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EDITOR'S LETTER

It's (Not) My Data?

The data economy is here, and Brussels is open for business. First, though, it must clear up a list of contradictions. Open data is a priority; so is data privacy. There is a place for public data and another for proprietary (private?) data. Some data fits into the "low-value datasets" bucket, while other data can be packaged as "high-value datasets." There's enterprise data, of course, which must be governed by the twin paradoxes of "fair use" and "competitive differentiation." Someone must explain how these two can coexist.

Then there is consumer data, which poses a different set of hurdles for those who would harvest them. Citizen consent cannot, must not, be assumed. To use and share collected consumer data, enterprises need a different set of signatures for specific usage. Consent to be contacted does not imply an agreement to receive all mailings. Naturally, the evidence of each consent must be preserved in case someone raises a challenge. It's enough to give corporate compliance officers ulcers.

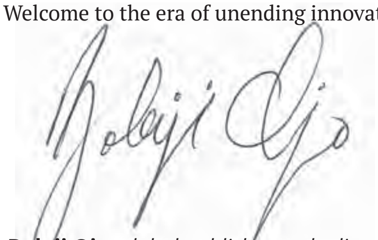
There's a flipside to all this angst, though. Big data is also big business. The collection, analysis, and storage of data are proving very lucrative for tech companies. If you haven't closely followed the trend, these three functions are now full-blown professional disciplines attracting billions of dollars in investment. Graduate study programs in data analytics are proliferating, pulling in degree holders in engineering, mathematics, and physics. Lawyers, too, have found a sweet niche; someone must interpret the cascading laws governing the collection and usage of data.

Thank goodness there is always an engineer working somewhere on finding a solution to problems created by other engineers. Design engineers at electronics enterprises are working to offer hardware and software solutions to the challenges posed by the torrent of data our society is now generating and sorting. Many career opportunities exist in ensuring that the products of these design efforts deliver on the promise of data without overstepping the boundaries set by state regulatory bodies.

As a result, the key innovations that we were told would drive exponential growth in the first half of this century are being pressed into service. Artificial intelligence, the internet of things, and the various forms of wireless connectivity are gearing for the new data-dominated world. Most of the hardware and software products we now discuss in the various issues of EE Times Europe magazine and online — even the ones that address things such as power consumption and environmental protection — converge on the proving ground of data.

This is further evidence that there is no better playground for human ingenuity than the engineering hub. It is home to astounding and positive breakthroughs that — paradoxically — often harbor perplexing problems whose solution requires a further investment of engineering time and resources.

Welcome to the era of unending innovation. ■



— **Bolaji Ojo**, *global publisher and editor-in-chief at AspenCore Media*

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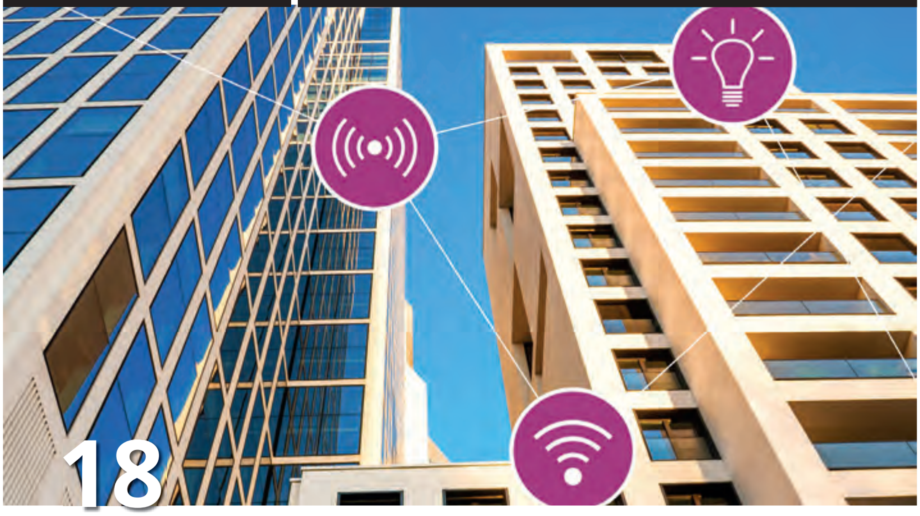

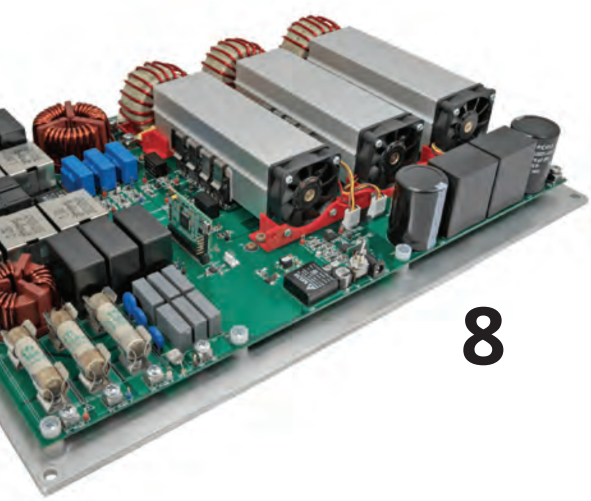

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OPINION | **5G**

European Technological Sovereignty: An Essential and Achievable Goal

By Bertrand Guilbaud, CEO, b<>com

There appears to be consensus at the very top in Brussels that Europe needs to achieve technological sovereignty. A relatively new buzzword in EU circles, "technological sovereignty" means establishing ownership of key technologies in Europe — a major challenge considering the dominance of the U.S. and Chinese tech giants on which most tech depends.

French President Emmanuel Macron recently acknowledged that with two major European telecom equipment vendors, Nokia and Ericsson — both international players — and a technological evolution that puts 5G infrastructure at the core of the French national economy and sovereign services, there are many sovereignty issues at the European level and for each of the EU member states.

In her "agenda for Europe," Commission President Ursula von der Leyen called for Europe to achieve technological sovereignty in critical technology areas. "We must have mastery and ownership of key technologies in Europe," she said. "These include quantum computing, artificial intelligence, blockchain, and critical chip technologies." Importantly, she added, "We will jointly define standards for this new generation of technologies that will become the global norm."

Standardization is critical to the development of projects such as artificial intelligence, immersive video and audio, cybersecurity, 5G networks, cloudification, and data. Thus, technological sovereignty is not possible without serious participation in major global standardization bodies, which dictate future market standards.

Thierry Breton, the new European Commissioner for the internal market, said in his pitch to members of the European Parliament that 5G, blockchain, artificial-intelligence, cybersecurity, cloud, and quantum technologies would enable the EU to be a key industrial player. But he also stressed the need to regulate tech, information, and cyberspace, as well as ensure that single-market rules are properly implemented and that the EU is protected from outside competition.

Brussels will need to set the rules of engagement for tech companies and follow through with a "value focused" action philosophy. This approach, supported by partners like Orange and Nokia, is bearing fruit, with multiple leading European consortia partnerships. The teams are also being enlisted in the fields of augmented reality, content protection, e-health, and software and hardware engineering.

Europe does have some significant technological innovation initiatives and numerous projects, including major ones relating to 5G and beyond. For instance:

- The 5G-EVE project aims to provide 5G pilot sites to industrial sectors in four European countries: Spain, France, Italy, and Greece.
- The H2020 5G-TOURS project is exploring the field of e-health via a use case in the operating room of the future (wireless).

b<>com has been working on 5G since its creation. A test operator since May 2016, its campus has a 5G antenna system, software radio base stations, a software-defined core network, and test frequencies assigned by ARCEP. Its teams have also developed and are evolving a 5G core network solution, ***Wireless Edge Factory***, which has been deployed at multiple sites, including Bristol, U.K.; Aveiro, Portugal; Rennes, France; Lannion, France; and Madrid, Spain.

Technological sovereignty in Europe is possible, but it requires those engaging in groundbreaking research and development to go one important step further and engage with global standardization bodies, which will ultimately dictate future market standards. Europe needs to put its stamp clearly and effectively on the tech it champions if it is to get the recognition and traction it deserves. ■

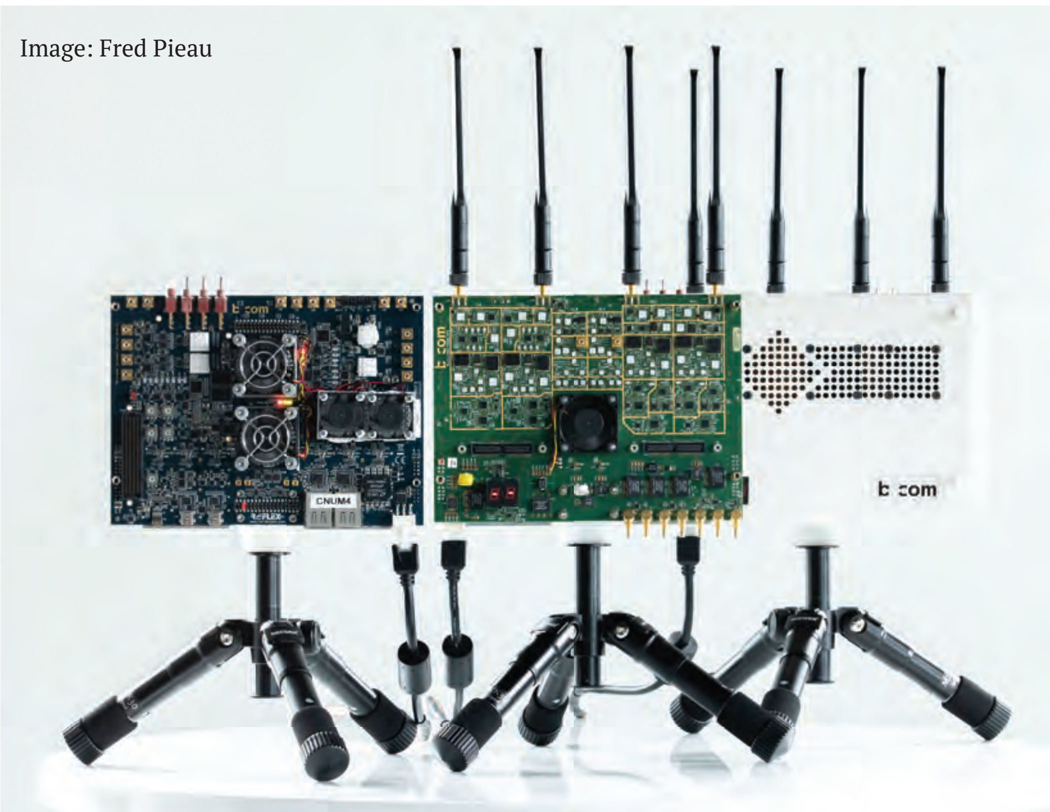

Image: Fred Pieau

Bertrand Guilbaud *has been the chief executive officer of the b<>com Institute of Research and Technology since it was created in November 2012.*

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WIDE-BANDGAP MATERIALS

Silicon Carbide Vendors Tackle Production Challenges for Power Electronics

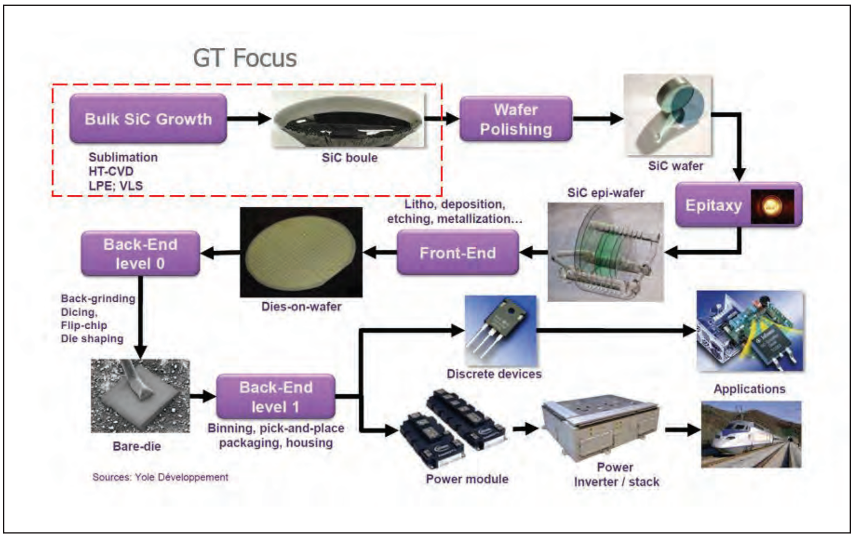
By Maurizio Di Paolo Emilio

Silicon carbide is an exceptionally efficient material with high-power and high-temperature characteristics.

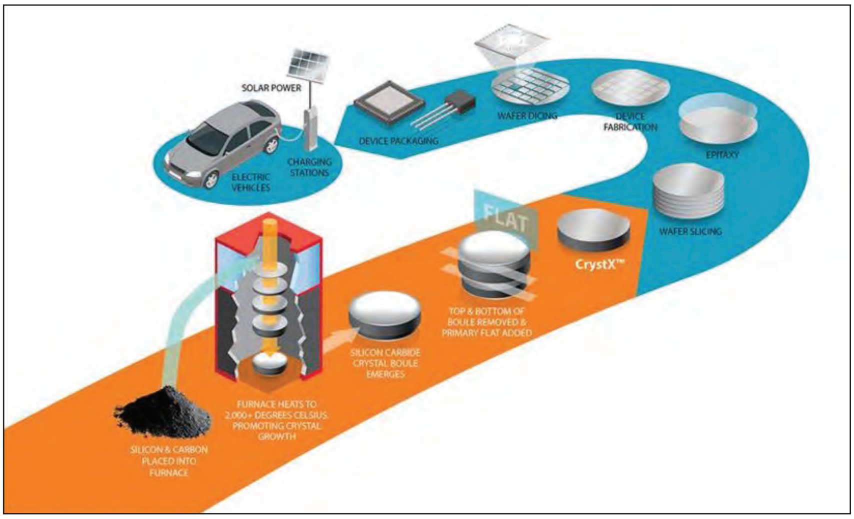
Silicon carbide (SiC) semiconductors are innovative options for improving system efficiency, supporting higher operating temperatures, and reducing costs in power electronics designs. SiC is a compound of silicon and carbon, a semiconductor material with an allotropic variety. Current density can easily reach 5 or even 10 A/mm², and the discharge voltage is generally in the range of 100 V/µm for SiC, compared with 10 V/µm for silicon. The characteristics of silicon carbide make it an ideal material for use in biomedical materials, high-temperature semiconductor devices, synchrotron optical elements, and lightweight, high-strength structures.

Because SiC has high thermal conductivity, it dissipates heat more quickly than other semiconductor materials. SiC devices thus can operate at extremely high power levels and still dissipate the vast amounts of excess heat generated by the devices.

"Growth rates for SiC are significant, and it will be challenging for the SiC suppliers to meet rapid demand growth," said Orlando Esparza, strategic marketing manager for the Discrete and Power Management business unit at Microchip Technology. "SiC power devices are not commoditized, and there are real differences in performance, reliability, and ruggedness. It is unlikely that the lowest-cost devices will satisfy the high-reliability requirements for mission-critical applications given the various design, development, and manufacturing [circumstances] from different vendors. Designers need to ensure they carefully evaluate — on their own bench and systems — device performance, reliability, and degradation in performance under stringent conditions."



Manufacturing process of a silicon carbide component
(Image: GT Advanced Technologies)



From material to finished product (Image: GT Advanced Technologies)

SiC BULK CRYSTAL: A NEW BUSINESS MODEL

The strong market demand and the continuing trend for SiC products have led companies to optimize the SiC production process. Revolutionizing the substrate supply chain could provide a rapid response to the growing demand for high-power solutions.

GT Advanced Technologies supplies crystals to wafer manufacturers to enable them to expand into the substrate production market rapidly. GT's business model allows the company to avoid competing directly with incumbents and new competitors and instead lets it scale more efficiently and quickly, providing high crystal quality and reducing costs.

"Our business model is one where we sell the crystal itself, the bulk crystal, in a form factor where it's ready to be wafered," said Greg Knight, president and CEO at GT Advanced Technologies. "We grow the crystal, grind it to the specified diameter, slice it down to a certain form factor, and that's the product we sell. Our customers take that [crystal], put it into a wire saw, and away they go.

"What you learn very quickly with silicon carbide is there are no simple elements anywhere," said Knight. "It's very difficult to grow the crystal. And once you have the crystal, because it's a very hard, brittle, monocrystal material, nothing comes easy. We focus on the crystal growth, which right now, I think, is the most difficult step in the material value chain. The reason it's difficult is because it's a completely blind process; you can't see or directly measure what you're doing. You have to have very, very robust process control on a blind process."

SiC AND PACKAGING

The high performance offered by SiC has enabled smaller, more thermally efficient packages, although they must be designed with a symmetrical layout to minimize circuit inductance.

Silicon carbide is not available as a natural mineral. SiC doping is a difficult process, and the challenges of producing larger SiC wafers with fewer defects have kept manufacturing and processing costs high. It is therefore essential to offer a good development process from the start.

Gate driver evaluation platform (Image: Littelfuse)

"Silicon carbide is not defect-free; actually, compared with silicon, it's a highly defective material," said Knight. "As a material supplier, it's very much on us to improve that quality and continue to get those defect levels lower."

GT Advanced Technologies has "made massive strides in quality in a very short time," he added. "About a year ago, we started an endeavor to drastically improve the quality of our crystal and have completed that step change to now provide what we think is some of the highest quality in the market. We need to continue to improve the quality of the crystal; that's a continuous effort, one that will never end."

High yields are also critical, said Knight; the higher the yields, the lower the cost. And "innovation doesn't stop at the device; there's a whole host of challenges around packaging and thermal management. Innovation has to continue to occur throughout the ecosystem."

Companies such as Tesla have developed sophisticated battery, motor, and control technologies that enable high-performance electric vehicles (EVs) with an operating range of 300 miles or more on a charge. One way to improve EV efficiency is to use more efficient semiconductor switches in the drivetrain, with an increasing number of electrically powered auxiliary vehicle systems. The motor-control electronics used in the drivetrain are regarded as safety-critical functions, however, so designers must use well-proven technologies.

SiC's low switching losses, high-temperature capability, and high switching frequency make it ideal to meet best hybrid EV/EV (xEV) requirements. "The growth in silicon carbide is going to continue to come from industries like automotive as more and more fleets convert to electric vehicles and you see the growth of MOSFETs over IGBTs. The big user today is Tesla," said Knight.

To demonstrate the continuous operation of SiC power MOSFETs and diodes in a half-bridge configuration, Littelfuse has built a gate driver evaluation platform (GDEV). The platform provides a set of well-defined test conditions and quick-connection functionality to evaluate and compare the performance of different driving board designs with different driver ICs. It also features a full thermal solution that allows for the continuous operation of power devices under high voltage and high current with real power delivery.

SiC technology is finding applications in higher-power projects such as motors, electric drives, and inverters or frequency converters, such as powertrain inverters and on-board chargers (OBCs).

"Some motor applications switch at lower frequencies, not taking full advantage of the fast switching capabilities of silicon carbide," said Esparza at Microchip Technology. "Electric-vehicle motor drive applications are targeting silicon carbide to benefit from higher power density, higher junction temperature, and smaller overall design."

Microchip's MSCSICPFC/REF5 is a three-phase Vienna power factor correction (PFC) reference design for hybrid EV/EV chargers and high-power switch-mode power supplies. The reference design achieves 98.5% efficiency at 20-kW output power and is capable of operation to 30 kW.

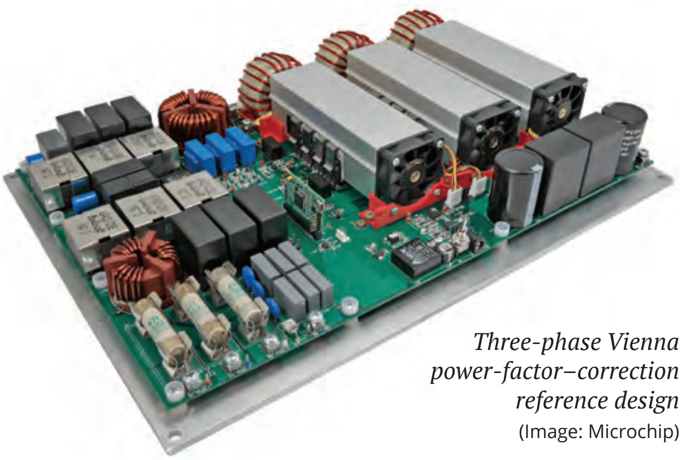
"Industries need to evolve their thinking from silicon-based designs to silicon carbide technology," said Esparza. "A system-level approach and evaluation looking at the entire topology, system, and bill of materials needs to be done to justify the move to silicon carbide. All industries can benefit from SiC, and we are seeing interest and applications across various industries: medical, industrial, automotive, computing, aviation, defense, space, and more."

OTHER WIDE-BANDGAP MATERIALS

SiC isn't the only wide-bandgap material that's seen as a replacement for silicon in certain applications. Gallium nitride (GaN) components also are changing the world of power electronics, starting with power supplies at about 100 W. GaN technology is also making inroads into RF amplifiers, thanks to the same features that make them suitable for conversion and power systems.

The only wide-bandgap group IV semiconductor materials, however, are SiC and diamond.

"Diamond is obviously a wide-bandgap material with some amazing properties," said Knight. "The ability to grow large single-crystal diamond is not there yet. It's done in very, very, small crystals at very, very low yields. But if I think of a material that would eventually replace SiC, maybe that would be diamond. It's a whole new level of technical challenges."



Three-phase Vienna power-factor–correction reference design (Image: Microchip)

We are experiencing a revolution in how society uses electrical power. Wide-bandgap materials are able to improve efficiency in power-conversion applications compared with legacy materials such as silicon. SiC, together with its group III–V counterpart, GaN, offers advantages in terms of energy that have made it the focus of attention for power electronics development. ■

Maurizio Di Paolo Emilio *is a staff correspondent at AspenCore, editor of Power Electronics News, and editor-in-chief of EEWeb.*

AUTOMOTIVE PLATFORMS

OEMs See No Easy ADAS-to-AV Path

By Junko Yoshida

PARIS — Daimler chief executive Ola Källenius revealed late last year that the automaker would scale back its investment in robotaxis. Although the comment did not come as a shock to the automotive industry, Daimler's decision exposed a hard and important reality: The development track for assisted driving is different from the development track for autonomous driving, and automotive OEMs are going to have to pick a lane.

The design principles for assisted driving and autonomous driving are still worlds apart. That poses a dilemma for chip suppliers pitching their solutions as universally applicable.

Vehicle manufacturers are under tremendous pressure to develop advanced driver-assistance systems (ADAS) and to create autonomous vehicles (AVs). The assumption that the former would lead to the latter has persisted even as evidence has accumulated that, though ADAS and AVs have parallels, the two are not directly related.

"ADAS and autonomous have been, of necessity, on very different development paths, typically with different teams," noted Ian Riches, executive director for the Global Automotive Practice at Strategy Analytics.

And it is becoming apparent that most carmakers cannot afford to keep those parallel projects alive at the same time.

The sorts of sensor suites, processing power, and vehicle architectures required for autonomy are still way too expensive for mass-market ADAS features, said Riches. "There is no easy way to scale down an L4 [SAE Level 4 autonomy]-architected system to meet the cost points needed for standard-equipment, NCAP [European New Car Assessment Program]-required features at present.

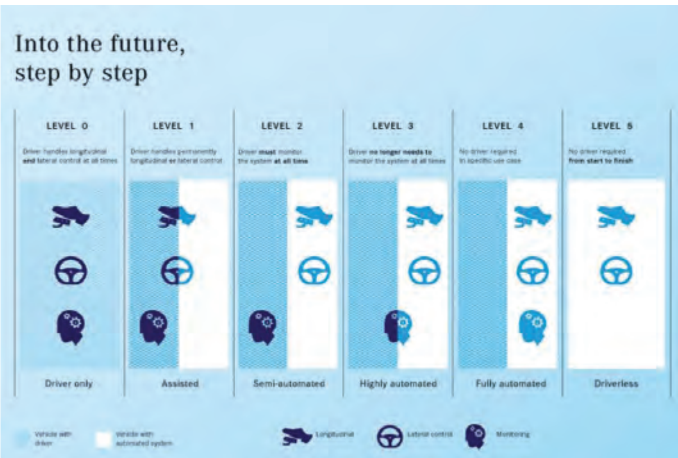
"The reverse is also true," he added. "The typically standalone, discrete architectures, modest processing power, and limited sensor suites required by ADAS do not easily scale up to an L4 solution."

Does this mean that auto companies shouldn't plan to upgrade their current ADAS models to L3, L4, and L5 AVs?

"I'm not sure anyone has truly been thinking that ADAS can evolve into autonomous," said Riches. "There have typically been completely separate development teams" for the two platforms, at least thus far.

In the current ADAS/AV development environment, leading automotive chip suppliers such as Intel/Mobileye and NXP Semiconductors have been pitching a variety of chips designed to proliferate ADAS features. Many of those same semiconductor companies are promoting separate silicon solutions with beefed-up processing power to target AVs.

For example, Xilinx recently expanded its family of automotive-qualified 16-nm devices with the Zynq Ultrascale+ MPSoC Zu7, for L2 and L2+, and Zynq Ultrascale+ MPSoC Zu11, a single-chip domain controller designed for L2+ and above. The FPGA company is positioning both programmable chips to address everything from ADAS to in-cabin monitoring and automated driving, all of which are evolving rapidly.



Though Daimler has charted a "step by step," gradual transition from ADAS to AV, there is no linear path for product development. (Image: Daimler)

INCREMENTAL ADVANCES?

The question, then, becomes whether ADAS development will ever intersect with AV innovation and, if so, where and when.

Phil Magney, an automotive electronics consultant and the founder and principal of VSI Labs, told EE Times Europe that he doesn't believe that ADAS and robotaxis are mutually exclusive. "Incremental automation is what Tesla is doing," he said. "You build up the fundamentals and collect as much data as you can. Eventually, you will have gained enough know-how to apply it to robotaxis."

Magney was referring to Tesla's third-generation "full self-driving car computer," equipped with two artificial-intelligence (AI) processors that the automaker designed in-house.

Riches said he's hopeful that "the crossover point where a combined development team and approach may make sense is perhaps coming into sight" and posited that "the growing interest in so-called L2+ features could be the point [at which] these two worlds start to come together. This [L2+] could emerge as an L4-style architected vehicle, with centralized control but without the redundancy across sensors, processing, and actuation to make it fully robust for L4 operation."

But it's still just a theory.

"The optimist in me sees L2+ as a way of bringing the maximum safety benefits to the widest audience as soon as possible," said Riches. "The cynic in me sees it as a way of potentially finding some sort of ROI on 'failed' L4 development programs."

THE DESIGN PRINCIPLE DIVIDE

In the meantime, the ADAS-versus-AV debates persist. Safety experts and people with real-world experience running autonomous vehicles in cities claim that the fundamental principles of designing a car for a human driver and designing a car for an automated driver are worlds apart.

"As the famous saying goes, 'Electric light did not come from the continuous improvement of candles,'" said Carlos Holguin, an urban mobility expert and a co-founder of AutoKAB. "Better ADAS would not make a fully autonomous vehicle."

That poses a dilemma for chip suppliers with a vested interest in portraying their solutions as universally applicable from Level 2 ADAS to Level 4 highly automated vehicles. It could be particularly problematic for the suppliers designing more generic, highly programmable solutions such as GPUs, FPGAs, and graph streaming processors (GSPs). Nvidia, Xilinx, and even some startups — notably Blaize — fall into that category.

Willard Tu, senior director of Xilinx's Automotive Business Unit, noted that as ADAS and AV developers keep adding sensors such as

OEMs See No Easy ADAS-to-AV Path

4D radar and LiDAR, the race among automotive chip suppliers boils down to one issue: "How do you stay ahead of the innovation game?"

Blaize co-founder and CEO Dinakar Munagala said that the company's clients "keep coming back to tell us, 'I wish your chip could do XYZ.'" Munagala believes that's where his GSP could shine. The GSP will be applied to intelligent telematics, ADAS, driver monitoring, and occupant assessment. Blaize's single-GSP architecture for many automotive applications is getting the company's foot in the door at OEMs and Tier 1 suppliers, said Munagala.

As intelligent features rapidly evolve, the automotive industry wants a platform that extends from ADAS to AVs. Xilinx's Tu noted that although the industry has not converged on a common approach for an ADAS-to-AV transition, automakers are looking for thermally efficient programmable solutions that can accommodate the continuous innovation demanded by Euro NCAP, fast-changing AI algorithms, and flexibility in the data pipeline to reduce AI latency.

AV Prototype: Mercedes-Benz F 015 Luxury in Motion (Image: Daimler)

CONFUSION AMONG AUTOMAKERS

The L2+ pitch by technology suppliers rose in volume in early 2019. Rather than promote L4 as an endgame, both automakers and chip suppliers have become increasingly vocal on the need for L2+.

But Riches offered a reality check. "What I think is undoubtedly true is that the consumer has yet to be truly consulted and has very little conception of how L2+ could be of benefit," he said. "Automakers need to ensure that they are not implementing technology for technology's sake but are indeed offering true user benefits at an affordable price."

In other words, regardless of whether a vehicle is L2+ or L4, it is quite possible that car OEMs — including Daimler — still aren't sure what consumers want.

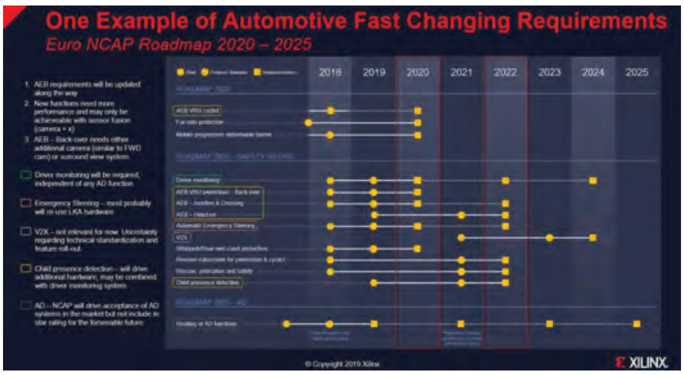
Automotive OEMs can't dismiss L4/L5 right off the bat. They have been developing AVs out of the fear they could be replaced by tech companies such as Waymo or Uber. At the same time, despite little evidence of a market need, OEMs have latched onto the idea of L2+ to justify their investment in L4/L5 development.

"I believe Daimler/Mercedes was never as committed to L4/L5 AVs as other OEMs," said Magney. "Daimler would produce 'concept AVs' for major shows that were never capable of self-driving other than some remote-control maneuvers, but they always lagged in developing self-driving solutions.

"I feel as though the Germans are not willing to throw in the towel on human driving, something they take national pride in."

BOTTOM LINE

Daimler's recent decision is best explained by the bottom-line realities of today's automotive business.



Automotive chip suppliers are chasing multiple moving targets, as this Euro NCAP Roadmap analysis shows. (Image: Xilinx)

"The global downturn in the automotive market is causing financial realities to hit home," said Riches. "Electrification/CO_2 reduction has to be carried out; there are strict targets to be met."

In contrast, "there is still no guaranteed ROI for a robotaxi," he said. "Uber has yet to make the business model work with a driver, and simply removing the driver doesn't magically fix everything. The capital investment required for a significant robotaxi fleet will also be huge. It's no surprise to me that some ambitions are being scaled back."

