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5G EXPOSED!

As anticipation and expectations grow, here's what you should know p18

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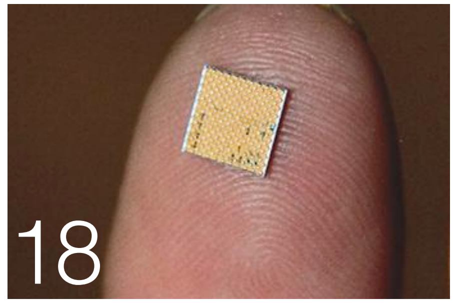

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EDITORIAL MISSION:
To provide the most current, accurate, and in-depth technical coverage of the key emerging technologies that engineers need to design tomorrow's products today.

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ON ELECTRONICDESIGN.COM

Echoes of "Little Green Men Attack!"

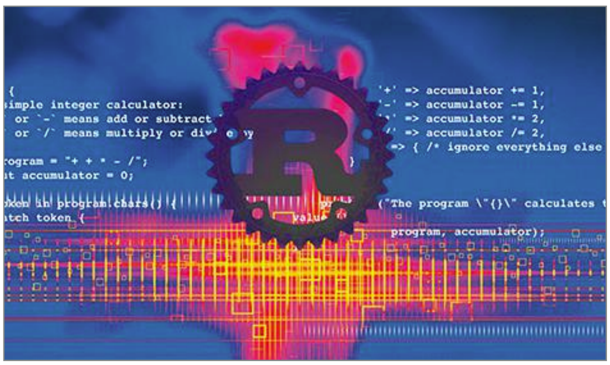
What do Amazon and "little green men" have in common? To take over the world, of course. That is, at least, according to Technical Editor Bill Wong, whose latest blog draws parallels between visitors from outer space and the retail and technology giant. See if you agree.

http://electronicdesign.com/blog/echoes-little-green-men-attack

BeagleBone Robots Takes a Bite of Bluetooth

BeagleBoard.org's BeagleBone Blue targets robots and mobile embedded devices with plenty of control interfaces and Bluetooth connectivity. It's already finding a home in robots and drones.

http://electronicdesign.com/embedded/beaglebone-robots-takes-bite-bluetooth



Rust and SPARK: Software Reliability for Everyone

Programming languages often defer reliability and security issues to tools and processes. Two initiatives—SPARK and Rust—state that language is key to reaching these objectives.

http://electronicdesign.com/industrial/rust-and-spark-software-reliability-everyone

Exploring the Jetson TX2

Trying out NVidia's Jetson TX1 was fun, but checking out the Jetson TX2 is even better. The Jetson TX2 doubles the performance of its older sibling. Alternatively, it can replace the Jetson TX1 while consuming half the power. Both approaches have merit, and many designs will take advantage of the lower power operation and higher performance.

http://electronicdesign.com/blog/exploring-jetson-tx2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Editorial

NANCY FRIEDRICH | Director of Editorial Content
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Where's the Fun in ASSISTED DRIVING?

I love driving. I absolutely adore it. There is something about opening the windows and/or sunroof on a nice day, pumping up some great music, and just seeing the road stretch ahead of you as you hit the gas pedal. To someone like me, as much as I care about safety, the thought of autonomous or assisted driving sounds like a bit of a buzzkill. Where is the fun in tackling the open road if the only thing you're controlling is probably the windows, thermostat, and entertainment?

At the same time, my travels in my beloved cars haven't always been without frightening or dangerous incidents. So it's with mixed feelings that I watch all of the innovations going into automotive development to make cars and driving safer. As someone who has been watching electronics evolve for going on 20 years, the technology development supporting these automotive advances is truly breathtaking. Numerous technologies and applications are being developed and implemented simultaneously, breaking ground individually while supporting the enhanced capabilities of a total solution.

As a mother whose kids will be driving in a too-near future, I also welcome the safety aspects. According to the U.S. Department of Transportation (DOT), the combination of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) safety applications could reduce the severity of—or completely eliminate—up to 80% of non-impaired-driving crashes.

TECH ON DECK

Much attention has been given to the DOT's Notice of Proposed Rulemaking since its release this past December. Its goal is to enable vehicle-to-vehicle (V2V) communication technology on all new light-duty vehicles so that vehicles can talk to each other. Using dedicated short-range communications (DSRC), V2V communications systems will exchange information with other vehicles concerning location, speed, direction, braking status, and more. That data would be updated and broadcast up to 10 times per second to nearby vehicles. Using this data from other cars, V2V devices can determine if a warning should be given to the driver to help prevent a crash.

Clearly, we all can benefit from V2V applications like Left Turn Assist (LTA), Forward Collision Warning (FCW), and Blind Spot Warning (BSW). We will literally have eyes everywhere in terms of awareness of our surroundings and what is happening with other vehicles. I want to know that my kids will return safely when they take the keys and head out the door.

However, I also want them to have that feeling of excitement and anticipation that comes with driving—not passively sitting, but actually controlling the car—on a long, open stretch of road. The next step, as the DOT notes, is to combine such sensing and warning with automated driving.

Will we still be able to enjoy truly driving a car once all of these technologies are in place? Or will we someday have to sign a bunch of waivers to drive a completely human-controlled vehicle on a designated track? Maybe we'll have to pay a fee or schedule time on an open road. I'm all for a world where fatalities or injuries caused by car crashes are a thing of the past. But part of me mourns the joy of driving—truly driving—and the fact that future generations won't know the joy of the open road. I would love to hear your thoughts; feel free to email me at nancy.friedrich@penton.com. ed

News

DEVICES IN PERIL
Without System for Security Updates

Last year, a malicious strain of code called Mirai recruited millions of security cameras, routers, and other gadgets in a digital assault on servers that act like the internet's switchboard. The attack crippled websites in large swathes of the United States, a spectacular display of the security holes in the Internet of Things.

After the dust settled, a Chinese electronics firm recalled 4.3 million cameras using its circuit boards, which the so-called botnet had enlisted to carry out the attack. Xiongmai Technologies could not fix the security flaws remotely, so it recalled the offending devices and sent out an update for customers to install in newer models.

The episode is a textbook example of how not to repair security flaws in connected devices, according to security researchers. That response would never work in smart cities, they say, where millions of connected sensors will be embedded in street lights, traffic signals, and even roads to gather data on traffic and even crime.

This year, General Electric's Current business will install cameras, microphones, and other sensors on 3,200 street lights in San Diego in an attempt to better monitor traffic and crime. *(Image courtesy of GE)*

> "The confluence of rapid technology evolution and the unknown trajectory of its adoption create even greater future uncertainty."
> *—The Department of Homeland Security report*

These devices will never be perfectly secure. But it is vital, security researchers say, to have a way to monitor millions of devices and push out automatic updates, which may be too expensive to install manually. The software must also verify authorized updates to block hackers from dropping in malicious code.

"People want to deploy something like an internet connected trash can and they don't realize that they're going to have to update it every month, just like you update your laptop," said Tom Cross, chief technology officer of security firm Drawbridge Networks and a former manager of IBM's Security X-Force Research unit.

The issue is that most software for connected sensors and other devices cannot be patched, he said in a smart-cities panel discussion at the recent South by Southwest festival in Austin, Texas. "Something will be out there for 20 years and vulnerabilities will be disclosed for it and there's no way to get it fixed."

Even though smart-city devices could be built to last for decades, manufacturers are not making software that can receive updates, said Robert Hansen, another panelist and founder of security research firm Outside Intel. With a system for automatic updates, engineers can patch software as vulnerabilities arise and code new capabilities.

The need for automatic updates was made clear in 2014 when the research firm IoActive found that hundreds of thousands of traffic control sensors in New York, Washington, D.C., and other cities could accept unauthorized updates. The sensors were embedded in streets to detect cars at traffic lights and optimize when the lights change.

Cesar Cerrudo, IoActive's chief technology officer, found that hackers could potentially break into the sensors and hijack the lights, causing accidents or severe traffic. In the end, the company that makes the sensors, Sensys Networks, issued a patch to customers later that same year so that local officials could wirelessly update the sensors without digging up their streets.

"If you have to dig up a city to upgrade something, it's probably not going to happen," Hansen said.

So far the drive to patch flaws automatically has been slow. Google said that its Android Things operating system will give developers an "infrastructure" to refresh firmware in household devices when it is released this year. In October, ARM introduced a software platform called mbed Cloud that lets developers manage, monitor, and update firmware inside devices remotely.

Others are thinking along the same lines. A technology startup called Particle hopes that sales of its microcontrollers will lure developers to its cloud, which offers tools for sending over-the-air updates. Resin, a four-year-old company, has devised a platform using containers to develop and manage embedded code, while Mender released last month an open-source system with similar objectives.

The automotive industry is also considering changes to how it mends software in vehicles. Tesla was the first to send out new versions of its software to patch security flaws and upgrade its driving systems. Now, companies from Harman to Movimento have started offering "reflashing" services for connected cars, which is causing highway officials to rethink how recalls are issued.

But in the view of security researchers, manufacturers are still skimping on security because it is seen as too expensive. Not only that but most companies will not continue updating devices after models are released, said Hansen. Engineers also might not want to spare battery life in remote sensors for large security updates.

"Like all engineering, it's all about trade-offs," said Hal Kurkowski, managing director of security at Maxim Integrated, in an interview last year about embedded security. "When you go to the hardware store, there's not just one lock hanging in the aisle where you buy locks."

But most industry groups believe that automatic updates can't be sacrificed. The Industrial Internet Consortium, for instance, has advised rolling out very small updates to help save bandwidth and battery life. The group recently published a security framework for devices used in everything from infrastructure to oil processing plants.

The Department of Homeland Security also underlined the pitfalls of manual security updates for smart cities in a 2015 report. The report warned that "the impact of the exploitation of a vulnerability may be understood but the risk and consequence to the infrastructure and its connected components is not."

"The confluence of rapid technology evolution and the unknown trajectory of its adoption create even greater future uncertainty," the report said.

Key to securing smart cities is not treating infrastructure like smartphones or laptops, whose hardware and software are improved with every generation. The software in these embedded devices must be constantly upgraded, updated, and patched over its entire lifetime, Cross said.

"Generally what companies like to do is ship something and then refine. They say, we will get this thing out there, let people buy it, and then we'll work on improving the quality of it," he said. "But really, security testing is a kind of quality assurance testing." ■

MENTOR GRAPHICS BETS ON RAW SENSOR DATA for Autonomous Driving

MENTOR GRAPHICS, as a major supplier of electronic design automation tools, likes to help engineers with complex systems. That explains why its automotive division, which sells operating systems for dashboard displays and other tools, wants to iron out the complexity of self-driving cars.

It will try doing that with a new system called DRS360 that the company unveiled at the recent SAE World Congress in Detroit. It aims to help automakers build everything from fully autonomous cars to advanced safety features like lane departure warnings and adaptive cruise control.

But its defining characteristic is not an ultrafast computer chip for machine learning like many other platforms for self-driving cars. Instead, the system is based on a unique architecture for fusing raw sensor data inside a central processing unit. The car makes decisions based on the centralized data.

In advanced driver assisted systems, the microcontrollers inside camera, radar, and other sensors filter through raw data. These sensor modules send some of that data onto separate modules, which enable safety applications like blind spot warnings or cross traffic alerts. But this distributed system is not ideal for self-driving cars because useful sensor information is at risk of being lost in translation.

"If we think about [fully] autonomous cars that don't have steering wheels or brake pedals, this architecture won't work," Glen Perry, vice president of Mentor's embedded systems division, said in an interview. It heaps cost, complexity, and latency onto the system, he added.

The new platform uses specialized sensors to pump unfiltered data to a central processing unit. High-speed sensor links, such as lvds or FPD III Link, transport the raw data to the central processor, where algorithms fuse it into a detailed view of the car's environment, filling in the blind spots of each sensor in the vehicle.

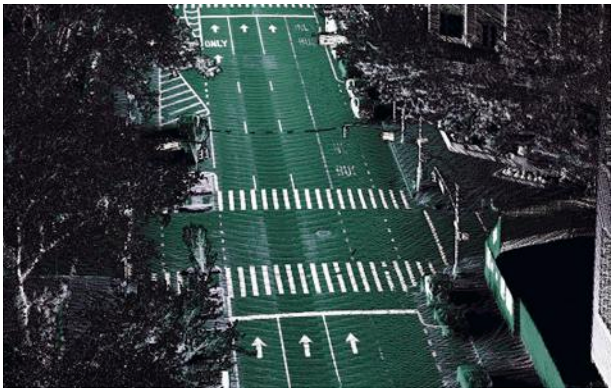
This is almost like traditional sensor fusion, but the raw data allow cars to view the road more clearly. The raw sensor data lets system sensors fact-check each other's readings more accurately, providing what is known in the automotive industry as "redundancy." It is also more efficient, said Perry.

This translates into fewer hardware interfaces and lower latency between the sensors and the central processing unit. The new architecture also cuts down on power consumption, cost, and overall complexity. In addition, the company says that machine learning programs run faster and more efficiently on raw data, resulting in a power envelope around 100 watts.

The benefits are not without trade-offs. It is extremely difficult to write algorithms that combine the three-dimensional models captured by lidar, the coordinates from radar, camera images, and other types of raw sensor data. The central processor also must be powerful enough to crunch those data, which could get expensive.

Mentor's view that sensor fusion holds the key to automated driving might seem counterintuitive in the context of new advances in machine learning. But the company believes that DRS360 provides a pathway to driverless cars, making it easier for automakers personalize code for their vehicles.

Lidar, a type of laser scanning technology, is one of the many sensors that Mentor's new autonomous driving platform supports. *(Image courtesy of Here)*



High-definition maps, like this one created by Here, are a core technology for self-driving cars. *(Image courtesy of Here)*

In this way, Mentor is aiming to give automakers more freedom to develop cars that stand out from competitors. They can slip their own algorithms into the DSR360 development board, which supports more than 15 raw data sensors. That offers more customization than closed off systems from the likes of Google, Mobileye, and Nvidia.

The company underlined that idea in the DRS360 hardware, said Ian Riches, director for automotive electronics at research firm Strategy Analytics. It uses an FPGA to handle the sensor fusion algorithms, but customers can attach either an x86 or ARM chip to the decision-making side of the board.

But the system's flexibility might also isolate lower-end automakers. It might provide more freedom than what small engineering teams are looking for, Riches said. "With freedom comes a big blanket empty space that you need to fill," he added.

Nvidia, for instance, is no longer just making graphics chips but also the autonomous driving software that runs on them. Its software can make driving decisions and create high-definition maps of lane markings and street signs – both extremely critical types of data for self-driving cars.

Nvidia is tuning its graphics chips for "end-to-end" deep learning, in which software teaches itself how to drive by watching the road through a front-facing camera. This approach requires little human training but potentially makes it more difficult to understand why programs make decisions on the road.

Others guard the data streaming through cars even more closely. Intel's reasoning for its $15.3 billion acquisition of Mobileye last month was that the firm holds exclusive rights to the driving data gathered by its vision sensors. Mobileye uses those data to teach automated driving software and create high-definition maps, which Intel can sell to automakers.

But locking all that information in a black box limits how much automakers can customize their vehicles, Perry said. "You can't let the customer work with the algorithms, you can't integrate additional sensors into the platform, you can't access the raw data or the data that it sees," he added. ■

APPLE DROPS IMAGINATION TECHNOLOGIES in Favor of Homegrown Graphics

APPLE WILL STOP using graphics chips from Imagination Technologies in a future generation of smartphones, tablets, televisions, and watches. The company has notified Imagination that its in-house chip engineers are already working on new graphics technology.

