like to see the Crazyflie project switch over to SPARK, but I suspect that C++ aficionados are not taking the hint. In the meantime, I hope to get a chance to do some SPARK coding. ed

# Sub 0.2mΩ DCR Sensing Current Mode Controller




## Breakthrough Controller Enables High Efficiency at >40A

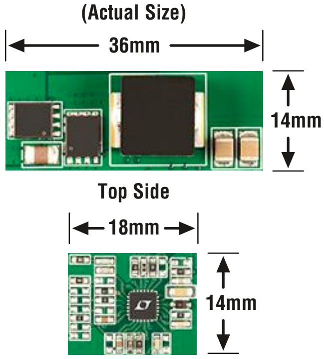
The LTC®3866 is the first true current mode controller to break through the sub-1mΩ DCR sensing barrier while maintaining stability and eliminating the switching jitter commonly found in low DCR applications. It can operate with a peak-to-peak sense voltage of just a few mV for optimum efficiency at high output current. The LTC3866 also includes a high speed differential output remote sense amplifier and a ±0.5% accurate reference for small total DC $V_{OUT}$ error over the full operating temperature range.

### Features

- $V_{OUT}$ Maximum Total DC Error: ±0.5% over Temp
- Remote $V_{OUT}$ Sense Amp
- Temperature Compensated Inductor DCR Sense
- Integrated FET Drivers
- Compatible with DrMOS and Power Blocks
- Synchronizable and Easily Paralleled for Multiphase Outputs
- Integrated Thermal Shutdown

**LTC3866 Demo Circuit**

**(Actual Size)**




### Info & Free Samples

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