Magney expressed a like sentiment when he said of Daimler's decision, "I don't really know what to make of this other than to appease the shareholders and the conservative board members."

Note, however, that Daimler and Bosch have picked San Jose, California, as the pilot city for trials of a highly and fully automated driving (SAE Level 4/5) on-demand ride-hailing service, using automated Mercedes-Benz S-Class vehicles. The service was scheduled to begin in the second half of 2019, but that plan has been rolled back.

"It is kind of odd, as the Daimler CEO's words are a contradiction to their 'self-driving' pilot program in San Jose with their partner Bosch," said Magney.

He added, "Daimler also entered a partnership with BMW to develop self-driving technology. Only [a few] months ago, Daimler and BMW signed an agreement for a long-term strategic cooperation, which will focus on joint development of technologies for driver-assistance systems and automated driving."

However, Magney noted, "I am not really surprised by this news. And I would not be surprised to see other OEMs doing something similar. The bean counters are not fond of spending billions on something where the economics are not clear."

DAIMLER AND ADAS

Magney called Mercedes "a pioneer in ADAS" and predicted it will continue to enhance its ADAS feature set incrementally. Early last year, he noted, "Mercedes said they would offer low-speed Level 3 'traffic jam assist' in 2020."

And let's not knock the ADAS approach. "It's not necessarily a bad thing," Magney said. "Sales of series-production cars over the next 20 years are not going to look much different than they do now. L2/L3 is the new ADAS, in my opinion."

Finally, Magney noted, "Who says you need to own the AV stack?"

There are numerous full-stack providers from which to source, he said. "At the end of the day, Mercedes-Benz will focus on building better cars, as they have done for 100 years.

"Fifty years from now, when human-driven cars are replaced by robotaxis, Mercedes-Benz remains a premium coachbuilder — and there is nothing wrong with that." ■

Junko Yoshida *is global co-editor-in-chief of AspenCore Media and chief international correspondent at EE Times Europe.*

MOTOR CONTROL DESIGN

Designer's Guide to High-Performance Motor Control for Robotics

By Maurizio Di Paolo Emilio

An optimal motor design entails careful selection of the motor type, driver, and electrical isolation solution.

A robotic manipulator is programmable on three or more axes that specify the movements of robotic arms or bodies. These manipulators are automatically controlled and reprogrammable without physical modification, and they are adaptable to different applications of the control system.

Such adaptability suits the increasing use of robotics in industrial environments, where highly complex and integrated robots perform many previously manual operations in a more precise and faster way than humans could achieve.

A robotic system primarily consists of four subsystems: mechanical, actuator, measurement, and control. One key challenge is that the requirements for low speed and high torque for motion control of the joints don't effectively leverage the mechanical characteristics of servomotors, which, contrarily, produce high speed and low torque under optimum operating conditions.

Therefore, the function of a drive unit is to ensure that the speed and torque of the motors and the loads are compatible and enable the transfer of mechanical torque from one to the other. The transmission components also make it possible to improve static and dynamic performance by lightening the mechanical structure through the positioning of the motors at the base of the robot.

Joint movement is entrusted to motors that allow the desired motion of the mechanical structure. Among the three key types — permanent magnet, direct current (brushed), and electronic commutation (brushless) electric motors — the one that best optimizes the requirements for low inertia and high positioning accuracy is the brushless DC motor, or BLDC (**Figure 1**).

Brushed motors use mechanical switching schemes in which rotating armatures with brushes are used to make electrical connections. BLDCs, in contrast, do not use mechanical switching. The resultant reduction of moving parts gives the brushless motors a long life, limited only by the wear of the ball bearings. In addition, the windings improve heat dissipation and overload capacity, offering high efficiency compared with other DC solutions. Because they have no brushes, BLDCs also exhibit excellent durability and low noise characteristics.

There are two main types of structures: surface permanent magnet (SPM) and internal permanent magnet (IPM). SPM motors have the magnets attached to the exterior of the rotor surface. IPM motors, instead, have the permanent magnet embedded into the rotor itself.

DC MOTORS AND DRIVERS

BLDCs offer high efficiency, but above all, excellent torque and speed values that are used in many applications. They use a stationary magnet with a rotating armature that combines various parts to provide electronic switching.

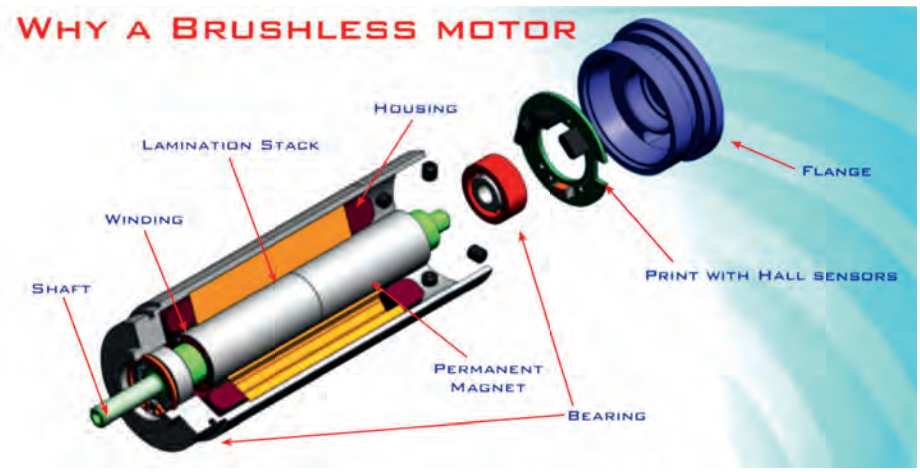


Figure 1: *A brushless DC motor diagram* (Image: Portescap)

Figure 2: *Portescap's Ultra EC motor* (Image: Portescap)

The design of a BLDC aims to optimize the torque, which represents the amount of rotational force of a motor and is related to the magnet and coil winding. The greater the number of pole pairs in the magnet, the greater the motor torque.

One example is Portescap's Ultra EC platform, consisting of three families: the ECS, ECT, and ECP. These brushless mini motor families, depending on torque and speed requirements, can be used in a range of applications. The patented U coil offers minimal iron losses and thus delivers good efficiency and cooler operation (**Figure 2**).

Maxon Motor AG's EC-i brushless motors are available in small diameters that are suitable for robotic applications. They offer a 30-mm diameter and are characterized by high-dynamic and high-torque features.

The EC-i family is available in several sizes, each in a standard version and a high-torque version, with a maximum nominal torque of up to 110 mNm at 75 W. In all versions, the EC-i 30 motors can be expanded with encoders, gearboxes, servo controllers, or positioning controllers (**Figure 3**).

STMicroelectronics, together with Maxon, has developed a new kit to accelerate the design of robotic and industrial applications. The EVALKIT-ROBOT-1 kit offers precise positioning in robotic applications.

The kit contains ST's STSPIN32F0A intelligent three-phase controller and a complete inverter stage, built with ST power transistors ready for connection to the motor. The STSPIN32F0A contains critical motor control circuits, including an STM32F031C6 microcontroller and a three-phase inverter driver in a compact 7 × 7-mm VFQFPN package (**Figure 4**).

Figure 3:
Maxon Motor's EC-i motor
(Image: Maxon Motor)

Motor control firmware allows designers to start the engine and start sending commands to easily optimize their project. The kit includes a 100-W Maxon BLDC motor (EC-i 40) with a built-in 1,024-pulse incremental encoder. Also included are Hall sensors for rotor-position detection.

A BLDC motor is quite efficient, but the pressure to meet increasingly stringent demands requires companies to improve not only the construction of the motor but also the driver. In particular, they are working to reduce overall energy consumption and optimize thermal management.

In many cases, these designs incorporate integrated drivers that minimize the number of external components required and system-on-chip solutions that allow for a high level of integration. Benefits include space and energy savings, improved overall system reliability, and reduced costs.

Because the BLDC does not have a structure to switch the direction of the current mechanically, this must be done electronically. The waveforms can be divided into two main types: trapezoidal and sinusoidal. Due to the temperature limitations and costs, there are cases when the position of the rotor (magnet) is estimated from the three-phase current or induced voltage without using the sensors.

Drivers must ensure correct motor control so that they can control speed and direction accordingly in the application. Modern microcontrollers (MCUs) are perfect for providing the level of performance and computational functionality needed to develop high-efficiency control loops for DC (and AC) electric motors.

Many MCUs support signal-processing functions that allow complex algorithms to be processed in real time using positioning data. This is important because more and more applications are trying to eliminate sensors that provide positioning data. There are many MCUs that have peripherals specifically designed for motor control applications.

For example, Renesas Electronics' RL78/G14 microcontrollers balance the current consumption level with low levels of current drain (66 µW/MHz when the CPU is in operation and 240 nA in standby, or STOP, mode), offering high calculation performance of 51.2 DMIPS (32 MHz). The integrated safety functions support the safety standard, IEC/UL 60730, for household appliances.

In BLDC motors, the drive also becomes more complex. The speed and torque are controlled by the on/off duration ratio of the transients; normally, this takes the form of a PWM signal used to drive the windings. This condition is further complicated by the use of single-phase, two-phase, and three-phase motors. Today, many integrated devices are used as a drive stage. Typically, they include gate drivers to drive external power MOSFETs that are used to excite up to three phases of a motor.

The motor requires a high amount of current while the controller circuit operates on low-current signals. So the function of the motor drivers is to take a low-current control signal and then transform it into a higher-current signal that can drive a motor.

Infineon Technologies AG offers a variety of integrated products for controlling variable-speed drives. The iMOTION ICs integrate all the control and analog interface functions required for sensorless field-oriented control (FOC). In addition, they feature the company's proven motor control engine (MCE) algorithm, which eliminates software coding from the control protocol development process.

Other space savers are the smart gate drivers from Texas Instruments (TI). These drivers integrate passive components to reduce board size, component count, complexity, and design costs. They also enable designers to optimize switching and electromagnetic interference (EMI) performance.

In its extensive driver portfolio, TI offers the DRV8313 with three individually controllable half-H-bridge drivers. The device is designed to drive a three-phase brushless DC motor, although it can also be used to drive solenoids or other loads. An integrated comparator allows the construction of current-limiting circuits or other functions.

Another example is the TC78B025FTG brushless three-phase motor driver IC with a closed-loop speed control function from Toshiba Electronic Devices & Storage Corp. The device operates with a power supply in the voltage range of 4.5 V to 16 V and provides a sine drive with 150° switching. The low ON resistance of 0.2 Ω (typ.) reduces the IC's self-heating during operation, thus extending the support to high driving currents.

ELECTRICAL ISOLATION

In general, designers of electric motors know that they must comply with international insulation standards to prevent interference from an external source and to ensure the electrical safety of users. The use of digital isolation offers several benefits, including faster response, which allows for the integration of overcurrent protection and reduced downtime. This provides a more progressive variation in output voltages, thereby improving torque control.

Because photocouplers are based on opto-electronic technology, they are an extremely robust method of ensuring electrical isolation without any physical contact. This offers many advantages over the traditional approach based on the use of electromechanical components such as relays. Key benefits include wear-free operation, relatively low cost of complementary components, minimal board space, EMI immunity, high reliability, and long operating life.

In motor drive applications, two main parts of the circuit require isolation: the gate drive for the insulated gate bipolar transistor, or

Figure 4:
The ST EVALKIT-ROBOT-1 development kit
(Image: STMicroelectronics)

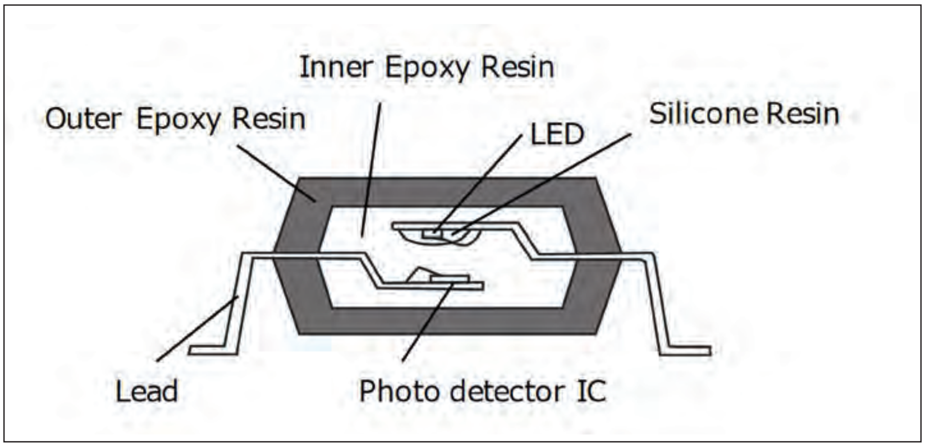


Figure 5: *Cross-section view of Renesas Electronics' RV1S92xxA and RV1S22xxA*
(Image: Renesas)

IGBT (devices with a collector and emitter on one side and driven by a gate on the other), in bridge inverters and the current-phase detection in the motor. Phase-current sensing provides protection to the IGBT and feedback to the controller to maintain control over the closed-loop current.

Here are a few examples of photocouplers that can be used in robotic applications:

The RV1S92xxA and RV1S22xxA photocouplers, with a package length of 2.5 mm, from Renesas Electronics allow the PCB area to be reduced by 35% compared with similar devices, helping designers reduce the size of their robotic systems. Thanks to their reinforced insulation, the RV1S92xxA and RV1S22xxA allow 200-V and 400-V systems to exceed safety standards. All devices comply with the stringent UL61800-5-1 motor control standards and UL61010-2-201, which applies to control systems such as PLCs (**Figure 5**).

Toshiba's TLP5214 is a highly integrated 4-A output current IGBT gate drive photocoupler housed in an SO16L package. The TLP5214 has advanced built-in features such as IGBT desaturation detection, isolated fault status feedback, soft IGBT shutdown, active Miller blocking, and undervoltage lockout (UVLO). It is suitable for driving IGBTs and power MOSFETs used in inverter applications.

CONCLUSION

Whether the motor is used in industrial or non-industrial operating environments, the design of high-end motion controls with accurate positioning capabilities is complex and requires extremely reliable drive solutions and optimal mechanical construction.

In more recent years, electric motors have also been linked to emerging robotic applications such as drones and Agriculture 4.0, which have seen accelerated advancements thanks to new manufacturing systems such as rapid prototyping, dedicated operating systems, and integrated control systems. ■

Maurizio Di Paolo Emilio *is a staff correspondent at AspenCore, editor of Power Electronics News, and editor-in-chief of EEWeb.*

SENSORS

Why Industry Should Implement Sensor Fusion

By Joe Hoffman

Sensor fusion is a hot topic, coinciding with growth trends for the internet of things and especially connected with autonomous vehicles and advanced driver-assistance systems (ADAS). The concept itself is not new; a search on Google Scholar identifies concepts that date back to the 1960s and earlier. But today, there is a growing body of knowledge around which sensor inputs a system should fuse and how to apply the resulting insight. How much is enough depends on the application and the cost/risk benefits.

How much sensor fusion is enough depends on the application and the cost/risk benefits. (Image: SAR Insight and Consulting)

Sensor fusion is more important than ever, as the persistence of individual malefactors and state intelligence agencies poses growing threats to autonomous systems everywhere. While much of the political world frets about potential information security risks in 5G networks, a greater risk arises from malware attacks that can disrupt and extort autonomous-system owners. System architects should not underestimate these risks and must avoid the mistakes of automobile and aviation manufacturers. Ford Motor estimated the worth of a human life at US$200,000 — less expensive than fixing the fuel design of the Pinto sedan (1971–1980). However, personal-injury lawyers and trial juries thought otherwise. The current tale of woe belongs to Boeing, which made critical sensor fusion and redundancy for its 737 MAX jet available for an extra fee. As a result, Boeing and its supply chain suffers through the current agony, the end of which may take years to play out.

Finally, the economic and health benefits from systems that advance sensor fusion for human activity and industrial applications are apparent now.

FAULT TOLERANCE AND RESILIENCE

All sensors and models have a tolerance error, and using multiple sensors that measure the same quantity can increase reliability and provide resilience to failure that could otherwise prove disastrous. Redundancy adds cost and complexity, but as the Boeing and Ford examples show, a short-sighted decision leading to a single point of failure can be catastrophic.

ATTACK RESISTANCE

Hackers with malware will find ways to attack sensor-based systems, but the appropriate data fusion and security protocols, including artificial intelligence, can ensure robust operation in the face of such attacks. One means of attack injects false signals to the input sensors; these signals are not mitigated with ordinary digital security because they occur in the analog domain. These attack surfaces can include:

- signal spoofing (LiDAR and cameras);
- signal cancellation and interference (ABS magnetic sensors, vandalized traffic signs); and
- side leakage (implanted malware that uses sensors to harvest sensitive information).

HUMAN ACTIVITY MULTI-SENSOR

Interpreting and monitoring human activity with multiple sensor fusions will achieve better health outcomes and lower costs as populations age. Applications of wearable- and ambient-sensor fusion for human activity include eldercare and assisted living, fall detection and postural recognition, security and surveillance, athlete and first-responder status, and localization and navigation assistance for the impaired.

DATA FUSION IN THE NETWORK

Data fusion and analytics historically happened on a computer or in a data center (the cloud). The miniaturization and cost reduction of sensing technology enable sensor fusion (and artificial intelligence/machine learning) at the edge-device level. In the future, hybrid network architectures will perform sensor data fusion and analytics at three layers:

- Low-level data fusion will take place on smart devices or the gateways that aggregate multiple sensor inputs.
- Middle-level data fusion will support more intensive analytics and data fusion with a wider range of devices and is associated with a hub gateway and edge computing.
- High-level data fusion will reside in a data center or the cloud to provide the highest perspective of the managed system of edge devices.

LOWER OPERATING COSTS

Sensor fusion will cut operating costs by extending the range and application of devices such as unmanned aerial vehicles (UAVs) and robotics with autonomous features. Savings will also result in cases in which sensor fusion will let remote operators do more, or from low-cost labor centers. Applications include automatic collision avoidance for inspection drones and remote driver intervention for mostly autonomous transportation systems.

TRENDS

Expect continued miniaturization and cost reduction in sensors, computing, and connectivity as consumerization takes root in the industrial and IoT ecosystem. CES 2020 demonstrations included MEMS sensor innovation, such as the miniaturization of LiDAR mirrors that benefit automotive and intelligent transportation systems.

The go-to method for sensor fusion is a class of computer algorithm known as a Kalman filter, which models the previous and current states of a system with continuous measurement and prediction. False signal injection into highly complex systems through the sensor inputs will lead system architects to implement machine learning and neural networks for security and data fusion.

Sensor fusion increases system integrity, reliability, and robustness for normal operation and provides additional benefits against sensor network attacks originating from the analog domain. By carefully implementing sensor fusion into their systems, designers and architects can mitigate the risk from malfunction or malevolent action that can cause injury to people, property, or economic prosperity. ■

Joe Hoffman *is director of wireless connectivity and machine sensing at SAR Insight & Consulting, where he focuses on the emerging strategies and shifting value chains of the machine economy. He holds a B.S.E.E. from the University of Kentucky, an M.S.S.E. from Virginia Tech, and an M.B.A. from Arizona State University. His career includes posts at IBM, Lockheed-Martin, Motorola, and Nokia.*

COVER STORY

Smart Buildings: Making Buildings Smarter, Greener, and More Energy-Efficient

By Manuel Hollfelder and Julia Fichte, Emerging Applications Managers, Infineon Technologies AG

In the future, more and more people will live in cities. The United Nations predicts that by 2022, 56% percent of the world's population will be urban dwellers; by 2050, the total is set to rise to 68%. This means that existing resources have to be used more efficiently, and overall energy consumption and carbon dioxide emissions have to be reduced.

Buildings can play a decisive role in solving this challenge. In the European Union alone, buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions. At the same time, 75% of the existing building stock in the EU has been assessed as energy-inefficient. Clearly, there is huge potential for improving energy efficiency in buildings.

As a result, the European Union has agreed on a new set of rules for its Energy Performance of Buildings directive, which requires that EU members ratify national policies to improve energy efficiency in the building sector.

The directive specifies smart-building technology as a key element for reaching this goal. Having proved their benefits in Industry 4.0, smart sensors and technologies are now being used in building automation. Intelligent building automation and control systems can significantly increase the efficiency of a building's operation by leveraging sensor-based data insights. A Smart Readiness Indicator for buildings is also being developed. The indicator will rate a building's capacity to use new technologies and electronic systems in order to reduce energy consumption and emissions and to adapt buildings to the needs of their occupants.

Higher efficiency is not the only benefit that smart buildings deliver. Intelligently placed sensors and actuators can continuously monitor and adjust air quality and lighting settings, guaranteeing optimal working environments, increasing productivity, and maximizing occupants' comfort.

The Edge, in Amsterdam, is a prime example of how smart technology is already cutting costs and increasing productivity in buildings. This 40,000-m^2 office building is equipped with approximately 28,000 sensors that enable the building management system (BMS) to collect information about crucial parameters such as humidity, brightness, and temperature. Based on those parameters, the BMS automatically triggers adjustments in the building's operations, ensuring that heating, ventilation, and air conditioning (HVAC) systems, lighting, and other systems run as effectively as possible. As a result, The Edge consumes 70% less electricity than conventional office buildings, making it one of the most energy-efficient and intelligent structures in the world.

While The Edge is an exception today, smart buildings are definitely on the rise. Recent market research predicts that the market for smart-building devices will double

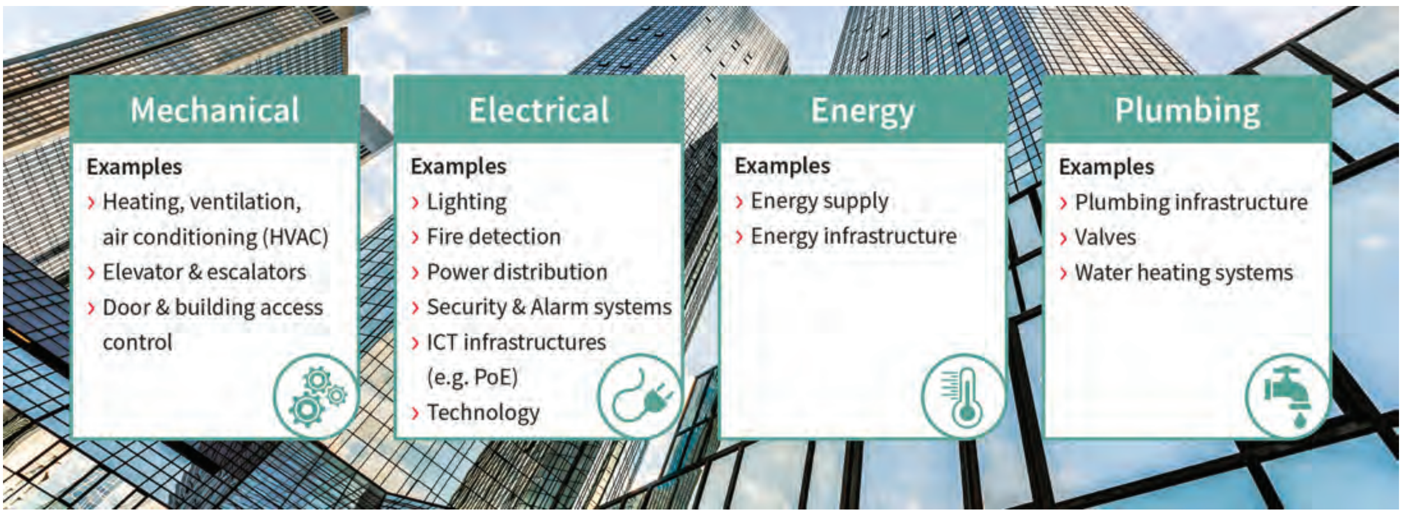


Figure 1: *Elements of a smart building*

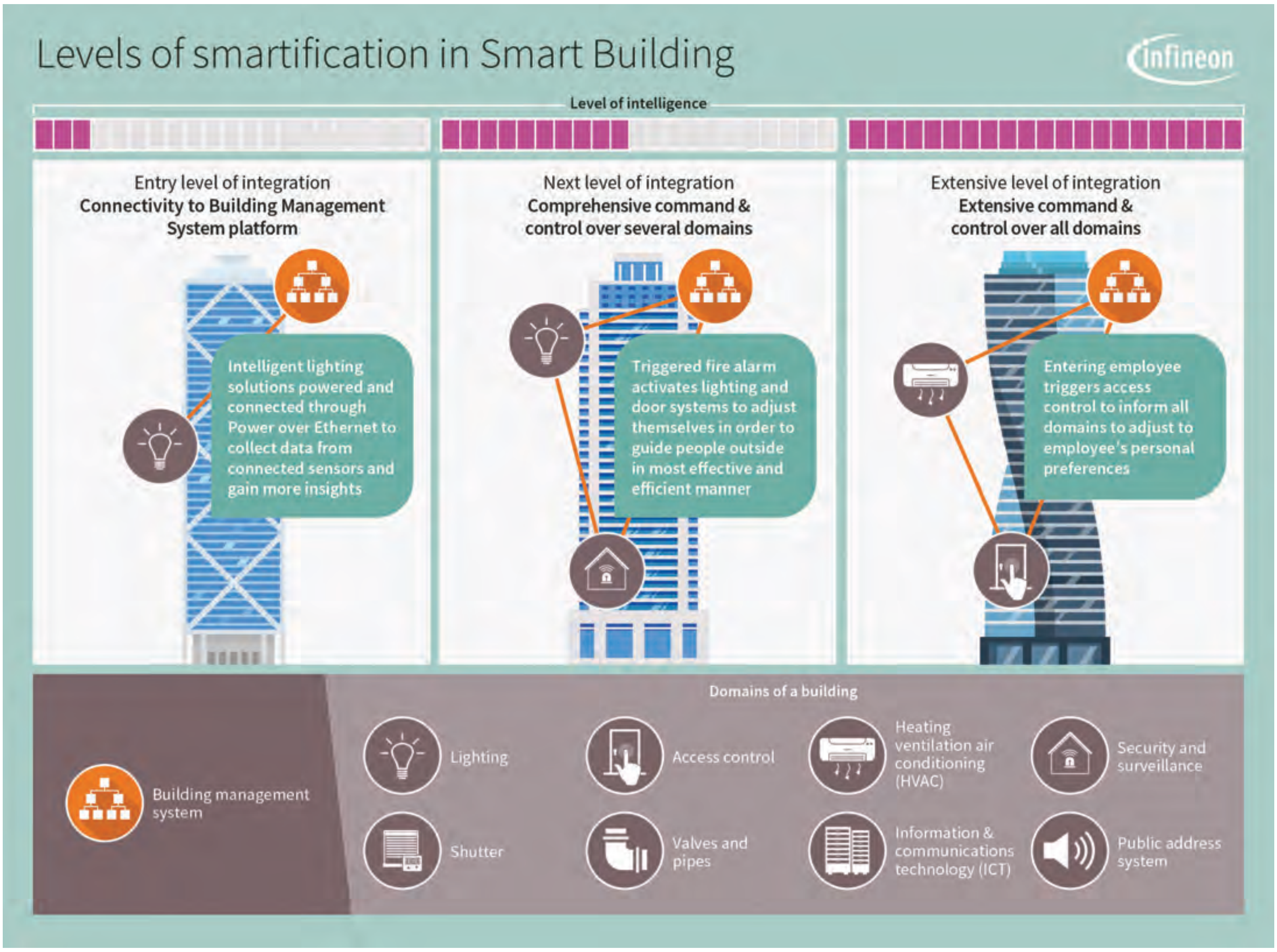


Figure 2: *Levels of smartification in smart buildings*

by 2022 at a compound average growth rate (CAGR) of 16%.

WHAT IS A SMART BUILDING?

Unlike smart homes, smart buildings are non-residential buildings such as office complexes, shopping centers, and hotels. Equipped with sensors that are connected to devices, these buildings can provide in-depth information on consumption levels and make automated decisions to optimize operations.

The smart downlight that Infineon Technologies is slated to showcase at this year's Light + Building trade fair in Frankfurt, Germany, is a prime example. The light combines power and sensor solutions to create powerful insights into building performance. In these systems, the XDPL8221 digital control IC monitors relevant error conditions such as undervoltage, overvoltage, open load, or output short at the LED driver. A 24-GHz radar sensor enables presence detection and counts occupants, allowing the system to dim the lights and save energy when a space is unoccupied. The sensor can also send this data to the BMS and the building operator for further analysis and building system optimization.

Following a more abstract version of "sense, compute, actuate," an array of connected sensors collects environmental information and data about a building's operations and usage. This information can either be processed at the edge (edge computing) or sent to a central BMS running locally or in the cloud. The information is then used to trigger automated actions that adjust HVAC systems, lighting systems, shutters, and many other devices inside a building.

Buildings can thus be "smartified" by using sensors, actuators, and control units to cross-connect domains (**Figure 1**). With connectivity providing the skeleton for the smartification of a building, the actual devices and control units form the muscles and the brain of the building.

This interplay of smart components enables ventilation, for example, to be controlled based on indoor air quality (IAQ) and CO_2 levels in rooms. Lighting can also be automatically adjusted based on the presence of people and additional factors such as indoor brightness. This can significantly cut energy consumption while improving occupants' comfort and well-being.

Buildings can be classified into three smartification levels (**Figure 2**):

- **entry level**, or basic connectivity of individual domains to a building management system;
- **intermediate level**, enabling comprehensive command and control over several integrated domains, including sensor-based data collection; and
- **extensive level**, or extensive command and control over all domains with cross-domain intelligence and actuation.

It goes without saying that today's buildings will not reach the extensive level of smartness overnight. Instead, many small steps are needed. Next, we spotlight two examples — Power over Ethernet (PoE) and Condition Monitoring — to show how buildings can transition to the next level of smartness.

EXAMPLE 1: POE AS CONNECTIVITY BACKBONE

The ability to transfer large amounts of data with high bandwidth between domains and the BMS is a key enabler of smart buildings. Consequently, having a capable and reliable information and communications technology (ICT) infrastructure is the backbone of any smart building.

Internet Protocol (IP)-based network connectivity is already well-established in both industrial and residential applications. It is easy to install and maintain, integrates well with existing platforms, and has an extensive implementation stack spanning both hardware and software. However, Ethernet has one disadvantage: Even though it provides connectivity to devices, power from the electrical grid still needs to be drawn from separate cabling.

With the introduction of the first-generation IEEE Power over Ethernet standard for Type 1 and 2 devices, this challenge was overcome for low-power devices like IP phones and conference systems. With PoE, power-sourcing equipment (PSE) such as a PoE switch is capable of providing power and connectivity along twisted-pair Ethernet cabling for multiple connected powered devices (PDs). As a result, only one physical connection, the Ethernet socket, is required, and it can be handled exclusively by IT experts. This approach also reduces wiring effort and simplifies device management, thereby lowering installation and operation costs.

Until recently, only devices up to 30 W could be powered by PoE, hampering its widespread adoption. With the release of the IEEE 802.3bt standard in September 2018, Type 3 and Type 4 PoE use all four pairs of the twisted-pair Ethernet cabling, increasing the available power per port to 100 W. This has opened the door for PoE in higher-power applications such as PoE-powered 5G small cells, LED luminaires, high-power Wi-Fi access points, and public announcement (PA) systems.