Imagination said in a statement that Apple would stop using its intellectual property in smartphones and other products in around 15 to 24 months. The company, which collects royalties on devices sold with its technology, stands to lose half its annual revenue when Apple switches to homegrown graphics.

"Apple has asserted that it has been working on a separate, independent graphics design in order to control its products and will be reducing its future reliance on Imagination's technology," the statement from Imagination read. The company's stock fell 61.6% in response to the news.

The abrupt end of its relationship with Apple would be the latest blow to the 32-year-old company. Last year, Imagination

(Image courtesy of Karlis Dambrans, Creative Commons)

Apple is not new to making custom chips for its smartphones and other gadgets, but Imagination's technology is deeply woven in those products. Apple has been paying for Imagination's designs since 2008 and has poached engineers from its employee ranks. Apple owns almost 10% of the chip designer and once thought about buying it outright.

That long history could be setting the stage for patent conflicts. "Apple has not presented any evidence to substantiate its assertion that it will no longer require Imagination's technology, without violating Imagination's patents, intellectual property and confidential information," the company said.

revealed plans to cut 350 jobs - or a fifth of its workforce - and its founder Hossein Yassaie quit after eighteen years as chief executive. At the same time, the company vowed to focus on its flagship PowerVR graphics chips, which dominate high-end smartphones.

Imagination is skeptical that Apple's new graphics architecture will be completely divorced from its designs. In the statement, the company said that "it would be extremely challenging to design a brand new GPU architecture from basics without infringing its intellectual property rights." ■

MARIA GUERRA | Technical Editor

Dual-Voltage Systems Slash CO_2 Emissions

To comply with lower CO_2 emission legislation, auto manufacturers can opt for a highly attractive 48-V board net solution, thus raising the need for bidirectional dc-dc controllers.

Automakers across the U.S., Europe, China, and Korea must achieve CO_2 emissions reduction to comply with the current legislation *(Fig. 1)*, which means most EU OEM hybrids will feature 48-V systems by 2020. Upscaling to a 48-V automotive architecture can help carmakers more successfully wrangle with power efficiency and CO_2 emissions.

A new trend within the automotive industry is the "dual-voltage system." Each manufacturer is quickly developing its own solutions, spurred on by the chance to reduce wiring harness weight and losses while meeting CO_2 emission goals. Note that electrified vehicles not only include electric and hybrid vehicles, but combustion vehicles, too. Power-electronics advances in the latter are further extending their automation and safety features, among others.

Solutions on the drawing board include the 48-V board net, which would power loads such as air-conditioning compressors, start-stop systems, and electric superchargers/turbos. Also, a 12-V board net alternative will power the lighting, infotainment, and audio systems *(Fig. 2)*.

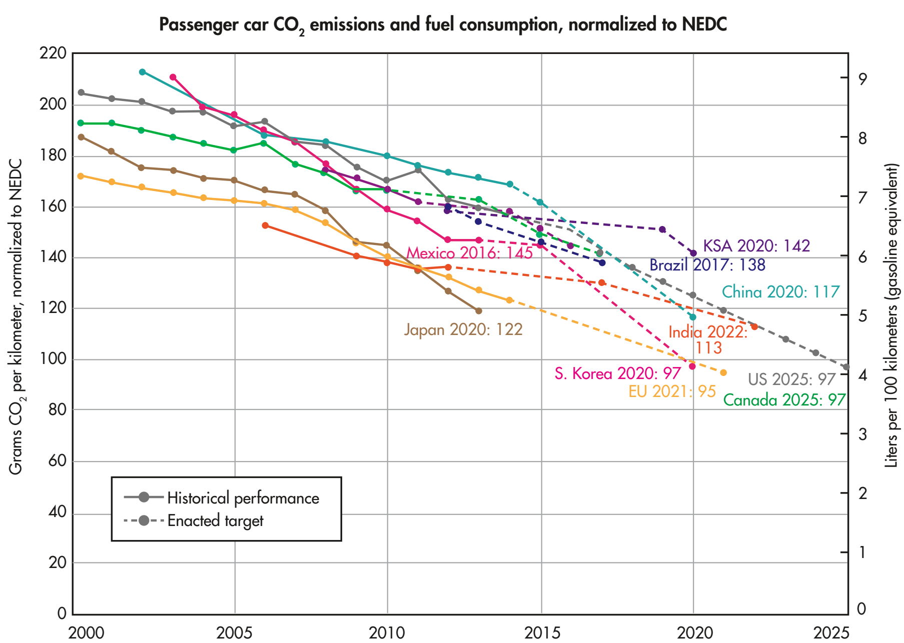
The technology for that isn't here quite yet, though. For the near future, a 48-V/12-V dual-battery system becomes the best option before total adoption of a sole 48-V power system, where switches and sensors can be safely used at higher voltages. "At least in Europe, it might take up to 10 years to start seeing 12-V system components converted into 48-V components," says Ed Kohler, Intersil's Senior Marketing Manager.

USHERING IN BIDIRECTIONAL DC-DCs

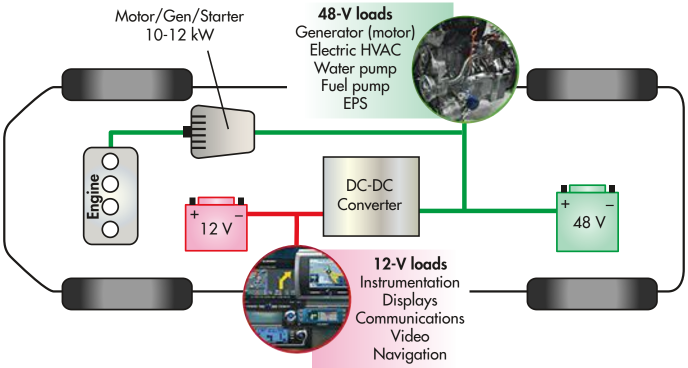
Stepping up and down will require safe and efficient transfer of power using dc-dc converters. In this case, bidirectional dc-dc controllers will help to link both voltage systems.

When studying the new bidirectional converter architectures aimed at automotive applications, several trends are emerging that reflect the move toward 48/12-V systems and the increased importance of bidirectional dc-dc controllers. Tier 1 suppliers and OEMs in the automotive industry already include dual voltages in their designs.

For instance, Audi's next SQ8 will have a 48-V system that will be used to drive an Integrated Starter Generator, which will regenerate the energy to quickly reload a 0.9-kWh lith-



1. The EU 2021 CO2 emission target of 95 g/km is the most stringent numerical standard to date, surpassing the US 2025 target of 97 g/km in NEDC terms. *(Courtesy of ICCT)*



2. The 48-V system supports heavier loads. *(Courtesy of Intersil)*

ium-ion battery. Increasing voltage will also help efficiently deliver high-in-demand technologies like stop-start and regenerative braking.

PAVING THE WAY FOR 48-V SYSTEMS

Two products in particular stand out as examples of the latest trends permeating the automotive space:

Intersil's ISL78226 is a six-phase bidirectional PWM controller that delivers up to 3.75 kW in either direction at greater than 95% efficiency. This automotive-grade AEC-Q100 qualified product integrates PMBus system control to support functional safety requirements (ISO 26262). If a fault condition is detected, depending on the level of the fault condition, the ISL78226 provides warning flags, auto/start, hiccup, or latch-off functions in response.

The ISL78226 doesn't include FET drivers; therefore, the controller could be placed away from the FETs and avoid the associated noisy switching nodes without negatively impacting the FET gate-drive loops. This system partition allows for optimal EMI, efficiency, and regulation accuracy.

Because balance current is extremely valuable, the ISL78226 includes internal phase-to-phase current balancing and ISET/ISHARE pins for current balancing between devices to equalize stress on the power stages. With each stage delivering 30 to 60 A of average current, small mismatches can cause large temperature variations and uneven stresses that can lead to reduced operating life and reliability concerns. Intersil offers a 2.5-kW six-phase bidirectional evaluation board (ISL-78226EVAL1Z) and GUI for users to modify any of the control settings of the IC and to monitor fault flags.

Linear Technology's LTC3871 is a bidirectional PolyPhase synchronous two-phase buck or boost controller that maintains up to 97% efficiency. The controller, which meets AEC-Q100 automotive specifications, is designed with intrinsic

(Continued on page 46)

LOU FRENZEL | Contributing Editor

5G EXPOSED!

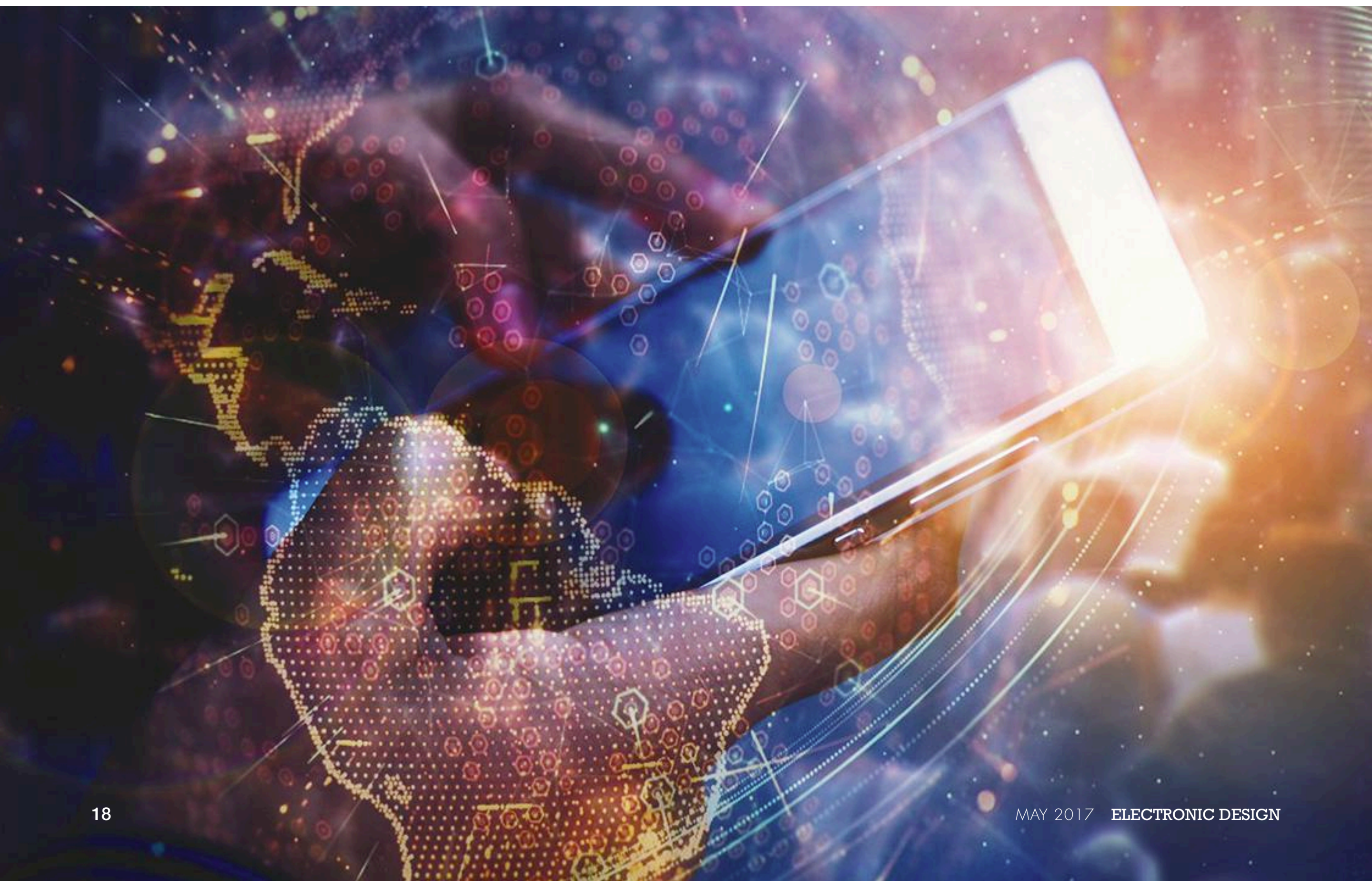
Answering the how, why, and—most importantly—when of 5G wireless.

We have been waiting for 5G for years now and everyone is wondering about its ETA. But there is no one ETA. The launch and rollout of 5G is going to be like other cellular standards, gradual over a period of years rather than all at once. Some trials are going on now and we could see an early pre-standard system in 2018 whereas a widespread deployment is still not expected until 2020 as predicted. Here is a summary and update on this enigmatic technology that is expected to enhance our lives.

THE 5G RATIONALE

The question about need always arises when speaking of 5G. Why are we going to so much trouble to develop this over-the-top system? The basic answer is "because we can." That's engineering for you, developing stuff just because we have the means and knowledge and want the intellectual challenge. We can figure out why we want it later. But do we really need it? Probably not right now, but there are some justifications.

The first rationale is always the need for speed. We can never really get enough downlink speed, it seems, thanks to the constantly rising access to video of all types. More over-the-top (OTT) 4K movies are on the way, without buffering in 5G. Video eats up speed like nothing else so let's have it. Second, new applications are expected to stress the capabilities of the current 4G systems. The Internet of Things (IoT) and machine-to-machine (M2M) applications are growing fast



and millions of connected devices will be using the cellular system for communications. Current systems probably cannot handle the expected load, therefore the eventual need for greater subscriber capacity.

Self-driving vehicles and the safety requirements of the Advanced Driver Assistance Systems (ADAS) program may also use cellular as part of the vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications that make driving safer. Such systems are not here yet, but will represent a major load when implemented.

While data rate is always a major consideration, another factor has emerged as critical to driving safety as well as many IoT/M2M uses in factory automation. That is the issue of latency, the delay time between when an action signal is initiated and the time the action is carried out. Many robotic and other machine actions require millisecond (ms) range latency for competent operation. Current 4G radios can usually achieve 25 ms or more latency that is just not good enough. The goal with 5G is a latency of 1 ms or less. That is expected but not fully confirmed.

Finally, most cellular network operators are always looking for new ways to squeeze more profit out of their network investments. 5G offers that opportunity.

TECHNOLOGY UPDATE

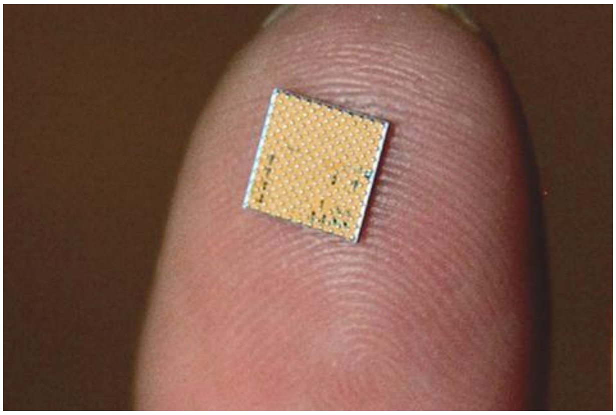
The Third Generation Partnership Project (3GPP) is the organization developing the 5G standards. That standard is now officially named New Radio (NR). NR is to 5G as LTE is to 4G. In case you have not been following the 5G NR movement, here are the highlights of this overly complex radio and networking technology.

