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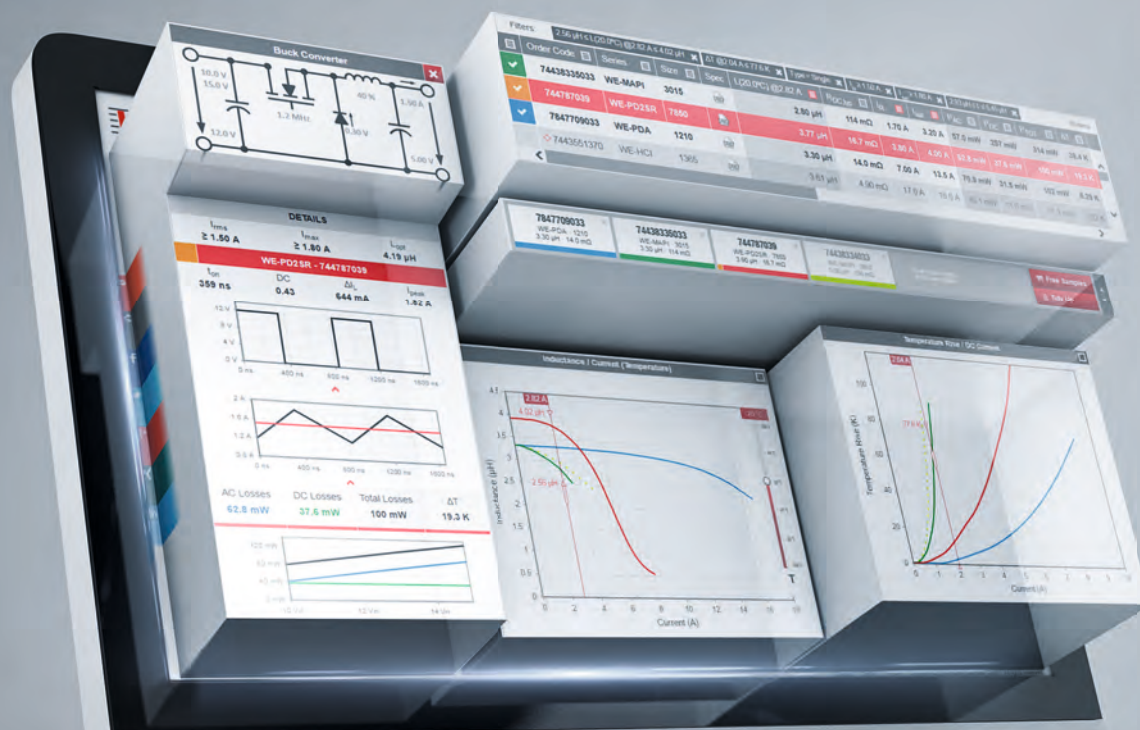
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EDITOR'S LETTER

Industry Adrift? Not at All



The global economy is in a rut. It will shrink 3.2% this year, led by a 5% decline in developed countries and a smaller decrease in other parts of the world, according to economists at the International Monetary Fund. At the beginning of the year, expectations were vastly different. In January, IMF economists were projecting 3.3% global

economic growth for 2020 and 3.4% for 2021.

That was before Covid-19. All the prior estimates have been erased, replaced by IMF expectations for a deep contraction and the likelihood of “even more severe outcomes.”

Technology companies aren't immune to the nasty impacts of the coronavirus pandemic. They are rethinking and retooling many parts of their operations. Manufacturing must periodically be recalibrated to compensate for a lack of visibility into market demand and as cracks appear in the supply chain. This time, though, managing the shocks to the supply chain is more difficult because of the huge uncertainties engendered by the actions taken to reduce the spread of the novel coronavirus and contain its societal fallout.

We can go on ad nauseam about how bad the economic conditions are likely to get. Look beyond the negatives, though, and a clearer image emerges. First, 2021 will be much better. Buoyed by fiscal policy initiatives, the global economy will rebound in 2021 with a 5.8% spurt, according to the IMF. The lifting of restrictions on movement and other activities will trigger massive spending by businesses and consumers. Pent-up demand will be unleashed, helping to fuel a rebound in spending and consumption.

Electronics manufacturers will benefit from the efforts to resume normal business activities. Sure, many constraints will remain. For example, companies may still restrict business travel, and telecommuting will likely become a staple offer to employees whose jobs can be performed outside of the traditional office environment. Even this will have a positive impact on technology companies as the new wave of home office workers acquires the necessary tools to meet productivity requirements.

The tech sector has too many innovations lined up — addressing business as well as consumer interests — to stay in the doldrums too long. Growth areas include automotive, communications and connectivity, industrial, medical, power, and transportation. Semiconductors are becoming a staple of the equipment used in many sectors of the economy, and that trend will only accelerate as more companies pursue the competitive advantages of automated manufacturing processes.

This industry, like other sectors of the economy, may have slowed down over the last couple of months, but it has certainly not been set adrift. Even at the height of the pandemic, innovation has not wavered.