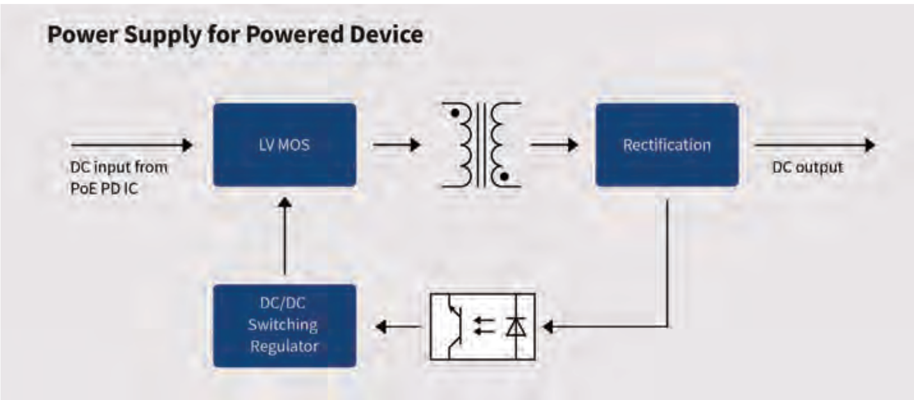
The amendment also addresses overall energy efficiency, with lower standby power consumption and a protocol to manage the available power in a more granular way with power classes. But those provisions pose new challenges in switched-mode power supply (SMPS) designs for PoE devices.

First, up to 100 W per port is added to the PoE switch power budget on the PSE side to fully support the latest standard. To avoid an increase in the form factor required for the SMPS, the power density of the SMPS needs to be scaled up. This means that efficiency, power density, and reliability are key requirements for the main SMPS in PSE designs.

Second, the right semiconductor solutions need to be matched to the respective SMPS topology (e.g., active clamp flyback [ACF] or LLC). Choosing efficient and reliable solutions like Infineon's superjunction CoolMOS™ MOSFETs maximizes available power and extends the lifetime of the devices. Thanks to their high efficiency, energy consumption is also reduced.

Efficiency, cost-effectiveness, and power density all play a crucial role on the isolated DC/DC SMPS converter stage for PDs. Every watt saved by increasing overall SMPS efficiency can be used by the PD itself.

When combined with reliable and efficient semiconductor solutions like Infineon's OptiMOS™ and StrongIRFET™ families for PD SMPS systems or CoolMOS™ for SMPS in PSE, Power over Ethernet plays a crucial role in creating a reliable ICT infrastructure in a smart building. It can also unlock additional cost savings.



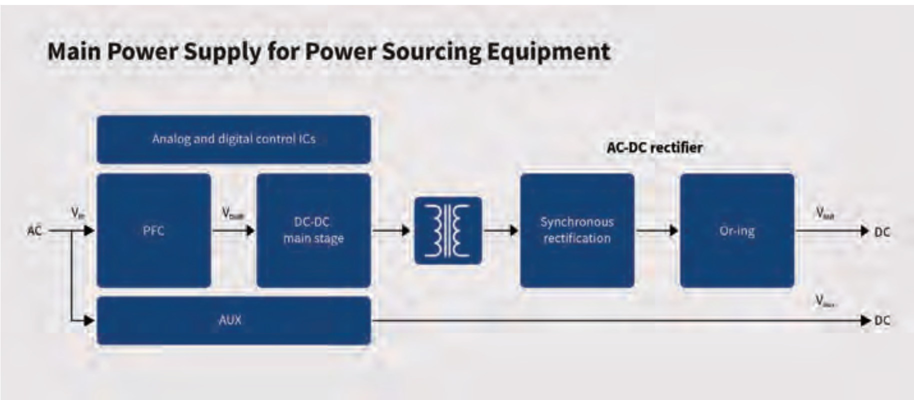


Figure 3: *PDs make use of a generic isolated DC/DC converter solution (top) unless targeting specific applications such as LED lighting. The PSE requires an efficient PFC and low-loss switches using an isolated topology (bottom).*

EXAMPLE 2: CONDITION MONITORING

Device and system failures such as broken elevators and air-conditioning units are huge disturbances that can disrupt the smooth operation of a building. In interconnected smart buildings, even small problems can lead to significant disruptions in a building's operation. Building operators are therefore desperately looking for options to monitor the condition of the installed device base and predict failures before they happen.

Sensors play a decisive role in monitoring a device's condition. Placed inside or outside the device, they collect data on the various parameters that reflect its operational status. Examples include airflow monitoring in HVAC devices using barometric air pressure sensors, current flow measurement in motor drives using current sensors and sound anomalies, and vibration measurement using microelectromechanical system (MEMS) microphones. These sensors allow deviations from defined optimal states to be detected in real time.

Predictive maintenance is the next logical step after the implementation of condition monitoring. It can be used to estimate when a device is most likely to fail and trigger proactive maintenance in a timely manner.

This trend was evident at this year's AHR Expo in Orlando, Florida, and is likely to be in the spotlight at Light + Building in Frankfurt.

Having identified this trend, Infineon will showcase an end-to-end demonstrator for condition monitoring and predictive maintenance in HVAC systems at Light + Building. Developed in collaboration with end-to-end IoT and cloud solutions developer Klika Tech and powered by Amazon Web Services (AWS), the demonstrator illustrates the potential of sensors in condition monitoring and predictive maintenance solutions for smart buildings.

The demonstrator focuses on the key problems of HVAC devices, including airflow measurement. It integrates multiple Infineon products, listed below, to ensure precise and reliable data recording.

Sense:

- XENSIV™ DPS368 barometric pressure sensor
- XENSIV™ TLI4970 current sensor
- XENSIV™ TLV493D-A1B6 3D magnetic sensor
- XENSIV™ BGT24LTR11 24-GHz radar sensor

Compute:

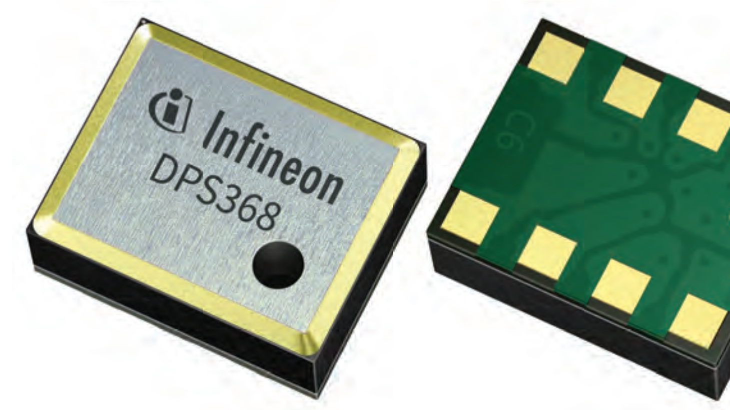
- XMC™ XMC4800 IoT Amazon FreeRTOS connectivity kit

Secure environment:

- OPTIGA™ Trust X

Using devices in Infineon's XENSIV™ sensor portfolio, critical components in an HVAC device such as the compressor, fans, motors, and filters are monitored together with overall system vibrations. The sensors collect data directly at component level. The collected data is pre-processed locally using the XMC™ microcontroller and sent to the AWS cloud for data intelligence and anomaly detection. Embedded hardware security safeguards the entire data flow from the edge to the cloud.

HVAC devices are just one example of a domain in which sensors can enable condition monitoring and predictive maintenance, unlocking added value for building operators, tenants, and device manufacturers. Elevators, valves, and lighting are other critical domains in which application-specific semiconductor solutions and advanced software intelligence can address maintenance problems and provide in-depth insights.



Infineon XENSIV™ DPS368 pressure sensor enables airflow monitoring in HVAC systems. Thanks to its waterproofness and robustness (IPx8), it is well-suited to collect data in rugged environments such as HVAC.

SUMMARY

Next-level building automation requires input from sensors in order to trigger actuators and automatize decisions across all domains. Semiconductor solutions provide the basis of smartification, with sensors, power management ICs, microcontrollers, and security ICs providing the crucial link between the real and the digital worlds. Thanks to advanced technologies and smart connectivity solutions, the buildings of today can be turned into the self-aware, green, intelligent buildings of tomorrow, helping to solve the challenges that urbanization and climate change pose to society. ■

OPINION

An IoTa of Ambition: Risk and Reward in the Fragmenting IoT Market

By Mark Lippett

Historically, the electronics marketplace has been dominated by a select number of vertical markets that ship in very high volume: personal computers, digital cameras, mobile phones, and so on. A disproportionate number of the trillion or so semiconductor units shipped each year would typically go to these markets.

As a result, the vendors of products for the dominant applications have exercised significant control over the actions of semiconductor suppliers since the industry began. And with relatively few device categories to consider, semiconductor manufacturers were able to confidently commit their resources to serving huge, well-defined and -understood requirements.

This is changing, largely because of the growth of the internet of things — a term that refers not just to one market with one set of requirements but to potentially tens of thousands of applications.

It's perhaps easiest to think of the IoT market as a forest that was once dominated by very tall trees. A couple, like digital cameras, have been chopped down, but the forest has continued to grow. The tallest trees aren't quite as conspicuously tall as they once were. And there's a plethora of new trees establishing themselves, demanding our attention.

This is what we mean by market fragmentation. Larger and traditionally dominant markets break out into smaller, more numerous markets that don't stand out as much but represent an even larger opportunity overall. In the case of the IoT, this phenomenon is rapidly accelerating.

TRADITIONAL TROUBLES

As the demands on our traditional systems increase and diversify, our challenges likewise take on new dimensions. We are now entering the age of the artificial intelligence of things — the convergence of AI and the IoT to make intelligent, communicating devices — and 5G will enable increasingly complex interaction between those devices. The need for interconnectivity is paramount; just about everything has wired or wireless connectivity. The fragmentation of customer demand and the relentless innovation in computing and communications exert unprecedented pressure on diversity and performance requirements in semiconductor vendor roadmaps.

Our very approach to semiconductor design may have to change as a result. While the overall opportunity of the IoT is vast, the individual feature sets required for many IoT applications will be of smaller volume. Feature sets will also remain more volatile through the product design life cycle, as user expectations will consolidate more slowly.

This is a problem for traditional chip design approaches, which require high returns and stable feature sets to ensure that a profit can be made from the long-term bets that are placed when a design project commences. To continue the forest analogy, the tall trees that once sustained us are comparatively less rewarding; the landscape is full of new trees that grow quickly with specific nutrition but are more challenging to harvest.

Organizations want to mitigate this risk. If they stick doggedly to the traditional, one-size-fits-all ethos, it's inevitable that some will suffer from a constrained market or simply from backing the wrong horse.

On the other hand, if we embrace the changing market as an opportunity to think about how we design and utilize semiconductors, it's an opportunity for the industry to evolve.

SEMICONDUCTOR SCRUTINY

To address this challenge, future silicon products need to balance several qualities, and versatility is one of the most important. This means more programmability — offering an assortment of features on the same platform that can be combined to support a wide array of disparate IoT markets.

Flexibility is key to maximizing a solution's market share. The more individual markets that a semiconductor design can address, the more likely that that particular product will be

IMAGE: SHUTTERSTOCK

profitable. A note of caution here, though: This flexibility must be accessible to the customer, and it must be available at the right price and through the right design methodology. It's no use designing a chip that can accommodate every IoT market if it costs the earth or if only an expert can program it.

Manufacturers will respond in different ways. Some will choose to build a traditional, fixed-function solution that isn't quite what many of their customers need, relying on additional components to fill in missing capabilities. Others will innovate and deliver flexibility into the hands of their customers — the ability to flex the I/O, control processing, DSP, and AI in the final design. These suppliers will enjoy a larger available market but will be challenged to deliver the requisite flexibility in a manner that is both affordable and easy to use.

At the end of the day, we should listen to our customers, whose needs are becoming increasingly diverse in ever-fragmenting markets. Maximum versatility is critical for those looking to drive the evolution of AI and the IoT. As AI and other high-performance processing workloads continue to move to the network edge, so will the demand for processor solutions like the new XMOS crossover processor, xcore.ai, designed to deliver fast processing and neural network capabilities locally, with actions taken on-device within nanoseconds.

By doing so, it's possible to enable smarter sensing technologies to be integrated seamlessly into our lives. ■

Mark Lippett *is CEO of fabless semiconductor company XMOS (Bristol, U.K.).*

POWER MANAGEMENT

GaN Semiconductor for Fast Electric Charging Systems

By Maurizio Di Paolo Emilio

Navitas's GaNFast integrated gallium nitride (GaN) solutions enable electric charging systems (such as those that allow you to recharge your smartphone, for example) to operate up to 100× faster than those with conventional silicon (Si) components by offering 5× higher power density, 40% more energy savings, and 20% lower production costs.

Power GaN was initially brought to the aftermarket space in mid- to late 2018 with 24-W to 65-W chargers from Anker, Aukey, and RAVpower. In 2019, we saw additional accessory releases and "in box" adoption from 27 W to 300 W by OEMs such as Samsung, Verizon, Oppo, and Asus/Nvidia, with millions of units shipped.

GaN is a new production semiconductor that is expected to replace silicon in many applications in the coming years, and battery charging is the first high-volume market to demonstrate such adoption. Nowadays, most of the chargers being used for electronic products use silicon transistors, and for years, these have been the best solution for efficiency and size. Silicon is gradually reaching its physical limits, however, especially with regard to power density, in turn limiting how compact a device equipped with silicon power components can be. GaN's performance is superior to silicon's at very high voltages, temperatures, and switching frequencies, thus allowing significantly higher energy efficiency.

The continued demand for more powerful smartphones, tablets, and laptops with larger screens and 5G features has created a market for the next generation of AC adapters to charge larger and larger Li-ion batteries very quickly (**Figure 1**).

As silicon power devices are swapped out for GaN replacements, the days when we're compelled to carry huge electric bricks and multiple cables to run our devices may end. The time we wait to charge smartphones and laptops could be significantly reduced, and the surprisingly hot charger may be a thing of the past. With a multitude of chargers and GaN adapters ranging from 27 W to 300 W in mass production, powering everything from phones to drones, the mobile charger market is set to change dramatically.

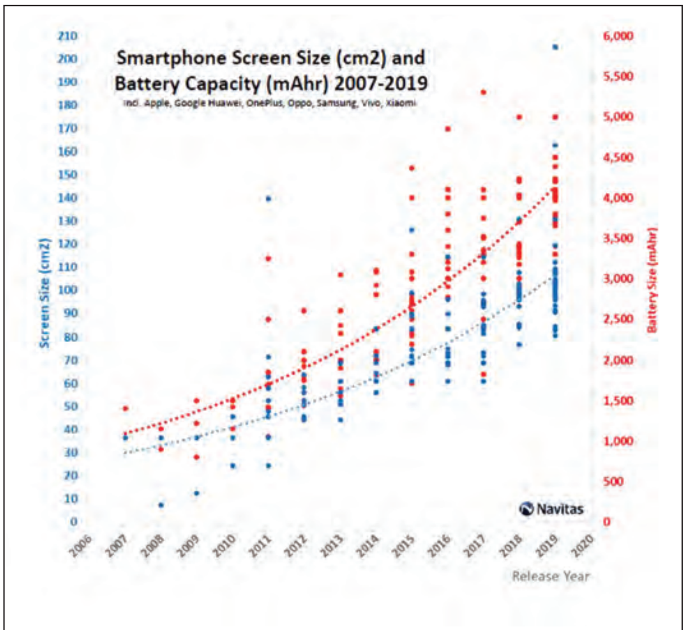


Figure 1: *Smartphone screen size (cm²) and battery capacity (mAh), 2007–2019*

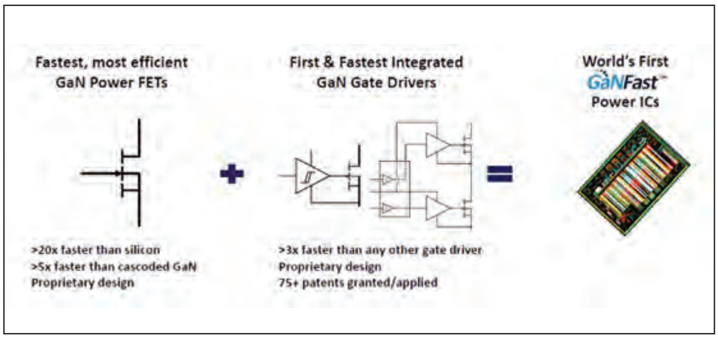


Figure 2: *Integration of GaNFast* (Image: Navitas)

"People want faster charging for their mobile devices, which means more power is needed, but they don't want the large size and weight of a silicon-based adapter," said Gene Sheridan, Navitas CEO. "Phones have increased from only 5-W charging a few years ago to 50 W or more on high-end, premium phones today and with up to 120 W claimed for new platforms. Laptops are already 50 W to 60 W with big, bulky chargers, and GaN is a big opportunity to deliver that high-power fast charging but in a dramatically smaller and lighter-weight form factor."

After years of academic research on discrete GaN in the 1990s and integrated GaN in the 2000s, GaNFast power integrated circuits are now an industry-proven, commercially attractive, next-generation solution for designing smaller, lighter, faster chargers and power adapters.

"GaN is very good at about 600 V, dramatically better than silicon in terms of chip area, circuit efficiency, and switching frequency, so it's a very nice sweet spot to use GaN to replace silicon in these wall chargers," said Sheridan. "The combination of soft-switching topologies with our GaN ICs dramatically improves efficiency. Using a mobile charger example, with silicon and a traditional flyback topology, efficiency was only 87% to 89%. With GaN in a soft-switching topology, we're looking at 93% to 95%."

Single and half-bridge GaNFast power ICs are 650-V GaN-on-Si FETs with monolithic integration of drive and logic, packaged in quad flat no-lead (QFN) packages. GaNFast technology allows switching frequencies up to 10 MHz, which enables the use of smaller and lighter passive components. The monolithic integration of a field-effect transistor (FET), drive, and logic creates an easy-to-use constituent component that allows designers to create an ultra-fast, ultra-compact, and ultra-efficient integrated powertrain.

Integration is key to minimizing delays and eliminating the parasitic inductance that has restricted the switching speed of silicon and earlier discrete GaN circuits. With propagation delays down to 5 ns and robust dV/dt up to 200 V/ns, traditional 65-kHz to 100-kHz converter designs can be accelerated to megahertz speeds and beyond. These integrated circuits extend the capabilities of traditional topologies such as flyback, half-bridge, resonant, and others at frequencies on the order of megahertz, allowing the commercial introduction of revolutionary projects (**Figure 2**).

GaNFast technology will also soon make its way into the world's fastest laptop: the Asus ProArt StudioBook One. ProArt One, an Nvidia RTX Studio system, is the first laptop to feature the Nvidia Quadro RTX 6000

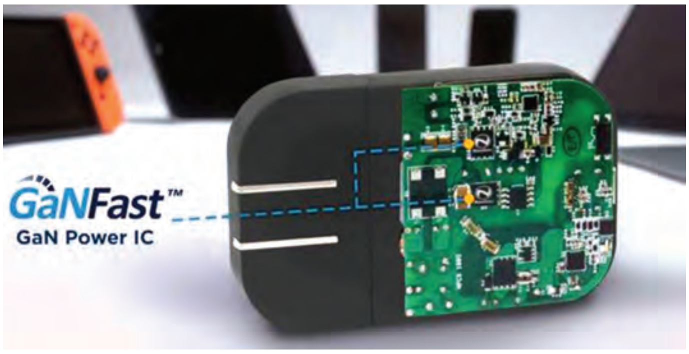


Figure 3: *The inside of a battery charger with GaNFast technology*

GPU and is based on Nvidia's ACE reference architecture. Developed in collaboration with Nvidia, the new 300-W AC/DC design leverages Navitas's high-speed GaNFast power IC power-conversion technology to create a powerful yet lightweight and small, portable charger.

"Creatives and other professionals demand the highest computing performance with extreme mobility," said Sheridan. "Navitas's dedicated technologists worked alongside the Nvidia engineering design team to address this challenge as part of the Nvidia ACE reference design, delivering a 300-W laptop adapter in less than half the size and weight."

GaN solutions enable compact adapter designs that are more efficient and more compact. The material provides the world's fastest transistors, which are essential for ultra-efficient power conversion. The new technology reduces the size of power electronics by more than 50%, making it possible to create truly universal battery chargers for mobile devices.

Using GaN semiconductors, you can create chargers that not only are more efficient but also deliver the same power in a much smaller footprint than traditional chargers. These power supplies stay cooler — there is much less dissipation, and they require fewer components and are cheaper (**Figure 3**). ■

Maurizio Di Paolo Emilio *is a staff correspondent at AspenCore, editor of Power Electronics News, and editor-in-chief of EEWeb.*

OPINION

How Will We Power the Future of the IoT?

By Maurizio Di Paolo Emilio

It happens to all of us: The battery on our portable device suddenly dies — usually just when we need to make an urgent phone call — and there's no charger at our disposal.

Our world revolves around an ever-increasing number of battery-powered devices that we always carry with us. In this continually evolving tech environment, devices are becoming smarter and more powerful, which means they all require more energy to work.

Energy management is one of the biggest challenges facing the world. This is especially true in the mobile world, where the internet of things has vastly expanded the universe of standalone devices and smartphones used for applications that didn't exist just a few years ago, such as the medical apps that let you use your smartphone to monitor your vital signs.

Energy efficiency in wireless sensor networks has been explored mainly at the communication level, with protocols and routing mechanisms developed ad hoc. To ensure excellent performance, however, development effort needs to be expended at the energy level.

Harvesting energy from both artificial and natural sources could be a significant technological step.

The question we should be asking is: How can we make devices energy-free? That is, how can we make batteries even more autonomous without worrying about recharging them?

The answer is energy harvesting. Harvesting energy from both artificial and natural sources could be a significant technological step for the future of connected devices.

Mobile-device manufacturers are looking to improve their batteries through new chemistries or software and hardware solutions that enable optimal charge management. Scientists and startups have been hard at work on different ways of harvesting energy and producing electricity from our daily activities.

In the field of high-power systems, photovoltaics is set to become the cornerstone of the market, with new challenges relating to efficiency gains estimated at more than 30%. In the low-power field of wearable devices and mobile phones, kinetic, thermal, and RF energy solutions should drive the global market at a considerable pace.

The mere act of walking is a potential source of usable energy for devices. SolePower used this principle to create a revolutionary sole that can be inserted into existing shoes so that walking to work or the shops can generate power to charge a battery or device.

Scientists are also developing a fabric that can generate electricity from heat and movement. The material is both piezo-active (meaning that it generates energy from movement) and thermoelectric (it uses the Seebeck effect). It can be folded and placed on the back of devices so that they can be recharged while stowed in a trouser pocket, benefiting from the heat and movement produced by the body.

A project of American origin has made it possible to create a radial thermoelectric generator (TEG) that can be wrapped around any hot-water pipe to generate electricity from waste heat. These generators can be used to power wireless-sensor networks that monitor environmental or operating conditions.

The harvesting of radio waves is nothing new. Many scientists have developed sensors to collect tens of microwatts from multiple TV channels, Wi-Fi, and cellular electronic devices, allowing the systems to harvest power on the order of milliwatts. ■

Maurizio Di Paolo Emilio *is a staff correspondent at AspenCore, editor of Power Electronics News, and editor-in-chief of EEWeb.*

HIGH-PERFORMANCE COMPUTING

Protocol Promises Reliable Quantum Compute Results

By Maurizio Di Paolo Emilio

The test reportedly lets a quantum machine check its own answers to previously intractable problems.

Noise in a quantum computing system is any variable, such as temperature fluctuation, that influences the hardware state of the quantum machine and can thereby hamper the accuracy of its results. Now, researchers Samuele Ferracin, Theodoros Kapourniotis, and Animesh Datta of the University of Warwick have developed a protocol that they say allows a quantum computer to control its responses to difficult problems by quantifying the effects of noise on the output. The researchers recently published their results in the New Journal of Physics.

The test produces two analysis percentages that allow quantum computing researchers to determine whether their machines are working properly, with an eye toward improving the accuracy of the results. The Warwick team calls its approach a crucial first step in establishing the utility of quantum computing.

"A quantum computer is useful only if it does two things: The first [is] that it solves a difficult problem; the second, which I think is less appreciated, is that it solves the hard problem correctly," said Datta. "If it solves [the problem] incorrectly, [thus far, we have] had no way of finding out. What our paper provides is a way of deciding how close the outcome of a computation is to being correct."

The method proposes performing a series of already known calculations as a basis for establishing the accuracy of a quantum machine's results. Using these findings, researchers can define a statistical limit on how far the quantum computer can be from the correct answer in solving a given problem, known as the target calculation. The procedure is analogous to what programmers use to check the status of large programs in classical computers, with small functions whose outputs are known *a priori*. If a program responds correctly to these, then the programmer can be sure that the whole program is correct.

Ferracin, lead author of the Warwick paper, said that the researchers had "spent the last few years thinking about new methods to check the answers of quantum computers and proposing them to experimentalists. The first methods turned out to be too demanding for existing quantum computers, which can implement only 'small' computations and perform restricted tasks.

"With our latest work, we have successfully developed a method that suits existing quantum computers and encompasses all their main limitations. We are now collaborating with experimentalists to understand how it performs on a real machine."

Quantum computing leverages the properties of quantum physics, whereby particles can exist in more than one state at any given time. In a radical departure from current digital technology, quantum processing allows data to be analyzed in all of those states simultaneously, giving it an enormous advantage over classical calculus. Some types of problems, such as those found in a code violation and in chemistry, are particularly suitable for exploiting this property.

The quantum arms race is accelerating exponentially. With the biggest quantum computers doubling in processing capability every six months, quantum supremacy — a targeted milestone in the development of quantum computers in which a quantum machine performs a function that would require an unreasonably large amount of processing time using a classic computer — is a virtual certainty. Indeed, Google claimed to have achieved quantum supremacy using a programmable supercomputing processor late last year, publishing its results in Nature.

Testing, programming, and chip packaging are some of the challenges that engineers are working to overcome. The Warwick researchers are betting their proposed method will successfully address some of the test issues. ■

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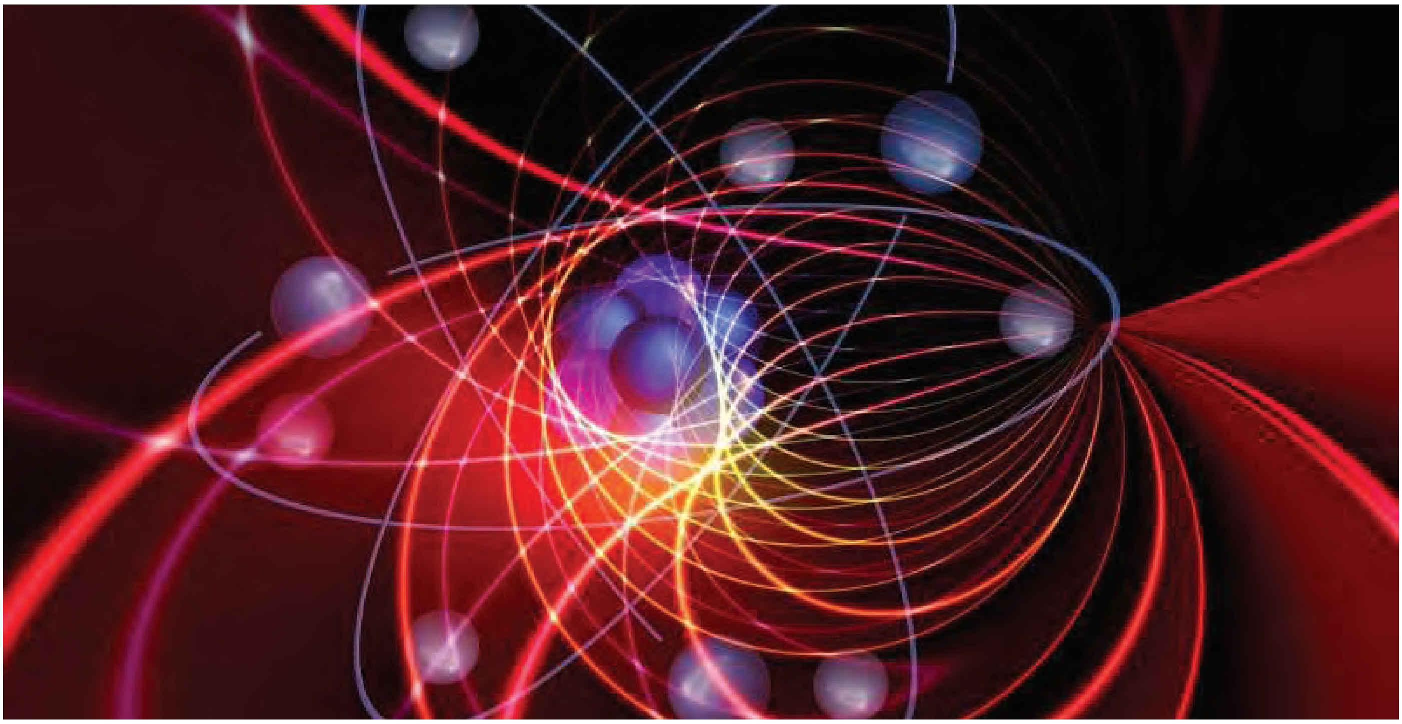

POWER MANAGEMENT

Improving Energy Efficiency with SiC Isolated Gate Drivers

By Maurizio Di Paolo Emilio

Maxim Integrated has introduced a silicon carbide (SiC) isolated gate driver for use in high-efficiency power supplies for the industrial market. The company claims that the new device has 30% lower power loss and a 30% smaller carbon footprint than competing solutions.

System manufacturers are increasingly interested in increasing the power efficiency of their designs; the combination of energy efficiency and reduced costs is becoming critical for market leadership. Considerable progress has been made in this area from a semiconductor materials perspective, and there are now products that can switch at high speeds, improving system-level efficiency while reducing solution size.

As devices become smaller, power supplies need to keep pace. Therefore, today's designers have a priority objective: Maximize power per volume (W/mm³). One way to achieve this is to use high-performance power switches. The path to new power electronics is already being paved with gallium nitride (GaN) and SiC, even if further R&D programs are needed to improve performance and safety and even though designing with these wide-bandgap (WBG) materials requires extra work during the design phase.

Properties such as bandgap, breakdown field, thermal conductivity, electron mobility, and electron drift velocity are the main benefits that engineers can gain from the use of WBG semiconductors such as GaN and SiC. The advantages of WBG-semiconductor–based power switch modules include high current density, faster switching, and lower drain-source resistance ($R_{DS(on)}$).

SiC will set the rate of power in several industrial applications. It has a bandgap of 3.2 electron volts (eV), and the energy required to move the electrons in the conduction band provides higher-voltage performance than silicon of the same packaging scale. SiC's higher operating temperatures and high thermal conductivity support efficient thermal management.

Many switching power applications are adopting SiC solutions to improve energy efficiency and system reliability.

The high switching frequency in power supplies causes operational difficulties for noise-creating transients, making the overall system inefficient. The chemical structure of the new technologies, compared with that of silicon, makes the new devices low-charge and fast-switching.

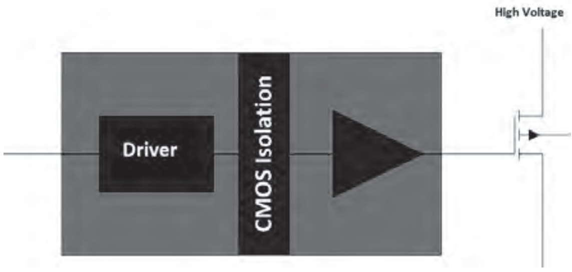

Figure 1: *General block diagram of an isolated gate driver*

Isolated gate drivers are widely used to drive MOSFETs and IGBTs and provide galvanic isolation. Switching frequencies above 10 kHz are common in MOSFETs and IGBTs. However, SiC- and GaN-based systems can operate at even higher switching frequencies without significant power losses during the transition. Significant advantages are size reduction and less distortion (**Figure 1**).