- 5G is expected to use mostly new spectrum, although some systems will use bands below 6 GHz. Most of the usual bands in the 700 MHz to 2.6 GHz range are full but some operators are expected to build some 5G systems in this range as their spectrum holdings permit. The FCC also opened up 150 MHz of spectrum in the 3.5 GHz band called the Citizens Broadband Radio Service (CBRS). This is shared spectrum but some may use it for 5G. Otherwise most 5G systems will be implemented in the millimeter wave (mmwave) bands. In the U.S. the 27-28 and 37-40 GHz bands are available with most operators implementing systems in the 28 GHz band. These frequencies offer the bandwidth to achieve the promised data rates.
- Data rates are expected to top 1 Gb/s with a peak of 10 Gb/s depending upon the bandwidth allotted and signal path environment. Ordinary data rates for mobile will be hundreds of megabits per second.
- Carrier aggregation (CA) will be used to piece together different segments of spectrum into a unit to support the desired higher data rate. CA bands can be contiguous or non-contiguous; even unlicensed spectrum can be aggregated.
- Modulation is expected to be some variation of OFDM. Multiple schemes have been under investigation and some carriers have decided on their favorite. Waveforms under consideration are FBMC (filter-bank multicarrier), f-ODFM (filtered-OFDM), GFDM (generalized frequency division multiplex), and UFMC (universal filtered multicarrier). For example, Verizon has selected standard CP-OFDM (CP=cyclic prefix) used now with 75 kHz subcarrier spacing. The final standard has not been announced.
- Increased use of time division duplexing (TDD). Most LTE is frequency division duplex (FDD) and uses separate spectrum segments for up and down links. 5G may use it as well. However, by using TDD only half the spectrum is needed.
- Small cells are expected to form the primary 5G network. Small cells the size of a shoe box can be bolted to light poles and the sides of buildings rather than require separate towers. Some will be indoors. Called HetNet densification, this topology uses many small cells to cover a given area because of the short range of mmwave signals. A key issue is getting permission from municipalities and companies to attach the cells to the various structures. The FCC is trying to ease and facilitate this need.
- Backhaul will be fiber where it is possible to lay it, otherwise mmwave backhaul will use the 70 to 80 GHz bands. Some front haul, links between cells, is also expected.
- Massive MIMO is also an essential feature to be implemented. Massive MIMO, usually meaning more than 64 antenna systems, can serve multiple users and provide beamforming. MIMO is a key technical feature of 5G as it provides the multiuser service as well as the higher data rates.
- Increased sectorization with beamforming provides spatial multiplex capability and enables frequency reuse. Adaptive beamforming boosts signal power and lets small cells avoid interference and initiate more reliable links.
- Software-defined network (SDN) and network function virtualization (NFV) will form the basis for the 5G network. While beyond the scope of this article, these software technologies will manage the small-cell network, dynamically reconfigure the network of small cells, and provide faster, easier implementation of new subscribers.

APPLICATIONS

The new applications of automotive and IoT/M2M have already been mentioned. In addition, 5G will also implement the usual cellular uses of texting, email, and internet access. But no voice. Voice service will be via older 3G systems or by way of 4G voice over LTE (VoLTE) where implemented. Mobile service will be faster than ever.

A new application is broadband connectivity. Some rural areas still do not have a fast internet connection via cable or DSL. A 5G high-speed internet connection is possible and could be one of the first 5G services to be implemented. A 5G wireless link will finally provide the speeds at home and office that metropolitan area user expect and are accustomed to.



1. Intel's 5G modem Supports coverage in the sub- 6GHz and 28 GHz mmwave bands and manages 2x2 and 4x4 MIMO configurations. *(Courtesy of Intel)*

WHAT ABOUT LTE?

So what happens to the current 4G LTE system? It will carry on and continue to be upgraded and supported. LTE or long-term evolution has been around since about 2009 and has grown significantly to today it is the mainstream cellular network in most of the developed world. It is fast and reliable. And many carriers have yet to implement upgrades to LTE-Advanced and LTE-Advanced Pro that put into service higher data rates and other features. LTE-A according to the International Telecommunications Union (ITU) is the real 4G.

LTE-Advanced implemented carrier aggregation that accommodates up to five 20 MHz carriers for a total of 100 MHz bandwidth that supports downlink rates to 150 Mb/s. LTE-A also added 256QAM modulation for a further boost in data rate. LTE-Advanced Pro goes further, allowing up to 32 carriers to be aggregated for even greater bandwidth and adding 4x4 MIMO permitting 1 Gb/s LTE.

Another feature of the LTE-A Pro update is the use of unlicensed spectrum to further increase bandwidth. Advanced Pro accommodates Licensed Assisted Access (LAA) and LTE-WLAN (LWA) that stitches together LTE spectrum and unlicensed 5 GHz spectrum used with Wi-Fi 802.11ac/ax. To minimize interference to Wi-Fi connections, a listen-before-talk feature is implemented. Another similar technology called LTE-U for unlicensed is also available to expand transmission bandwidth using the 5 GHz band and boost downlink speed.

LTE-A Pro provides for IoT/M2M connectivity with new versions that use less bandwidth for lower speeds and power savings. LTE-M uses only 1.4 MHz of bandwidth to achieve speeds up to 1 Mb/s. An ever more frugal version called NB-IoT uses only one OFDM resource block of 180 kHz to achieve a data rate to 250 kb/s. These new versions are expected in many current IoT applications and in vehicle-to-everything (V2X) applications like ADAS and self-driving cars.

LTE Advanced also offered up several other variations. An interesting feature is device-to-device (D2D) communications that lets LTE handset owners talk directly to one another rather than through a cell site. This allows LTE handsets to be used like two-way radios with the usual push-to-talk (PTT) capability. D2D handsets use something called Proximity Services (ProSe) to discover one another and implement a link with or without assist from a nearby cell site. This feature was added as an incentive to public safety organizations to use LTE networks over other digital radio technologies like P25 and TETRA.

The LTE-A Pro version also implements LTE Broadcast. LTE-B is the use of LTE for video broadcasting. It uses channels in the 470 to 694 MHz UHF band. When implemented, it will provide video broadcasting to support the growing OTT video content vendors.

LTE is entrenched. It is not going away even when 5G comes along. ABI Research projects that high-speed downlink LTE-Advanced Pro subscribers will reach 641 million in 2021. ABI further says that 50% of the global population will be able to connect to a 4G LTE network by 2022. ABI also reports that it expects more than15 mobile operators will be offering Gigabit LTE to subscribers by the end of 2017. We will just have to make do with LTE until 5G arrives.

THE DESIGN CHALLENGES OF 5G

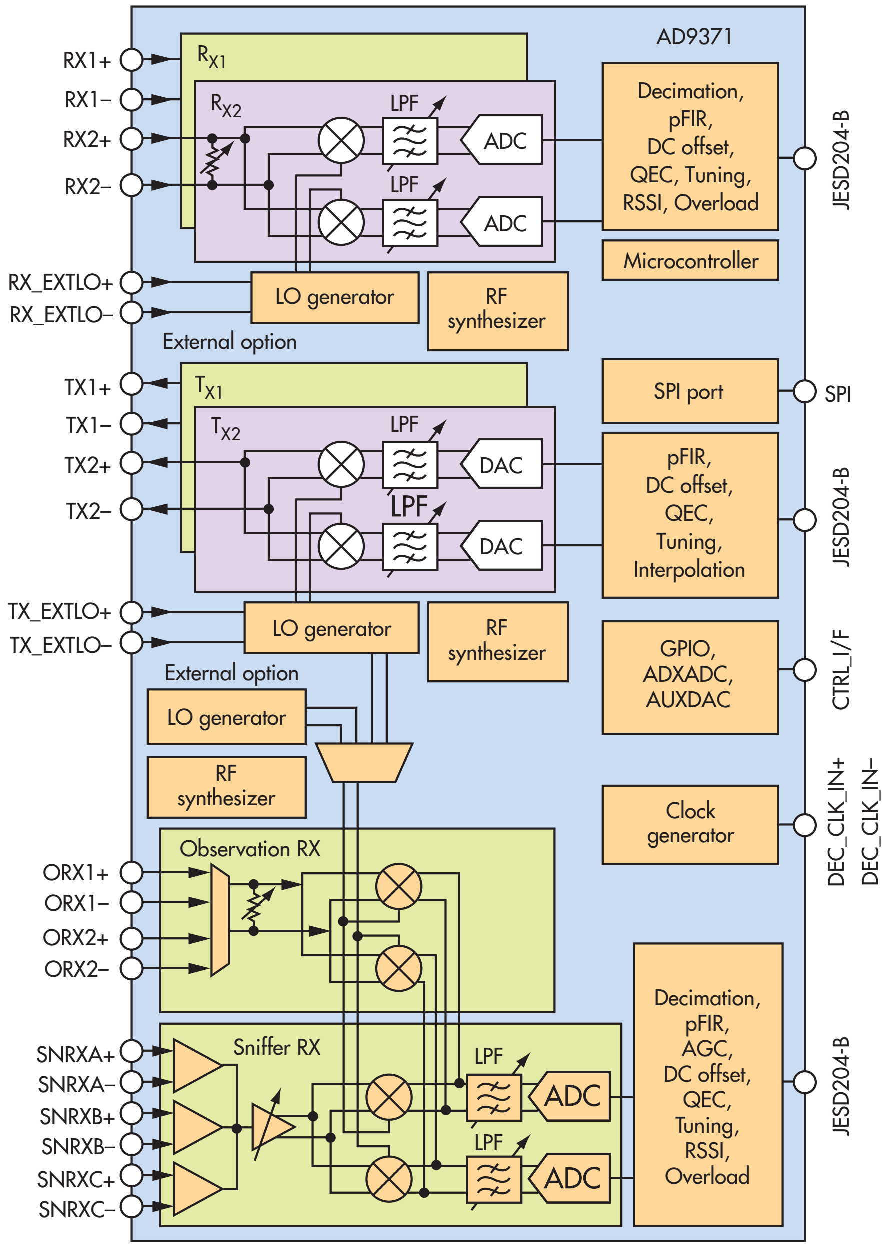
4G LTE systems are complex but 5G adds much more complexity in the basestations and handsets. Early prototypes have used FPGA designs that can be revised as needed for testing purposes. Test-equipment vendors have provided considerable hardware and software to make R&D possible. Once the standards have been completed the semiconductor companies can make 5G chips. Already both Qualcomm and Intel have announced 5G modems. The Qualcomm modem X50 is based upon its Snapdragon processors and supports 5G NR sub-6GHz and mmwave bands as well as gigabit LTE. The Intel modem, nicknamed "Goldridge" *(Fig. 1)* also covers the 5G NR sub-6GHz and mmwave bands as well as 4G LTE.

Another useful 5G chip is Analog Devices AD9371, a dual RF transceiver that targets basestations, small cells, and backhaul units *(Fig. 2)*. In addition to the dual receivers and transceivers, the chip also integrates ADCs, frequency synthesizers, and related DSP. The tunable range is 300 MHz to 6 GHz. This device should be one good solution to implementing large-scale MIMO systems.

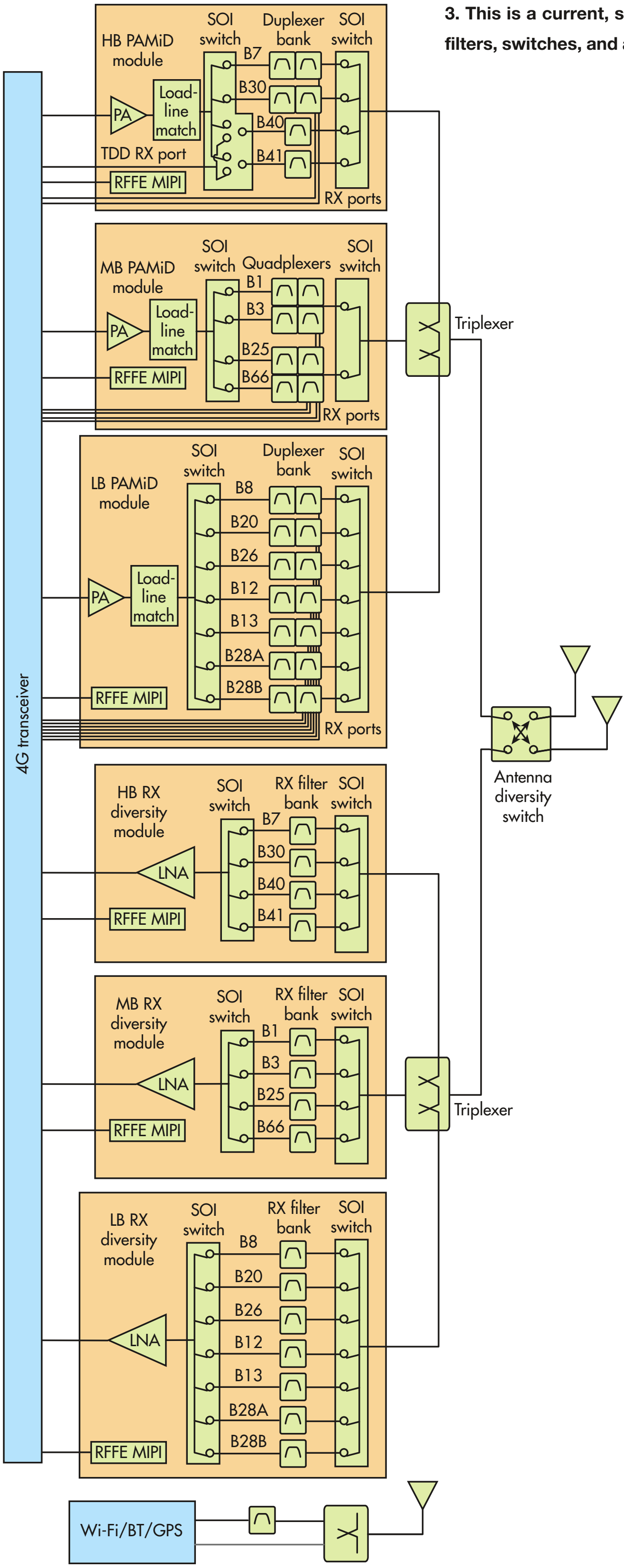
Single-chip modems and transceivers are great but the real design problem is the radio frequency front-end (RFFE). The RFFE is that section of a cell phone that includes the antennas, LNAs, filters, switches, and PAs. *Figure 3* shows a typical RFFE for a 4G phone as an example. The complexity comes from the need to cover multiple bands. This means many filters for each band on both the transmitters and receivers. The usual arrangement is to divide the RFFE into sections for low bands (698-960 MHz), mid-band (1710-2200 MHz), and high-band (2400-3800 MHz). 5G would add another section. And let's not forget the circuitry and antennas for Wi-Fi, Bluetooth, and GPS. Filters are usually surface acoustic wave (SAW) or bulk acoustic wave (BAW) types. Good filters are essential to minimize cross talk and intermodulation distortion. The new phones will still cover the needed LTE bands but also new mmwave 5G band's filters along with the related LNAs and PAs. Multiplex switches will be more complex. A different type of filter will be needed for the mmwave bands.

Filter company Resonant has developed a design tool that can produce structures that outperform traditional designs. As for the antenna arrangements, they will be complicated by the MIMO configurations and/or the use of phased arrays for beamforming. Eventually some of the circuitry will be fully integrated to save space.