The results will be out soon. ■

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

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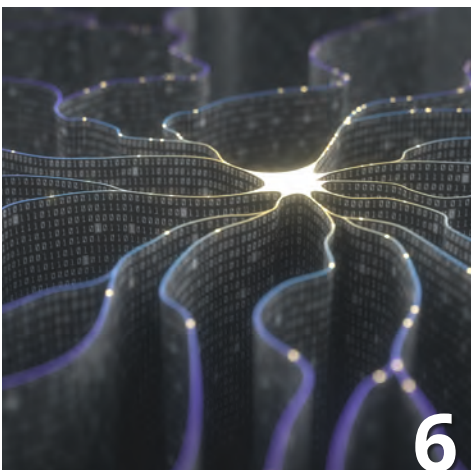


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OPINION | ARTIFICIAL INTELLIGENCE

The Practicality of Predictability

By Dennis Goldenson



Over the last several weeks, I've had a lot of time (as have many others) to think about Covid-19. I've wondered whether any artificial-intelligence technology can predict outbreak patterns and warn us of a pandemic's intended path. While many brilliant epidemiologists are searching for a coronavirus cure, other researchers are considering how AI can be effectively utilized to simulate and predict how diseases will spread and how diseases can be contained. This is the art of practical AI and the merging of science and technology to predict the needs of a public health crisis worldwide.

Part of the science in predicting is the ability to predict in real time, based on unplanned scenarios or across various internal and external environmental conditions. Our machines must be able to adapt and respond like humans in order to provide more spontaneous and accurate responses, especially in times of dire need.

There is no shortage of research on how artificial intelligence is making all our connected machines smarter and more intuitive. However, it's important not to overlook one of the most important aspects of AI: the ability to predict specific outcomes and anticipate trends to help prepare for various conditional factors (e.g., pandemics).

There is also a need for AI and machine-learning systems to go beyond pattern recognition by providing correlations and beginning to address underlying causality. Can machines learn cause and effect?

EVERYTHING HAS A PATTERN

Predictive analytics is the method of utilizing statistics, probabilities, data mining, and modeling to project or make predictions. In basic terms, software will extract information to analyze historical data trends and patterns to anticipate future trends. It's sort of like linear or multiple regressions on speed. We want our machines to use variables to learn a model and predict the value of the response variable. While we can now predict future intent based on previous customer behavior and purchase patterns, the ability to project scientific outcomes in applications such as health care is actually the most fascinating use case.

ARTIFICIAL NEURONS

The amount and quality of data are the crown jewels in the accuracy of these AI systems. The AI data should be verified against real-world outcomes to ensure its accuracy. With appropriate design and training, various data sources can be leveraged to expand the predictable nature of unforeseen events. Much of the data we work with is unstructured; computers cannot glean much meaning from it. Unstructured data can be in the form of text, email messages, Word files, audio files, photos, video, and multimedia content. On the other hand, structured data — such as numbers, groups of words, and dates with defined length and format — is more tabulated and usually requires considerable processing for computers to understand and interpret it.

Now, with the advent of neural networks and deep-learning architectures, we can derive more meaning from unstructured data. The algorithms cycle through these interconnected neural networks and layered processors like the 86 billion neurons in your brain. The data is passed from one layer to the next in a cycle or in a feedback loop. This is the deep-learning approach through which the algorithms learn how to identify various objects.

It all comes down to training the neural-network algorithms to understand unstructured data and to recognize the pieces of various items. For example, we can teach an algorithm to recognize new strains of a virus mutation by training it with microscopic images to identify various characteristics of an infectious agent. It can then begin to recognize unknown virus patterns with various components and characteristics.

There are, of course, other training use case applications for artificial neural networks, such as emotion detection. AI algorithms are increasingly accessing neural networks to identify specific emotional responses and create insights that can affect behavior and how we think. This capability can be applied to cause and effect in understanding what triggers emotion.



The other area of exploration is advancing AI contextual and adaptive reasoning, thereby providing machines with the capacity to react to change by reusing existing data and information for new and unfamiliar problems. A strong key to AI success is its ability to react dynamically to ever-changing context, selecting the best course of action. This, too, can be applied to cause and effect in understanding what triggers logical thinking, reflection, explanation, and justification.

AI FOR THE COMMON GOOD

All of this comes down to prioritization and the practical application of AI and predictive analytics for the common good. This may be the future of AI — training to understand not what we intend to do but why and how we intend to do it for future application.

Artificial intelligence and predictive analytics are powerful tools that hold great promise for the enterprise space, including health care, financial services, manufacturing, and retail. The effectiveness in predicting outcomes and “outbreaks” will be contingent on the quality of data and the ability to provide real-time analytics on performance, preferences, and pathways based on the relationship between cause and effect. ■

Dennis Goldenson is director of artificial intelligence and machine learning at SAR Insight & Consulting, where he focuses on digital assistant platforms, natural-language processing, user interface technologies, and machine learning to provide comprehensive coverage on AI market trends and developments.