Fast switching produces noise transients that can cause latch-up, leading to modulation loss or even permanent system damage. To solve the problem, it is necessary to improve the noise immunity of the components used to drive the system. Furthermore, switching-related power dissipation and conduction losses produce heat that must be dissipated through heat sinks, increasing the solution size.

The intensity of these transients may result from the driving circuit of the spurious pulse gate, resulting in a short-circuit condition. The drive circuits controlling the power converters must be designed to withstand these noise sources and thereby avoid secondary short-circuits. The ability of a driver circuit to withstand common-mode noise transients is its common-mode transient immunity (CMTI), expressed in kV/µs. CMTI is a key parameter for all gate drivers that handle differential voltage between two separate ground references (isolated gate drivers).

Understanding and measuring sensitivity to these transients is an important step in the design of new power supplies. The capacitance across the barrier provides the path for fast transients to cross the isolation barrier and corrupt the output waveform.

Maxim Integrated's new MAX22701E driver has a high, 300-kV/µs CMTI, resulting in longer system uptime. The driver is designed for switching power supplies in high-power industrial systems such as solar inverters, motor drives, and energy storage systems. The MAX22701E is compatible with both SiC and GaN for driving FETs based on either WBG material. Its technical specifications reduce downtime and energy losses, according to the company.

The MAX22701E is available in an eight-pin (3.90 × 4.90-mm) narrow-body SOIC package with an extended temperature range from −40°C to 125°C (**Figure 2**).

High CMTI determines the correct operation of the two sides of the driver, minimizing errors and thereby enhancing the robustness of the gate driver used. CMTI is one of the three key features associated with isolators. The others are propagation delay matching and the working voltage. The MAX22701E offers the industry's lowest part-to-part propagation delay matching of 5 ns (maximum) between the high-side and low-side gate drivers, according to Maxim Integrated. This helps to minimize the transistor's dead time and maximize power efficiency. The part offers galvanic isolation of 3 kV_{rms} for 60 s.

"With the increasing progress and adoption of power semiconductor devices such as SiC and GaN, the industry is moving toward more energy-efficient and [more] reliable solutions," said Suravi Karmacharya, senior business manager for the Industrial and Healthcare Business Unit at Maxim Integrated. "The equipment requires increasingly high-performance switching frequencies, with high-dV/dt characteristics when switching transients on and off compared with conventional MOSFET and IGBT solutions. Our isolated SiC gate driver provides a solution to maximize system power efficiency and increase uptime in noisy environments." ■

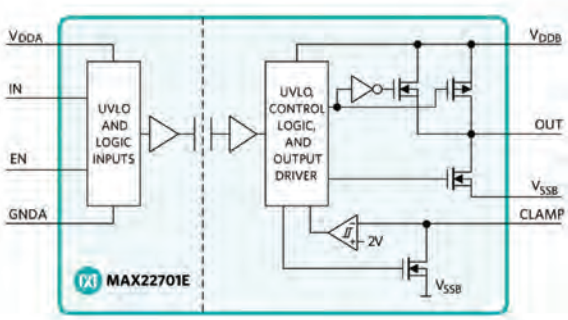

Figure 2: *Block diagram of the MAX22701E* (Image: Maxim Integrated)

Maurizio Di Paolo Emilio *is a staff correspondent at AspenCore, editor of Power Electronics News, and editor-in-chief of EEWeb.*

POWER MANAGEMENT

Driver Options for Reliable Power LED Performance

By Maurizio Di Paolo Emilio

LEDs are devices with a nonlinear electrical characteristic. If low voltage is applied to an LED, it will not conduct. By increasing the voltage, a threshold value is reached above which the device immediately enters conduction by emitting light and absorbing a fair amount of current. If the voltage is increased further, however, the LED overheats and burns out within a short time. To ensure correct and long-lasting operation, the LED must therefore operate in the narrow band of voltages that separates the conduction from the interdiction states (**Figure 1**).

The problem is that the operating voltage range is not constant; rather, it varies from

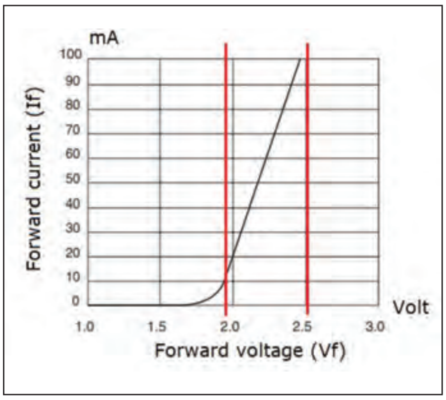

Figure 1: *Operating voltage range (in red) of a power LED*

LED to LED based on temperature and even the age of the device. Power LEDs can have a forward voltage (VF) variability of up to 20%. Thermal management is thus an important factor for power LEDs, considering that about 60% of the energy supplied to LEDs is dissipated in the form of heat.

To solve VF variability-related issues, the LED can be driven with a constant current instead of a constant voltage. The driver circuit automatically adjusts the output voltage to maintain constant current in all conditions. This circuit, applicable to both single LEDs and LED strips connected in series, ensures that all LEDs have the same brightness, even if the VF on each of them differs. Because LEDs are not overdriven, the circuit ensures optimal duration of the same. And if one LED fails short-circuit, the remaining LEDs continue to operate correctly.

The simplest type of constant-current driver consists of a constant-voltage generator that powers the LED through a resistance. This solution, although economical, does not offer accurate current regulation and dissipates a lot of heat. Furthermore, if an LED fails short-circuit, the resistance is overloaded, burning out in a short time.

Another common constant-current driver is the linear current regulator. The feedback circuit in the regulator keeps the current constant within very narrow limits. The excess power must be dissipated through special heat sinks. Because of the high dissipation, the efficiency of these circuits is not very high.

The best constant-current driver is the switching regulator. It is a more expensive solution, but both the regulation accuracy (up to ±3%) and the efficiency (up to 96%) are relevant to cost/performance. Furthermore, a DC/DC switching regulator has a wide range of input and output voltages, allowing the connection of different combinations of LED strips with different lengths and supporting LED dimming within a wide range of values.

CONNECTION OF LED STRIPS

Most constant-current driver circuits are represented by buck or step-down converters, in which the maximum output voltage is lower than the input, limiting the number of LEDs that can be connected. To address this, we can use a boost converter (in which the output voltage is higher than the input voltage) or use two or more LED strips connected in parallel.

The easiest and safest way to drive LEDs is to use a single strip for each LED driver. If any LED of the strip fails open-circuit, the current passing through the other LEDs is interrupted. If any LED fails short-circuit, the current flowing through the remaining LEDs is unchanged.

By connecting multiple strips to the same LED driver, it is possible to drive more LEDs, but there can be problems if an LED fails. With two strips in parallel, in the case of an open-circuit LED failure, the constant current supplied by the driver passes through all the LEDs of the remaining strip, quickly burning them out. Because power LEDs are highly reliable, this type of failure does not occur very often, so it remains fairly common to connect multiple LED strips to the same driver circuit. Nonetheless, when connecting multiple LEDs in parallel strips, it is useful to include a circuit (such as a current mirror) that can protect the LEDs in the event of an open- or short-circuit failure by balancing the current that passes through each LED string.

LED DRIVER ICS

Infineon Technologies offers a portfolio of DC/DC LED driver ICs that supports current between 150 mA and 3 A, suiting the ICs for high- and ultra-high-power LEDs in general lighting applications. For buck topology, the ILD4000 and ILD6000 families are the best fit. The ILD1150 family, meanwhile, supports buck/boost, boost, and single-ended primary-inductor converter (SEPIC) configurations.

Texas Instruments' LM3404 and LM3404HV are monolithic switching regulators designed to deliver constant current to high-power LEDs. Suited for automotive, industrial, and general lighting applications, the TI devices contain a high-side N-channel MOSFET switch with a current limit of 1.5 A for step-down buck regulators.

If the driver does not integrate thermal regulation, a good fit may be a temperature sensor such as Maxim Integrated's MAX6575H/L, a monostable, externally triggered sensor that lets a microprocessor interface with up to eight temperature sensors via one control line (**Figure 2**). Temperatures are sensed by measuring the time delay between the falling edge of the external triggering pulse and the falling edge of the subsequent pulse delays reported from the devices. Different sensors on the same I/O line use different timeout multipliers to avoid overlapping signals. ■

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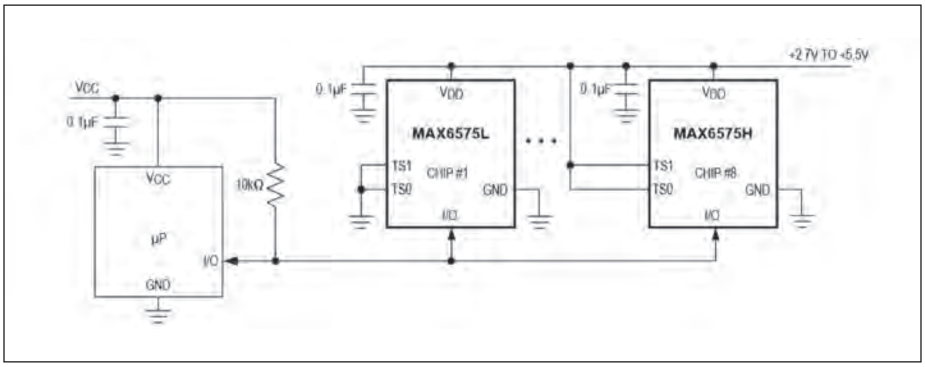


Figure 2: *Typical operating circuit for the MAX6575H/L sensor* (Image: Maxim Integrated)

TEST AND MEASUREMENT

Rohde & Schwarz's Pauly on T&M Implications of 'a More Connected World'

By Nitin Dahad

As the 5G rollout and the internet of things drive up integration and connectivity, how do you ensure that devices and applications work as they should: safely and securely? EE Times Europe spoke with Andreas Pauly, executive vice president for the test and measurement division at Rohde & Schwarz, to understand the trends and the challenges.


Andreas Pauly

EE TIMES EUROPE: The electronics industry has rapidly advanced and penetrated almost all walks of life and industry verticals. What has been the biggest change you've seen from a test and measurement viewpoint over the last five to 10 years?

Andreas Pauly: It isn't an exaggeration to say that antenna technology for consumer wireless devices is exploding. [The first reason is] the number of antennas built into even handheld devices; MIMO really does mean "multiple" these days. Second, the techniques used with active beamforming are adding performance well beyond the passive multipath propagation initially introduced with multiple antennas.

While just a few years ago almost all wireless devices included a special interface to connect a cable for test purposes, this is no longer the case. As well as 5G user equipment, there are whole markets for very small, inexpensive wireless devices — personal network technologies such as Bluetooth, LoRa, or Zigbee — and, of course, the enormous variety of IoT devices that do not include a test interface for a mixture of cost and space reasons.

Then there are more complex devices with multiple miniature antennas where it would be physically impossible to connect a cable. Last but not least, with increasing frequency, the mechanical difficulties of making a reliable physical connection also increase out of proportion. Over-the-air test, with all communication with the device under test via the antennas it uses for normal operation, has introduced whole new complexities to test and measurement, requiring new fields of expertise on our part.

The evolution in the physical properties of signals to be tested actually [amounts] to a revolution. Originally launched with an already wide, 160-MHz analysis bandwidth, the R&S FSW spectrum analyzer has now increased that capability to 5 GHz. During the same time, the output power of our analog generator has increased by a factor of more than 10. It's a similar story everywhere; customer requirements for frequency, data rate, bandwidth, power, any property you care to name, are permanently pushing T&M equipment to new limits.

EETE: What are the biggest market opportunities for R&S in the next five years?

Pauly: 5G and IoT will be among the most significant opportunities. Providing 5G as the successor to 4G will build on the existing mobile radio base. Beyond this, 5G is adding performance to satisfy the requirements of completely new applications and customers.

For example, 5G low latency is making applications such as advanced driver-assistance systems (ADAS) realistic. The automotive industry will need to adopt testing to exacting standards for accuracy and reliability, [and that will only be] possible with close support from the T&M industry.

For IoT, it's a similar story. New requirements mean that completely new groups of customers are emerging with their own T&M requirements — as an example, for monitoring all sorts of physical properties with small remote devices and communicating status change via the internet for everything from maintenance for chainsaws to water meters.

Both 5G and IoT come together as just parts of the solution to the demands of Industry 4.0. The trend toward automation and data exchange in manufacturing technologies and processes means that smart factories will require efficient, low-latency, interference-tolerant data communication that will be largely wireless. The drive for smart cities using data communication to make more efficient use of infrastructure and resources has different demands and goals. What both [Industry 4.0 and smart-city technologies] have in common is the need for efficient data communication plus efficient sensors and monitors; many of the solutions and test requirements will be similar.

EETE: OK, so 5G and IoT are clearly two of the biggest topics in the industry right now. What do you see as the big challenges in these markets?

Pauly: For 5G, the sheer speed with which this market is developing means that customers are looking for test solutions for specifications that are anything but finalized. Parts of the industry are vastly underestimating the physical difficulties arising from using higher frequencies for mobile wireless applications.

The range of possible ways to offer 5G services will be much larger, and the potential applications [will extend] way beyond the end-user mobile radio and data up- and download, such as videos, that we are familiar with in 4G. Most equipment using 5G for data communication will make use of only a fraction of the possible 5G capabilities; being able to provide all customers with test functions for the subset of 5G they are interested in using will require a degree of personalization of T&M equipment way beyond anything previously experienced.

So far, mobile radio networks have either been open to anyone with a suitable SIM card or niche requirements for authorities such as public safety. A wide range of completely new customers for private networks with new requirements that can be addressed for the first time with 5G are now emerging. For example, our own factory in Memmingen [Germany] is implementing its own 5G network to meet in-house data communication requirements.

For IoT, power is very much an issue. Since

IoT will likely consist of remote devices that are expected to provide many years of occasional data communication, issues such as battery life and power management are just as important as RF performance.

Customers expect T&M solutions to meet their specific application needs, which is a given, as quickly as possible out of the box or after installation. For applications with additional requirements that cannot be met with standard T&M functions, our application engineers provide customized functions to meet individual needs. As a response to the breakneck pace particularly of 5G development, this requires further liaison with customers to provide updated functions between official software releases.

EETE: What are the strengths of R&S in these markets?

Pauly: Single-box solutions for 5G and IoT signal analysis, signal generation, and production test providing the best RF performance, widest bandwidth, and simplest calibration and setup; for 5G network rollout, leading drive-test scanners and network engineering tools.

For the moment, IoT remains a pre-5G technology. R&S is the only T&M company supporting all 4G improvements for IoT (3GPP Releases 14 and 15), many of which are of huge significance for increasing the usability of IoT devices and are being implemented throughout the market.

EETE: How would you summarize the state of the T&M industry and where its focus needs to be?

Pauly: For many years, we have been increasing our expertise and competence in several areas — such as RF chip and device testing for the component and mobile radio industries, microwave components primarily for aerospace and defense, and over-the-air test at wideband frequencies — as market leaders in EMC test and measurement.

5G combines all these requirements. Rohde & Schwarz is ideally placed to utilize this extensive expertise [in] addressing largely independent applications to address the newer demands requiring the consolidation and/or merging of many of these competencies in 5G.

Whether we are considering autonomous vehicles or data-driven Industry 4.0 factories, the focus is clearly to enable that combined knowledge to develop the T&M solutions needed for a more connected world and enable them to operate within the higher safety standards that are expected. ■

Nitin Dahad *is a staff correspondent at AspenCore.*

ADVERTISERS INDEX

MOTOR CONTROL DESIGN

Noise Reduction in Stepper Motors

By Maurizio Di Paolo Emilio

The amount of noise in a motor depends on the type of motor, environmental conditions, and the specific application. Permanent magnet and hybrid stepper motors are generally quieter, as they have a more consistent rotation. Conversely, variable reluctance stepper motors are the noisiest, regardless of the application in which they are used.

To better understand the origins of noise, we need to think about how the rotation movement takes place. When a stepper motor performs a step, it does not stop immediately but continues to move slightly forward and backward before stopping completely. This behavior can be overcome by adopting specific control logic in the motor driver. During motor operation, the driver commands the movement of the next step one moment before the motor has stopped after completing the previous step. This continuous and regular motor advancement helps to reduce both noise and vibration.

It should also be noted that each stepper motor has a resonance frequency, which typically occurs when the motor moves at speeds between 150 and 300 steps per second. Many designers tend to avoid this operating speed range in order to minimize both noise and vibration. The insertion of gearheads, appropriately designed and sized, can help to reduce vibration. Rear-mounting dampers positioned on the crankshaft are another traditional solution for reducing vibration.

NOISE-REDUCTION TECHNIQUES

Most stepper motors are controlled by a pulse-width modulation (PWM) signal, which continuously forces the switching of the H bridge between the on and off states, thus regulating the current that feeds the motor. Driver circuits based on this technique are commonly called chopper drivers because they supply the motor windings with a constant current by chopping the output voltage following the application of the PWM waveform.

Unlike the L/R technique, which instead aims to keep the voltage applied to the windings constant, current chopping has the advantage of being a very efficient, compact, and economical solution, generating a small amount of heat.

One caveat is that the modulated signal applied to the stepper motor can generate an audible signal, even more so if the PWM frequency falls within the audio band. Experimentally, it is indeed easy to verify how a stepper motor can generate noise even when it is stopped or when it holds the position. This phenomenon occurs mainly at switching frequencies below 20 kHz. Thus, it can be deduced that the first method to reduce noise is to increase the switching frequency. Most chopper drivers offer the capability to increase the switching frequency by modifying the value of an external resistor or capacitor. The effect is to change the duration in the off state of the PWM signal used for current regulation. The shorter this duration, the higher the switching frequency.

It is not necessary to exceed the frequency value, however, because beyond a certain limit, the switching losses also increase. An appropriate switching frequency value could be between 30 and 50 kHz. If this technique is not sufficient, the current applied to the motor windings can be reduced. Lower current means, in fact, a reduction of vibration and, therefore, of noise.

However, a side effect is a reduction in torque, which, if too low, can cause the loss of steps during operation. Because the motor is controlled in an open loop, the motor must be supplied with the amount of current sufficient to cover all operating conditions, even the most severe. A good compromise is to reduce the current during periods when the motor is stopped.

Normally, the current required by the motor to maintain the position is considerably lower than the current required to accelerate or move the motor at a constant speed. Virtually all stepper motor drivers allow setting the current value by modifying the analog reference voltage V_{REF}. The trip current, I_{Trip}, is a function of both the external R_{SENSE} resistor and the V_{REF} reference voltage. Because the first, once chosen by the designer, has a fixed value, at run time, it is possible to modify I_{Trip} by changing V_{REF} on the fly.

If further noise reduction is required, the motor may be operated in slow-decay mode instead of fast- or mixed-decay modes. This mode minimizes the driving current ripple, reducing the noise and increasing the driver efficiency. Slow-decay mode, however, is not always the best solution, especially if you want to use the microstepping technique.

STEPPER DRIVERS

Integrated drivers have been designed to offer easy configuration and advanced control functions for every type of application. Integrated encoder options make stepper motors a suitable choice for synchronized position applications. The stepper motors are driven by connecting the coils to power transistors and the transistors to a control circuit.

Allegro MicroSystems, a leader in the design and manufacturing of brushed DC and stepper motor drivers, provides a broad portfolio of safe and robust solutions with integrated and MOSFET gate drives. Suitable for low- and high-power applications, Allegro's A3982 is a complete stepper motor driver with a built-in translator for easy operation. Designed to operate bipolar stepper motors in full- and half-step modes, the driver can provide an output signal up to 35 V and ±2 A. The current decay mode (slow or mixed) can be selected by applying a signal at the STEP input pin, as shown in the schematic block diagram of **Figure 1**.

In mixed mode, chopping control is initially set to a fast decay for a period amounting to 31.25% of the fixed off time, then to a slow decay for the remainder of the off time. This current decay control scheme

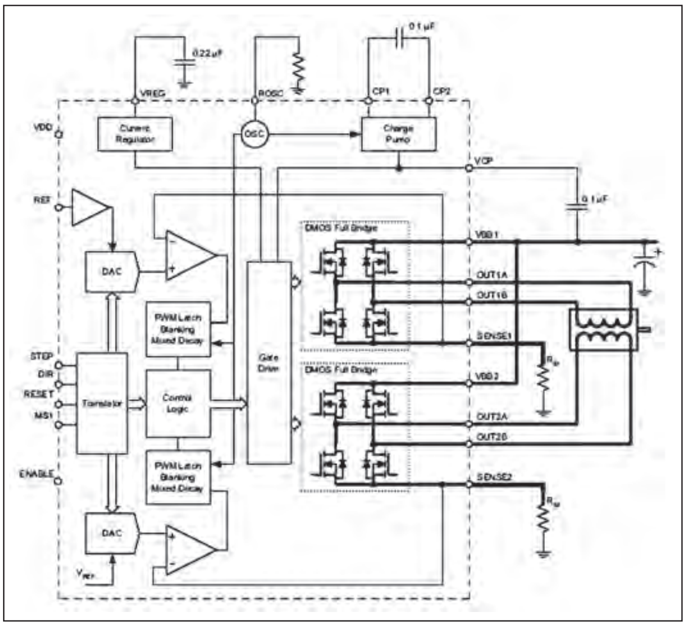


Figure 1: *A3982 block diagram* (Image: Allegro MicroSystems)

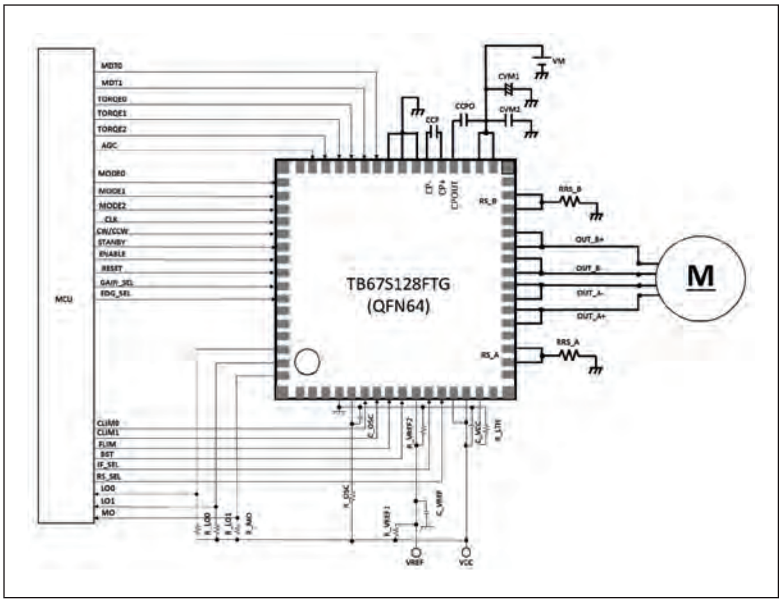


Figure 2: *Typical application of the TB67S128 motor driver* (Image: Toshiba)

results in reduced audible motor noise, increased step accuracy, and reduced power dissipation.

The translator feature greatly simplifies the design of the motor control system. By applying one pulse on the STEP input pin, the motor is driven one step. No phase sequence tables or high-frequency control lines are needed, making the A3982 the right choice for applications in which a host microcontroller is unavailable or is overburdened.

Toshiba Electronic Devices and Storage Corp. also offers a wide selection of stepper motor drivers. The TB67S128/249/279/289 devices feature the proprietary Active Gain Control (AGC) technology. AGC dynamically adjusts the stepper motor driving current in order to address heavy torque conditions, resuming normal current value in real time and in open-loop designs. AGC technology saves significant power and reduces or eliminates a more complex closed-loop design.

The TB67S128/249/279/289FTG devices provide 5.0 A, 4.5 A, 2.0 A, and 3.0 A, respectively, with 10-V to 42-V motor operating voltage. These devices also include a 32-step and 128-step microstepping capability in one quadrant that makes them suitable for a wide range of industrial precision motor control applications (**Figure 2**).

Stepper motors have a simple structure and are easy to control. As a digital electronic component, stepper motors are widely used in many open-loop control systems. However, they have a disadvantage in relation to the noise that affects the overall performance. The noise and the resonances come mainly from the drive circuit and from the mechanical structure of the resonance. Most stepper motor applications require smooth movement. To obtain extremely fluid movements, some engineers modify the voltage, the current, and, more often, the microstep setting. ■

Maurizio Di Paolo Emilio *is a staff correspondent at AspenCore, editor of Power Electronics News, and editor-in-chief of EEWeb.*

OPEN SOURCE

Arduino's Violante on Open-Source Hardware in the IoT Era

By Maurizio Di Paolo Emilio

Fabio Violante

Arduino is an open-source electronics platform based on a simplified hardware and software management system. Probably the best known Italian brand in the digital world, Arduino has become an icon for its pioneering open-source boards.

With Arduino, it is possible, in an extremely fast way, to develop devices that integrate not only classic electronic components but also sensors, servomechanisms, and communication devices. Arduino breaks down the barriers to entry that the world of electronics experienced with information technology and opens up a universe of possibilities to the legions of modern makers who like to experiment and prototype electronic devices at low cost.

Arduino Uno arrived in 2005 and has since become a pillar of the maker movement. But the world has changed dramatically since then. EE Times Europe spoke with Arduino CEO Fabio Violante about the evolution of open-source hardware in the age of "industrial makers" and the internet of things.

EE TIMES EUROPE: I grew up with Arduino. I saw it come to life and grow up — grow up a lot. I saw the emergence of startups with Arduino as the basic element of their prototypes. And now, it has a huge community, potentially the largest. What's Arduino trying to get to?

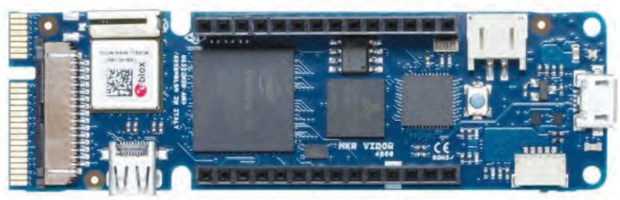
Fabio Violante: It's always great to hear that people grew up with Arduino, and we're pleased to see our products continue to be widely used as a prototyping platform for startups going on to be successful companies in their own right. Arduino now has over 30 million active community members, many of whom are looking for the simplicity that made Arduino so popular in the hardware market to be carried over into IoT applications — basically, to simplify the process for designing connected devices in the IoT.

Therefore, we are focusing a lot of effort on the Arduino IoT Cloud to facilitate low-code application development — i.e., in true Arduino style, make it quick and easy for users to seamlessly develop their applications. For example, we recently announced improved support for LoRaWan on our cloud. This is a quantum leap compared with existing solutions, where most of the work to transform sensor data into packets is performed manually by developers.

EETE: The latest Arduino Portenta aims to give Arduino a bigger push into the industrial market. The so-called industrial makers are being born. What advantages is this board going to offer the industrial market, and what are the main applications? What could be the design challenges?

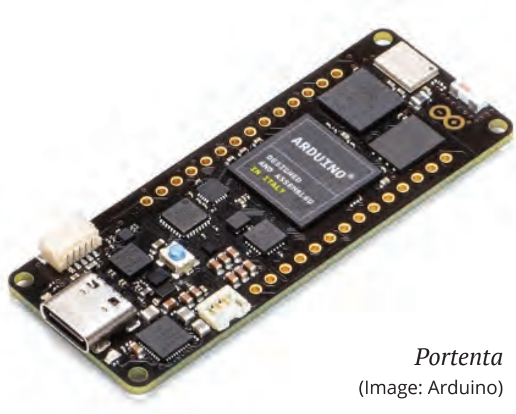
Violante: Very often, industrial makers require industrial-grade components. Quality, product longevity, and industrial temperature range are paramount. We designed the Portenta family to meet these criteria. With the help of selected partners like STMicroelectronics for the Portenta H7, we were able to create not only a reliable product but also the most powerful dual-core-microcontroller–based module with low power consumption on the market.

Furthermore, by standardizing on two high-density connectors (located at the bottom of the module), we aim to open up a big opportunity for partners, design firms, and the ecosystem to develop a number of vertical applications using our modules as the "brain" in their devices. More computing power on the edge means more sophisticated applications, including signal processing, machine learning for predictive maintenance, and simple vision tasks.



The MKR Vidor 4000

(Image: Arduino)



Portenta

(Image: Arduino)

EETE: We have many MCU-based boards. FPGA-based Arduino could be a new way with the MKR Vidor 4000. Is there a particular reason to choose a microcontroller instead of an FPGA as the core of the board?

Violante: Historically, Arduino has been built around microcontrollers — we live and breathe them — but as you pointed out, FPGAs are very promising technology that probably never became mainstream in our community due to complexity in both development and assembly.

Our aim with the Vidor was twofold: Build a multicore accessible board on which the FPGA can be seen as an "infinitely flexible peripheral," and, more importantly, build a tool to simplify the usage of FPGAs by less sophisticated engineers and makers.

The development of the tool, unfortunately, took longer than planned, with multiple prototyping iterations required to get the usability right. We are confident we've nearly solved the usability challenge and will release the tool later this year, initially as a beta to be followed by general availability when our users confirm if we've "cracked it."

EETE: How did you come up with the Arduino shield? Its shape could be replaced by the MKR.

Violante: The answer is very simple: We misplaced the connectors by accident, and this made it impossible for people to easily use the board on breadboards, but we had a huge batch of boards already manufactured. More importantly, though, I would like to highlight that the objective for the Arduino Uno board was to use the least amount of parts needed to make something useful, in contrast with development boards of that time that tended to be large, expensive, full of parts, and very complicated.

In order to make the board expandable, we came up with this idea of stackable modules, which would be easy to plug even for a beginner. The combination of Arduino-plus-shields enabled a lot of people to build applications quite quickly. This created an ecosystem of hundreds of manufacturers. The name "shield" was jokingly invented by [Arduino co-founder] David Cuartielles, starting from the fact that Arduino was the first king of Italy in the year 1000, so these modules would be the king's shields.

When the amount of Uno pins became a limiting factor, we introduced an additional connector on the Due/Mega form factor, and that is still a very widespread solution. As size constraints became an important consideration, many of our users were asking for a smaller form factor. We came out with the MKR family, which is more compact and introduces the concept of built-in communication modules.

With the Portenta form factor, we're evolving on from the MKR by adding two high-density connectors. These will ease usage in industrial applications, in which the board needs to be used as a module, by hosting as many as 160 pins to facilitate a multitude of interfaces for the user.

EETE: What are the programs for the Arduino integrated development environment [IDE]?

Violante: While we are committed to maintaining and improving the traditional Java Arduino IDE, we recently started the development of a more advanced environment called the Arduino Pro IDE. Many users over the years have manifested their desire to have advanced editing features like auto-completion of code and debugging capabilities. The new Pro IDE is now available and can be downloaded and alpha tested from the *arduino.cc* website.

Listening to the users' feedback, we created a CLI [command line interface] tool that implements all the "back end" functions of the Arduino IDE so that people can use whatever editor they like while effortlessly generating the same executables as the official IDE.

There is also an online version of the IDE, *create.arduino.cc*, available for people who like to develop in the cloud. It has already proved to be very popular and successful, with more than 1.3 million users to date.