Others addressing the RFFE problem are Cavendish Kinetics and Qorvo. Cavendish offers a line of RF MEMS switches and antenna tuners. The antenna tuners are selectable switched capacitors for tuning antennas over a wide range *(Fig. 4)*. This minimizes the number of antennas needed. The MEMS switches have very low loss, a quality needed for so much band switching. The whole rationale for an antenna tuner is to improve antenna efficiency. For electrically small antennas, efficiency is directly related to antenna volume and inversely related to operational bandwidth.



2. Analog Devices AD9371 transceiver is the kind of IC needed to build 5G equipment. *(Courtesy of Analog Devices)*



3. This is a current, state-of-the-art RF front-end architecture of a 4G smartphone showing filters, switches, and amplifiers. *(Courtesy of Resonant)*

Qorvo covers the whole RFFE with GaN PAs, LNAs, and switches. Their QPB9318 and QPB9319 are highly integrated dual-channel switch-LNA modules that support frequency bands below 5G. These modules pair with the QPA2705 GaN PA to provide a complete massive MIMO RF solution.

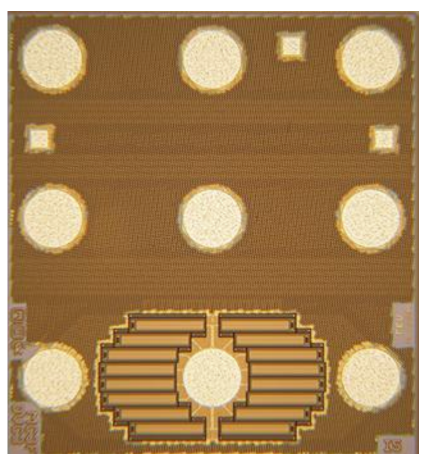
Research firm Yole Developpement of Lyon, France, says that 4G and 5G are changing the front-end industry. They project that the RFFE business will grow from $10.1 billion in 2016 to $22.7 billion in 2022.

THE 5G DEBUT WHILE WAITING ON 6G

When will we actually see 5G? It will come gradually in stages. The Third Generation Partnership Project (3GPP), the organization developing 5G, agreed to complete one part of the standard by March 2018. This is earlier than initially agreed upon, but it will give all parties a head start in building chips and workable systems. Some operators have said that they will use their existing 4G LTE network along with the new 5G physical layer for initial operation. The remaining standards will come along in 2019 with final ITU blessing in 2020. Both AT&T and Verizon have pre-standard test networks in place now and could offer limited early service in 2018. Some carriers have indicated they will initially use their 5G capability for wireless broadband for rural areas and as a competition with cable, DSL, and fiber ISPs. Residents of remote and underserved areas will really appreciate the gesture.

There has been little word so far about the phones themselves. No doubt they are under development but are hampered by the lack of final standards as well as chips.

So shouldn't we start thinking about 6G? Some researchers are probably already working on the options. Will it be in the 100 GHz+ spectrum or optical-based? Or satellite? My guess is that 6G is probably going to be more evolutionary than revolutionary as the technology may not be there yet. Think 2030 time frame. In the meantime, enjoy your 4G LTE and brace for 5G. ed



4. Bottom view of the Cavendish Kinetics MEMS switched capacitor antenna tuner.

WILLIAM WONG | Technical Editor

Development Testing for Safety and Security

Safety and security need to be addressed early in the design process and so should testing.

Safety and security are mantras for the Internet of Things (IoT) with over 60% of the respondents in the recent *Electronic Design* Embedded Revolution survey indicating that these were important to their design. But what does it mean and how do we get there?

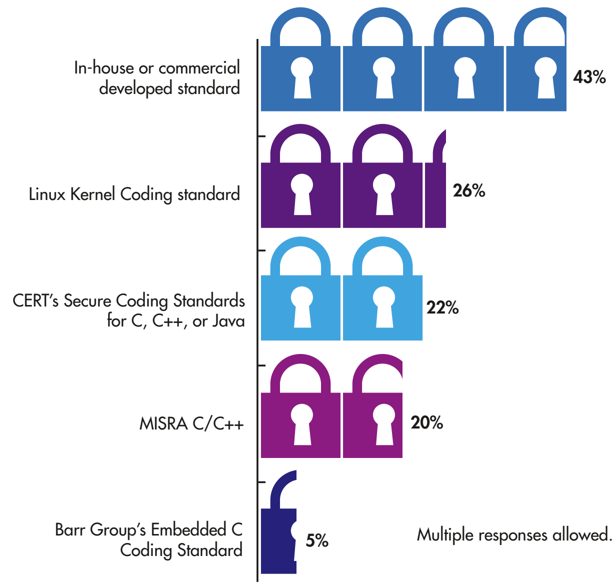
At one end of the spectrum is the initial system design and at the other testing to make sure the application does not break and cannot be compromised. The problem with the latter is that, like bug fixing, testing costs rise exponentially the farther from the development process one goes and the number of potential items to test rises as well.

The development is an iterative process and bugs are introduced and fixed in this process. This includes ones associated with safety and security as well as functional bugs that affect the intended application use. This is where coding standards, static analysis, and dynamic analysis come into play because they lighten the developer's burden to create bug-free code. Unfortunately, the current state of affairs is not good.

According to the Barr Group's 2017 Embedded Systems Safety & Security Survey:

- 9% of IoT designers don't keep their source code in a version control system
- 56% don't perform regular source code reviews for bugs and security holes
- 60% don't use a static analysis tool to check the source code
- 25% don't have a bug database or other system to track known issues
- 37% don't utilize a written coding standard, and others don't enforce one consistently

Likewise, our Embedded Revolution survey shows that only 43% have a coding standard. Coding standards are sometimes developed internally but many employ standard coding practices like MISRA C/C++.



Not all companies are employing coding standards in their development process (from *Electronic Design's* 2017 Embedded Revolution survey).

The results are even worse for the use of static analysis tools. The problem is that automatic checking of coding standards and the use of static analysis tools can significantly reduce the number of undetected bugs that need to be fixed later in the design process. The costs in time and money to use these tools and procedures is not minor, but the payoff is significant simply because the cost of fixing bugs grows exponentially as the software moves from the developer to the field.

"Static analysis is a fundamental capability for identifying and eliminating potential coding flaws, weaknesses, and vulnerabilities," says Jim McElroy, vice president of marketing for LDRA. "When used early and throughout the development process, static analysis can analyze and report on code clarity, maintainability, and testability, as well as help developers adhere to coding standards such as MISRA and CERT. This results in eliminating potential problems early where they are less costly to fix."

The trends show more companies and developers employing coding standards and analysis tools but we are still well short of where we should be to provide products that will be safe and secure as the number of IoT devices moves into the billions.

MARK PITCHFORD | LDRA

Cost-Effective Unit Testing and Integration in Accordance with ISO 26262

Staying on track with ISO 26262 to meet automotive functional safety standards requires automation throughout the software lifecycle. The result is cost-effective production of high-assurance software.

The modern automobile is a maze of interactive electromechanical systems. Many of them, such as brakes, steering, airbags, powertrain, and adaptive driver assistance systems, are critical to human life and safety. Others—such as entertainment systems—not so much. However, they all rely on an exploding volume of software, and in many designs these component systems also share the same internal communication infrastructure. That means that functional safety from a systems perspective as well as at the independent unit level must be assured during the development and testing of this code.

THE PURPOSE AND SCOPE OF ISO 26262

ISO 26262 is a functional safety standard for road vehicles that defines requirements and processes to assure safety along a range of hazard classification levels called Automotive Safety Integrity Levels (ASIL). These specify functional safety measures for levels A (least hazardous) to D (most hazardous). ISO 26262 specifies a process that begins with general requirements, the specification of actual safety requirements, the design of the software architecture, and the actual coding and implementation of the functional units. There are also steps for testing and verification of each of these.

The necessary and detailed work of specifying system design requirements and safety requirements can be done at a fairly abstract level using spreadsheets, word processing tools, and more formal requirements-management tools. However, these requirements must also flow down to both the individual software components that implement them and the verification activities that prove them. Under ISO 26262, bi-directional traceability is critical to ensure a transparent and open lifecycle of development. Similarly, if code needs to be rewritten it is important to understand from which upstream requirement it was derived.

SOFTWARE ARCHITECTURE DESIGN AND TESTABILITY

Design-for-testability is often an overloaded term, but the concept is clear under ISO 26262. The software architectural design, called out in Section 7 of the standard, specifically sets out to produce a software architecture that meets the software safety requirements. Modeling tools are often used during this early phase to explore the solution space for the software architecture. Some companies still rely on manual methods of high-level design, using documents or even high-level coding (that is, minus the detailed behavior). Regardless of the method, during design as well as during implementation, the architectural design must be verified. For lower levels of safety integrity, i.e., levels A and B, techniques such as informal walkthroughs and inspections may suffice. For higher safety-integrity levels such as C and D, automation techniques allow developers to cost-effectively perform architectural analysis and review, including in-depth control flow and data-flow analysis. Ultimately, under ISO 26262 the architectural design should lead to a well-defined software architecture that is testable and easily traceable back to its functional safety requirements.

ISO 26262 also requires a hierarchical structure of software components for all safety-integrity levels. From a quality perspective, the standard includes example guidelines such as:

Software components should be restricted in size and loosely coupled with other components.

- All variables need to be initialized.
- There should be no global variables or their usage must be justified.
- There should be no implicit type conversions, unconditional jumps, or hidden data or control flows.
- Dynamic objects or variables need to be checked if used at all.

Without automation, the process of checking all these rules and recommendations against the unit under implementation would be painstaking, costly, and error-prone.

CODING STANDARDS AND GUIDELINES IN THE CONTEXT OF ISO 26262

Within the requirements of ISO 26262, software unit implementation contributes to a more testable, high-quality application. While ISO 26262 does not specify a particular coding standard, it does require that one be employed. Appropriate standards and guidelines such as MISRA C:2012, MISRA C++:2008, SEI CERT C, CWE, and others share the goal of eliminating potential safety and security issues and are supported by automated tool suites. The coding guidelines can be regularly checked and enforced using an integrated static analysis tool that examines the source code and highlights any deviations from the selected standard.

Beyond adherence to coding standards, fully integrated software tools can check and enforce guidelines for quality design of software units and facilitate their integration and testing according to the defined software architecture and the system's requirements. Applying and enforcing such principles at the unit coding level makes it more certain that the units will fit and work together within the defined architecture. Ideally, an integrated tool suite should collate these automated facilities so that they can be applied to all stages of development in the standard "V" process model *(Fig. 1)* and can coordinate requirements traceability, analysis, and testing over all stages of product development.

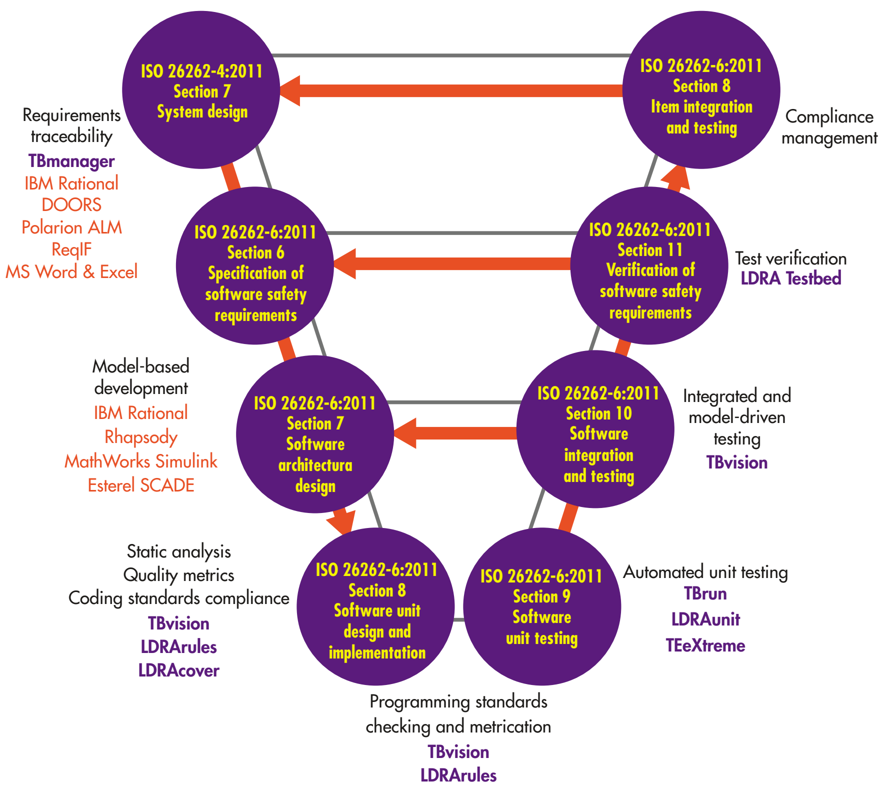
STATIC ANALYSIS AND SOFTWARE UNIT TESTING

From a broad perspective, ISO 26262's practices are aimed at making code more understandable, more reliable, less prone to error, and easier to test and maintain. For example, restricting the size of software components and their interfaces makes them easier to read, maintain, and test, and therefore less susceptible to error in the first place. Static analysis can check a host of guidelines to ensure that variables are initialized, global variables are not used, and recursion is avoided. The existence of global variables, for instance, can cause confusion in a large program and make testing more difficult. Applying static analysis throughout the code-implementation phase can highlight violations as they occur, and ultimately confirm that there are none present. In addition, tools can generate complexity metrics to make it possible to measure and control software component size, complexity, cohesion, and coupling *(Fig. 2)*.

Software unit testing demonstrates that each software unit (function or procedure) fulfills the unit design specifications and does not contain any undesired behavior. Once that is proven, unit integration testing demonstrates the continued correctness of that behavior as these units are deployed as part of a system, and then that this integration actually realizes the software architectural design laid out at the higher level. Perhaps the ultimate integration test is a system test, when all of the software is operated as a coherent whole.