AUTONOMOUS VEHICLES

Full AV Stacks: Five Years In, Does the Progress Measure Up?

By Junko Yoshida

The road to Level 4 and Level 5 self-driving cars is still long and winding, and these days, even the AV industry is conceding the point.

Delayed autonomous-vehicle launches by multiple leading automakers and tech suppliers are sufficient evidence, but a stronger telltale sign is that discussions have begun among tech companies and car OEMs acknowledging that the development of fully autonomous vehicles can't be achieved without an ecosystem to support it.

While commitments by each company might vary, automakers and tech companies have begun forging collaborations to tackle the challenge of making self-driving cars drive safely. This pragmatic approach contrasts vividly with the heady days five years ago, when the emerging market was flush with venture capital funding and riddled with bombastic AV claims and market predictions.

It is now a foregone conclusion that AV startups propped up by hype and cheap VC money will vaporize as the investment community's enthusiasm for L4 and L5 wanes and Covid-19 gnaws away at the broader economy. Also clear, however, is that those who have already made substantial investments — and certain progress — in the development of AV platforms aren't walking away from the development of their own full AV stacks. They see it as the tech challenge of a lifetime and the one that will determine their fortunes in the long haul, if not for the immediate future.



Over the past five years, EE Times has covered a lot of wheeling and dealing among the carmakers and tech suppliers pursuing the AV dream. Where do all those deals and partnerships stand now? What progress has really been made?

To get some answers, we enlisted the help of Egil Juliussen, research director and principal analyst for Automotive Technology at IHS Markit, to review the shifting AV landscape. Our goal was to identify the survivors still developing their own AV software stacks. We wanted to explore the who, what, where, and when of their projects.

The first task was untangling the web of “announced” partnerships among the leading players. The relationship map — who's in bed

with whom — is messy. In an attempt to make sense of it all, Juliussen sorted the AV-platform chaos into three bins: robotaxis, OEMs, and high-tech software (Figure 1).

ROBOTAXI PLATFORMS

In the robotaxi bin, Juliussen listed ride-hailing companies Uber, Lyft, and Didi along with five others: Aptiv-nuTonomy, FiveAI, Oxbotica, ZMP, and Zoox. Among these, Juliussen highlighted three that appear to be making headway: Aptiv-nuTonomy, Didi, and Uber. He identified Aptiv-nuTonomy and Zoox as having their own AV software stacks.

Zoox, founded in 2014, is working to develop a robotaxi AV from the ground up. For the time being, however, Zoox has retrofitted Toyota Highlanders with its self-driving system and is running trials in San Francisco's Financial District and North Beach area.

Aptiv (formerly Delphi) three years ago bought nuTonomy, a Massachusetts Institute of Technology spin-off focused on the development of software for self-driving cars and autonomous mobile robots. In September, Aptiv announced a US\$4 billion 50-50 joint venture with Hyundai. The deal, completed in March, is considered a coup for Aptiv-nuTonomy.

Relationships get muddled, however, when OEMs start making multiple deals on AV stacks with robotaxi platform vendors and high-tech software suppliers.

For example, Hyundai's allegiances remain unclear. The South Korean automaker was among the early investors in Aurora, which launched in January 2017 and is developing a full AV stack called Aurora Driver. Aurora

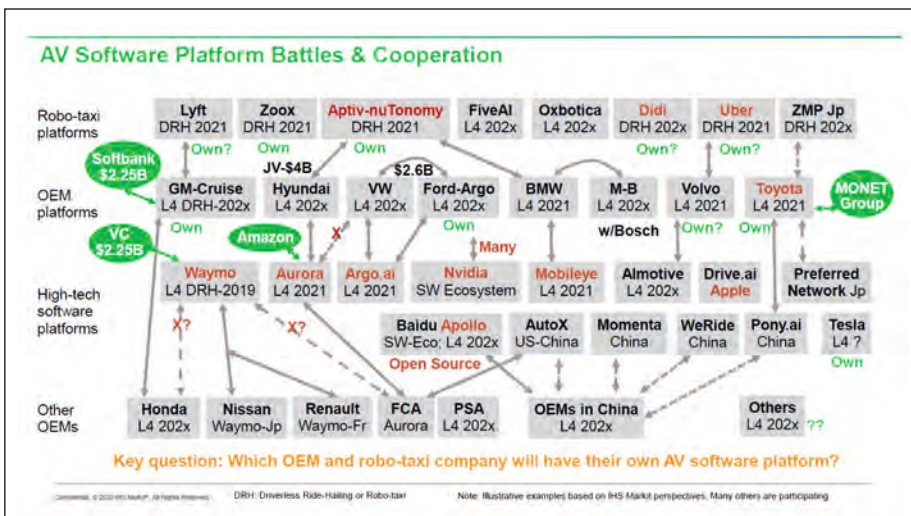


Figure 1: Relationships are messy. (Image: IHS Markit)

IMAGE: SHUTTERSTOCK

Full AV Stacks: Five Years In, Does the Progress Measure Up?