EETE: Do you have any special collaborations planned? Other IoT boards? Artificial intelligence? Is anyone thinking of acquiring Arduino?

Violante: Sure, we are strengthening our technology partnerships with vendors of advanced technologies with the aim of democratizing access to sophisticated technology. We are going to make some important announcements in the forthcoming quarters.

Of course, Arduino is a popular platform, and we continuously receive interest from different companies and financial investors.

EETE: We know the difference with Raspberry Pi. Are you planning to create a similar board but with an Arduino OS, for example? What features of Raspberry Pi do you like and don't like?

Violante: Raspberry Pi had a tremendous impact on the world by making a powerful microprocessor available at a really low price. In this area, we really appreciate what they have done. We have a good relationship with them and have even embedded a Raspberry Pi into the Arduino Pro LoRa Gateway. As Arduino, we tend to stay close to the microcontroller world for the execution of real-time tasks, and we are evaluating multicore technologies combining MPUs and MCUs that will enable the best of both worlds, with emphasis on low power and industrial-readiness.

But we are not planning by any means to enter the low-cost Raspberry Pi space, where we recognize they have done a great job and they are continuing to democratize the access to powerful general-purpose Linux-based computers.

EETE: Can you envision the state of open-source hardware in 20 years?

Violante: I think open source is a great way to foster innovation, freedom, and creativity. As far as the business models are concerned, for sure, there will be some adjustments in the future because there is a bit of imbalance between people like us who spend a lot of time and energy designing the core technologies, writing tons of lines of code, firmware and libraries, and people who just take our designs and code, clone it as it is, and then release a cheaper product on the market. In many cases, [those products] violate our trademarks — for example, you cannot call a clone product Arduino Uno R3, even though you can build a legal clone identical to our Uno R3 — our USB identifiers, etc.

In most cases, while we have a lot of collaboration on the software side, we see very limited contribution back on the open-source hardware designs. At Arduino, we try to contribute a lot to existing projects. In the near future, we will be partnering with a number of other organizations to support the development of the most complex projects and will provide more visibility to the ones we deem important for the community.

As a final remark, I do believe that very likely combinations of SaaS [software as a service] and hardware revenue models will help sustain the open-source hardware companies.

EETE: What do you recommend to those who want to start an Arduino-driven startup?

Violante: Go for it! Of course, we encourage people when building their startups to keep leveraging Arduino as a prototyping tool, as a production tool, and eventually as an enabling IoT cloud.

I would suggest that startup [players] in this field carefully evaluate the challenges related to starting a manufacturing business from scratch. It can be very exciting but also quite daunting. As a possible alternative, we see a lot of startups embracing Arduino especially in areas where they have some value-added innovation in software, algorithms, and business models but they don't want to become experts in hardware. They tend to build products based on combinations of tried and tested Arduino modules plus a small percentage of custom hardware. This gives a much faster time to market, which is what a startup needs to achieve momentum.

EETE: I'd like your opinion on the impact of the COVID-19 coronavirus outbreak, which has disrupted the Chinese market. What is the impact on the electronics market, as China is a key market for global manufacturing?

Violante: At this point, we haven't seen any tangible impact from the coronavirus on our supply chain. Like the majority of companies in the electronics world, we depend on components that, in many cases, are supplied by Chinese factories; hence, we may expect some shortages in the future. We have received some advisory notes from distributors in the supply chain about potential minor slowdowns in supply, but we believe they will not substantially affect our ability to deliver.

We continue monitoring the situation, and we are putting in place some countermeasures to mitigate the effects. ■

Maurizio Di Paolo Emilio *is a staff correspondent at AspenCore, editor of Power Electronics News, and editor-in-chief of EEWeb.*

OPINION

AI Developers Unleash Its Confounding Clarity

By David Benjamin

'I don't understand why we're spending all this money on artificial intelligence when we can get the real thing for free.' — JOHN M. KETTERINGHAM

The current artificial-intelligence algorithms for facial recognition appear to have the scientific rigor and social sensibility of a Victorian eugenics quack. However, this judgment would not do justice to the army of eugenics quacks who operated (often literally, tying tubes and performing lobotomies) from the 1890s well into the 1930s, because they were driven by a deep-seated racist bigotry.

The National Institute of Standards and Technology (NIST) recently completed a massive study, finding that state-of-the-art facial-recognition systems falsely identified African American and Asian faces 10 to 100 times more than Caucasian faces. "The technology," noted the New York Times, "also had more difficulty identifying women than men." It proved uniquely hostile to senior citizens, falsely fingering older folks up to 10 times more than middle-aged adults.

An earlier study at the Massachusetts Institute of Technology found that facial-recognition software marketed by Amazon misidentified darker-skinned women as men 31% of the time. It thought Michelle Obama was a guy. (Since then, Amazon — along with Apple, Facebook, and Google — is refusing to let anyone test its facial-recognition technologies.)

Unlike the eugenicists and phrenologists of old, facial-recognition algorithms are racist without preconception or bigotry. A closer analogy would be to compare them to German concentration-camp guards, who — when tried for war crimes — advanced the argument that they were not motivated by race hatred. They were simply following orders. They had no opinion either way.

This analogy also fails because the guards were lying. Algorithms can't lie. Algorithms don't think; you can't have a conversation with one. They have no opinions. In this respect, algorithms are inferior to dogs. I've had conversations — largely one-sided but strangely edifying — with dogs, and I've gotten my point across. Moreover, dogs have opinions. They like some people and dislike others, and their reasoning for these preferences is often evident.

Algorithms might someday form viewpoints. But, as sci-fi prophets Arthur C. Clarke and Philip K. Dick have intimated, this might not be a welcome breakthrough. If you recall, in the film "Blade Runner," based on Dick's novel, "Do Androids Dream of Electric Sheep?," Harrison Ford makes little headway when he tries to persuade a couple of highly opinionated replicants named Roy and Pris that they ought to cheerfully acquiesce to their own destruction. Instead, they try to kill him.

Luckily, our technology has yet to create artificial intelligence as balky as Roy, Pris, HAL 9000 ("2001: A Space Odyssey"), and the devious Ash in "Alien." A more accurate movie parallel — I think about these things — might be Joshua, the WOPR electronic brain in "War Games." Joshua had enough power and speed to simulate a million H-bomb scenarios in a minute or so but could not be swayed, by reason and evidence, that the very concept of global thermonuclear war was futile and — at bottom — evil. Joshua arrived at this purely pragmatic conclusion only after processing several yottabytes of data and blowing every fuse at NORAD.

Data, not persuasion, convinced Joshua not to end the world. Conversely and perversely, there are intelligent humans who could not be similarly convinced, regardless of the volume of data provided. Some zealots today cling implacably to the belief that a nuclear war can be won and that several billion human lives is a tolerable price to pay for that sweet victory.

This sort of wrongheaded but thoroughly human opinion is unattainable in any foreseeable iteration of algorithms. It will be undesirable when it becomes possible. And it will be easier to accomplish with nuclear holocaust than with facial recognition.

The human face is vastly more varied than the face of war. There is no extant algorithm that can master all its nuance, expression, and mutability, nor does that magic formula seem imminent. In the meantime, facial-recognition technology will be only as objective and accurate as the humans who are creating it. This means that facial AI today is both as racist as the Ku Klux Klan and as innocent of racism as a newborn baby. And we don't know when it will be which.

Because AI is so impenetrably neutral, so passively absorptive of the data fed into it, it cannot help but reflect the biases — conscious or oblivious — lodged in the hearts and minds of its human developers. It will have opinions without knowing how to form an opinion. The consequences are both ominous and familiar.

Throughout human history, bigots have been influencing — often dictating — public life. Now, naively, we have well-meaning technologists creating surveillance devices that can't tell girls from boys, Asian grannies from crash-test dummies, or criminals from saints.

The unaccountable purveyors of these astigmatic robo-spies — namely, Amazon, Apple, Facebook, and Google — are putting them into the hands of agencies with the power to assemble dossiers, issue subpoenas, kick open doors, deny bail, put people in jail, and throw children out of the country.

It's been argued that studies evaluating facial-recognition AI are flawed only because the samples have been too small. But the NIST study was huge. It tested 189 facial-recognition algorithms from 99 developers. And it found, like every previous study, that features as basic as five o'clock shadows, comb-overs, skin tone, and makeup tend to befuddle the algorithm.

Police and prosecutors are coming around to the realization that eyewitness identification is an unreliable tool for solving crimes because it is fraught with haste, myopia, fear, prejudice, and a host of other human flaws. We're learning now that the algorithms devised to digitally correct this sort of mortal error are as prone to the same emotions, bigotry, and malice as any bumbling eyewitness. This is true because we can't help but make our machines in our own malleable and elusive image. ■

David Benjamin *is a novelist and journalist who splits his time between Paris and Madison, Wisconsin. For more of his work, visit* lastkidbooks.com.

IMAGE: SHUTTERSTOCK

MOTOR CONTROL DESIGN

Microstepping for High-Performance Motion Control

By Maurizio Di Paolo Emilio

Stepper motors are brushless synchronous electric motors powered by direct current that rotate in steps, keeping the rotor stationary under a specific power supply. Pulse-width–modulated (PWM) pulses, sent in a well-defined sequence via electronic drivers, turn the stepping motor in one direction.

Stepper motors exhibit a special feature: the ability to rotate the rotor shaft by a few degrees very precisely and without the need for sensors to detect the shaft's angular position. In short, a complete revolution of the motor can be divided into a certain number of steps. The stepper motor's width determines the number of steps.

Inside a stepper motor, there are several windings/coils arranged circularly on the stator that operate like an electromagnet. The stator converts the magnetic field to electric current. The number of steps declared by the manufacturer corresponds to the number of groups of coils (called phases) electrically connected to each other. Within each group, there are several pairs of coils in parallel. Each coil pair is arranged and electrically connected around the stator. Each phase is activated in sequence to allow the motor to rotate, one step at a time.

The stepper motor operates with accurate positioning and speed control by synchronizing with the pulse signal output from the microcontroller to the motor driver. The motor driver reacts to the microcontroller's signals by delivering power pulses to the stepper motor at the output.

The stepper motor is operated by electrical impulses that feed a part of the stator in sequence. The sequence with which the stators are excited determines the direction of rotation. Through the technique of microstepping, it is possible to obtain a more fluid and linear movement and better positioning. There are different microstepping modes, with lengths from 1⁄3-full-step to 1⁄32-full-step.

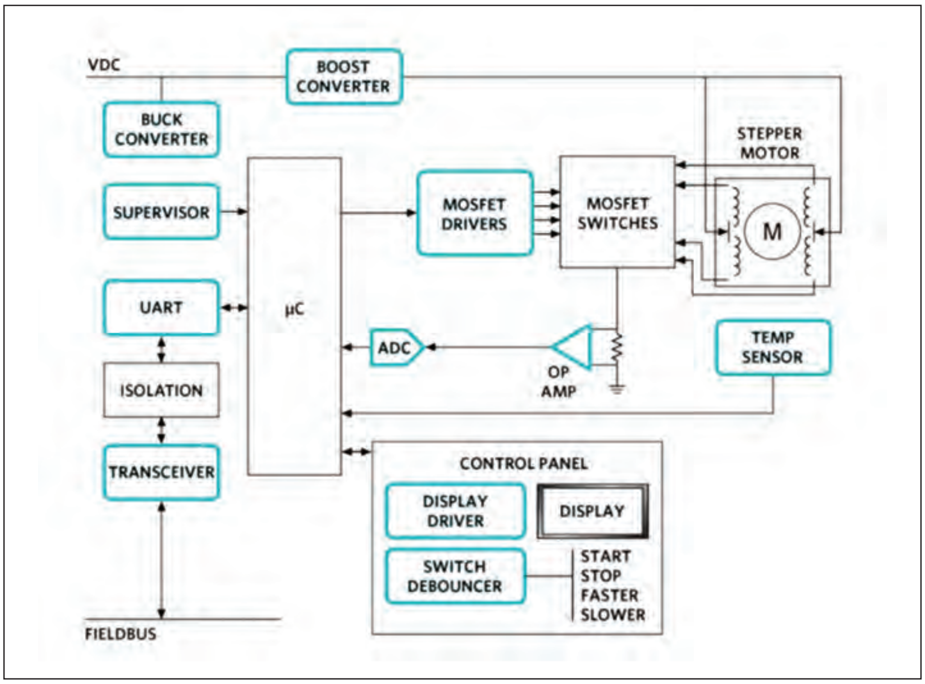


Figure 1: *Electrical diagram of a stepper motor and main components* (Image: Maxim Integrated)

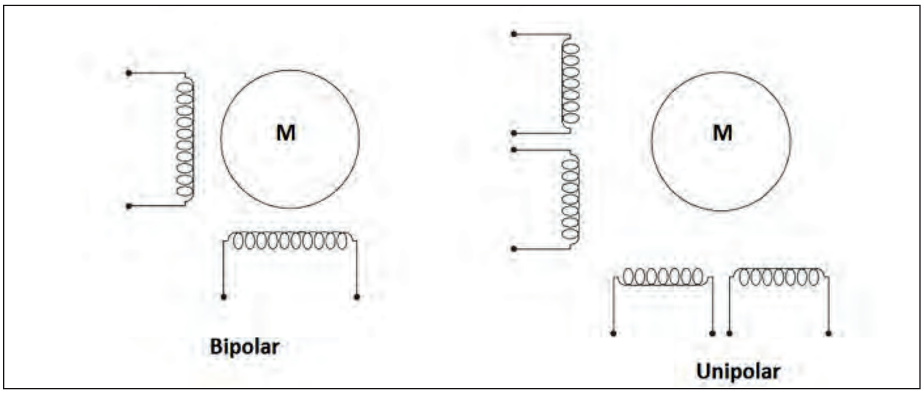


Figure 2: *Generic layout of a bipolar and unipolar motor* (Image: Maxim Integrated)

DRIVERS FOR STEPPER MOTORS

The stepper motor forms an incremental motion drive. With every command pulse that reaches the system, the motor completes a finite rotation. The rotation is achieved by powering the phases in a given sequence and with a given current direction (**Figures 1** and **2**).

There are different stepper motor configurations and even more ways to drive them. The most common stator configuration is two coils. These are arranged around the stator's circumference in such a way that when driven with square-wave signals, the motor turns. To turn the motor in the opposite direction, simply reverse the ratio between phases A and B of the signals.

The main applications for stepper motors are robots, office automation (OA) equipment, and medical/nursing equipment, which require motors with superior precision motor control and better resistance to environmental influences. Motor control solutions such as resolvers and encoders are used to optimize the movement and guarantee the correct position of the motors.

Stepper motors with a resolver enable high-precision motor control even in harsh environments with heat, dust, or vibration and maximize the available torque. The resolver is a type of inductive displacement transducer — an electromechanical device for the measurement of angular displacement. The device detects the variation of magnetic induction flux in the solenoid.

As an example, Renesas Electronics Corp. has developed a resolver-to-digital converter (RDC) that supports MinebeaMitsumi's new

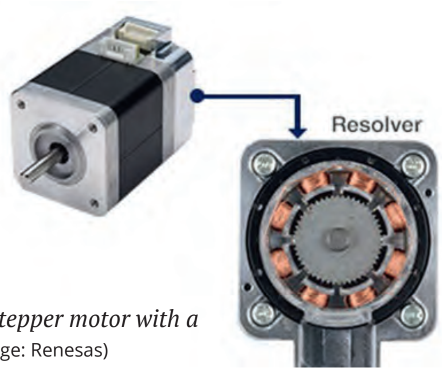


Figure 3: *Stepper motor with a resolver* (Image: Renesas)

stepper motors, as well as control driver software for controlling the RDC with a 32-bit RX MCU. Renesas and MinebeaMitsumi have developed sensor-based stepper motors and motor control solutions that meet extreme-precision application requirements in harsh environments (**Figure 3**).

Toshiba Electronic Devices and Storage Corp.'s driver solutions incorporate Active Gain Control (AGC) technology, which detects the motor load torque and automatically optimizes the motor drive current. This prevents a motor from slipping while simplifying high-efficiency motor control.

Maxim Integrated offers the MAX15024/MAX15025 MOSFET gate drivers, which are suitable for high-frequency and high-power circuits capable of operating at frequencies up to 1 MHz with large capacitive loads. The MAX15024 can absorb a peak current of 8 A and generate a peak current of 4 A. An integrated adjustable LDO voltage regulator provides gate-drive amplitude control and optimization.

Infineon Technologies AG offers the TLE 8444SL, a protected quad-half-bridge IC for automotive and industrial motion control applications based on the company's intelligent mixed-technology SPT, which combines bipolar and CMOS control circuits with DMOS power devices. The PG-SSOP-24-7 package is advantageous, as it saves space and costs on the PCB. Integrated protection and diagnostic functions improve system reliability and performance.

MICROSTEPPING

Stepper motors can perform positioning with higher resolution than a full step when combined with drivers capable of electronically splitting the mechanical step of the motor. Microstepping is used to achieve higher stepper motor resolution, offering smoother movement at low speeds.

For example, a stepper motor with a pitch angle of 1.8° results in a rotation of 200 steps (resolution) for each complete revolution of the motor (360 ÷ 1.8). Because of this discrete movement, the motor rotation is not perfectly smooth.

A reduction in the size of the motor steps using the microstepping technique can deliver smoother movement at low speeds. The microstepping control divides each complete step into smaller values: For example, a 1.8° pitch can be divided up to 256 times, providing a pitch angle of 0.007° per revolution.

This data indicates the resolution of the position and not its accuracy, which depends on the electromechanical precision of the engine, as shown in the engine's specifications (5% for good-quality hybrid engines).

Microstepping uses PWM voltage to control the motor current. While the current in one winding increases, the other decreases. This results in a smooth movement. Microstepping is sometimes considered a good alternative to mechanical gears because it does not introduce kickback into the system or reduce the maximum system speed (**Figure 4**).

Microstepping makes it possible to obtain a wide range of intermediate positions between two steps. The closer the rotor is to a position of equilibrium, the greater the current will be in the corresponding phase.

Microstepping is more energy-efficient and uses smaller, more frequent pulses, allowing stepper motors to reach slightly higher speeds than usual. The compromise is that the motor torque is often reduced slightly.

There is a variety of integrated microstepping motor drivers available in the market. One solution is Allegro MicroSystems' A4988 DMOS microstepping motor driver with an output drive capacity of up to 35 V and ±2 A. The A4988 is supplied in a surface-mount, 5 × 5-mm, QFN package and offers the ability to operate in slow or mixed-decay mode. Mixed-decay current control reduces audible motor noise, increases pitch accuracy, and reduces power dissipation (**Figure 5**).

Another example is the L6470H dSPIN driver for microstepping from STMicroelectronics. Built on analog mixed-signal technology, the microstepping driver integrates a dual low-$R_{DS(on)}$ DMOS bridge

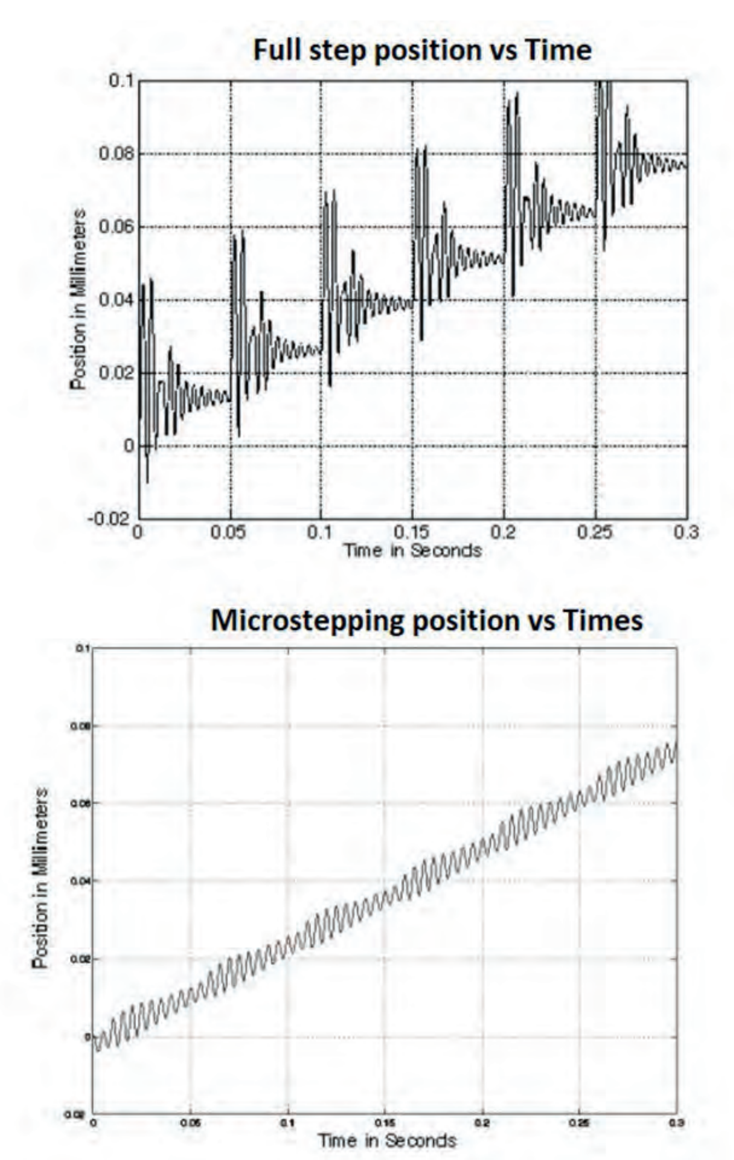


Figure 4: *Microstepping significantly reduces position oscillation in the motor.* (Image: Dover Motion)

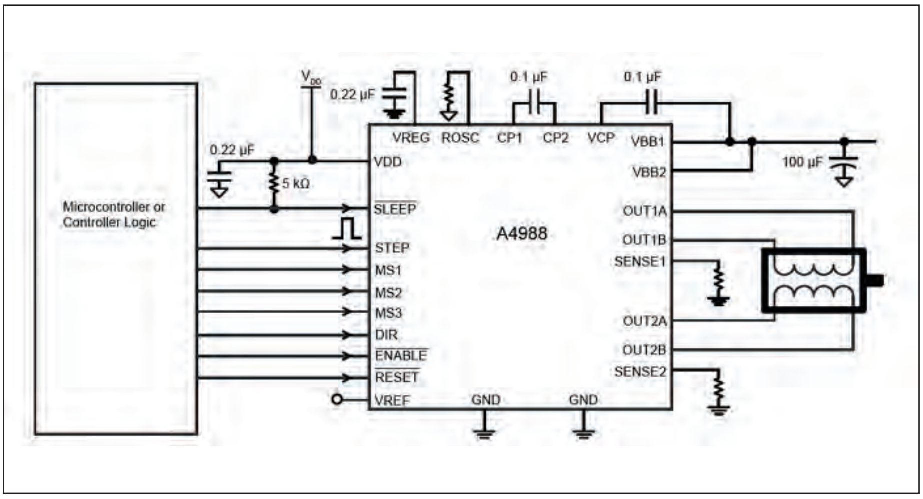


Figure 5: *Typical application diagram* (Image: Allegro Microsystems)

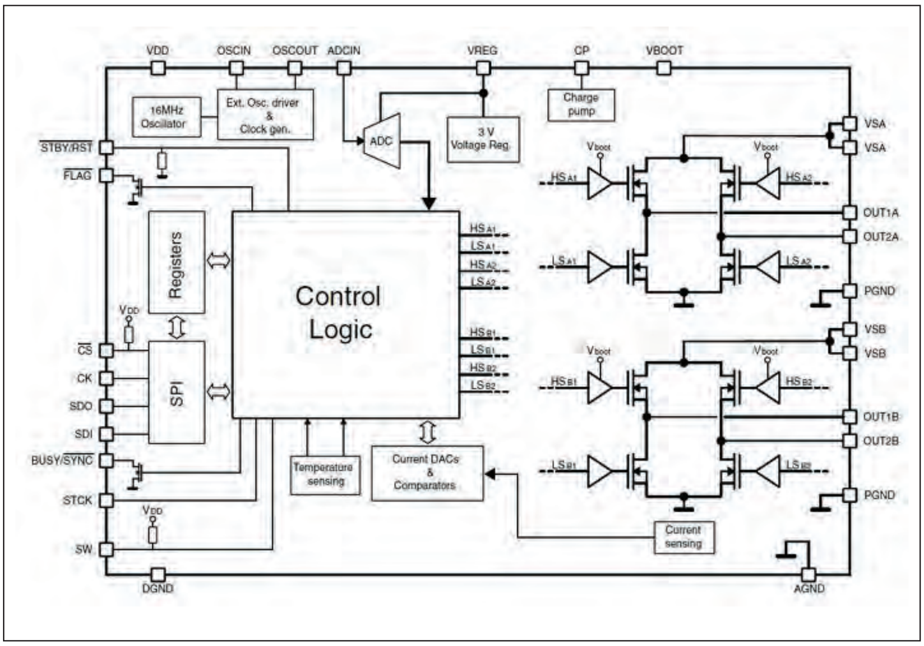


Figure 6: *Circuit diagram of the L6470H* (Image: STMicroelectronics)

complete with accurate current-sensing circuitry and overcurrent protection.

The digital control core of the L6470H is programmed through a dedicated set of registers. It includes protection circuitry, delivering a fully protected design as required by the most demanding motor control applications (**Figure 6**).

The DRV8880 and DRV8881 motor drivers with AutoTune technology developed by Texas Instruments eliminate complex and tedious manual circuit adjustments, which often require several weeks of design and optimization, by automatically tuning the stepper motors for optimal current regulation performance while compensating for motor variation and aging effects.

Drivers with AutoTune technology are able to configure off-time PWM modulation with microstepping above 1/16 step. They can be connected in parallel to obtain higher output currents, and in the case of the DRV8880, an internal DAC controls load torque.

Stepper motors can be controlled with a digital circuit, such as a microcontroller, with great ease and precision without requiring devices that detect angular position. Microstepping is used to achieve higher resolution, higher energy efficiency, and smoother motion at low speeds. It delivers a more linear operation, eliminating step noise and resonance issues.

However, the use of microstepping can reduce torque by up to 30%. Thus, it will be necessary to evaluate the electrical specifications of the motor to select the right driver. ■

Maurizio Di Paolo Emilio *is a staff correspondent at AspenCore, editor of Power Electronics News, and editor-in-chief of EEWeb.*

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Aspencore Media GmbH
Rauwagnerstr. 5
85560 Ebersberg / Germany

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CONTRIBUTING EDITORS
George Leopold, *gleopold@gmail.com*
Ann Thryft, *athryft@earthlink.net*

STAFF CORRESPONDENTS
Matthew Burgess, *matthew.burgess@aspencore.com*
Anthea Chuang, *anthea.chuang@aspencore.com*
Nitin Dahad, *nitin.dahad@aspencore.com*
Maurizio Di Paolo Emilio, *maurizio.dipaolo@aspencore.com*
Yvonne Geng, *yvonne.geng@aspencore.com*
Amy Guan, *amy.guan@aspencore.com*
Susan Hong, *susan.hong@aspencore.com*
Illumi Huang, *illumi.huang@aspencore.com*
Barbara Jorgensen, *barb.jorgensen@aspencore.com*
Clover Lee, *clover.lee@aspencore.com*
Shao Lefeng, *lefeng.shao@aspencore.com*
Jenny Liao, *jenny.liao@aspencore.com*
Elaine Lin, *elaine.lin@aspencore.com*
Luffy Liu, *luffy.liu@aspencore.com*
Challey Peng, *challey.peng@aspencore.com*
Gina Roos, *gina.roos@aspencore.com*
Fendy Wang, *fendy.wang@aspencore.com*
Sally Ward-Foxton, *sally.wardfoxton@aspencore.com*
Demi Xia, *demi.xia@aspencore.com*
Franklin Zhao, *franklin.zhao@aspencore.com*
Momo Zhong, *momo.zhong@aspencore.com*

COPY AND DESIGN
Adeline Cannone, Design Director, *adeline@cannone.com*
Lori O'Toole, Chief Copy Editor, *lotoole@aspencore.com*
Diana Scheben, Production Chief, *diana.scheben@aspencore.com*

TECHNICAL AND ADMINISTRATIVE SERVICES
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The Hufmann Agency, *victoria@hufmann.info, norbert@hufmann.info*
Todd Bria, *todd.bria@aspencore.com*

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Technical Magazine for the Embedded Systems Designer March 2020

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COVER STORY

Open-Source Platform for Industry 4.0

By Maurizio Di Paolo Emilio

The Intelligent Condition Monitoring Box (iCOMOX) is an open-source development platform for condition-based monitoring of equipment, assets, and industrial facilities. The goal of the board is to monitor operating conditions at the equipment surface to identify potential failures and reduce the risks associated with equipment operation and maintenance. Condition-based monitoring extends equipment operating life while minimizing unplanned downtime and maintenance costs. The open-source platform thus advances the goal of Industry 4.0 automation to increase production efficiency through digital solutions.

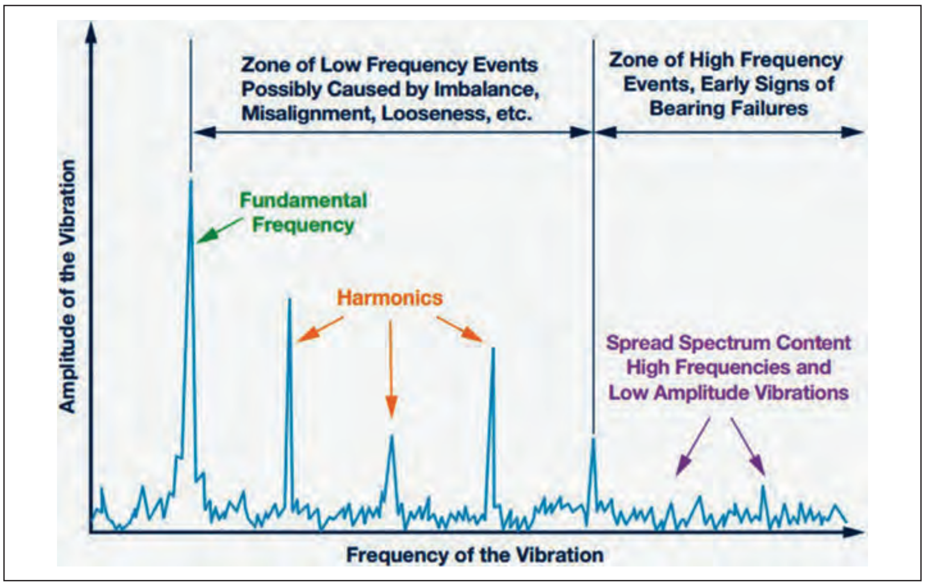


Figure 1: *Vibration frequency analysis for fault detection* (Image: Analog Devices)

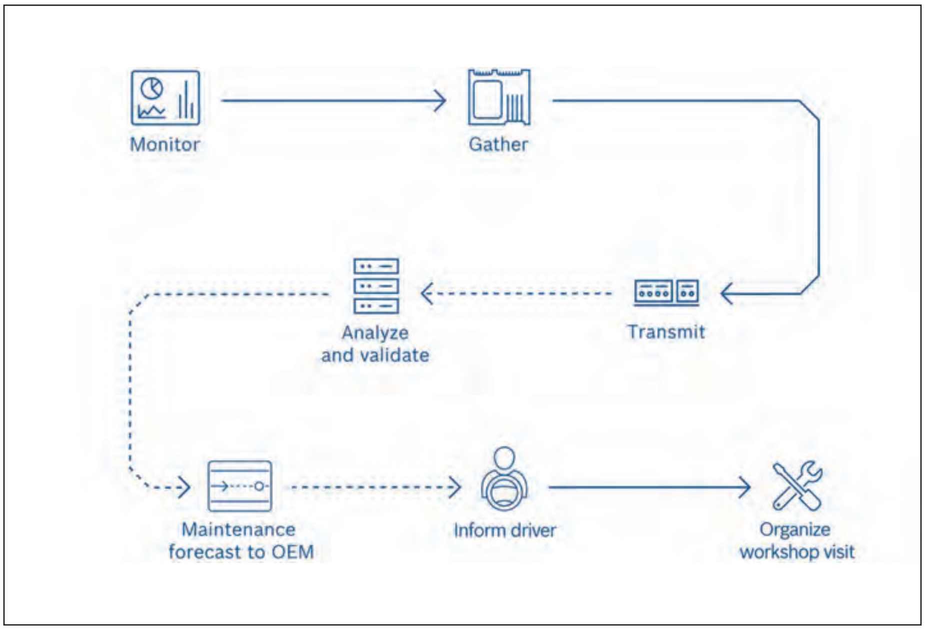


Figure 2: *Predictive maintenance* (Image: Bosch)

PREDICTIVE MAINTENANCE FOR INDUSTRY 4.0

Predictive maintenance is a true strategy, supported by intelligent IoT sensors and embedded control solutions that offer advanced business models to create additional value between company and customer and achieve significant maintenance cost savings. Sensors can be used to monitor key equipment continuously, and production data can be recorded and wirelessly transmitted in real time to the cloud for predictive-maintenance analysis to optimize flow and enhance security. Consulting firm McKinsey & Co. estimates that effective use of predictive maintenance in factories can reduce downtime by up to 50% and save 10% to 40% on equipment maintenance costs.