Unit testing and unit integration testing uses this framework to provide a harness to execute a subset of the code base, and verify that the functionality of the software interfaces is

(Continued on page 34)



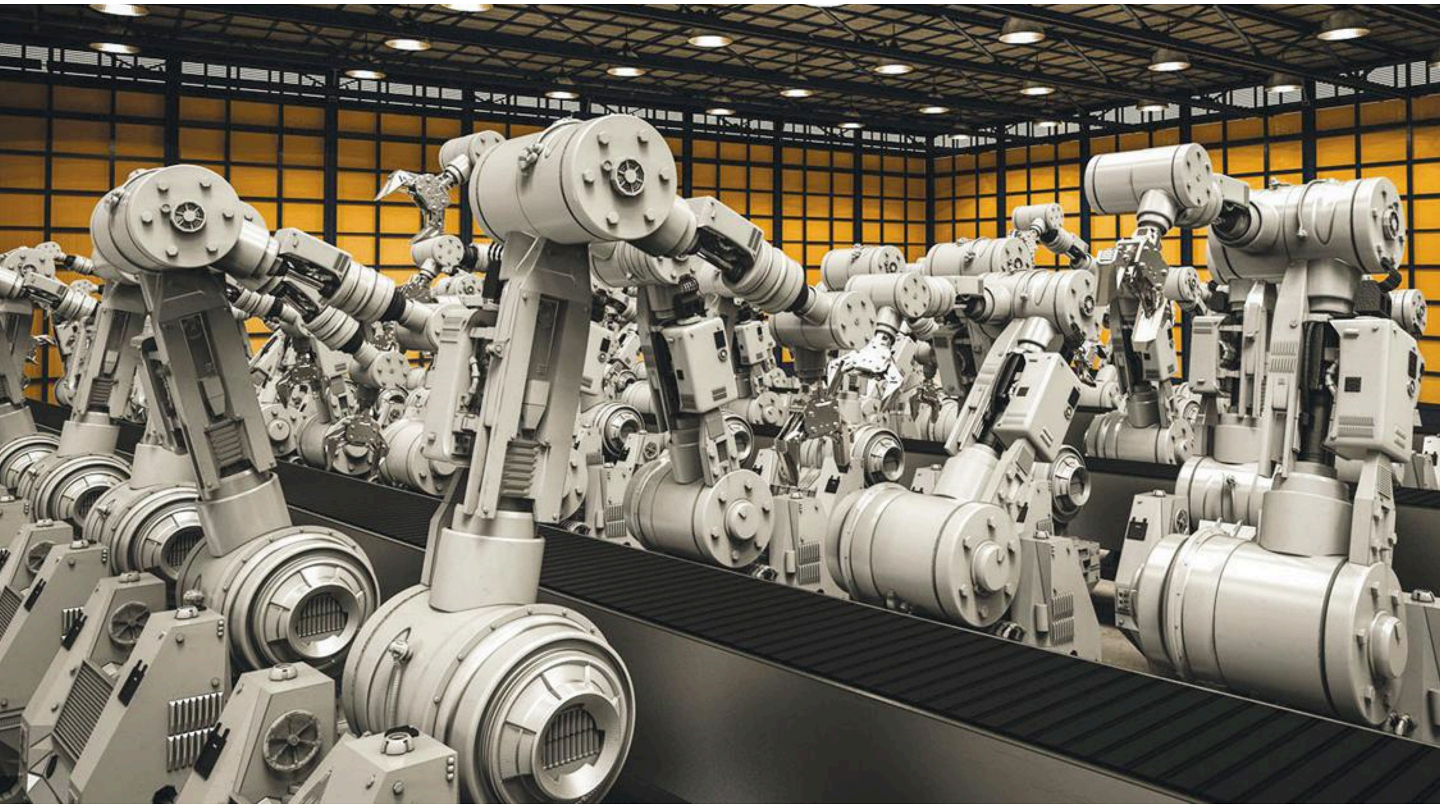
1. The diagram above illustrates the capabilities of an automated tool chain to the ISO 26262 process guidelines.

LOU FRENZEL | Contributing Editor

Factory Automation Banks on Wireless and AI Technology to Succeed

Communications and intelligence are the key cogs in creating a productive, efficient factory-automation environment. Here's a primer to get you started.

As more factories become automated, it's clear that communications between machines, robots, and the computers that direct them is critical. The more information that's communicated, the greater the productivity. But with ever-larger amounts of data being communicated, the need to analyze and interpret the information, and use it in decision-making, becomes that much more critical. Integration of wireless sensor networks and artificial intelligence (AI) helps meet those demands.



SHORT-RANGE WIRELESS TECHNOLOGIES USED IN FACTORY AUTOMATION				
Technology or standard	Frequency	Range	Features	Common applications
Cellular	Common cellular bands	Several km	Longer range	M2M
Dust Networks	2.4 GHz	10 m	TDM, security	Mesh networks
IEEE 802.15.4	2.4 GHz	<10 m	Multiple protocols available	Wireless networks
ISA100a	2.4 GHz	<10 m	Extra security and reliability	Industrial monitoring and control
ISM band	Part 15 frequencies	<10 m	Low cost, simplicity	Monitor and control
RFID	125 kHz, 13.56 MHz, 902-928 MHz	<1 m	Low cost	Tracking inventory, access
6LoWPAN	2.4 GHz	<10 m	Internet access	Monitor and control via internet
Wi-Fi	2.4 and 5 GHz	<100 m	High speed, ubiquity	Local networks, internet access, broadband
Wireless HART	2.4 GHz	<10 m	HART protocol	Industrial monitor and control
ZigBee	2.4 GHz	<10 m	Mesh networks	Home, industrial monitor and control

INDUSTRIAL INTERNET OF THINGS (IIoT)

The ultimate solution, of course, is the industrial internet of things or IIoT. This is the application of standard IoT concepts to manufacturing. IIoT is essentially the monitoring and control of factory equipment using wireless methods, internet cloud connectivity, and advanced data analysis incorporating artificial intelligence. You may also know of this as Industry 4.0, the German reference to the current fourth generation of manufacturing that incorporates better communications and intelligent computers and software to greatly improve manufacturing through automation.

IIoT advocates connecting all possible devices with sensors to a network that's able to send the data to computers that can store, analyze and display the data. Software will analyze the data and harvest the knowledge it contains to help make smart decisions that will succeed in achieving the productivity objectives previously set.

Virtually every employee, tool, robot, or device contains valuable data that can potentially improve your manufacturing operations. Such data will identify inefficiencies, spot potential problems, and provide improved quality control. The outcome could produce a competitive edge. An IIoT system can also spot trends, help streamline the manufacturing process, avoid downtime, and optimize your existing assets. The whole approach involves new hardware and software.

WIRELESS FACTORY COMMUNICATIONS

In the past, wired communications was the norm in factory automation. Many special networks and fieldbuses were created to connect sensors and controlled devices to computers and one another. Many of these networks are still used. In addition, Ethernet has emerged as THE networking technology of choice for industrial applications, sometimes replacing older legacy technologies.

Furthermore, wireless technology has become more reliable with many flexible choices. Thus, it's emerging as a way to not only replace older systems, but also to increase the amount of sensor monitoring, further increasing the breadth of useful machine data. Below is a rundown of some choices to consider when looking to expand the communications capabilities for a factory automation system *(see table)*.

IEEE 802.15.4

IEEE 802.15.4 is designed to support peer-to-peer links as well as wireless sensor networks. The standard defines the basic physical layer (PHY), including frequency range, modulation, data rates, and frame format, and the media-access-control (MAC) layer. Separate protocol stacks are then designed to use the basic PHY and MAC. Several wireless standards use the 802.15.4 standard as the PHY/MAC base, including ISA100a, Wireless HART, ZigBee, and 6LoWPAN.

The standard defines three basic frequency ranges. The most widely used is the worldwide 2.4-GHz ISM band (16 channels), which has a basic data rate is 250 kb/s. Another range is the 902- to 928-MHz ISM band in the U.S. (10 channels). The data rate is 40 or 250 kb/s. Then there's the European 868-MHz band (one channel) with a data rate of 20 kb/s.

All three ranges use direct sequence spread spectrum (DSSS) with either binary phase-shift-keying (BPSK) or offset quadrature phase-shift-keying (QPSK) modulation. The multiple-access mode is carrier sense multiple access with collision avoidance (CSMA-CA). The minimum defined power levels are –3 dBm (0.5 mW). The most common power level is 0 dBm, while a 20-dBm level is defined for longer-range applications. Typical range is less than 10 meters.

6LOWPAN

Developed by the Internet Engineering Task Force (ITEF), 6LoWPAN provides a way to transmit IPv6 and IPv4 Internet Protocols over low-power wireless point-to-point (P2P) links and mesh networks. The 6LoWPAN standard (RFC4944), which is short for IPv6 protocol over low-power wireless PANs, also permits the implementation of the Internet of Things on even the smallest and remote devices.

The protocol provides encapsulation and header compression routines for use with 802.15.4 radios. If your wireless device must have an internet connection, this is your technology of choice.

CELLULAR

With services from most network carriers, cellular radio provides data-transmission capability for machine-to-machine (M2M) applications. M2M is used for remote monitoring and control. Cellular radio modules are widely available to build into other equipment. Older 2G and 3G modules are now being replaced by 4G LTE modules such as NB-IoT. The working range is from 1 to 10 km, which is the range of most cell sites today.

DUST NETWORKS

Dust Networks was acquired by Linear Technology, which in turn was acquired by Analog Devices. Its SmartMesh technology is based on the 802.15.4 and 6LoWPAN standards. The prime benefit of this technology is its ability to form ad hoc, self-repairing mesh sensor networks that increase range and reliability. Other key features are its 10,000-hour battery-lifetime modules and NIST-grade AES-128 security.

SmartMesh networks communicate using a time-synchronized channel-hopping (TSCH) link layer, a technique whereby all nodes are synchronized to within a few microseconds. Network communication is organized into TDM time slots that permit channel hopping and full path diversity. They also offer a version of a HART wired network called WirelessHART (see below).

ISA100A

Developed by the International Society of Automation, ISA100a is designed for industrial process control and factory automation. It uses the 802.15.4 PHY and MAC, but adds special features for security, reliability, feedback control, and other industrial requirements.

ISM BAND

Most of these standards use the unlicensed ISM bands set aside by the Federal Communications Commission (FCC) in Part 15 of the Code of Federal Regulations (CFR) 47. The most widely used ISM band is the 2.4- to 2.483-GHz band, which is used by Wi-Fi, Bluetooth, 802.15.4 radios, and many other devices. The second most widely used band is the 902- to 928-MHz band, with 915 MHz being a sweet spot. Modulation is typically ASK/OOK or FSK. Other popular ISM frequencies are 315 MHz for garage-door openers and remote-keyless-entry (RKE) applications, and 433 MHz for remote temperature monitoring.

RFID

Radio-frequency identification (RFID) is used primarily for identification, location, tracking, and inventory. A nearby reader unit transmits a high-power RF signal to power passive (unpowered) tags and then read the data stored in their memory.

RFID tags are small, flat, and cheap, and can be attached to anything that must be tracked or identified. They have replaced bar codes in some applications. RFID uses the 13.56-MHz ISM frequency, but other frequencies are also used, including 125 kHz, 134.5 kHz, and frequencies in the 902- to 928-MHz range. Multiple ISO/IEC standards exist.

WI-FI

Wi-Fi is the commercial name of the wireless technology defined by the IEEE 802.11 standards. Next to Bluetooth, Wi-Fi is by far the most widespread wireless technology. It's in smartphones, laptops, tablets, and ultrabooks, as well as TV sets, video accessories, and home wireless routers. On top of that, it's deployed in many industrial applications. Wi-Fi is now showing up in cellular networks, where carriers are using it to offload some data traffic like video that clogs the network.

The initial version, called 802.11b, was popular because it offered up to 11-Mb/s data rates in the 2.4-GHz ISM band. Since then, new standards have been developed including 802.11a (5-GHz band), 802.11g, and 802.11n using OFDM to get speeds up to 54 and 300 Mb/s under the most favorable conditions.

More recent standards include 802.11ac, which uses multiple input, multiple output (MIMO) to deliver up to 3 Gb/s in the 5-GHz ISM band. Wi-Fi is readily available in chip form or as complete drop-in modules. The range is up to 100 meters under the best line-of-sight conditions. This is a great option, where longer range and high speeds are needed for the application.

WIRELESS HART

HART is the Highway Addressable Remote Transducer protocol, a wired networking technology widely used in industry for sensor and actuator monitoring and control. Wireless HART is the wireless version of this standard. The base of it is the 802.15.4 standard in the 2.4-GHz band. The HART protocol is a software application on wireless transceivers.

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ZIGBEE

Emanating from the ZigBee Alliance, it's a software protocol and technology that uses the 802.15.4 transceiver as a base. It provides a complete protocol stack designed to implement multiple types of radio networks that include point-to-point, tree, star, and point-to-multipoint. Its main feature is the ability to build large mesh networks for sensor monitoring. And, it can handle up to 65,000 nodes.

ZigBee also provides profiles or software routines that implement specific applications for consumer home automation, building automation, and industrial control. Examples include building automation for lighting and HVAC control, as well as smart meters that implement home-area-network connections in automated electric meters. ZigBee is widely used in factory automation and can be used in other M2M and Internet of Things applications as well.

CRITICAL DESIGN FACTORS

The performance of a wireless link is based on pure physics as modified by practical considerations. In implementing a short-range wireless product or system, the important factors to consider are range, transmit power, antenna gains if any, frequency or wavelength, and receiver sensitivity. Basic guidelines include:

- Lower frequencies extend the range if all other factors are the same. This is strictly physics. A 900-MHz signal will travel farther than a 2.4-GHz signal, and a 60-GHz signal has substantially less range than a 5-GHz signal.
- Lower data rates will also extend the range and reliability for a given set of factors. Lower data rates are less susceptible to noise and interference. Always use the lowest possible data rate for the best results.
- Latency is a major factor today in many automation scenarios. Latency is that time delay between the initial trigger of an event and the actual start time of the event. Robot operations are sometimes critical of timing. Latency is usually in the millisecond range, but varies with the technology used. Check your needs before choosing a technology.
- Security may be important if the company fears outside tapping into valuable production data available via wireless. Most wireless products today incorporate security in the form of AES-128 encryption that's sufficient to protect most systems.
- Losses through walls, surrounding equipment, or other obstacles should also be considered.
- Add fade margin to your design to overcome unexpected environmental conditions, noise, or interference. This ensures your system will have sufficient signal strength over the range to compensate for unknowns. Increase fade margin if the signal must pass through walls and other obstructions.

What good is added sensor data if you can't interpret it or use it to boost efficiency?

Keep in mind that antennas can have gain. By making the antenna directional, its beam is more focused with RF power and the effect is the same as raising the transmit power. Half-wave dipoles and quarter-wave verticals aren't considered to have gain unless compared to a pure isotropic source.

ARTIFICIAL INTELLIGENCE (AI)

What good is added sensor data if you can't interpret it or use it to boost efficiency? Data-acquisition software can help sort the data and graph it for interpretation. That is positive, but often engineers discover that specialized software is needed for the specific processes involved. As more experience is gained, engineers are finding that AI software can help do more in less time and with minimal injection of human decision-making operations. AI can quickly analyze data and implement process changes to boost productivity on the fly.

One example of an AI application is predictive maintenance. This is the practice of being able to determine what parts might fail in each machine tool and schedule replacement during regular scheduled shutdowns. This prevents unexpected failures that occur during regular production runs and shuts all or many parts of the factory. Unscheduled failures cost massive amounts of money in lost output.

AI software can be built to use regular maintenance data in a knowledge base that records parts replaced in each machine and other factors such as time between breakdowns and other critical data. The AI software analyzes all of these factors and then decides what to replace or service next during a regular maintenance period. This process of predictive maintenance can boost uptime and save thousands if not millions of dollars in lost productivity.

Such AI software needs to be custom-designed in most cases. In some situations, machine learning with neural networks can be used to learn from past maintenance data about what can go wrong and with what frequency.

While the details of AI are beyond the scope of this article, the ultimate goal of AI is to bring a degree of human intelligence to the application, intelligence that can assess a situation and take action. The idea is to analyze raw data and derive knowledge and understanding from it. Then the result is used to solve problems or make decisions. AI is a combination of hardware and special software that exploits search, logic, probability, and other special techniques like neural networks to work its human-like magic. ed

DESIGN NOTES

60V Low I_Q, Dual Output Synchronous Step-Down Controller with Adjustable Gate Drive

Design Note 562

Victor Khasiev

Introduction

The LTC®3892 is a dual output synchronous buck controller featuring a wide input voltage range of 4.5V to 60V and an output voltage of 0.8V to 99% of V_{IN}. The combination of the LTC3892's built-in FET drivers and external FETs yield high efficiency and high power capability, up to 97% efficiency and over 60A output current[2]. Its robust design—an IC operating junction temperature range of –55°C to 150°C—meets the needs of industrial, automotive, telecom, military, aerospace and distributed systems.