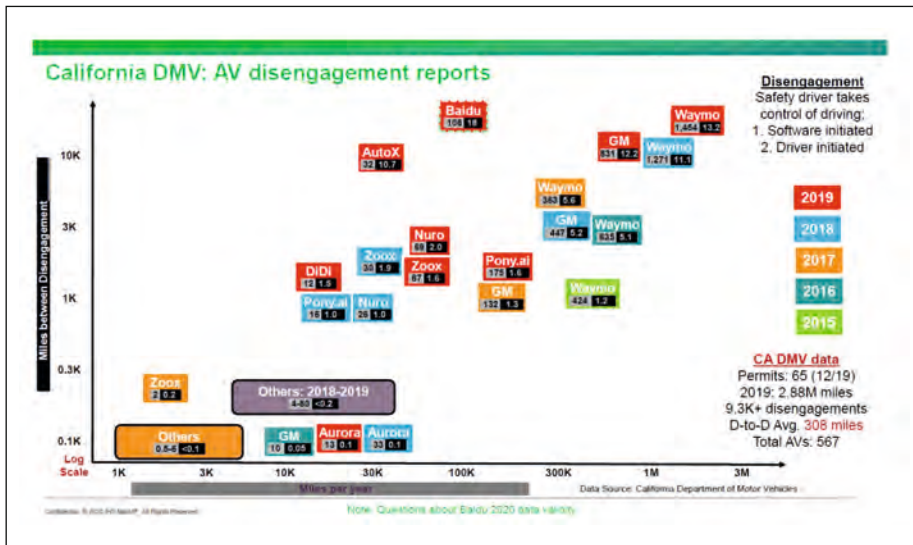


Figure 2: Evaluating AVs by counting disengagements can encourage bad behavior on the part of test drivers, some safety experts warn. (Image: IHS Markit)

previously announced a plan to expand its R&D program with Hyundai to develop a self-driving platform. Apparently torn between two lovers, Hyundai has said its new joint venture with Aptiv-nuTonomy won't affect its affair with Aurora. But it has been reluctant to kiss and tell, divulging few details about what it is actually doing with Aurora.

OEM PLATFORM

In the bin for OEM platforms, Juliussen listed GM-Cruise, Hyundai, VW, Ford-Argo, BMW, Mercedes-Benz-Bosch, Volvo, and Toyota. All have been testing their own autonomous vehicles but vary in where they stand on AV stacks.

Car OEMs with their own AV software platforms include GM-Cruise (built on Cruise's AV software platform), Ford-Argo (based on Argo AI's full AV stack), and Toyota (developed in-house). Volvo might have its own stack, but it announced previously a partnership with Almotive, a Budapest, Hungary-based software platform supplier (formerly AdasWorks).

BMW is married to Intel/Mobileye's AV software platform. Volkswagen, without its own AV software platform, last summer jilted Aurora and turned to Ford's Argo.ai. As mentioned earlier, Hyundai has an apparently bigamous, possibly precarious bond with Aurora and Aptiv-nuTonomy.

HIGH-TECH SOFTWARE PLATFORMS

In the bin that includes the software-driven high-tech segment, Juliussen lists Waymo, Aurora, Argo AI, Almotive, and Drive.ai in the United States and an Asian contingent that covers Preferred Network in Japan, Baidu (with the Apollo project), AutoX, Momenta, WeRide, and Pony.ai.

Leading AV chip suppliers Nvidia and Mobileye are also developing their own soft-

ware platforms. And of course, there's Tesla, building its own full AV stack.

The notables in this crowded bin are Waymo, Aurora, Argo AI, Intel/Mobileye, Nvidia, and Drive.ai. Last June, Apple snatched up Drive.ai — a Mountain View, California-based startup founded in 2015.

Baidu's Apollo is an open-source AV platform with a large ecosystem of developers.

SCANT PUBLIC DATA

The toughest question of all in the AV market is whose AV software platform is solid, ready to go, and better than others. Given the lack of disclosure from the developers, we turned to another source of data that provides insight into the AV landscape: the AV disengagement reports produced by the California Department of Motor Vehicles (Figure 2).

ment of Motor Vehicles (Figure 2).

By law, anyone actively testing self-driving cars on California roads must disclose both the number of miles driven and the number of miles driven between "disengagements" — those fraught moments when a human driver is forced to take the wheel. The DMV formally defines disengagement as "deactivation of the autonomous mode when a failure of the autonomous technology is detected or when the safe operation of the vehicle requires that the autonomous-vehicle test driver disengage the autonomous mode and take immediate manual control of the vehicle."