Predictive-maintenance environments include a platform to model, simulate, test, and deploy the solution. The tools include industrial data-integration and -analysis algorithms to detect patterns in machine data and root-cause–analysis tools to determine the corrective action to be taken.

Vibration, temperature, and pressure are just some of the parameters that can indicate equipment status and identify potential failures (**Figure 1**). Monitoring techniques are normally used on equipment such as compressors and pumps.

Because vibration is the most common symptom of imbalance, misalignment, and other anomalies, predictive maintenance is

Figure 3: *The iCOMOX kit*
(Image: EE Times Europe)

Figure 4: *The card (top) and the wireless hub for SmartMesh control*
(Image: EE Times Europe)

often based on vibration analysis of rotating machinery. Temperature sensors, meanwhile, monitor critical machine parts to detect changes in operating conditions.

Oil particle sensors monitor the level of particle contamination in lubrication systems; an increase in the number of particles can indicate machinery wear and tear. And current sensors monitor the power consumption of machine components. A typical application is monitoring the current consumption of a motor to gauge wear.

In addition to sophisticated industrial sensors, the implementation of a predictive maintenance model requires control technologies (often through production control software). The acquired data is sent to a programmable logic controller (PLC) via IO-Link or other control systems, with the aim of intelligently managing current and future machine operations (**Figure 2**).

Let's review the Shiratech iCOMOX board in collaboration with Arrow.

BOARD DETAILS

The elegantly presented iCOMOX kit provides two devices: the real board and the control hub (dongle) for SmartMesh wireless communication. The connection cable for firmware upgrade and the support structure for optimal mounting are included (**Figures 3** and **4**).

The platform is equipped with vibration,

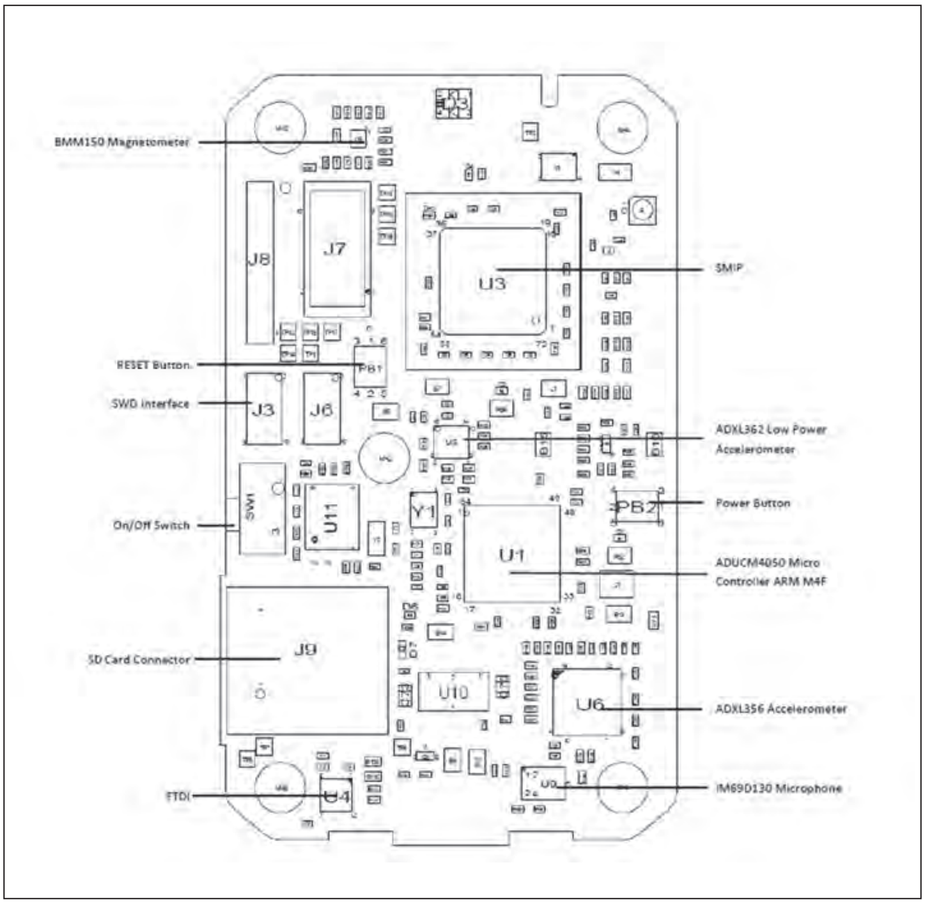


Figure 5: *Arrangement of sensors and components on the iCOMOX board* (Image: Shiratech)

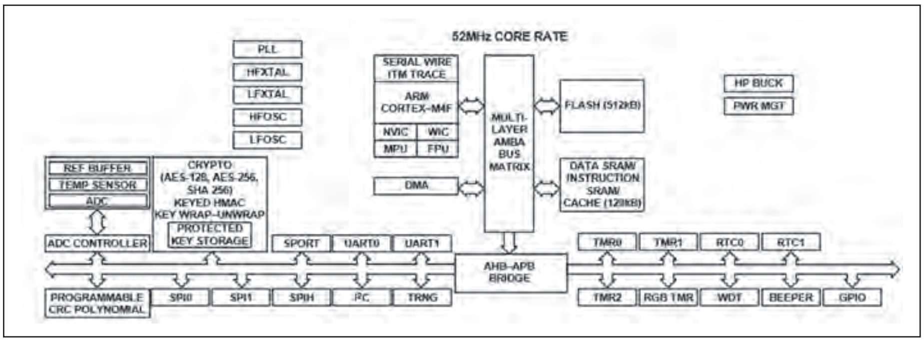


Figure 6: *Block diagram of the ADuCM4050* (Image: Analog Devices)

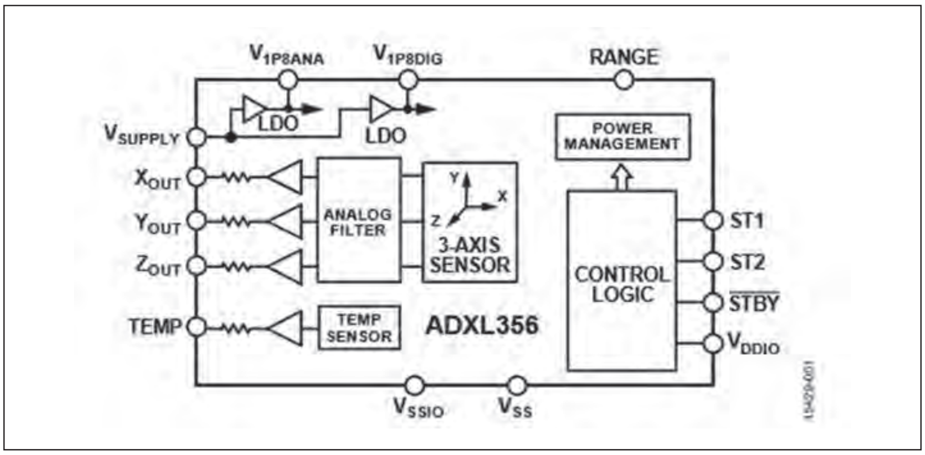


Figure 7: *Block diagram of the ADXL356 vibration sensor* (Image: Analog Devices)

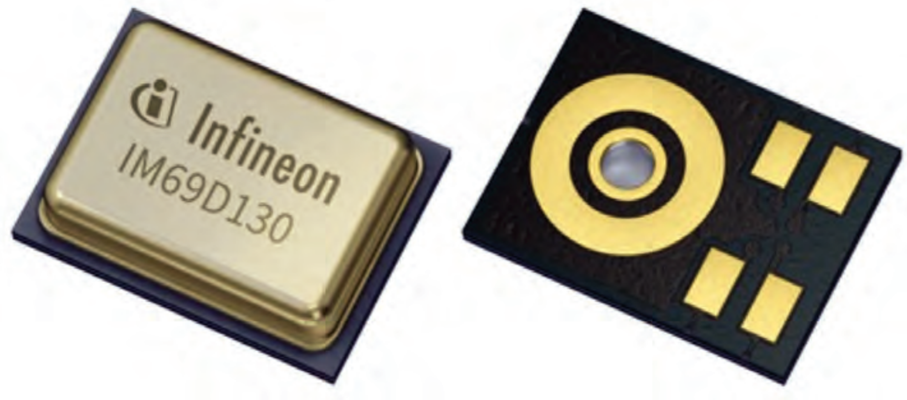


Figure 8: *The IM69D130 digital microphone* (Image: Infineon Technologies)

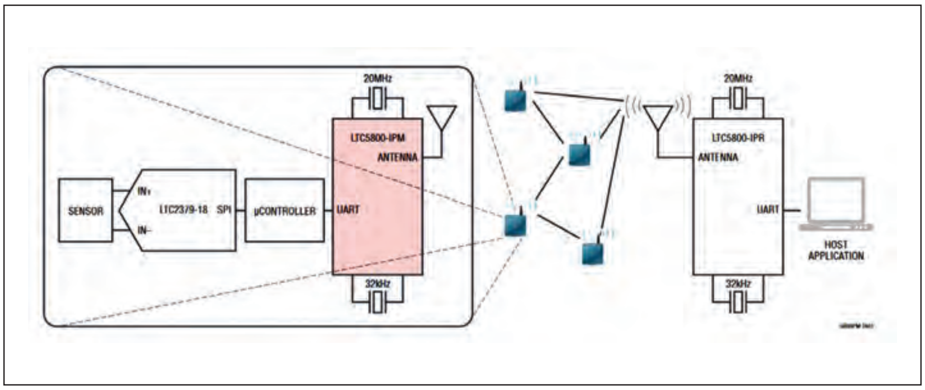


Figure 9: *SmartMesh network* (Image: Analog Devices)

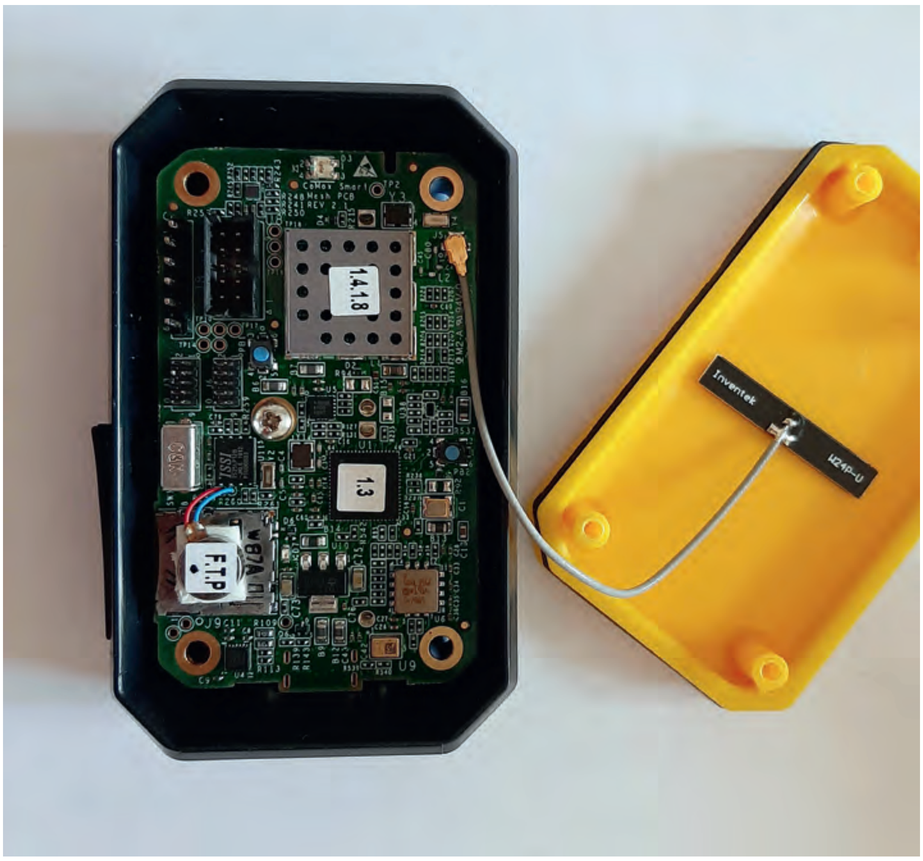


Figure 10: *Inside of the board with electronics on the left and SmartMesh antenna on the right* (Image: EE Times Europe)

magnetic-field, temperature, and audio sensors (**Figure 5**). It provides a wide dynamic range and an exceptional signal-to-noise ratio (SNR) for vibration analysis. In addition, it enables noise-emission detection and current analysis in motors to avoid overheating. SmartMesh communication enables low-power wireless communications. The board offers the ability to configure warning and alarm levels for each sensor. A compact form factor and CE and FCC certification round out the features.

At the heart of the system is an Analog Devices ADuCM4050 ultra-low-power Arm Cortex-M4F processor with integrated power management through SensorStrobe technology. The MCU also has a collection of digital peripherals, SRAM and built-in flash memory, and an analog subsystem that provides clocking, reset, and power management capabilities. An analog-to-digital conversion (ADC) subsystem is provided with a 12-bit successive approximation register (SAR) ADC and a 1.8-Msps, eight-channel converter for data acquisition (**Figure 6**).

The Arm Cortex-M4F processor, with up to 52-MHz performance and 512 KB of built-in flash with error correction code (ECC), offers an optional 4-KB cache for less active power and 128 KB of system SRAM with parity. The ADuCM4050 features cryptographic hardware that supports Advanced Encryption Standard (AES)-128 and AES-256 with Secure Hash Algorithm (SHA)-256 and the following modes: electronic code book (ECB), block encryption (CBC), counter (CTR), and block encryption (CCM/CCM).

The vibration sensor is an Analog Devices ADXL356 with a low-noise microelectromechanical system (MEMS) accelerometer (**Figure 7**). The IC offers excellent long-term stability from –40°C to 125°C. A Bosch BMM150 three-axis magnetic-field sensor provides absolute spatial orientation and motion vectors with high accuracy and dynamics.

Infineon Technologies' IM69D130 is a high-performance digital MEMS microphone that uses Infineon's Dual Backplate MEMS technology to provide a dynamic range of 105 dB and output linearity of up to 130 dBSPL (**Figure 8**). The results are crystal-clear audio signals, extended reception distance, and sensitivity to both soft and loud signals — from whispered speech to rock concerts.

The temperature sensor used in the platform is Analog Devices' ADT7410, with ±0.5°C accuracy and 16-bit resolution. It measures temperatures ranging from –55°C to 150°C.

The board offers data sharing and management through SmartMesh networks via the dongle and Analog Devices' LTC5800. The

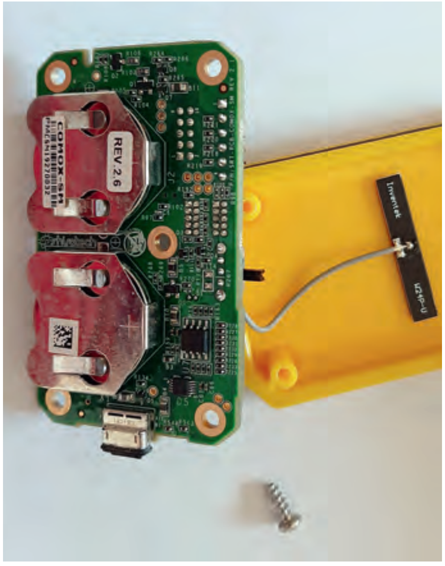


Figure 11: *The coin-cell batteries powering the board* (Image: EE Times Europe)

LTC5800-IPM system-on-chip, with a highly integrated, low-power radio design from Dust Networks and a 32-bit Arm Cortex-M3 microprocessor, allows the SmartMesh IP networking software to be run. The LTC5800-IPM SoC integrated into the board features a chip power amplifier (PA) and transceiver so that decoupling the power, crystals, and antenna with matching circuits is all that is required to create a complete wireless node.

SmartMesh IP, based on IPv6 over Low-Power Wireless Personal Area Networks (6LoWPAN), offers wireless mesh networks that are similar in reliability to wired solu-

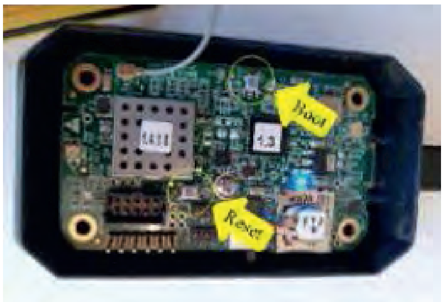
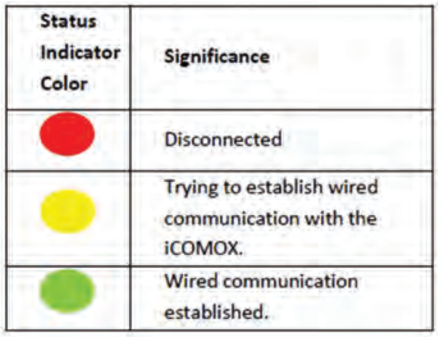


Figure 12: *The control buttons on the board for firmware installation* (Image: Shiratech)



Status Indicator Color	Significance
	Disconnected
	Trying to establish wired communication with the iCOMOX.
	Wired communication established.

Figure 13: *Explanation of the LED status indicators on the board* (Image: Shiratech)

Open-Source Platform for Industry 4.0

Figure 14: *The iCOMOX board connected to the USB port* (Image: EE Times Europe)

Figure 15: *The dongle connected to the USB port for SmartMesh communication with the board* (Image: EE Times Europe)

tions and are very low-power, enabling the safe implementation of battery-powered IoT sensors in harsh environments with a battery life of more than 10 years. Thousands of SmartMesh IP Blink nodes can reliably and securely send data to a SmartMesh network in mesh mode, consuming, on average, less than 3 µA of power. SmartMesh networks automatically perform creation, troubleshooting, and optimization while providing U.S. National Institute of Standards and Technology (NIST)-certified security (**Figure 9**).

The board also features an ultra-low-power, low-g ADXL362 three-axis MEMS accelerometer from Analog Devices for unlocking additional system-level power savings and an auxiliary port for connecting additional sensors. An optional Micro SD Card allows data storage with the possibility of offline analysis. Two CR2477 coin-cell batteries offer a longer life. The graphical user interface allows sensor management and fast Fourier transform (FFT) analysis where required. Cloud connectivity via an optional SmartMesh IP gateway or USB network manager offers cloud application implementations and advanced analysis (**Figures 10** and **11**).

FIRMWARE

The software installation is essentially a two-part process comprising installations of the firmware and of the control interface for analysis and data acquisition. The company provides a software development kit (SDK) package that can be downloaded at *shiratech-solutions.com/products/icomox/*. From this link, it is also possible to download all the documentation.

It is important to install the iCOMOX Flash Programmer, a Windows utility for programming the flash memory of the iCOMOX via the USB-C port. The utility is based on Analog Devices' CrossCore Serial Flash Programmer. Before installing the flash programmer, you will need to install the FTDI drivers, downloadable from the network. After performing the various steps for the final installation, you can open the board, as shown in **Figures 10** and **12**.

Locate the BOOT and RESET buttons on the iCOMOX and perform this sequence: Hold down both the BOOT and the RESET buttons, release the RESET button, and then release the BOOT button. Launch the iCOMOX Flash Programmer. Select the suitable COM port (USB serial port) from the drop-down menu and click Start after selecting the hex file to upload.

If the flashing was successful, "Done" will appear at the end of the status report. To verify that the flashing was successful, confirm that the Information tab displays the correct firmware version. Restart the iCOMOX by clicking the RESET button on the iCOMOX or by disconnecting the USB cable and switching the iCOMOX switch off and then back on.

Once those steps are completed, install the iCOMOX Monitor. Connect the iCOMOX board using the USB cable and launch the iCOMOX Monitor. The LED light should turn green after a short vibration. Remember to press the power switch located near the Micro SD slot (**Figures 13**, **14**, and **15**).

The interface is shown in **Figure 16** for directly connecting the board to the USB port or for connecting by means of the dongle. For the latter case, it is advisable to select the COM port with the highest number (**Figures 16**, **17**, and **18**). Then select the board to acquire.

The platform involves the use of multiple boards for different control stations. In the

Open-Source Platform for Industry 4.0

Figure 16: *The iCOMOX interface*
(Image: EE Times Europe)

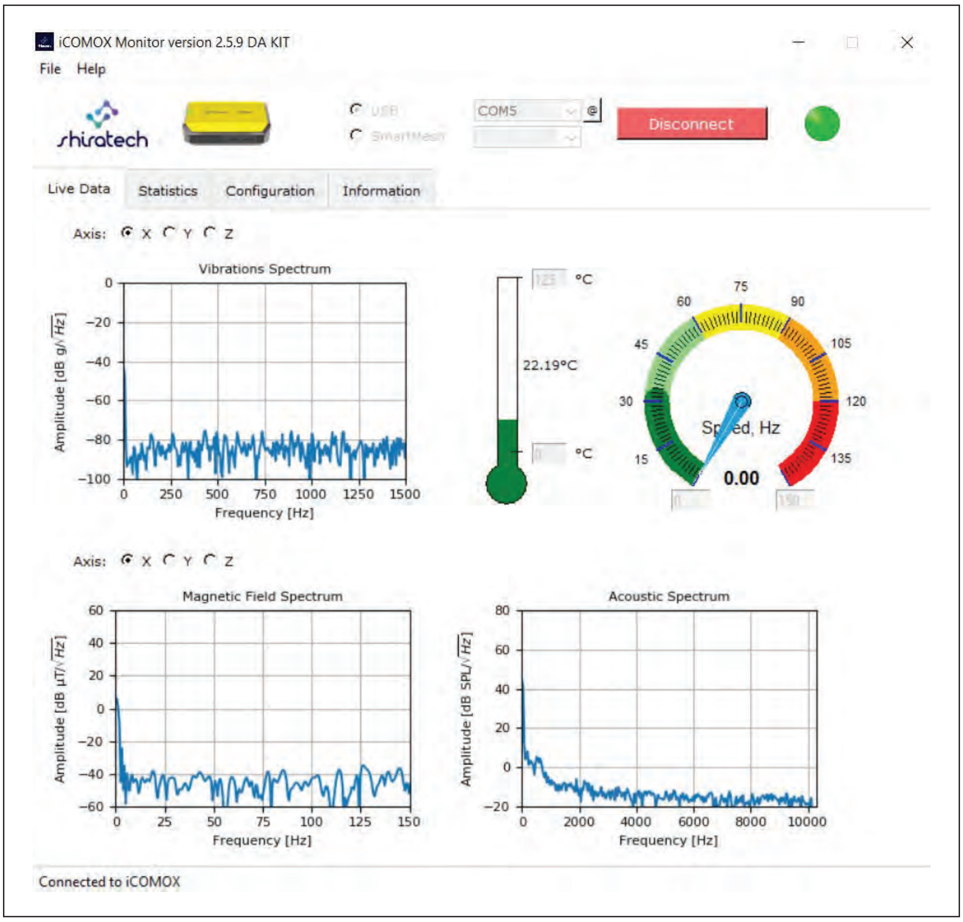


Figure 17: *The iCOMOX interface during data acquisition*
(Image: EE Times Europe)

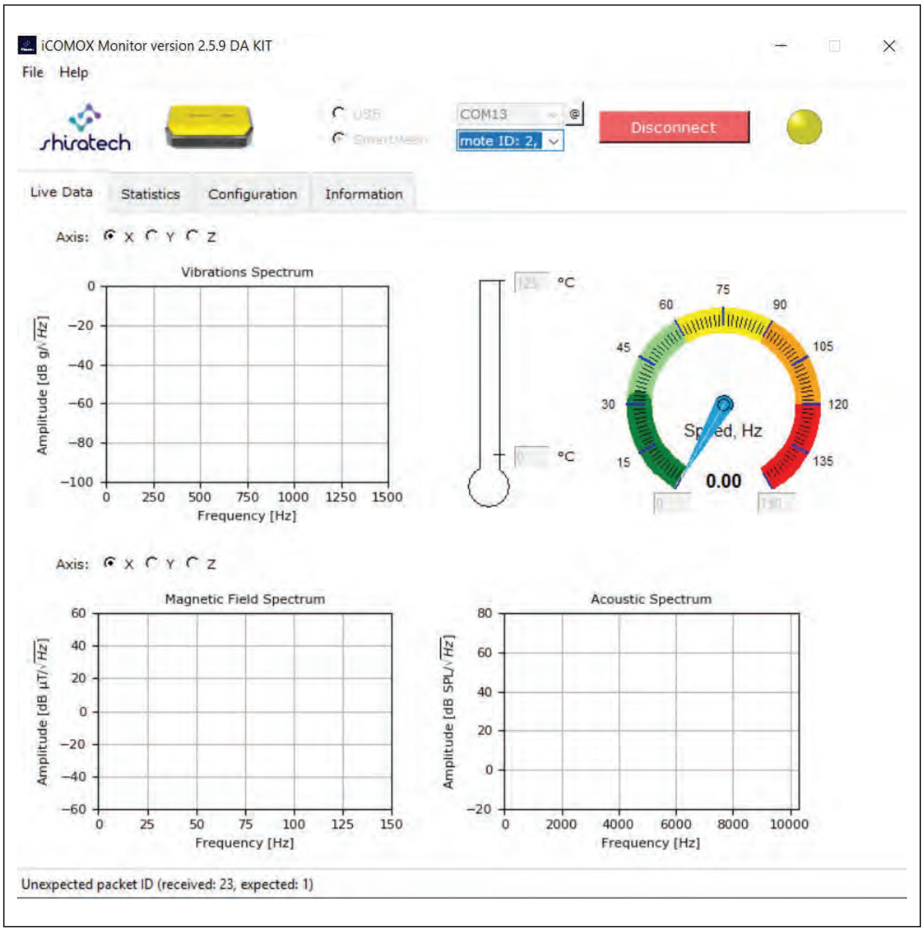


Figure 18: *The iCOMOX interface with the dongle* (Image: EE Times Europe)

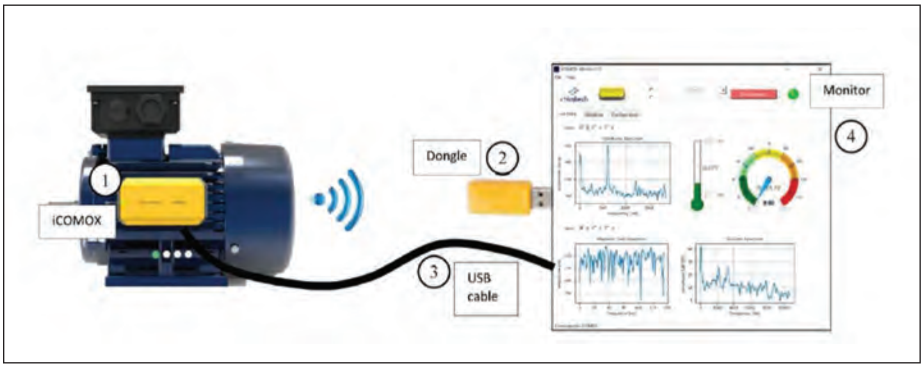


Figure 19: *Application example of the motor control board* (Image: Shiratech)

interface, you can easily identify vibration acquisition, temperature, and magnetic field.

APPLICATIONS

Predictive maintenance reduces the time needed to repair or recondition plant equipment in sectors such as transport, production machinery, and energy plants (**Figure 19**). Artificial intelligence can be applied to predictive maintenance and many other use cases in manufacturing, supporting Industry 4.0.

Shiratech's iCOMOX open platform — built with leading-edge Analog Devices technologies in sensing, ultra-low-power signal processing, communication, and power management — offers an easy-to-use solution for monitoring conditions from the surface of the equipment. With fully integrated vibration, magnetic-field, temperature, and audio sensors, iCOMOX provides early detection of machine failures in condition-based monitoring applications. The iCOMOX data acquisition kit and SDK help developers quickly create intelligent monitoring solutions. ■

Maurizio Di Paolo Emilio *is a staff correspondent at AspenCore, editor of Power Electronics News, and editor-in-chief of EEWeb.*

HIGH-PERFORMANCE COMPUTING

Quantum Computer Design: Electronic Circuits

By Maurizio Di Paolo Emilio

Qubits are "bits" of information for quantum systems and some elements of quantum mechanics. But how are qubits physically realized? How can electronics manage elements that belong to a quantum ecosystem? In this article, we will carve a path to explain all you need to know about digital quantum electronics.

QUBITS

The classic computer bits are 0 and 1, and two bits form four possible states: 00, 01, 10, 11. In general, with *n* bits, you can build *2n* distinct states. How many states can you get with *n* qubits? The space of the states generated by a system of *n* qubits has dimension *2n*: Each vector normalized in this space represents a possible computational state, which we will call quantum register of *n* qubits. This exponential growth in the number of qubits suggests the potential ability of a quantum computer to process information at a speed that is exponentially higher than that of a classical computer. Note that for $n = 200$, you get a number that is larger than the number of atoms in the universe.

Formally, a quantum register of *n* qubits is an element of the *2n*-dimensional Hilbert space, C^{2n}, with a computational basis formed by *2n* registers at n qubits. Let's consider the case of 2 qubits. In analogy with the single qubit, we can construct the computational base of the states' space as formed by the vectors |00>, |01>, |10>, |11>. A quantum register with 2 qubits is an overlapping of the form:

$$|\psi\rangle = \alpha_{00}\,|00\rangle + \alpha_{01}\,|01\rangle + \alpha_{10}\,|10\rangle + \alpha_{11}\,|11\rangle$$

with the normalization on the amplitudes of the coefficients.

LOGICAL PORTS

Like classical computers, a quantum computer is made up of quantum circuits consisting of elementary quantum logic gates. In the classical case, there is only one (non-trivial) 1-bit logical port, the NOT port, which implements the logical negation operation defined through a truth table in which 1 → 0 and 0 → 1.