The LTC3892's low I_Q is indispensable in battery-powered applications where idle current must be kept low. It features 29µA no-load quiescent current and 3.9µA shutdown current, maintaining battery charge as long as possible. The LTC3892's wide input voltage range satisfies the demanding requirements of industrial and automotive applications, which are distinguished by their lack of stable, high quality voltage sources. For example, in automotive environments, a 12V nominal voltage rail can range from a low 5V to above 50V during cold starts and load dumps. The LTC3892's ability to sustain the output in the face of high voltage inputs eliminates costly voltage suppressors; its low minimum input

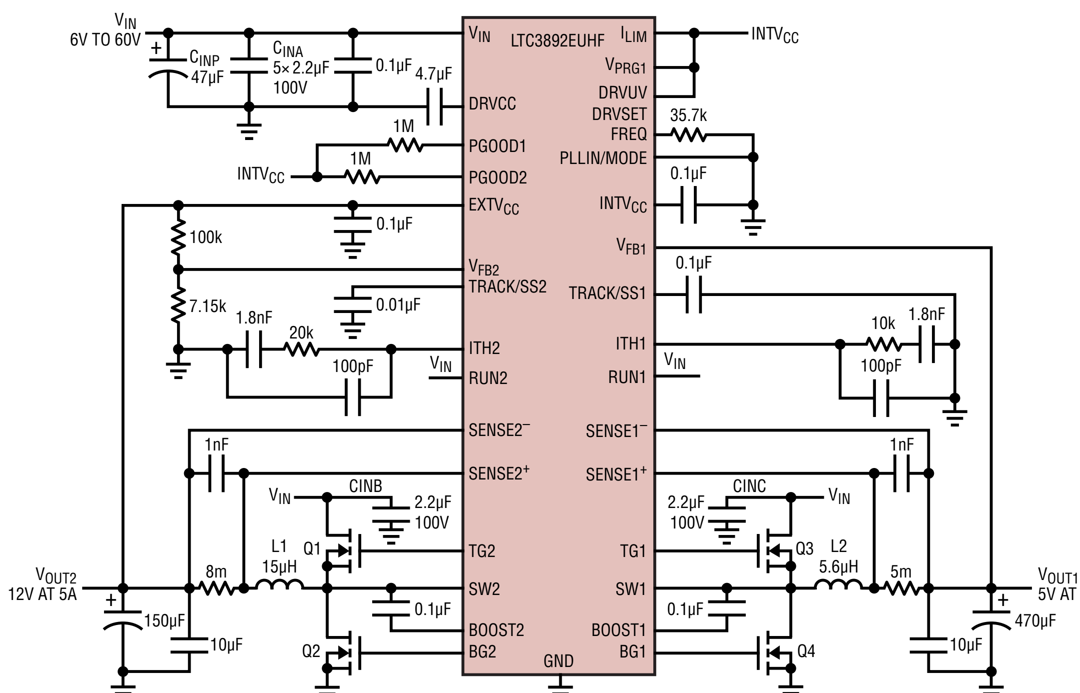

Figure 1. LTC3892, Dual Output DC/DC Converter Schematic

maintains an uninterrupted logic supply when the input voltage dips far below nominal.

Another key feature of the LTC3892 is its programmable gate voltage that can be set from 5V to 10V. This is important for many reasons. A designer can choose a standard (10V) gate drive level and select switching devices from the wide variety of MOSFETs offered by multiple vendors, optimizing the supply efficiency and reducing overall cost. However, if gate driver loss is important, then logic level (5V) FETs can be used. As a compromise, the gate voltage can be programmed to any intermediate value, providing acceptable gate and minimum conduction losses[1]. The LTC3892 features programmable undervoltage lockout (UVLO) and programmable $EXTV_{CC}$ via the DRVUV pin.

Circuit Description

Figure 1 shows a single LTC3892, dual-output solution: 12V out at 5A and 5V out at 8A. The LTC3892 controls two power trains, each with a pair of switching MOSFETs, inductor and output filter. This circuit demonstrates the ability for V_{OUT1} to be set to a fixed level by programming the V_{PRG1} pin. In this schematic it's set to 5V[1]; consequently V_{OUT1} is connected directly to the FB1 pin. The standard gate drive level is selected by tying the DRVSET pin to the $INTV_{CC}$ pin.

In the solution of Figure 1, the V_{IN} pin and the drains of the top MOSFETs of both outputs are connected to the same input voltage V_{IN}. However, these three ports can be connected to different voltages or power supplies if needed. Designers can bias the LTC3892 through the V_{IN} pin and apply a voltage from different sources to the drains of Q1 or Q3. Figures 2 and 3 illustrate the efficiency of the converter in Figure 1 at various input voltages.

Demonstration circuits[2] are available from the factory, designed to display a variety of load capabilities. Incorporating current mode control, a LTC3892 supply can be wired as a dual output supply as on the DC1998A demo board, as a 2-phase single output supply delivering 12V at 30A (DC2190A-B), or as a 4-phase single output supply generating 12V at 60A (DC2190A-A).

Conclusion

The LTC3892 is a versatile 60V input, dual output buck controller, optimized for high efficiency DC/DC solutions in automotive, industrial and telecom fields. Other salient features include programmable gate voltage, extremely low no-load and shutdown quiescent current, programmable frequency, internal bootstrap diodes and easy current sharing for high current designs.

References

1. http://cds.linear.com/docs/en/datasheet/38921fb.pdf, *LTC3892 Family Data Sheet*
2. http://www.linear.com/product/LTC3892#demoboards, *LTC3892 Family Demo Circuits*

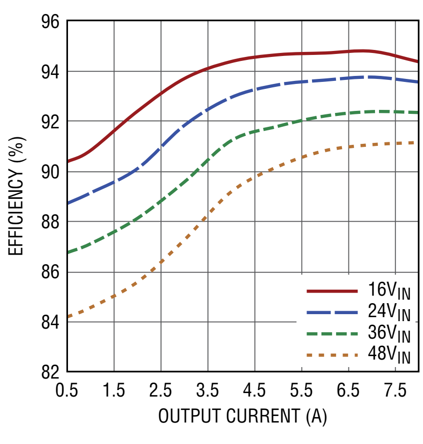

Figure 2. LTC3892, V_{OUT1}, 5V Efficiency Curves

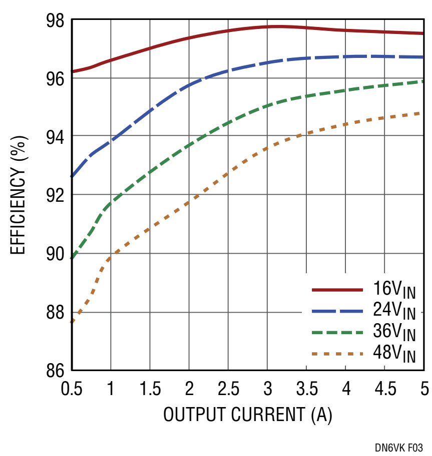

Figure 3. LTC3892, V_{OUT2}, 12V Efficiency Curves

Data Sheet Download

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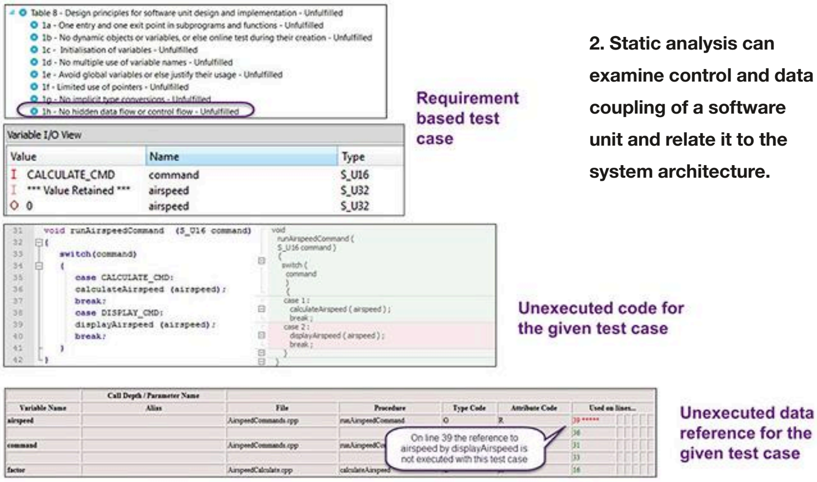
(Continued from page 26)



2. Static analysis can examine control and data coupling of a software unit and relate it to the system architecture.

in accordance with software design specification and requirements. That includes ensuring that only those requirements are met, and that the software does not include any unrequired (that is, undesired) functionality. This same unit test facility can be used to create fault-injection tests for functional safety, measure resource usage, and where applicable, ensure that auto-generated code behaves in accordance with the model from which it was derived.

While static analysis can perform an automated "inspection" of the source code to verify adherence to the ISO 26262 guidelines for coding and unit implementation, beyond that, the information derived from that static analysis can be used to provide a framework for dynamic analysis—the analysis of executed code. Ideally, all dynamic analysis should be implemented using the target hardware so that any issues resulting from its limitations are highlighted as early as possible. If target hardware is not available in the early phases of a project, the code should be executed in a simulated environment based on the verification specification. That can allow development to proceed with the caveat that testing on the actual target hardware will ultimately be needed.

ENSURING TRACEABILITY TO SOFTWARE SAFETY REQUIREMENTS

Integration testing, then, is designed to ensure that all units work together and in accordance with the architectural design and the requirements. In the case of an ISO 26262-compliant project, that implies the verification of functions relating to the ISO 26262 software safety requirements as well as more generic functional requirements. Again, these tests can initially use a simulated environment, but ISO 26262 then calls for analysis of the differences between source and object code and between the test and the target environments in order to specify additional tests for ultimate use in the target environment. In any event, testing on the target hardware must be completed prior to certification.

Where tests fail, it is likely that code will need to be revised. Similarly, requirements can change part-way through a project. In either case, all affected units must be identified and all the associated unit and integration tests must be re-run. Fortunately, such regression tests can be automated and systematically re-applied to assure that any new functionality does not adversely affect any that is already implemented and proven.

This constant attention to the faithful representation of requirements by the code is especially relevant to unit test and integration. The inputs and expected outputs for these tests are derived from the requirements, as are tests for fault testing and robustness. As units are integrated into the context of their associated call trees, the same test data can be reused.

Unit and integration testing with dynamic analysis ensures the software functions correctly, both as a unit and "playing well with others" when connected to other units in the overall program. However, in the latter context it is also necessary to evaluate the completeness of such testing as well as to make sure there is no unintended functionality. Function and call-coverage analysis tests to see that all calls have been made and all functions have been called. It is, however, necessary to more thoroughly examine the structure by executing statement and branch coverage, which assures that each statement has been executed at least once and that each possible branch from each decision point is taken at least once.

Where there are multiple conditions to consider at such a decision point, the number of possible combinations can soon lead to a situation where testing each of them is impractical. Modified Condition/Decision Coverage (MC/DC) is a technique that reduces the number of test cases required in such circumstances, calling only for testing to demonstrate that each condition can independently affect the result.

Coverage analysis at the unit level will verify the conditions within that unit but will obviously not exercise calls outside that unit. Unit tests, integration tests, and system tests can all contribute to the degree of coverage over the entire project.

To place all of this into context: the functions of the software units are determined by the software architectural design, which is in turn determined by the requirements. Both the requirements and architecture, which define the units, also define the testing required by each of those units. In turn, when the units are integrated, they are tested to verify their functional interaction as well as their compliance to the software architectural design and—for ISO 26262—both functional and safety requirements.

The requirements at the top of the V-model shown in Fig. 1 are often defined using specialized requirements tools such as IBM Rational DOORS, or modeling tools such as MathWorks Simulink. Having a software tool suite that interfaces with such tools can be an advantage in verifying the bidirectional traceability that is required by ISO 26262, even where modeling tools are used to automatically generate source code. These auto-generated units are subject to the same rigorous testing, verification, and integration procedures as hand-coded units, legacy code, and open-source code.

AUTOMATED TESTING AND VERIFICATION TOOLS KEEP ISO 26262 PROJECTS ON TRACK

It is easy to think of development as a stage-by-stage process, with test coming somewhere after coding. However, regular testing during development complete with bi-directional requirements tracing is vital because the later a failure shows up, the higher the cost in both time and money.

With all this concurrent activity, maintaining an up-to-date handle on project and traceability status by traditional means is a logistical nightmare. For example, the possible cause of an integration test failure might be a contradiction in requirements, something that is much easier to deal with if recognized early. If it is later and the requirements need to be modified, it will have an inevitable ripple effect through the project. What other parts of the software are affected? How far back do you have to modify and test to be sure the change is covered?

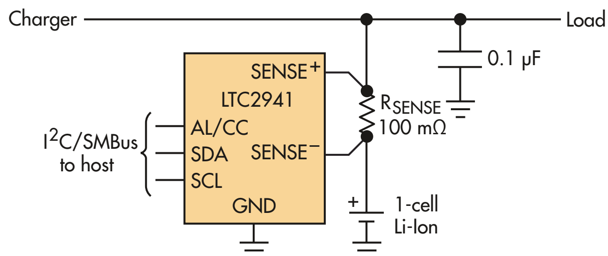
A similar unhappy scenario accompanies a coding error discovered late in the day. What other units are dependent on that code? What if there is an incorrect specification in one of the requirements but unit tests have already been run and are now at least suspect? How do you find your way to know that everything has been fixed?

In such situations, manual requirements tracing will at some point break down. At the very best, it will still leave a sense of uncertainty. However you collate your requirements, whatever design approach you adopt, whether you develop model-generated or hand-generated code, automated testing and verification tools can do more than just report on the status of a particular development stage. An integrated tool suite can provide traceability between the requirements, the design, and the source code—from the lowest-level functions and their test results up to the specified requirements. Staying on track with ISO 26262 from bright idea to a reliable and safely running system needs constant attention with a flair for detail that only automated tools can deliver. ed

High-Voltage Amplifier Extends Coulomb-Counter Range to ±270 V

By KRIS LOKERE | Linear Technology Corp.

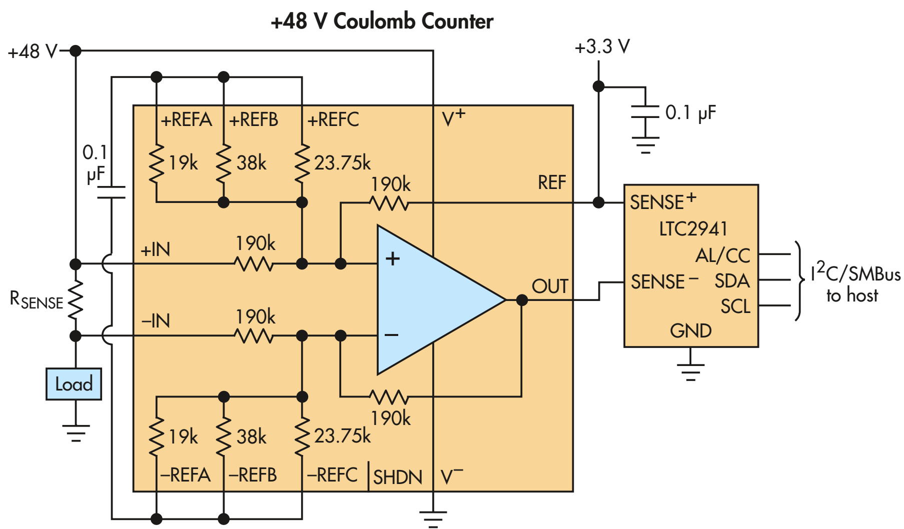
A COULOMB COUNTER can measure charge that flows into or out of a battery, and small, dedicated ICs can directly interface with low-to-medium battery voltages of up to about 20 V. By using a high-voltage amplifier as a level shifter, you can extend the input operating range to much higher voltages of the measurement circuit. The LT6375 voltage-difference amplifier includes some features that make this circuit work accurately up to surprisingly wide voltages.