Some safety experts believe that counting the miles between disengagements tends to encourage test operators to minimize their interventions, skewing the results and even putting the test drivers at risk. "Disengagement is the wrong metric for safe testing," said Phil Koopman, a Carnegie Mellon professor and co-founder of Edge Case Research.

Nevertheless, AV disengagement reports help the industry to peer into the readiness level of autonomous vehicles, if not determine their safety per se, argued Juliussen.

As of the end of last year, 65 companies had test-driving permits from the California DMV. Juliussen noted that while 567 vehicles were "qualified," only 420 AVs were on the streets.

A chart provided by Juliussen offers a plot line showing changes in the annual disengagement numbers of each AV platform from 2015 to 2019. But he questioned the validity of Baidu's disengagement data. Baidu last year reportedly drove 108,300 miles and told the California DMV that its vehicles went 18,000 miles between disengagements. Many industry watchers, including Juliussen, are skeptical because Baidu appears to be saying

Key Autonomous Vehicle Software Platforms: USA					
	Waymo Driver	Cruise	Argo AI	Aurora Driver	Aptiv
AV start	2009	2013	2016	2017	2013
AVs in-use	800+	250+	150+	50+	120+
Employees	1,500 range	2,000 range	700 (7/2019)	400+	700 (AV only)
AV rides	120K+ in Phoenix	Employees only	Tests only	CA permit 1/2020	110K+ Las Vegas
AV road miles	20M+: 1M/month	2M+	No public data	0.2M+	0.5M+
Virtual miles	15 B+: 1B/month	No public data	No public data	Millions/day	No public data
Partners	Waymo One Nissan-Japan Renault-France UPS-goods AVs	GM Honda Softbank	Ford Walmart & Lyft Domino-Postmates	Hyundai Fiat Chrysler Byton Amazon	Lyft Hyundai JV BMW Intel-Mobileye
AV use-cases	Robo-taxi Goods delivery Autonomous trucks	Robo-taxi Flexible route AVs Goods delivery?	Robo-taxi Goods delivery Flexible route AVs	Robo-taxi Autonomous trucks Flexible route AVs	Robo-taxi Flexible route AVs OEM-specific
Test areas	Phoenix, AZ California GA-MI-TX-WA 25+ cities total AZ-NM-TX (trucks)	San Francisco Detroit, MI Plan: New York	Pittsburgh & Detroit Miami, FL Washington DC Palo Alto, CA Austin, TX	California Pittsburgh, PA	Las Vegas, NV Boston, MA Singapore Pittsburgh, PA
L4 ready	August 2019	2021-22	2021	2022	2021-22

Figure 3: Companies are still targeting L4 readiness by 2022. (Image: IHS Markit)

Full AV Stacks: Five Years In, Does the Progress Measure Up?

that its AV software has suddenly gotten a lot safer than Waymo's (13.2k miles between disengagements) and GM (12.2k miles).

Juliussen has compiled a table listing five key AV software platforms in the United States, providing the scope of each AV software platform project, the targeted AV use cases, and the test areas (**Figure 3**). Most of these companies appear to claim that their AV software platforms will be L4-ready between 2021 and 2022. The exception is Waymo, which last fall announced the launch of "completely driverless Waymo cars" in certain areas of Arizona.

The number of AVs currently deployed by each AV platform developer varies. Waymo has the highest in numbers (800+ in use), with Aptiv at 120+ and Aurora at 50+.

In the Covid-19 era, however, all test driving on real streets in America has hit the brakes.

Waymo, for example, posted on its website, "All of our Waymo One rider services in Arizona are suspended for the time being, including our service with trained drivers and our fully driverless service within the early rider program."

But Waymo added, "While our service remains suspended, Arizonans will begin to see some Waymo vehicles back on the road starting May 11. This is the first part of our tiered approach to resume our operations safely, beginning with our test fleet and responsibly progressing to serve Waymo One riders again."

The full implications of the pandemic aren't yet known, but it's certain to have some effect on the progress of AV software platform development. For now, as reported by Axios, the AV industry's take is that "this pandemic, if anything, has shown the demand

for autonomous vehicles could be larger than expected."

Juliussen agreed that "AVs are more needed now than before" but added a caveat: "Many of the AV participants will not have the financial resources to continue at earlier investment levels. The major high-tech companies can do so — Google, Intel, and some Chinese companies. [But] most auto OEMs have to make some choices, such as investing in battery electric vehicles or AVs, and they will likely cut some in each segment until auto sales get closer to normal."

He added, "From a strategic viewpoint, battery EVs may be more important than AVs unless they want to give Tesla too much market share." ■

Junko Yoshida is global co-editor-in-chief at *AspenCore*.

AUTONOMOUS VEHICLES

AV Safety: Come Together, Right Now

By Junko Yoshida

How many safety standards does it take to screw in a light bulb in a highly automated vehicle? A few years ago, automotive market novices would have said, "None." These days, the number seems to keep increasing as the industry finally comes to grips with the technical challenges of producing demonstrably safe autonomous vehicles.