To define a similar operation on a qubit, we cannot limit ourselves to establishing its action on the primary states |0> and |1>, but we must also specify how a qubit that is in an overlapping of the states |0> and |1> must be transformed.

Intuitively, the NOT should exchange the roles of the two primary states and transform α |0> + β |1> into β |0> + α |1>.

Clearly, |0> would turn into |1> and |1> into |0>. The operation that implements this type of transformation is linear and is a general property of quantum mechanics that is experimentally justified.

The matrix corresponding to quantum NOT is called for historical reasons *X* and is defined by:

$$X\begin{bmatrix}\alpha\\ \beta\end{bmatrix} = \begin{bmatrix}\beta\\ \alpha\end{bmatrix}$$

with the condition of normalization |α|2 + |β|2 = 1 any quantum state α |0> + β |1>.

Besides NOT, two important operations are represented by the *Z* matrix:

$$Z = \begin{bmatrix}1 & 0\\ 0 & -1\end{bmatrix}$$

which acts only on the component |1> exchanging its sign and the Hadamard port:

$$H = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}$$

This last operation is very often used in the definition of quantum circuits. Its effect is to transform a base state into an overlap that results, after a measurement in the computational base, in a 0 or a 1 with equal probability. The effect of *H* can be defined as a NOT executed in half so that the resulting state is neither 0 nor 1 but a coherent superposition of the two primary (base) states.

The most important logical ports that implement operations on two classic bits are the AND, OR, XOR, NAND, and NOR ports. The NOT and AND ports form a universal set; i.e., any Boolean function can be achieved with a combination of these two operations. For the same reason, NAND forms a universal set.

The quantum equivalent of XOR is the controlled-NOT (CNOT) port, which operates on 2 qubits: The first is the control qubit, and the second is the target qubit. If the control is 0, then the target is left unchanged; if the control is 1, then the target is negated. That is:

$$|A, B\rangle \mapsto |A, B \oplus A\rangle$$

where A is the control qubit, B is the target, and ⊕ is the classic XOR operation (**Figure 1**).

Another important operation is represented by the symbol in **Figure 2** and consists of measuring a qubit |ψ> = α |0>+β |1>. The result is a classic bit *M* (indicated with a double line), which will be 0 or 1.

The CNOT port can be used to create states that are entangled. The circuit in **Figure 3** generates for each state of the computational base

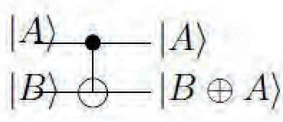


Figure 1: *CNOT port*

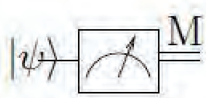


Figure 2: *Quantum measurement circuit*

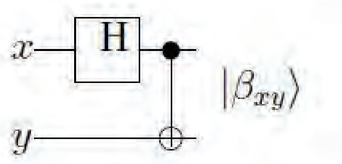


Figure 3: *Quantum circuit for the creation of Bell states*

|00>, |01>, |10>, |11> a particular entangled state. These states, which we indicate with β_{00}, β_{10}, β_{01}, β_{11}, are called Bell or EPR states (for Bell, Einstein, Podolsky, and Rosen, who first discovered their extraordinary properties).

QUANTUM CMOS

The way to encode information in modern digital computers is through voltages or currents on tiny transistors within integrated circuits that act as digital or analog elements. Each transistor is addressed by a bus that is able to define a state of 0 (low voltage) or 1 (high voltage).

Quantum computers have different similarities, and the basic idea is illustrated in **Figure 4**. In this figure, we observe a superconducting qubit (also called SQUID — Superconducting QUantum Interference Device), which is the basic element of a quantum computer (a quantum "transistor"). The term "interference" refers to electrons, which behave like waves within a quantum wave, interference patterns that give rise to quantum effects.

The Josephson effect is the development of current between two superconductors separated by an insulating junction. The effect is due to the tunnel effect of the electron pairs in each of the superconductors.

In this case, the basic element is niobium, not silicon, as in a classic transistor. The property of the material allows electrons to behave like qubits. When the metal is cooled, it becomes known as a superconductor and begins to show quantum mechanical effects.

The superconducting qubit structure encodes two states as tiny magnetic fields pointing in opposite directions. By means of quantum mechanics, we can control these states defined +1 and −1 or $|\psi\rangle = \alpha\,|0\rangle + \beta\,|1\rangle$.

By means of elements known as superconducting loop couplers, a multi-qubit processor is created. A programmable quantum device can be designed by putting together many of these elements, such as qubits and couplers (**Figure 5**).

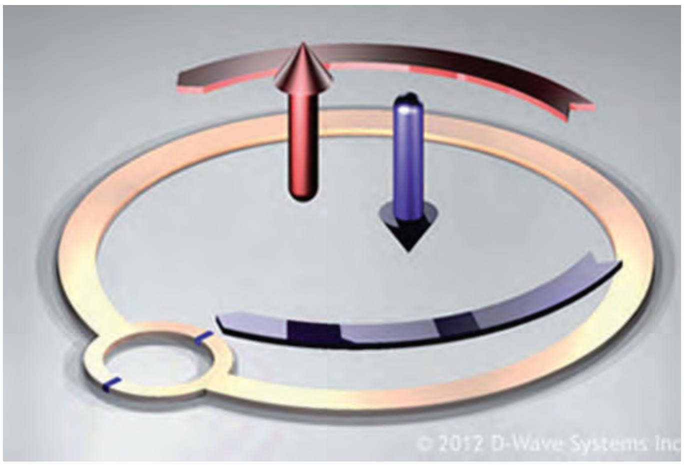


Figure 4: *Layout of a superconducting qubit. The arrows indicate the magnetic spin states that code the information bits' values. Unlike normal information bits, these states can be put into quantum mechanical superposition.* (Image: D-Wave)

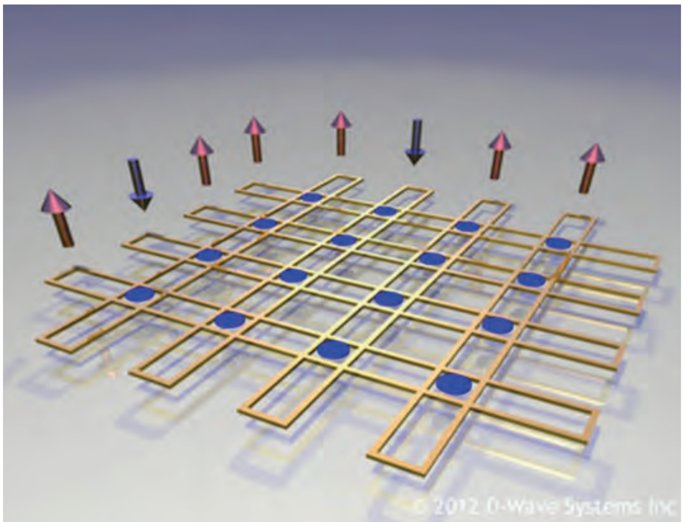


Figure 5: *A schematic illustration of 8 qubits. The blue dots are the positions of the 16 coupling elements that allow the qubits to exchange information.* (Image: D-Wave)

To control the operation of qubits, it is important to have a switch structure, consisting of Josephson junctions, that directs each qubit (routes pulses of magnetic information to the correct points on the chip) and stores the information in a local magnetic memory element to each device.

The Josephson effect is the development of current between two superconductors separated by an insulating junction, called a Josephson junction. The effect is due to the tunnel effect of the electron pairs in each of the superconductors. If the insulator is too wide, the probability of tunnel effect is low, and the effect does not occur.

Most Josephson junctions represent a quantum processing unit (QPU). The QPU has no large areas of memory (cache), as they are designed more like a biological brain than the common von Neumann architecture of a conventional silicon processor. One can think of qubits as neurons and couplers as synapses that control the flow of information between these neurons.

The requirements for a successful quantum implementation are encapsulated in the number of quantum bits, which must be large enough for high efficiency. This also implies that you must be able to perform a lot of quantum bit operations in a short time. The algorithms require the application of many logic gates on many quantum bits. To keep the probability of error low enough, the gates must be very precise.

COMPUTER COOLING

The quantum structure of the computer needs very cold temperatures to work properly. In particular, a temperature reduction to below approximately 80 milliKelvin (mK) is required. The performance of a quantum processor increases as the temperature drops; the lower the temperature, the better. The latest generation D-Wave 2000Q system has an operating temperature of about 15 mK. The QPU and parts of the input/output (I/O) system, which includes about 10 kg of material, is cooled to this temperature.

To reach temperatures close to absolute zero, the systems use liquid helium as a coolant. Liquid helium resides within a closed-loop system, where it is recycled and recondensed using pulse tube technology. This makes them suitable for remote use, as there is no need to replenish liquid helium on-site. ■

Maurizio Di Paolo Emilio *is a staff correspondent at AspenCore, editor of Power Electronics News, and editor-in-chief of EEWeb.*

MOTOR CONTROL

CoolSiC MOSFET Motor Drives Evaluation Board for 7.5-kW Output

By Maurizio Di Paolo Emilio

Infineon Technologies has developed an evaluation board for motor control applications that includes a three-phase SiC module. In particular, it uses the power of CoolSiC MOSFET modules in electric drives.

The board supports customers during their first steps in designing applications with the FS45MR12W1M1_B11 six-pack power module and the EiceDRIVER 1EDI20H12AH 1,200-V isolated gate driver. The module has a rated 1,200-V block voltage with a typical on-state resistance of 45 mΩ. It is optimized for motor drive applications with very high-frequency switching operation.

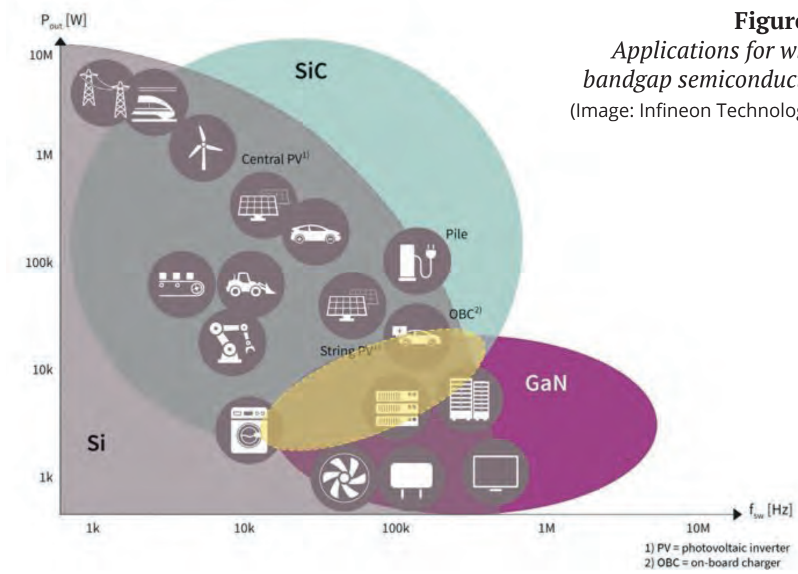


Figure 1: *Applications for wide-bandgap semiconductors* (Image: Infineon Technologies)

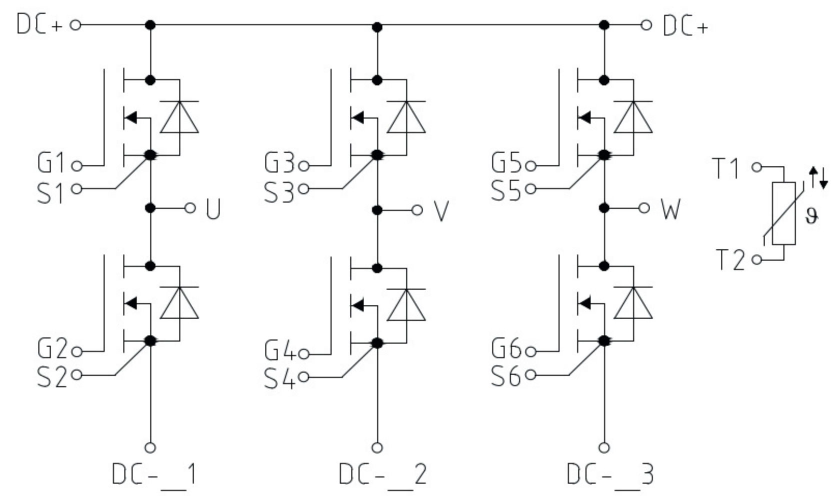


Figure 2: *Diagram of the FS45MR12W1M1_B11 module* (Image: Infineon Technologies)

COOLSiC MOSFET

Silicon carbide (SiC) is a compound of silicon and carbon with an allotropic variety. The advantages of SiC include:

- bandgap of 3.3 eV, versus 1.2 eV for silicon;
- breakdown field of 2.2 MV/cm, compared with 0.3 MV/cm for silicon;
- thermal conductivity of 4.9 W/cm*K (1.5 W/cm*K for silicon); and
- electron drift velocity of $2*10^7$ cm/s, compared with $1*10^7$ cm/s for silicon.

With SiC's 10× higher breakdown field, the active zone can be made much thinner, and many more free carriers can be incorporated. As a result, conductivity is substantially higher.

The material properties of SiC enable the design of fast-switching unipolar devices as opposed to bipolar IGBTs. Wide-bandgap–based power devices such as SiC diodes and transistors are established elements for power electronics design. MOSFETs, meanwhile, are commonly accepted to be the concept of choice (**Figure 1**).

Based on these SiC material advantages, SiC MOSFETs are becoming an attractive switching transistor for high-power applications, such as solar inverters and off-board electric vehicle (EV) chargers. Thanks to the specific trench structure, CoolSiC MOSFETs increase channel mobility as well as improve gate-oxide reliability.

Infineon recently introduced CoolSiC MOSFET devices that round out its 650-V/1,200-V product portfolio. The technology is intended to complement not only IGBTs in this blocking-voltage class but also the successful CoolMOS technology. CoolSiC MOSFET 650-V devices are rated from 27 mΩ to 107 mΩ. They are available in the classic three-pin TO-247 package as well as the four-pin version of the TO-247, which allows for even lower switching losses. Compared with competing silicon and SiC solutions, CoolSiC MOSFETs at 650 V offer benefits that include switching efficiency at higher frequencies and outstanding reliability, according to Infineon. Thanks to a very low on-state resistance ($R_{DS(on)}$) dependency on temperature, the MOSFETs feature excellent thermal behavior. The devices' robust and stable body diodes are said to retain a very low level of reverse-recovery charge (Q_{rr}) — roughly 80% lower than that of the best superjunction CoolMOS MOSFETs. The commutation robustness helps in easily achieving overall system efficiency of 98% — for example, through the usage of continuous-conduction–mode totem-pole power factor correction (PFC).

SiC MOSFETs with blocking voltages of 1,200 V are interesting in applications such as solar converters, uninterruptible power supplies, battery chargers, and industrial drives. The FS45MR12W1M1_B11 is an EasyPACK 1B 1,200-V, 45-mΩ six-pack module with CoolSiC MOSFET, NTC resistor, and PressFIT contact technologies (**Figure 2**). It provides the highest efficiency for reduced cooling effort with a low-inductive design, according to Infineon.

ROHM Semiconductor, for its part, offers the SCT3105KR 1,200-V SiC MOSFET, featuring

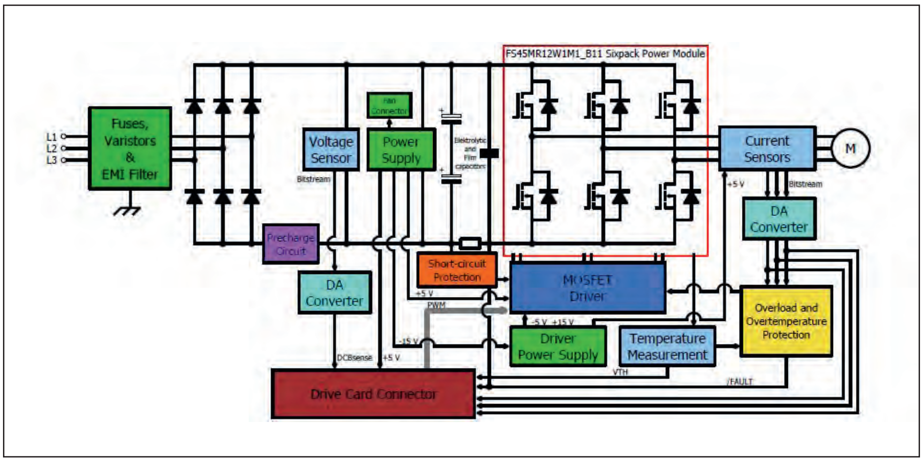


Figure 3: *Block diagram of the Eval-M5-E1B1245N-SiC evaluation board* (Image: Infineon Technologies)

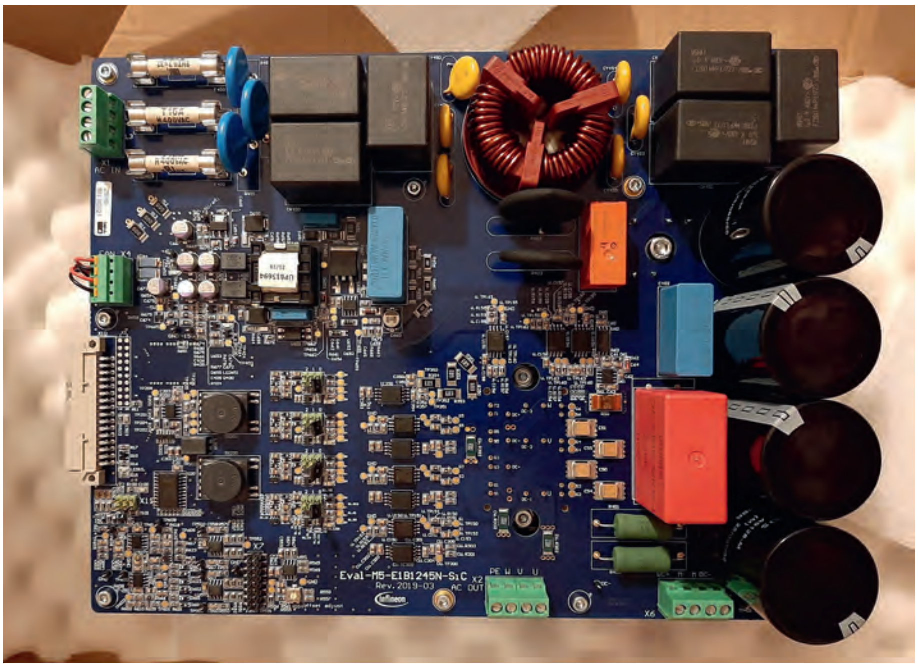


Figure 4: *The Eval-M5-E1B1245N-SiC board* (Image: EE Times Europe)

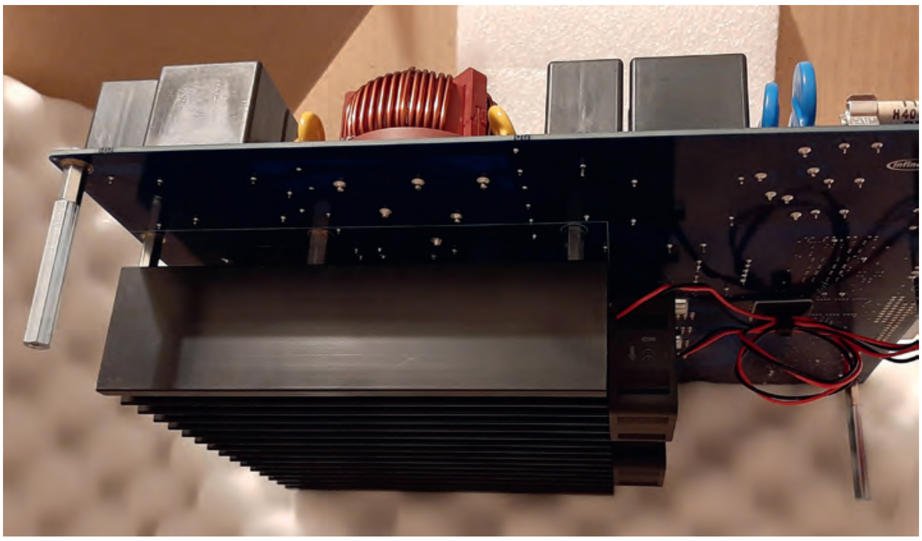


Figure 5: *The evaluation board and heat sink with fans* (Image: EE Times Europe)

a trench gate structure optimized for server power supplies, solar power inverters, and EV charging stations requiring high efficiency. A new four-pin package is used that separates the power and driver source terminals, making it possible to maximize high-speed switching performance. As a result, total turn-on and turn-off losses can be reduced by as much as 35% compared with the conventional, three-pin package (TO-247N).

THE EVALUATION BOARD

The Eval-M5-E1B1245N-SiC evaluation board is part of the iMOTION Modular Application Design Kit (MADK) platform, designed for use with a range of control boards and power stages. The board can be interfaced via the iMOTION MADK-M5 32-pin interface connector to control boards such as the XMC DriveCard 4400 or XMC DriveCard 1300.

The open-source card is equipped with phase output shunts that allow the implementation of control sensors. It has a three-phase AC connector, an EMI filter to minimize high-frequency emissions to the connected grid, a rectifier, a three-phase output for motor connection, an auxiliary power supply to provide 5 V, an integrated NTC temperature sensor, and a silicon carbide FS45MR12W1M1_B11 six-pack power module (**Figures 3** to **5**).

The Eval-M5-E1B1245N-SiC block diagram is shown in **Figure 3**. All measurement and control signals are available on a 32-pin drive card interface connector. The hardware circuit for overtemperature and overcurrent protection is also available on the board. The power and signaling zones are separated to avoid miscellaneous interference. Basic insulation isolates the signaling portion. The isolation design can be easily upgraded to safe electrical isolation by replacing the current MOSFET drivers and auxiliary power transformer (T650, TR200, TR201) with parts featuring the safety approval appropriate for the given application.

Additional features include:

- input voltage 340 to ~480 VAC;
- maximum 7.5-kW motor power output;
- isolated current sensing with delta-sigma ADC;
- isolated sensing of DC-link voltage via delta-sigma ADC;
- thermistor output;
- overload and short-circuit hardware protection;
- all six switches turned off during protection;
- rugged gate driver technology with stability against transient and negative voltage;
- auxiliary 5-V power supply;
- measurement test points compatible with standard oscilloscope probes; and
- RoHS compliance.

The board measures 259 × 204 × 1.6 mm

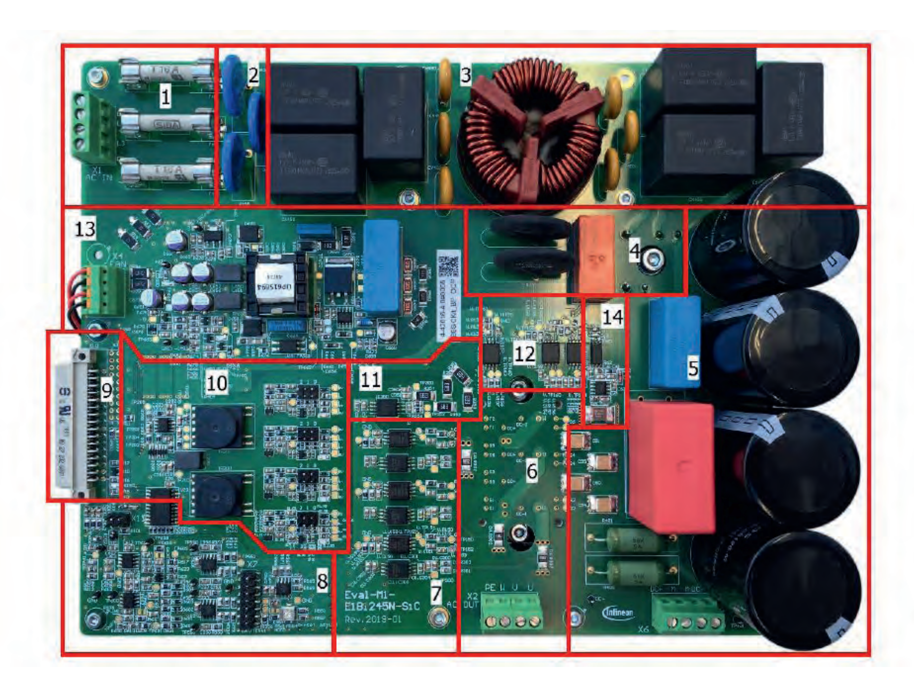


Figure 6: *Top view of the Eval-M5-E1B1245N-SiC (details in Table 1)* (Image: Infineon Technologies)

1	AC input connector with fuses
2	Varistors for overvoltage protection
3	EMI filter
4	Rectifier with precharge relay and precharge NTC resistors
5	DC-BUS capacitors, balancing resistors, and DC-BUS connector
6	Power module FS45MR12W1M1_B11 with phase-current shunts
7	High-side MOSFET drivers with ΔΣ DACs for shunt sensors
8	Low-pass filter of ΔΣ signals and overcurrent comparators
9	Connector for controller
10	Isolated power supply for MOSFET drivers
11	DC-BUS voltage measurement with ΔΣ DAC
12	Low-side MOSFET drivers
13	Flyback converter for auxiliary supply
14	Overcurrent detection and measuring shunt

Table 1: *Details of Figure 6*

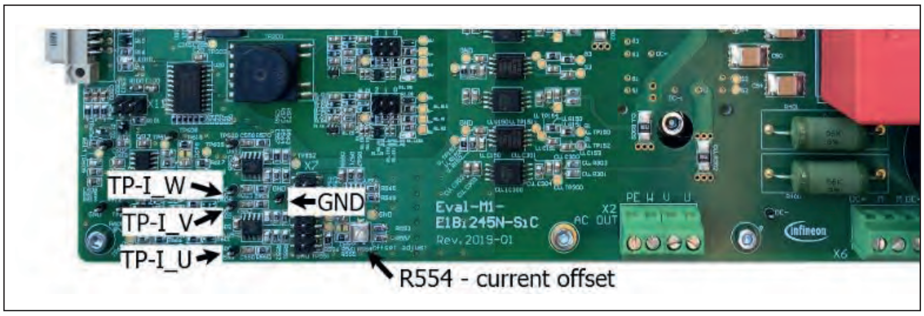


Figure 7: *Relevant parts for offset adjustments* (Image: Infineon Technologies)

and has four electrical layers, each with 35 µm of copper.

Figure 6 shows the details of the board, as described in **Table 1**.

To obtain an accurate measurement of output currents and symmetrical overcurrent detection, the offset voltage of the analog signals must be adjusted (**Figure 7**).

The basic board layout can be divided into four subcategories: the input circuit of the converter, the auxiliary supply, the power stage, and the measurements. The input circuit is equipped with two NTC resistors, which limit the inrush current.

All supply voltages are generated by a flyback converter, supplied from the DC-BUS. The supply circuit is implemented with an Infineon ICE5QSAG control IC. The supply voltages are isolated from the DC-BUS potential by basic insulation (**Figure 8**).

The flyback converter aims to generate three voltage levels: 17.6, 15, and 6 V. The 15-V supply voltage is mainly used for the power supply circuit of the MOSFET driver. From this voltage, a supply voltage of –5 V is derived from a linear regulator used for the negative power supply for the analog circuit of the board. The positive analog power supply is connected directly to the +6-V power supply. This voltage guide is also used to generate the +5 V for the regulator and overcurrent threshold generations.

The schematic of the power stage is shown in **Figure 9**. The three-phase pins of the FS45R12M1W1_B11 six-pack power module are connected to one film capacitor and four ceramic capacitors. At each phase, the output current is measured by a shunt resistor. The shunt voltages are measured by galvanically isolated delta-sigma DACs. Second-order low-pass filters perform the conversion with a bandwidth of approximately 6.5 kHz. For offset adjustment, the reference voltage of the low-pass filters can be adjusted via the R5564 potentiometer for all three currents.

The conducted EMI emission of the evaluation board was measured according to DIN EN 55011, connected to the grid via a 32-A –LISN. **Figure 10** shows the emission and the threshold limits for industrial use (DIN EN 55011, Class A, Group 1, ⩽20 kVA).