1. A low-voltage coulomb counter, such as the LTC2941, helps simplify low-voltage measurements.

Coulomb counters operate by measuring the voltage across a sense resistor as an indication of the current that needs to be integrated. *Fig. 1* shows the typical connection when using the LTC2941, a low-voltage coulomb counter. The important point is that a coulomb counter really measures voltage, then interprets it as current, and later reports it as charge. By removing the sense resistor, and somehow driving another voltage across the coulomb counter's sense pins, it will still interpret that voltage as a current and report an accumulated charge.

In *Fig. 2*, the LT6375's output is connected to the sense pins of the coulomb counter. The IC is a difference amp, which means it's an op amp plus precision resistors connected so as to shift the level of a differential input voltage. The operation of the difference amp drives its output voltage to a value of:

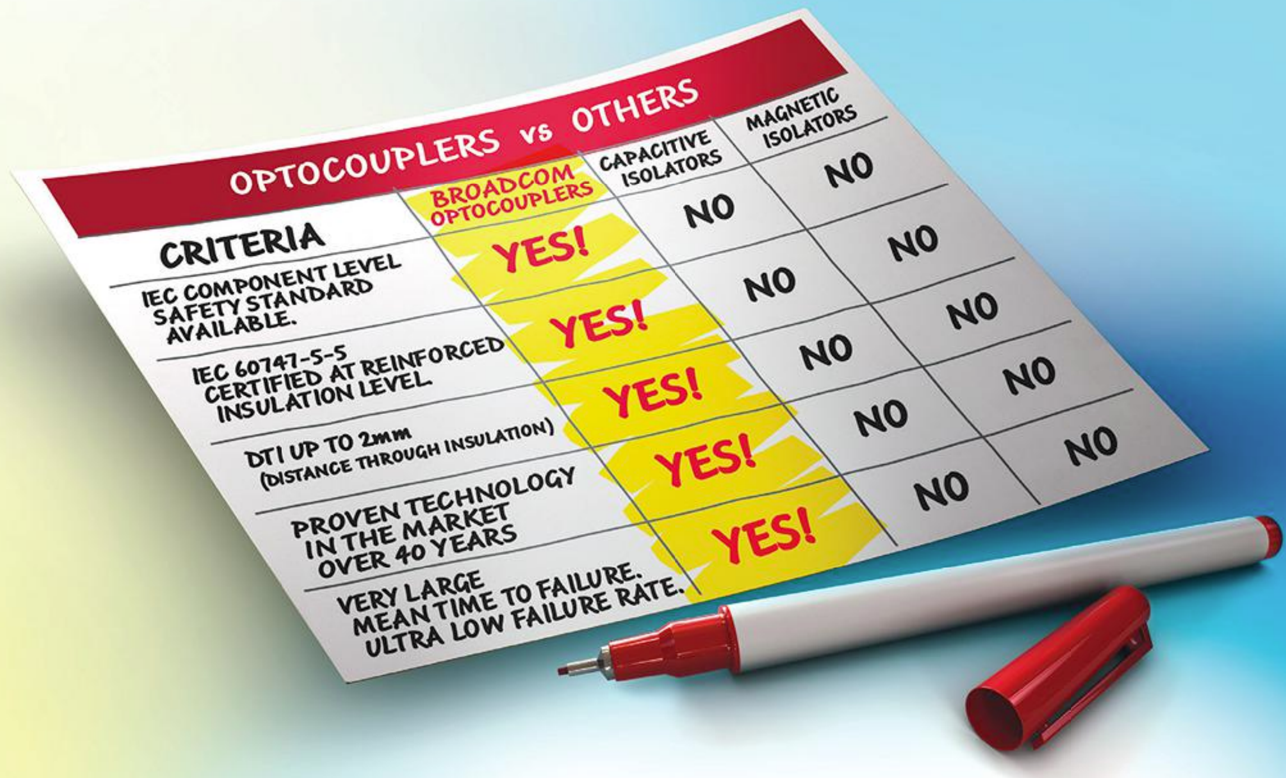


2. An added voltage-difference amplifier extends the voltage range over which the coulomb counting is possible.

$$\text{OUT} = \text{REF} + \text{GAIN} \times [(+\text{IN}) - (-\text{IN})]$$

The LT6375 drives its output pin, but the REF pin must be connected to a low-impedance source. Similarly, the LTC2941 expects a low-impedance source at its SENSE+ pin, which is also the supply pin for that IC. You can connect both REF and SENSE+ to the same logic rail used for the I^2C interface (such as 3.3 V). By connecting the LT6375's OUT pin to the SENSE– pin, the LT6375 will impose the difference between its inputs across the inputs of the LTC2941. In effect, the LT6375 acts as a fake sense resistor.

The accuracy of a difference amp depends to a great extent on the resistor matching. While it's obvious that resistor mismatch directly affects gain accuracy, it's less obvious and a more serious concern that this resistor mismatch will cause offset errors. A 1% resistor mismatch would cause an output offset equal to 1% of the voltage over which the circuit level shifts.



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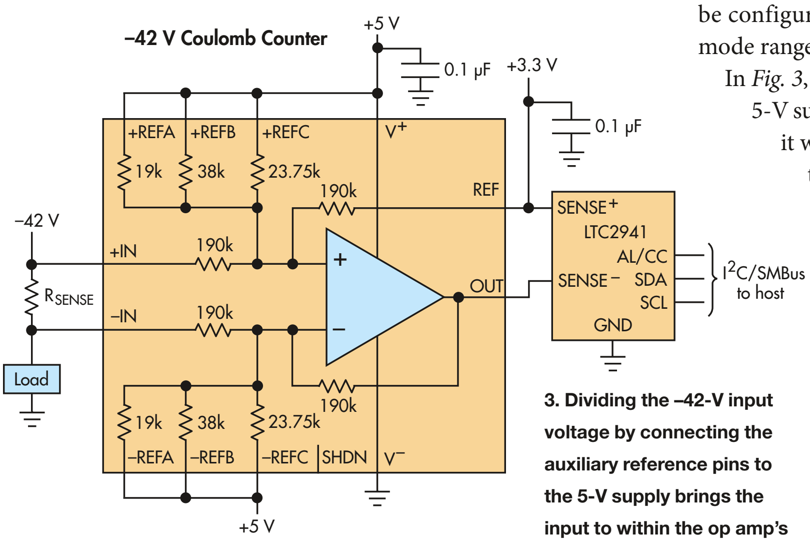
For example, a 48-V input that's level-shifted to 3 V would result in 450 mV of offset error, which is much too large for this kind of measurement. The LT6375A specifies a minimum common-mode rejection ratio (CMRR) of 97 dB, which means that a 45-V level shift causes an offset of less than 640 µV.

When designing a high-voltage level-shift circuit, it's critical to ensure that the op amp's inputs stay within their valid operating range. For the LT6375, the supply pin is rated up to 60 V, so in some cases, it can be powered from the voltage being measured. This is the arrangement of Fig. 2, where the LT6375 measures current from a 48-V supply.

Finally, the IC includes additional precision resistors that can be configured by external pins to divide the input common-mode range, while keeping the differential gain equal to unity. In *Fig. 3*, the auxiliary reference pins are all connected to the 5-V supply, which divides the –42-V input voltage to bring it within the op amp's supply range. For other applications, the op amp within the LT6375 has a unique feature whereby its inputs can operate at voltages higher than the supply pin itself. Combining these features, you can design circuits that can monitor supplies across an input range of ±270 V.



3. Dividing the –42-V input voltage by connecting the auxiliary reference pins to the 5-V supply brings the input to within the op amp's supply range.

KRIS LOKERE is the strategic applications manager for signal-conditioning and mixed-signal products at Linear Technology Corp. He and his team are responsible for amplifiers and high-performance ADCs. Kris has designed multiple op amps and received his MSEE degree from the Katholieke Universiteit Leuven, Belgium.

Simple Circuit Drives, Manages Laser Diode's Output

By ALAN STUMMER | University of Toronto, Canada, astummer@physics.utoronto.ca

THIS CIRCUIT WAS designed to meet a medical application's need to drive a laser diode with reasonable precision and minimized components and footprint (the device is now in clinical trials). The diodes are prone to short- and long-term drifts due to temperature changes and aging. Since they're usually driven from a constant-current (CC) source, their optical output power is monitored and the current adjusted due to varying output power.

The assembly's case was grounded, so the CC source is configured for the high-side drive of the laser diode rather than the simpler low side. Furthermore, the current had to be inherently limited to avoid "tattooing" the patient (not good).

In the single-supply +5-V circuit, current-sense/limiting resistor R1 and P-channel FET Q1 are in a source-follower configuration. As the FET's gate is brought to a less-positive voltage, the drain conducts, which causes a voltage drop across R1 as current flows through the laser. In the worst-case situation when Q1 saturates, the maximum laser current is defined by:

$$I_{laser} = (5V - V_{laser}) / (R1 + R_{ds\text{-}sat})$$

where $R_{ds\text{-}sat}$ = 25 mΩ and V_{laser} = 2.0 V

Values for both $R_{ds\text{-}sat}$ and V_{laser} were taken from the datasheets of Q1 and the laser diode, respectively. R1's value is determined by the maximum laser current required (in this case, 250 mA), adjusted by the laser diode's typical forward voltage of 2.0 V. Solving for R1:

$$R1 = (5V - V_{laser}) / I_{laser} - R_{ds\text{-}sat} = 12\ \Omega$$

where I_{laser} = 250 mA.

$R_{ds\text{-}sat}$ is so low that it can be ignored. With both R1 and the maximum current known, the power in R1 can next be determined by:

$$P = I^2 \times R = 0.25^2 \times 12 = 750\text{ mW}$$

so that a resistor rated for 800 mW will provide a small amount of extra margin for safety.

The ratiometric DAC provides the current setpoint. It takes its reference from the +5-V supply, and the DAC output tracks supply fluctuations. In operation, the DAC output is set to the required set-

point. R2 and R3 scale this relative to the supply's nominal +5-V rail.

For example, if the DAC is set to the midscale of value +2.5 V, the voltage between R2 and R3 will be +3.5 V—the non-inverting input of op amp IC1. In a negative-feedback loop, IC1 adjusts the gate of Q1 so that current flows through R1, Q1, and the laser diode. When the current through R1 drops the feedback voltage to +3.5 V, the circuit is stable. With a voltage drop of 5 V – 3.5 V = 1.5 V across R1, the current must be 125 mA. Similarly, if the DAC is set to minimum (0 V), then IC1's noninverting input voltage is +2 V. IC1 will drive Q1 until the voltage drop across R1 is 3 V, corresponding to 250 mA. This is the saturation point, where Q1 is fully on and +5 V, minus the drop across R1, is the laser diode's forward-voltage drop.

The complete circuit also includes R4 and C1 for loop stability, with rolloff frequency f:

$$f = 1/(2\pi\, R4\, C1) = 159\ \text{kHz}$$

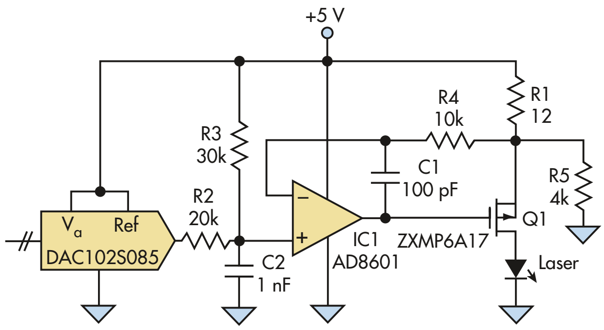
One subtlety of providing a setpoint to an op amp's non-inverting input (as opposed to summing setpoint and feedback) is the output tends to step with setpoint steps, as the op amp becomes a follower. C2 adds a pole to low-pass filter the setpoint; in this example:

$$f = 1/((2\pi\, (R2||R3)\, C2)) = 13.26\ \text{kHz}$$

where R2||R3 is 12 kΩ.

By having this setpoint frequency limit always be much lower than the feedback frequency, the op amp can track the slope of the setpoint steps with minimal overshoot on these steps.

R5 provides an offset by ensuring that a small current always flows through R1. When the DAC is set to full scale of +5 V, the op amp will always have slightly more current than requested. Therefore, it will saturate trying to turn off Q1. Without R5, the input offset voltage V_{os} of the op amp may see a slight false setpoint and turn on Q1 to balance it.



By using a ratiometric DAC configuration, this constant-current laser-diode drive provides stable setpoint performance and accurate low-current settings.

New Products

Inertial Sensors Reduce Weight, Improve Accuracy

THE EKINOX 2 SERIES, a new generation of SBG Systems' advanced and compact inertial navigation systems, incorporates accelerometers and gyroscopes to enhance attitude accuracy by a factor of two while improving resistance to vibrations and integrating the Beidou constellation.

The series of MEMS-based inertial navigation systems reduces weight and improves accuracy due to a complete redesign of the in-house IMU integrating the new gyroscopes and accelerometers. With higher accuracy for the same form factor, the systems are suited for industrial-grade vehicle navigation whether they are aerial, terrestrial, or marine. Providing 0.02 deg. roll and pitch, 0.05 deg. heading, and a centimeter-level position, the series targets demanding applications such as autonomous navigation, hydrography, mobile mapping, and antenna tracking. The addition of the Beidou constellation also improves signal availability in Asia.

An intuitive embedded web interface, where all parameters can be displayed and adjusted, simplifies configuration. For example, a profile (plane, car, etc.) can be chosen and the 3D view will provide a visualization of settings such as sensor position, alignment, lever arms, etc. ITAR-free, the Ekinox 2 Series will be available during the second quarter of 2017.

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Multichannel Probe Monitors Power Use in Mobiles

THE RT-ZVC02/04 multichannel power probe from Rohde & Schwarz can measure across large current and voltage ranges without having to switch ranges, making it possible to monitor the power consumption of chipsets, radio modules and wearables such as smartwatches. When used in combination with an RTE or RTO oscilloscope, the current drain can be clearly correlated with analog and digital control signals.

An 18-bit A/D converter for each current or voltage measurement channel allows measurement of low standby currents in the uA or nA range as well as high current peaks up to the A range within the selected current range without having to switch ranges. A 1 MHz bandwidth and 5 Msample/s sampling rate allow brief current pulses to be captured.

The RT-ZVC02 offers two current and two voltage channels, and the RT-ZVC04 four current and four voltage channels in addition to the analog oscilloscope channels. Up to two RT-ZVC02/04 probes can be connected to an RTE or RTO oscilloscope for up to 16 additional test channels.

The probes are currently available in combination with a CMW communication tester and CMW run software for battery life testing. RT-ZVC power probes will be available as accessories for the RTE and RTO oscilloscopes starting in June 2017.