Driven by the winner-takes-all internet platform business model, autonomous-vehicle zealots had been racing to develop the industry's first robo-car. Their goal was simple: Dominate the AV platform so completely that everyone else in the industry would be forced to follow and license.



TTTech's Stefan Poledna

Fast forward to 2020. The go-it-alone, my-way-or-the-highway approach is driving on fumes. In contrast to a few years ago, leading automotive OEMs, Tier Ones, and tech suppliers including chip vendors are more engaged in forming industry-wide coalitions to develop AV standards that have safety considerations at their core.

Close to 10 industry initiatives are in the works, seeking to address different aspects of AV safety. Prominent among them are the established ISO 26262 and ISO/PAS 21448 "Safety of the Intended Functionality" (SOTIF) and the newly published UL 4600.

So does this mean the automotive industry is finally coming together? Perhaps.

Collaboration has been an alien concept for participants in the auto industry. When it comes to safety standards, of course, "everyone has different opinions," said Stefan Poledna, CTO of TTTech Auto, in a recent interview with EE Times Europe. But a certain measure of cooperation now "is the general direction."

What changed?



The industry achieved Level 2/Level 2+ autonomy so quickly that it vastly underestimated how much more difficult it would be to take the next leap. It has finally dawned on the AV industry that developing a safety-related computing system for Level 3–5 autonomy is "a grand challenge that shouldn't be addressed by a single player but in an ecosystem," said Poledna.

When an L3, L4, or L5 vehicle goes the wrong way on a one-way street, it's no longer the driver who's responsible — it's the carmaker. "That's a big deal," said Poledna, trumpeting the obvious.

NEW ISO STANDARD ON HORIZON

Remember "Safety First for Automated Driving" (SaFAD)? That white paper, published last July by 11 industry leaders (Aptiv, Audi, Baidu, BMW, Continental, Daimler, Fiat Chrysler Automobiles, HERE, Infineon,

AV Safety: Come Together, Right Now

Intel, and Volkswagen), is on its way to becoming a new ISO standard.

The paper outlined “a comprehensive approach to safety-relevant topics of automated driving,” aiming “to systematically break down safety principles into safety-by-design capabilities, elements, and architectures and then to summarize the verification and validation methods in order to demonstrate the positive risk balance,” as its authors wrote. The ISO accepted their premise, giving the industry the go-ahead to develop and formalize SaFAD.



Intel/Mobileye's Jack Weast

Wondering what it might take to turn a “comprehensive approach” into a workable ISO standard, we reached out to Jack Weast, senior principal engineer at SaFAD member Intel and vice president of standards at Mobileye. “We take the original SaFAD paper, clean it up, get rid of any color commentaries, and reformat the technical meat of the document into the ISO standard,” he told EE Times Europe.

Simon Fürst, principal expert for autonomous driving technologies at BMW Group, heads the ISO committee working to formalize SaFAD and is hoping for a quick turnaround on the new standard. He announced in a webcast called “The Autonomous” that his group is shooting for mid-2020 to publish its ISO Draft Technology Report (DTR) 4804.



BMW's Simon Fürst

Weast described the DTR as the first step for ISO standardization.

Several auto industry sources called the new ISO standard a step in the right direction but warned that it would be years before the draft becomes the final standard. Furthermore, they said that they find it too generic and too high-level to help automotive OEMs in the short term.

Intel's Weast acknowledged that the scope of the document is “pretty broad.” But he defended it as “a big umbrella,” covering discussions of how to “define, derive, develop, and test an automated driving system end to end.”

Noting that the document offers “a useful structure,” Weast said that Intel/Mobileye is “obviously supportive of the safety-by-design principles.” The document provides “a very well-thought-out way of doing things,” he said. “This is why it's great to have an ISO document.”

GOING ONE OR TWO LEVELS DOWN

The Autonomous (creator of the eponymous webcast) is an initiative of TTTech Auto, which specializes in safe software and hardware systems for advanced vehicles. Poledna told EE Times Europe that TTTech Auto is convening many players in the automotive ecosystem at an event to “brainstorm and discuss” development of “a proving ground” for car OEMs, Tier Ones, and chip vendors to test out the safety of their AV systems.

“They need to have certain exchanges amongst themselves” at a time when everyone is struggling to figure out what it takes to bring safe L3 and L4 cars to market, he added.

The Autonomous is fully aware of the many

approaches — including computing architectures, software algorithms, and sensor fusion — pursued by different companies to ensure safety, said Poledna. Indeed, that was part of the impetus for launching The Autonomous. TTTech Auto contends that players in the automotive industry need solutions that are much more specific, more concrete, and quicker on the trigger. The aim of The Autonomous is to go one or two levels down from the upcoming ISO DTR 4804 standard, to conceive “a reference design implementation” the AV industry can use, he said.

The goal isn't about picking the winning black box, though.