The use of SIC devices in motor control and electrical power control applications represents a leap forward in energy savings, solution size reduction, integration, and reliability, with particular relevance in automotive and industrial automation control designs. The Eval-M5-E1B1245N-SiC is a complete evaluation board including a three-phase SiC power module for motor drive applications. ■

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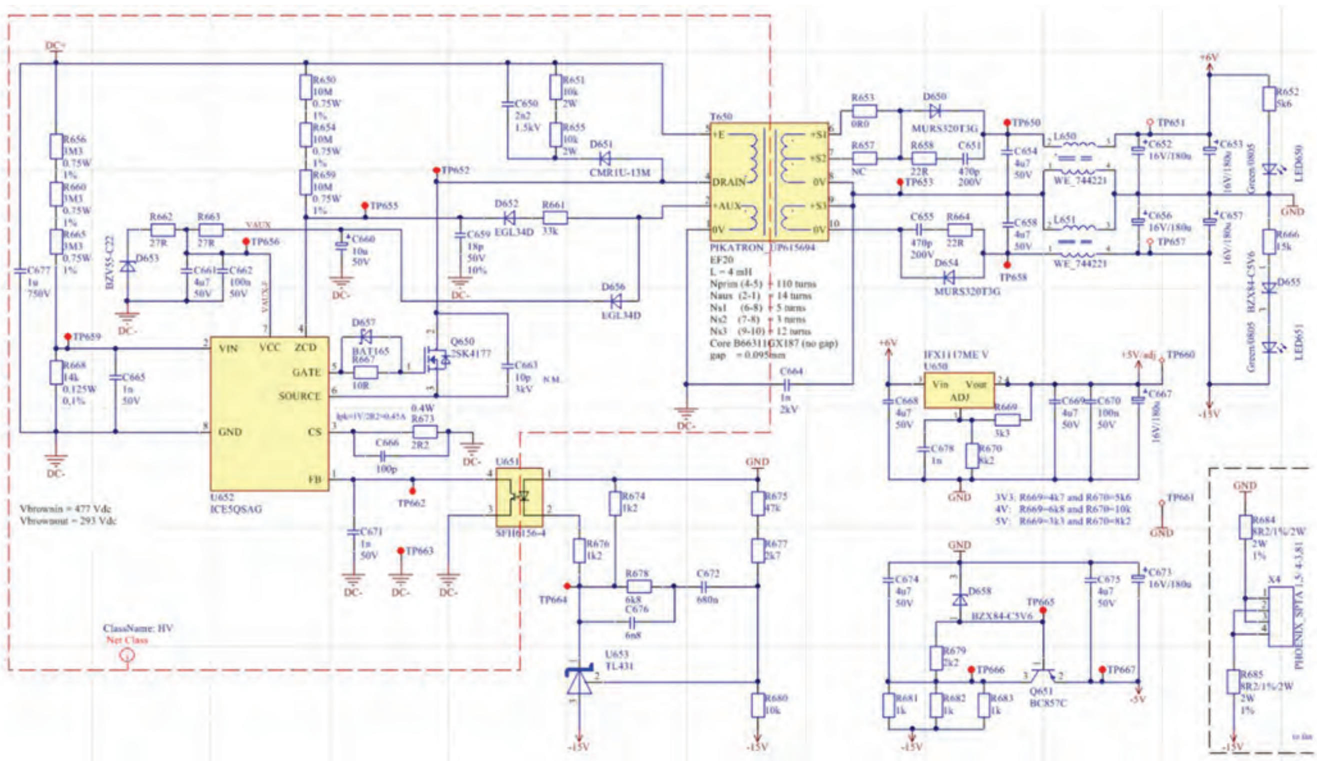

Figure 8: *Auxiliary supply* (Image: Infineon Technologies)

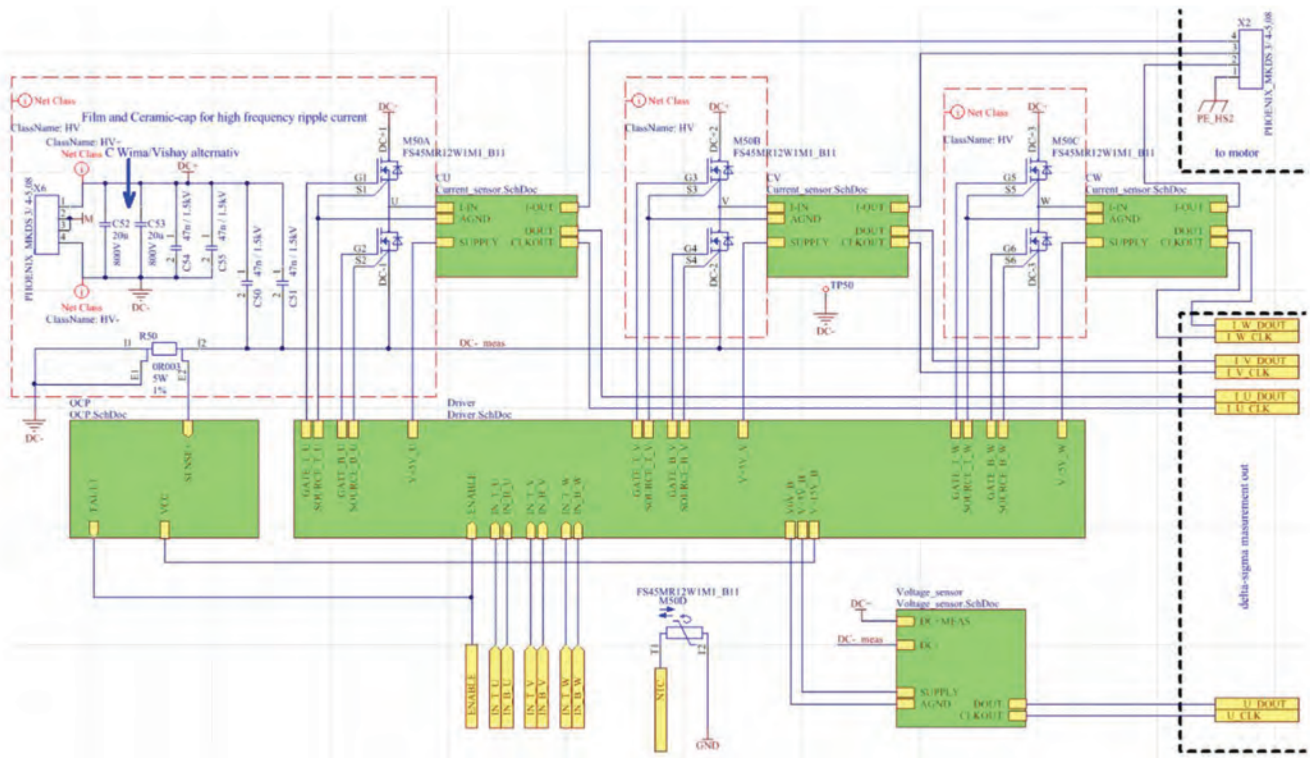

Figure 9: *Power stage schematic* (Image: Infineon Technologies)

CoolSiC MOSFET Motor Drives Evaluation Board for 7.5-kW Output

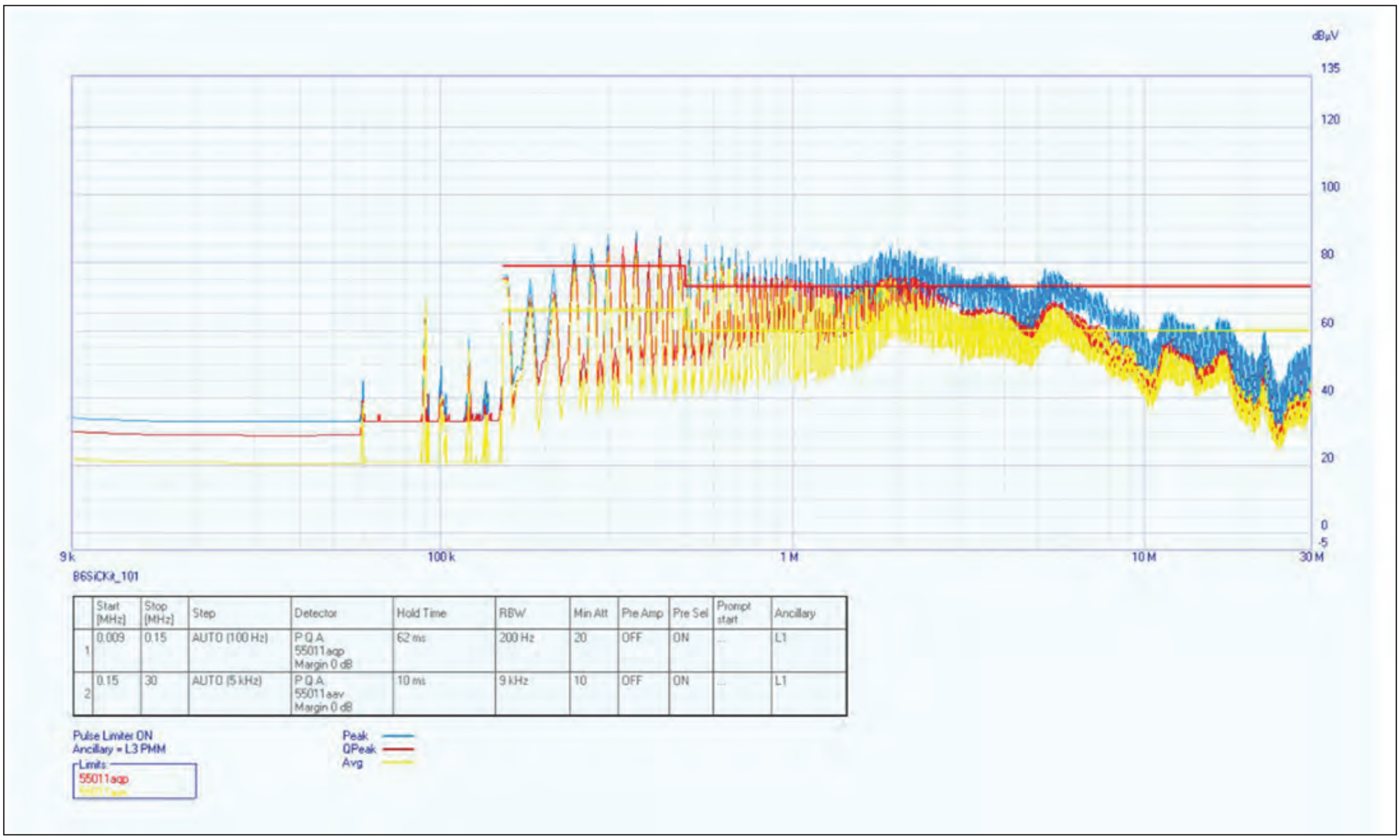

Figure 10: *Conducted EMI emission* (Image: Infineon Technologies)

SOFTWARE

PCB Design Considerations and Tools

By Maurizio Di Paolo Emilio

Proper printed circuit board (PCB) design is critical to the ability to produce electronics prototypes that are both operationally and commercially efficient. This is particularly true for embedded applications. Embedded circuits vary in size and type based on the microprocessor, components, and operating system, but above all on the complexity of the software, which can vary from a few hundred bytes to several megabytes of code.

From the circuit diagram developed, it is possible to perform simulations and design the PCB by exporting Gerber/drill files. No matter what the design, engineers need to know precisely how the electrical circuits (and electronic components) should be arranged and how they will work. For EEs, finding the right software tools for PCB design can be a daunting task. A software tool that's ideal for one PCB project might be a less appropriate fit for others. EEs want board design tools that are intuitive, include useful functionality, are stable enough to limit risks, and have a robust library that makes them applicable to multiple projects.

HARDWARE CONCERNS

For projects targeting the internet of things, in which integration is central to performance and reliability, the integration of conductive and non-conductive materials within a PCB requires IoT designers to study the interactions between the various electrical and mechanical aspects of the design. In particular, electrical heating on a PCB becomes an increasingly critical factor as component size continues to shrink. At the same time, functional requirements are on the rise. In order to achieve merit-based performance as designed, temperature response, electrical-component behavior on the board, and overall thermal management are critical to the functionality and reliability of the system.

A PCB must be isolated to ensure protection. Short-circuits are prevented by protecting the copper traces placed on the board to create the electronic system. FR-4 is preferred as a substrate material over lower-cost alternatives such as synthetic resin bonded paper (SRBP, FR-1, FR-2) because of its physical/mechanical characteristics, especially its ability to retain data at high frequencies, its high resistance to heat, and its ability to absorb less water than other materials. FR-4 is widely used for high-end construction and for industrial and military equipment. It is compatible with ultra-high insulation (ultra-high vacuum, or UHV).

But FR-4 faces a number of limitations as a PCB substrate that stem from the chemical processing used in production. In particular, the material is susceptible to the formation of inclusions (air bubbles) and streaks (longitudinal air bubbles), as well as deformation of the glass fabric. These imperfections lead to inconsistencies in dielectric strength and impair PCB trace performance. New epoxy glass materials solve these problems.

Other commonly used materials are polymide/fiberglass, which supports higher

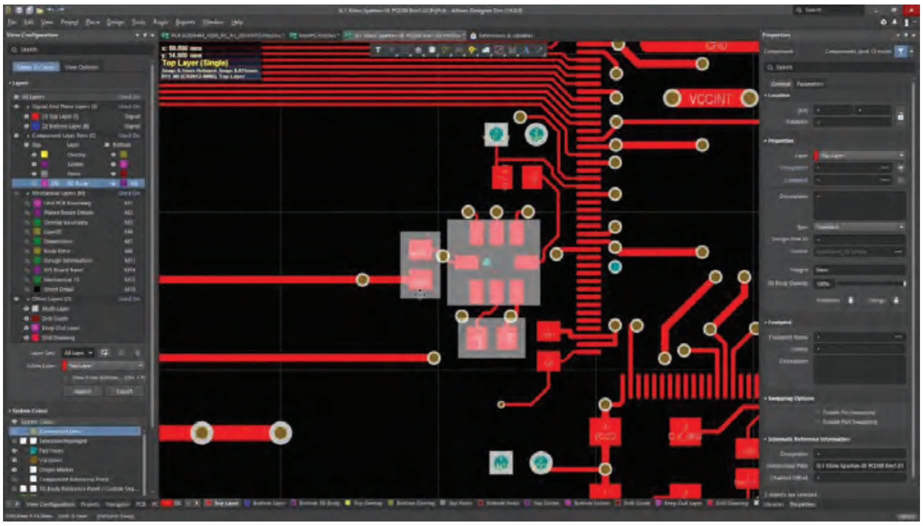

Figure 1: *Altium Designer* (Image: Altium)

temperatures and is more rigid, and KAPTON, which is flexible, lightweight, and suitable for applications such as displays and keyboards.

Factors to consider when selecting a dielectric material (substrate) include the coefficient of thermal expansion (CTE), glass transition temperature (Tg), thermal conductivity, and mechanical rigidity.

Military/aerospace PCBs require special design considerations, based on layout specs and 100% design-for-test (DFT) coverage. The MIL-STD-883 standard establishes methods and procedures for testing microelectronic devices suitable for use in military and aerospace systems, including mechanical and electrical testing, manufacturing and training procedures, and other controls, to ensure a uniform level of quality and reliability across the various applications for such devices.

The design of an electronic device for an automotive system must follow a series of rules in addition to meeting various standards, such as AEC-Q100 mechanical and electronics testing for packaged integrated circuits. Cross-talk effects can impede vehicle safety. To minimize those effects, PCB designers must impose a minimum distance between the signal and power lines. Design and standardization are facilitated by software tools that automatically highlight design aspects that need further modification to meet interference limits and heat dissipation conditions in order to avoid compromising system operation.

Interference from the circuit itself is not the only threat to signal quality. PCBs in cars are bombarded with noise that interacts in complicated ways with the car body, inducing unwanted current in the circuits. And peaks and fluctuations in voltage caused by the car's ignition system can push components well outside their machining tolerances.

SOFTWARE CONCERNS

Today's PCB layout tools must have a combination of features to meet the designer's requirements. Choosing the right layout tool should be at the forefront of PCB design considerations and should never be ignored. Offerings from Mentor Graphics, OrCAD Systems, and Altium are among today's most popular PCB layout tools.

Altium Designer is one of the most popular high-end PCB design software packages on the market today. With auto-routing functions, it supports trace-length tuning and 3D modeling. Altium Designer includes tools for all circuit design tasks from schematic capture to HDL and circuit simulation, signal analysis, PCB design, and FPGA embedded development (**Figure 1**).

Mentor Graphics' PCB layout platform addresses the key challenges faced by today's system designers: accurate, performance- and reuse-oriented nesting planning; efficient routing of dense and complex topologies; and electromechanical optimization. A key functionality of the platform, and a key innovation for the industry, is the Sketch Router, which provides the designer with complete and interactive control over the automatic/assisted uncoiling process, generating the same quality results as manual uncoiling but in much less time.

OrCAD PCB Editor is an interactive environment developed for board design at any technological level, from the simplest to the most complex. Thanks to its real scalability toward Cadence Allegro PCB Designer's PCB solutions, OrCAD PCB Editor supports the technological growth of design teams, enabling the management of the most advanced constraints (high speed, signal integrity, etc.) while maintaining the same graphical interface and file format (**Figure 2**).

GERBER FILES

The industry-standard Gerber file format is used to communicate design information for PCB production. In many ways, Gerber is analogous to PDF for electronics; it is simply a small file format written in the hybrid machine control language. These files are generated by circuit breaker software and sent to PCB manufacturers for upload to CAM software.

Integrating electronic systems securely into vehicles and other sophisticated systems poses significant considerations for both hardware and software. The goals for engineers are to minimize the number of design iterations and the development time, with significant advantages for designers implementing the workflow. ■

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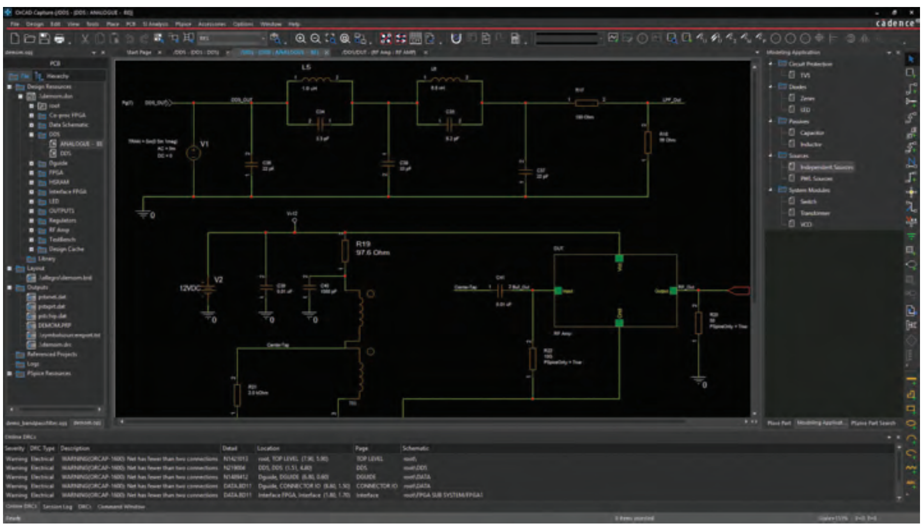

Figure 2: *OrCAD PCB Editor* (Image: Cadence)

OPINION

30 Reasons Why Licensing Huawei 5G Could Be a Bad Idea

By Joe Hoffman

Late last year, The Economist published an interview with Huawei founder Ren Zhengfei in which Ren proposed cloning Huawei's 5G technology stack by licensing patents, code, blueprints, and production know-how. The article points out that this would be an outlandish idea in normal times but then says it deserves consideration.

Patent licensing and trading are a normal part of a technology business, but this offer is much more than that: Huawei is offering the ability to replicate its entire cellular portfolio. Trying to replicate Huawei's product line sounds like a bad business idea, so let's break it down.

REASONS 1–23: THE TELECOM INFRASTRUCTURE ECOSYSTEM

It's not cynical to say the mobile telecom ecosystem is past the high-growth stage (2000–2010). **Figure 1** shows global population, cellular subscribers, and subscriber year-on-year growth from 1990–2025, with worldwide mobile subscriptions exhibiting a classic S-curve. This chart includes the cellular evolution from 1G to 5G, but the implications for infrastructure and handset markets are telling. Both markets evolve from new-market expansion to slower replacement sales. Equipment vendor opportunities come with the introduction of new technology, such as 5G, to operators and consumers. Without those sales, the ecosystem relies on replacement, densification, and population growth.

Is there enough business in countries where Huawei is banished to justify replicating Huawei's 5G portfolio?

Table 1 lists 23 of the major telecom infrastructure vendors from the global cellular rollout. The competitive forces that drive market rationalization are still present, with Huawei, Ericsson, and Nokia dominating the market for infrastructure and with newcomers facing long odds against the incumbents. Outside of the dominant vendors, most have left the business, have been acquired, or participate in local and small-cell markets.

REASONS 24–30: BUSINESS CHALLENGES

Markets. The primary markets for this proposal are those that have banned Huawei, namely the United States and some allied nations. In every market, the new company could expect fierce competition from others.

Patents. Huawei will include its patents in the stack, but the new entity would likely soon hear from intellectual-property rights (IPR) lawyers representing the other infrastructure vendors, including Qualcomm. Licensing Huawei patents will not shield the new entity, and it will need to make additional arrangements.

Field service. Telcos are notoriously conservative and look to long-term supply continuity, including the field service team.

Software. There are billions of lines of code here to parse through and support if the vendor wants to surmount the security allegations. Understanding and maintaining someone else's software is a Herculean task for any company to take on.

Legacy. 5G needs LTE to work in non-standalone (NSA) mode for the immediate future. It will be many years before telecoms shut down the legacy 4G technologies. Recent 4G LTE base stations are software-upgradable, reducing the market opportunity and raising barriers for a new entity.

Scale. Where does this new venture compete, and how does it gain sufficient economy of scale? The banishment markets are not enough, not even for Nokia and Ericsson.

Supply chain. Be sure that Huawei and China Inc. are working furiously to rid themselves of American choke points; it is an existential issue. What happens to the new entity when it needs to source the Chinese components and then sell into the banishment markets?

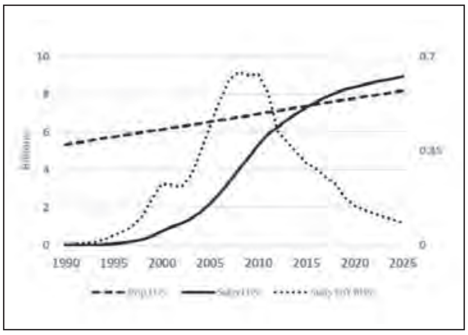

Figure 1: *Mobile subscribers: global population, cellular subscribers, and year-on-year growth* (Image: SAR Insight & Consulting)

BEEN THERE, DONE THAT

Sourcing someone else's kit can work but is fraught with risk, so why is this offer different? Motorola was a leading infrastructure vendor in 2G but stumbled with 3G and eventually sourced a Huawei kit for its 3G offering, which was interpreted by the market as a going-out-of-business strategy. Motorola could have borrowed the Zenith slogan, "The [Huawei] quality goes in before the [Motorola] name goes on."

While not an impossible task, building a new entity and executing a successful business plan are daunting in the telecom market, so don't expect to see a full-scale competitor based on Huawei technology any time soon. ■

Joe Hoffman *is director of wireless connectivity and machine sensing at SAR Insight & Consulting, where he focuses on the emerging strategies and shifting value chains of the machine economy. He holds a B.S.E.E. from the University of Kentucky, an M.S.S.E. from Virginia Tech, and an M.B.A. from Arizona State University. His career includes posts at IBM, Lockheed-Martin, Motorola, and Nokia.*

Survivors	Casualty	Emerging
AIRSPAN	ALCATEL	AUTOSTAR
CISCO	ALVARION	CASA SYSTEMS
ERICSSON	APERTO	COMBA TELECOM
FUJITSU	LUCENT	JMA WIRELESS
HUAWEI	MOTOROLA	MAVENIR
NEC	NORTEL	PARALLEL WIRELESS
NOKIA	SIEMENS	
PANASONIC		
SAMSUNG		
ZTE		

Table 1: *Telecom infrastructure vendors from the global cellular rollout* (Image: SAR Insight & Consulting)

POWER MANAGEMENT

Isolated Power Transfer in an SOIC Package

By Maurizio Di Paolo Emilio

An integrated transformer technology from Texas Instruments enables a 500-mW, high-efficiency isolated DC/DC power supply solution with low electromagnetic interference (EMI).

Signal isolation in power applications maintains integrity by preventing high-frequency noise propagation, thereby protecting sensitive circuits from high-voltage spikes. In such applications, an isolated power supply is needed to provide power to different electrical components. To ensure human safety, industry standards require reinforced isolation, which is twice the necessary level of isolation required for proper operation of the equipment.

In addition to proper isolation, the market is moving toward distributed power. Instead of a central power supply that provides for the full system, there are smaller power supplies and even micro power supplies to power the subsystems and their components, including integrated circuits. Form factor, cost, and thermal management are all key design elements to consider when choosing solutions that accommodate requirements for properly safeguarded, distributed power.

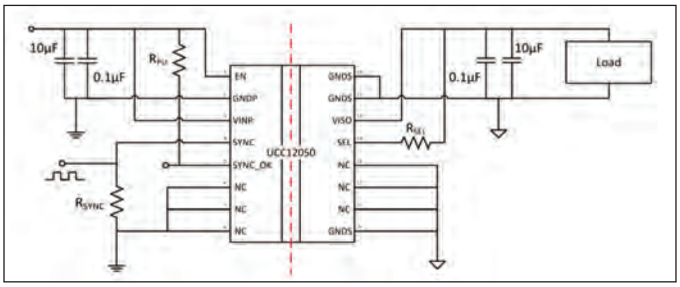

Figure 1: *Typical application circuit for the UCC12050*
(Image: Texas Instruments)

"Our solutions need to have higher levels of power density and efficiency," said Steve Lambouses, vice president and general manager of Texas Instruments' High Voltage Power business. "As we put these power supplies into a smaller space, and as we have more power supplies than ever connected to the grid, we can't afford to waste energy. We need to provide the highest-density and most efficient solutions. In addition, the electrification of vehicles, the increased need for factory automation as well as building automation, and other fast-growing areas, like medical, all require higher levels of robustness and reliability."

In each of these applications, the most significant concerns relate to EMI, as interference is amplified in tighter spaces. One common EMI source is the power supply itself. Energy quality is defined as the electrical power that drives a load and the ability of the load to function properly. Without a proper power supply that is capable of low EMI, a device (load) may not function properly or may be damaged.

To achieve EMI compliance, typically, engineers need to follow the correct design guidelines for interference reduction, adding external components such as filters or chokes to suppress noise while continually conducting the appropriate testing to optimize the design from the development stage.

This is a very iterative and arduous process. TI's new integrated transformer technology shields against noise emissions and delivers a low-EMI isolated power supply, greatly simplifying engineers' design tasks. The new UCC12050 also lets designers reduce the solution volume by 60% compared with power modules (**Figure 1**).

The UCC12050's 5-kVrms reinforced insulation and 1.2-kVrms working voltage protect against high-voltage spikes in systems such as industrial transportation, network infrastructure, and medical equipment. In these applications and others, the UCC12050 serves as a compact isolated DC/DC power supply companion device that can be used to power other ICs such as digital isolators, isolated current or voltage sensors, and communication devices such as isolated transceivers.

The device, available in a 16-pin, 10.3 × 10.3 × 2.65-mm small-outline IC (SOIC) package, eliminates some of the external components, such as low-dropout regulators and ferrite beads, usually required to meet EMI certification, shortening design time while shrinking the solution footprint and bill of materials. Its high efficiency and extended operating temperature range (from –40°C to 125°C) provide more power under extreme conditions.

TI's integrated transformer technology enables the conversion of high-density isolated DC/DC power while maintaining a low level of EMI. The surface-mount monoblock architecture provides designers with an easy-to-use, low-profile IC that operates efficiently over a wide temperature range.

"As a semiconductor manufacturer, we are able to integrate more external components on our die, and now, with this proprietary transformer technology embedded inside the package, we can also eliminate the need for external ferrite beads or chokes to mitigate EMI, which is typically done in systems today with just a native transformer," said Lambouses.

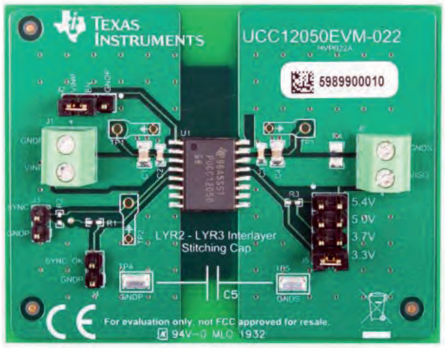

Figure 2: *UCC12050DVE isolated DC/DC power supply evaluation module*
(Image: Texas Instruments)

Medical applications require EMI robustness and safety isolation, and efficiency is key in test and measurement applications. TI's solution offers a technical combination to meet the stringent demands of both markets.

"Ten years ago, power density was not a big concern," said Lambouses. "We had big, massive systems. We had a single power supply. Today, [power density] is one of the key concerns from customers. With test and measurement, medical, and factory automation equipment [all becoming] smaller, and as power becomes more distributed, power density is key.

"As well, EMI is becoming a significant concern for our customers. They cannot afford to add cost and extra components outside of the chip. Instead, they are demanding that EMI is mitigated or reduced inside the chip, and that's something we focused heavily on with this proprietary transformer design."

The silent control scheme makes it easier for engineers to pass their projects for the Comité International Spécial des Perturbations Radioélectriques (CISPR) 32 Class B EMI test, with margin, on a two-layer printed-circuit board.

TI offers the UCC12050EVM-022 module to help designers evaluate the characteristics of UCC12050DVE quickly and easily for use in isolated systems. The EVM allows the supply's features to be enabled and disabled for test. ■

Maurizio Di Paolo Emilio *is a staff correspondent at AspenCore, editor of Power Electronics News, and editor-in-chief of EEWeb.*

OPINION

Sensors Surpassing Superman

By Anne-Françoise Pelé

It's a classic ice-breaking exercise that promotes team-building and encourages self-confidence in large corporations: If you could pick one superpower, what would it be? The first time I took the quiz, I answered teleportation, so I could zap myself around the planet. If I had to take it now, I would answer telepathy, to read the minds of my interview subjects, or time travel, to stay relevant and prepare for the future.

Another useful superpower is X-ray vision — the ability to see through anything and anyone, just like Superman, the Krypton native whose physical structure was "millions of years advanced of our own." Sent to Earth as an infant, he grew more and more powerful under the light of the yellow sun. But what if Superman's abilities were no longer "super" and were available to everyone?

Humans might not have attained actual superpowers, but they have been smart enough to develop extra powers, or extrasensory perceptive capabilities. Call them sensors.

Sensors can see, hear, feel, and intuitively understand their environment. Sooner or later, they will be fully context-aware, and Superman will have no choice but to take off his cape and live the normal life of Clark Kent. Unless…

NO CAPE REQUIRED

Superman was one of the first superheroes. When the first comic book was released in 1938, it seemed impossible for Superman to be overpowered. His supernatural abilities enabled him to run faster than an express train and lift a car effortlessly over his head. In later issues, he could hear sounds too faint for a human to hear, and at frequencies outside the human hearing range. Good for him — but ultrasound sensors, also known as ultrasonic transducers, now operate at 20 kHz.

Superman can survive underwater or in space without adverse effects. That sounds like Vesper Technologies' piezoelectric microelectromechanical system (MEMS) microphones, which are claimed to be waterproof, dustproof, particle-resistant, and shockproof. In other words, you can immerse them in water, coat them in particulate matter, or drop them on the ground, and they keep working properly.

Paired with AI, sensors will be able to learn the way humans and animals do, using their "senses" to make our lives safer and easier.

Superman can also project and perceive X-rays with the naked eye, allowing him to see through physical objects such as walls to locate criminals and rescue civilians. Interesting, but Israeli startup Vayyar Imaging Ltd. is going one step further.

Founded in 2011, Vayyar worked to develop an alternative to X-rays and sonograms for breast cancer detection, using RF to quickly and affordably look into human tissue and detect malignant growth. Eight years later, the company commercialized a small, sensor-based chip that, with its 72 transmitters and 72 receivers, tracks and maps everything without a camera. It detects obstacles and monitors people's location, movement, height, posture, and vital signs, wirelessly and in real time, under all lighting and weather conditions. A key differentiator is its ability to "see" through walls, closed doors, and other solid objects.

"In the case of a fire, Vayyar's sensors can see through smoke and identify if and where there are people in the building," co-founder and CEO Raviv Melamed told EE Times Europe.

Vayyar's sensors can scan the entrances and exits of a home to determine whether someone (such as a burglar or any intruder) has entered. They can monitor behavior and activity, such as an individual's breathing rate and sleep patterns, to enhance health and wellness. The sensors can also be used for home automation such as adjusting lights and air conditioning. "This is not only convenient but also has the added benefit of energy and cost reduction," said Melamed.

And because Vayyar uses RF waves to detect objects — unlike products that rely on cameras and optics — its sensors do not collect any optical data, protecting users' privacy.

Walabot Home (Image: Vayyar)

Vayyar's portfolio includes Walabot Home, which deploys an ultra-wideband 4D radar imaging chip, 21 wideband embedded antennas on a PCB board, and a machine learning-based fall-tracking system to keep elderly people safe at home. The platform sends out radio wave signals to the surrounding environment and receives back reflections from different objects.

"We use Tx/Rx antennas, which are able to both transmit and receive," said Melamed. "They send out thousands of signals per second, which travel all around the environment; [when the signals] reach objects, they send back reflections to the sensor. The reflections are unique based on what object they reach, so we are able to differentiate between a human entering a room versus furniture and other objects."

Asked how the sensor data is analyzed and converted into useful information for decision-making, Melamed said, "Our algorithms analyze all input and determine in real time a model of the environment, picking up occurrences such as a person entering as well as details about behavior and posture — whether they are sitting or standing or have fallen, which would trigger a call to their caregiver."

No cape is required: Per Vayyar's instructions, you just need to place Walabot Home on your wall, and it will scan for falls and automatically call your emergency contacts to get help when you need it.

Sensors are blending intelligence invisibly into our surroundings. Paired with AI, they will be able to learn the way humans and animals do, using their "senses" to make our lives safer, easier, and more enjoyable.

Is Superman outmoded? Never. The only limit to his powers is the imagination of those who tell his story. Maybe one day, Superman will possess extrasensory powers, and the "S" shield will have a double meaning: "S" for Superman and for Sensors. ■

Anne-Françoise Pelé *is editor-in-chief of* eetimes.eu.

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