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Modules in 62 mm Package Increase Power Density

INFINEON TECHNOLOGIES is expanding its offering of 62 mm IGBT modules to raise power density without increasing package size. This is realized by a larger chip area and an adapted DCB substrate in the 62 mm package.

With a blocking voltage of 1,200 V, the 62 mm module reaches a maximum current rating of 600 A. At 1,700 V blocking voltage, the maximum current rating is 500 A. The industrial standard sized package is equipped with a base plate. It can therefore be integrated into existing designs delivering, for example, 20% more output power when applied for drives. The portfolio uses the IGBT4 which offers high robustness and reliability.

INFINEON TECHNOLOGIES

www.infineon.com

3-Phase BLDC Controller Drives High Current Apps

THE AMT49413 is Allegro MicroSystems' new three-phase brushless BLDC motor controller for use with N-channel external power MOSFETs. The device incorporates much of the circuitry required to design a three-phase motor drive system with maximum supply voltages up to 50 V. Targeted at high current BLDC motor applications, the controller has been designed for battery powered power tools, lawn and garden equipment, as well as factory automation, pumps, fans, blowers, and appliance applications.

The charge-pump regulator provides >10 V gate drive for battery voltages down to 7 V. The device also operates with a reduced gate drive at supply voltages down to 5.5 V. A bootstrap capacitor is used to provide the above-battery supply voltage required for N-channel MOSFETs. An internal charge pump for the high-side drive allows for dc (100% duty cycle) operation. Internal fixed-frequency PWM current control circuitry can be used to regulate maximum load current, or to provide speed and torque control, allowing the internal current control circuit to set maximum current limit.

The AMT49413 is supplied in a 7 x 7 mm, 48-pin QFN with exposed thermal pad. It is lead-free, with 100% matte-tin leadframe plating and is priced at 2.700 each/1,000.

ALLEGRO MICROSYSTEMS

www.allegromicro.com

3,000 W AC-DC Power Supplies Achieve Titanium Efficiency

BEL POWER SOLUTIONS is expanding its front-end, ac-dc power supply portfolio to include the TET3000-12-069RA power supply for a range of server and networking applications. The 3,000 W power supply converts standard ac mains power into a main output of 12 Vdc for powering IBA in high-performance and high-reliability servers, routers, and network switches.

The device offers a 180-410 Vdc input voltage range and a 32 W/in3 power density, and it achieves Titanium efficiency (>96% efficient at 50% load) in a 69 x 40.5 x 555 mm package. The ac-dc stage uses soft switching resonant techniques to reduce component stresses in conjunction with synchronous rectification. An active O-Ring device on the output ensures no reverse load current and suits the supply for operation in redundant power systems.

The supply is hot-swappable and can be connected in parallel with active digital current sharing. Other features include: always-on +12 V, 36 W standby output; multiple protections such as overvoltage, overcurrent and overtemperature; and an I2C/PMBus protocol for system communications. The TET3000-12-069RA power supply is safety-agency certified per UL/CSA 60950-1 and meets the requirements of EN 60950-1 and EN 55022-A.

BEL POWER SOLUTIONS

belfuse.com/power-conversion

Implement Touch GUIs on WiFi Display Modules

4D SYSTEMS is introducing its gen4-IoD (Internet of Displays) series of intelligent display modules with resistive touch. With integrated WiFi capabilities, the display modules allow the creation of GUI applications with wireless connectivity. Three sizes are available initially, the 2.4-in. gen4-IoD-24T, 2.8-in. gen4-IoD-28T, and 3.2-in. gen4-IoD-32T. All feature a 240 x 320 pixel display with resistive touch and integrated WiFi.

Powered by an ESP8266 SoC device, the modules handle demanding levels of graphics functionality, and are able to connect and communicate with cloud data and other devices on the web. An on-board SD card socket enables the use of FAT16 or FAT32 formatted cards.

eGaN FETs Shrink Size, Raise Performance

EFFICIENT POWER CONVERSION is introducing the EPC2045 and the EPC2047 eGaN FETs. The 100 V, 7 mΩ EPC2045 cuts the die size in half compared to the prior generation. The 200 V, 10 mΩ EPC2047 also cuts the size in half so that it is now about 15x smaller than equivalently rated silicon MOSFETs.

The chip-scale packaging of eGaN products handle thermal conditions by dissipating heat directly to the environment, whereas the heat from the MOSFET die is held within a plastic package. With the EPC2045, a 30% reduction in power loss with a 2.5% better efficiency than the best comparable MOSFET was achieved in a 48 V to 5 V circuit operating at 500 kHz switching frequency.

Applications for the EPC2045 include single-stage 48 V to load Open Rack servers, point-of-load converters, USB-C, and LiDAR. For the 200 V EPC2047, applications include wireless charging, multi-level ac-dc power supplies, robotics, and solar micro inverters.

Three development boards are available to support in-circuit performance evaluation. The EPC9078 and EPC9080 support the EPC2045, and the EPC9081 supports the EPC2047. Low-volume pricing for the EPC2045 is $2.66 each/1,000, and for the EPC2047, $4.63 each/1,000. The development boards are priced at $118.25 each.

EFFICIENT POWER CONVERSION

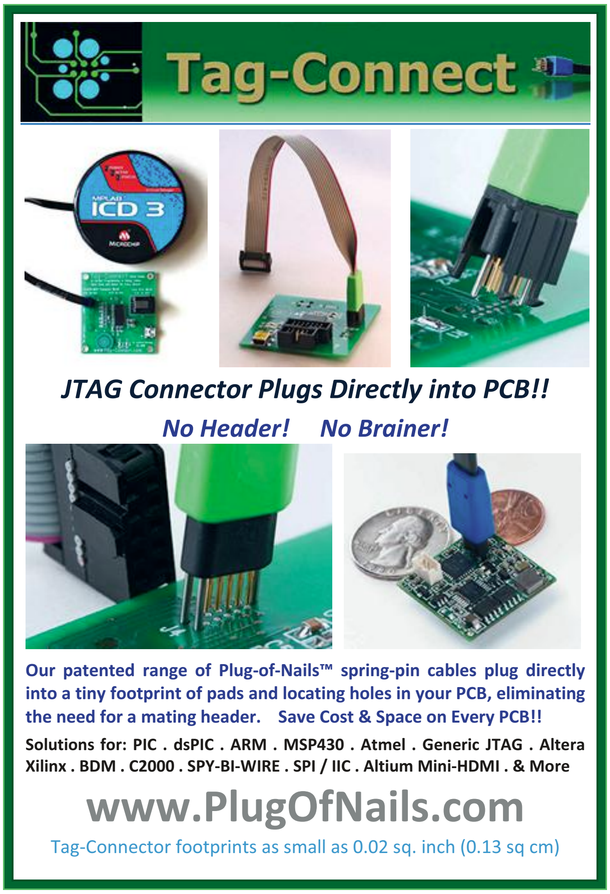
www.epc-co.com

The display modules are aimed at manufacturers and enthusiasts who need a professional solution for any wireless application requiring a GUI to display information from sensors, or to control devices and/or sensors using a touch screen.

The gen4-IoD modules provide the ability to design a GUI using Workshop4 IDE or Arduino IDE software, enabling drag and drop type programming, and eliminating the need to perform traditional coding.

4D SYSTEMS

4dsystems.com.au



Automotive Power

(Continued from page 16)

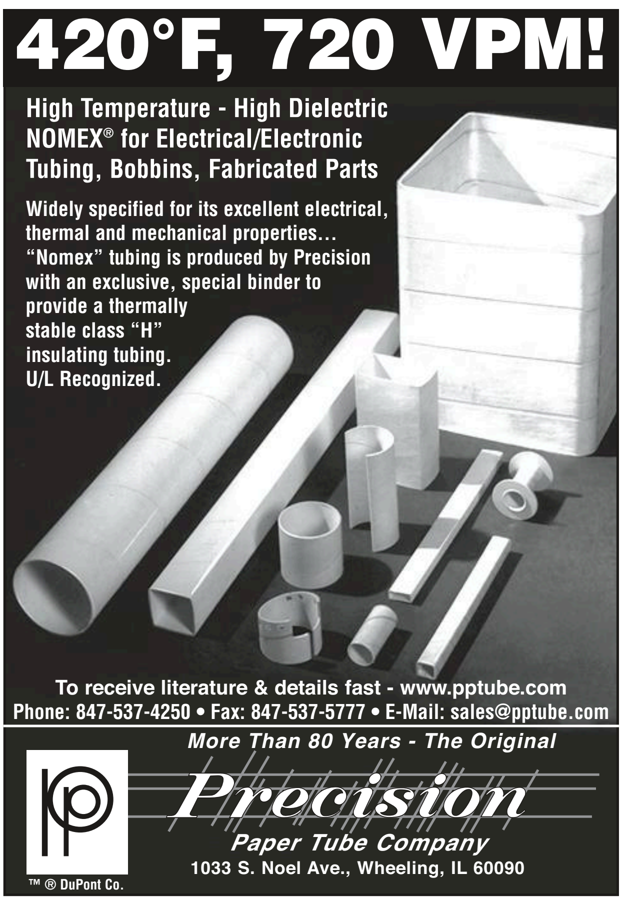
safety that's in accordance with ISO-26262. Four control loops, two for current and two for voltage, enable control of voltage and current on either 48- or 12-V systems.

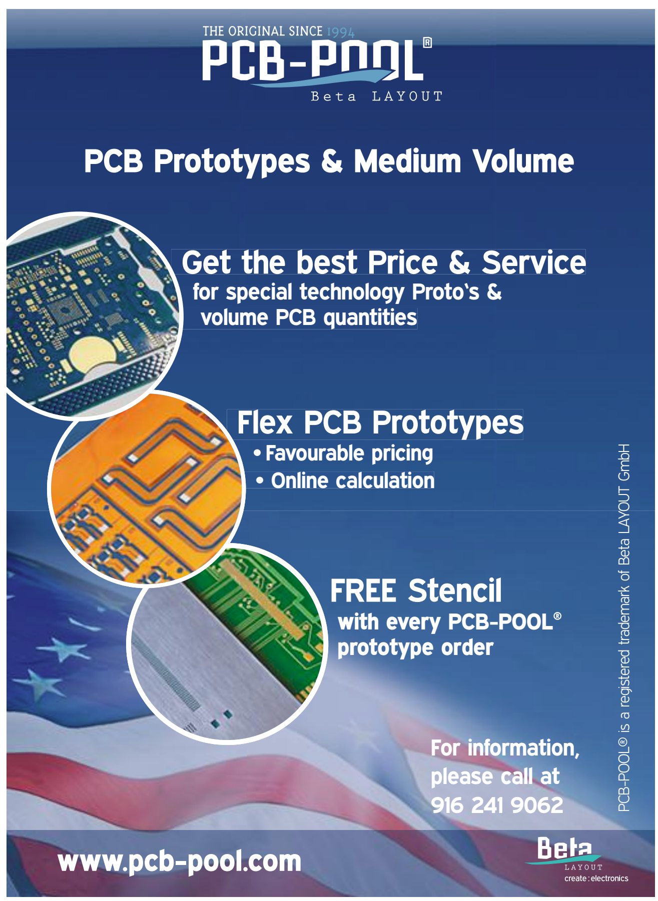
For output loads that demand high current, multiple LTC3871s can be daisy-chained to run out of phase to provide more output current without increasing input and output voltage ripple. Up to 3 kW can be supplied with a maximum of 12 phases when daisy-chained to run simultaneously out of phase with respect to each other. Linear Tech also offers a demo board; the DC2348A-A operates with two LTC3871 devices, each with four phases.

CONCLUSION

Audi, BMW, Daimler, Porsche, and Volkswagen have proposed the LV 148 standard to define a 48-V power supply, but the full adoption of 48-V systems might be accelerated by the creation of an international 48-V standard. Creating such a standard would require a collaborative effort from all members of the automotive industry to define the electrical architecture, including power-supply functions and interfaces.

In the meantime, dual-voltage subsystems offer great potential in reducing CO_2 emissions. They will also generate demand for highly efficient bidirectional converters that are certified to function in automotive applications. ed





Removable Lid Spring Pin Socket for LGA module

Ironwood Electronics introduced a new LGA socket addressing high performance requirements for custom pitch devices - CBT-LGA-5015. The contactor is a stamped spring pin with 14.5 gram actuation force per pin and cycle life of 100,000 insertions. The self inductance of the contactor is 0.98 nH, insertion loss of < 1 dB at 31.7 GHz and capacitance 0.067pF. The current capacity of each contactor is 4 amps. Socket temperature range is -55C to +180C.

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Turn Real-Time Trace Data into Something Useful

Percepio's Traceanalyzer turns tons of system trace dumps into useful analysis for real-time debugging.

Trace tools are one way to track the operation of applications in real time, unlike most debuggers that require an application to be stopped to examine its state. Breakpoints can facilitate the process; they can allow a developer to step through code to isolate where a problem is occurring, so corrective measures can be taken.

Unfortunately, stopping an application isn't always a viable option. Bad things happen when a motor control program stops while the rotor is still turning. Self-driving cars tend to do bad things if the software just stops, even for a fraction of a nanosecond. Network protocols usually time out if one side doesn't respond quickly enough.

The problem with trace tools is that they generate lots of data *(see figure)*. One tool that helps to turn tons of system trace dumps into useful analysis for real-time debugging is Percepio's Traceanalyzer. It uses hooks into operating systems like Linux and RTOSes like FreeRTOS, Keil's new RTX5, and Express Logic's ThreadX, which is used on Renesas' Synergy family of microcontrollers *(see "Dev Kits: Getting Synergy" on electronicdesign.com)*.

For Linux, Percepio took advantage of the LTTng Project's Linux Trace Tool (LTT). LTT instruments Linux to provide details about the operating system and applications, giving developers insight into how tasks are performing and what resources they are using. Traceanalyzer requires similar instrumentation for it to work with other operating systems. This support is often already available as with ThreadX, which is also supported by Express Logic's own TraceX *(see "Visual Debugging Hooks Into Your Applications" on electronicdesign.com)*.

Now, one might think that a simple graphical presentation of trace information with some basic filtering would provide everything a developer would need. The truth is much different, especially when multiple threads, cores, and services come into play. Likewise, the trace information can be used to pinpoint issues from deadlock to race conditions. Sometimes a developer can catch this by looking at more basic presentations, but having the trace tool do more analysis before presenting the data makes much more sense—hence the plethora of options and presentation graphics (more than 25 different views) that Traceanalyzer provides.

Would you rather analyze a text dump (a) or have a trace tool like Traceanalyzer (b) handle the analysis and present more useful insight into an application?

Other challenges with trace tools relate to whether they are post-debugging tools or real-time tools that are working off very recently generated data. For example, LTTng can be configured with a ring-buffer that is filled continuously and streamed to a debug host running the trace analysis tools.

The biggest challenge for developers unfamiliar with trace tools is understanding how they work and refining the techniques to obtain the desired information. This is akin to learning the use of a conventional debugger. Of course, one needs to use these tools to gain their advantages.

On the plus side, trace tools have the advantage of providing analysis mechanisms to identify normal and abnormal operations, making a developer's job easier. In many ways, this is similar to learning how to use of an oscilloscope or logic analyzer. It is easy to get started but it can take a long time to master. Good trace tools are invaluable in this age of networked, multicore system-on-chip (SoC) platforms that link IoT devices and the cloud, as well as deeply embedded real-time applications like motor control. ed