Instead of building AVs around black boxes, carmakers would like to be able to mix and match different modules — such as safety, doer-checker, and calculation modules — from different vendors. Assume that a safety module from Supplier A bears no resemblance to a safety module from Supplier B and that the differences pose critical compatibility issues. To avoid that scenario, Poledna said, the AV industry must have “a common understanding of what the safety architecture would look like,” with a common approach to elements such as interfaces and data structures.

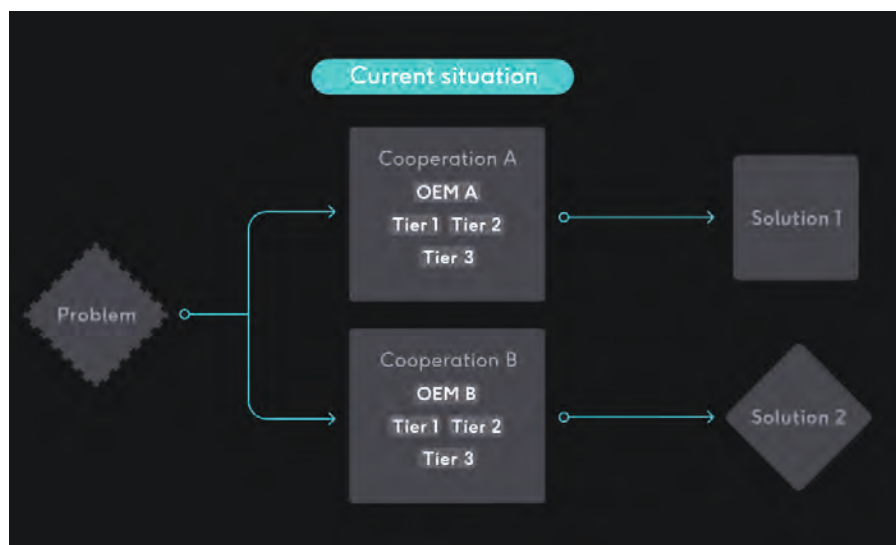
On the one hand, the ISO standard is deemed too generic. On the other, too many players in the AV industry are already implementing different safety solutions on their own. How does The Autonomous plan to succeed as a middle-ground solution?

“If we agree on ‘doer and checker’ as a generally acceptable safety approach, I'd consider it a huge achievement,” said Poledna. He'd like to see the industry come to a collegial understanding on data structure, interfaces, and a definition of free space. The Autonomous is holding a series of workshops focused on such issues as computing architecture, AI, security, and regulation. While participants are encouraged to share best practices, the goal for The Autonomous group is to foster amity among key automotive players and publish documents and technical papers reflecting state-of-the-art solutions in the industry.

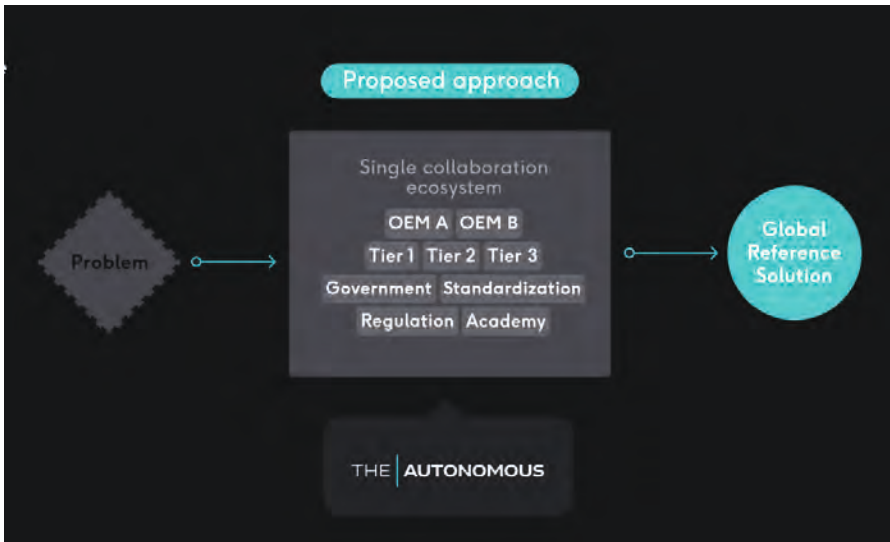
NARROW FOCUS

If The Autonomous is clicking one or two levels down from the ISO standard, Weast said that the IEEE P2846 working group, which he chairs, is boring down further into the details, focusing on “a very narrow area of decision-making capability.”

The benefit of being narrowly focused is that “we can go much deeper,” said Weast. In examining the decision-making process, “we also look at what kinds of assumptions we'd make about other road users.” Depending on the city or the situation (an intersection with an occluded view, for example) in which an AV is driving, knowledge of the



Everyone is struggling to figure out what it takes to bring safe L3 and L4 cars to market. (Image: The Autonomous)



The goal for The Autonomous is to foster amity among key automotive players and publish documents and technical papers reflecting state-of-the-art solutions.

(Image: The Autonomous)

assumptions that apply in those specific cases is essential to creating a safety model for a decision-making block, he said.

While IEEE P2846 is focused on that decision-making block, AV safety standards in the end are likely to require close to a dozen different technical blocks for the industry to define and implement safety, Weast speculated. “We will need, for example, a safe operation block,” which could be addressed by ISO 26262 and SOTIF. Others include a behavior and traffic block, “which maps well with what IEEE P2846 offers,” and a data recording block.

It is clear that “standards and interoperability are essential” to enable an ecosystem on which an entirely new market like AV can be built, said Weast. However, he acknowledged that setting industry standards is always a balancing act. You need to create a robust market, but companies must feel free to differentiate.

The specific technologies that require AV industry consensus would be those that will benefit everyone and lift all boats equally once various implementations are commonly available, said Weast.

Consider, for example, IEEE P2846. If AV companies can’t agree on what safety means (including a safe distance between cars, for example), they won’t be able to make convincing arguments to government regulators for the safety of autonomous vehicles, he said. The same goes for operational design domains (ODDs); without a



Edge Case Research’s
Phil Koopman

common template to define them, the industry can’t explain what a certain vehicle is capable of doing where and under what conditions.

Though the Covid-19 pandemic has put the brakes on most non-essential travel, Weast said that the IEEE P2846 group still wants to complete its draft by the end of this year or early 2021. To expedite the process, the group has broken the work into four subgroups. One is identifying safety-related scenarios in which there are assumptions about other road users. Another is examining the attributes of safety models used within decision-making. The third group is aligning definitions and taxonomy with those used by other standards as the best possible. The fourth group is documenting how the standard fits with or complements other standards “so that we can resolve some confusion and questions” about IEEE P2846, said Weast.

The IEEE P2846 group’s roster lists Aptiv, Arm, Baidu, Denso, Exponent, Fiat Chrysler (FCA), Google, Huawei, Horizon Robotics, Infineon, Intel, Kontrol, National Taiwan University, Nvidia, NXP, Qualcomm, Uber ATG, Valeo, Volkswagen, and

Waymo. In a recent election, the members selected Weast as the chair, a Waymo representative as vice chair, and an Uber delegate as secretary. For Waymo, this is a first; until now, the company has opted to go it alone.

“We now have a good representation from the chip industry, companies in the mobility-as-a-service business, car OEMs, Tier Ones, and robotics companies,” said Weast.

SAFETY CASE

Separately, Underwriters Laboratories has completed and published its first AV standard. UL 4600 is available at ULstandards.com.

Instead of prescribing how to design for safety by following certain steps, UL 4600 offers a guide to “build the safety case” for an AV design, said Phil Koopman, CTO of Edge Case Research, one of the authors of the standard. Acknowledging that no single standard can solve the world’s autonomous-product problem, the authors of UL 4600 have fixed a starting point by asking autonomous-product designers to make a safety argument.

UL recruited a diverse body of international stakeholders on its Standards Technical Panel (STP) to develop the document, said Koopman. The STP consists of 32 members with voting rights, including representatives of government agencies, academia, AV developers, technology suppliers, testing and standards organizations, and even insurance companies. Members include Uber, Nissan, Argo AI, Aurora Innovation, Locomotion, Zenuity, Intel, Infineon, Bosch, Renesas, Ansys, Liberty Mutual, AXA, and the U.S. Department of Transportation, among others. ■

Junko Yoshida is global co-editor-in-chief at AspenCore.

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ARTIFICIAL INTELLIGENCE

Startup Reinvents Neural Network Math, Launches 20-mW Edge AI Chip

By Sally Ward-Foxton

A Silicon Valley startup claims that it has reinvented the mathematics of neural networks and has produced a complementary edge AI chip, already sampling, that does not use the usual large array of multiply-accumulate (MAC) units. The chip can run the equivalent of 4 TOPS, with impressive power consumption of 55 TOPS/W, and achieves data-center class inference in under 20 mW (YOLOv3 at 30 frames per second), according to the company.

San Jose-based Perceive has been in super-stealth mode until now; as a spin-out from Xperi, it has been funded entirely by its parent since officially forming two years ago. The team comprises 41 people, with a similar number within Xperi working on apps for the chip. Founding CEO Steve Teig is also CTO of Xperi; he was previously founder and CTO of Tabula, a 3D programmable logic startup that closed its doors five years ago, and prior to that was CTO of Cadence.

Teig explained that the initial idea was to combine Xperi's classical knowledge of image and audio processing with machine learning. Xperi owns brands such as DTS, IMAX Enhanced, and HD Radio. Its technology portfolio includes image-processing software for features like photo red-eye reduction and image stabilization, which are widely used in digital

cameras, plus audio-processing software for Blu-Ray disc players.

"We started with a clean sheet of paper and used information theory to ask: What computations are neural networks actually doing, and is there a different way of approaching that computation that could change what is possible [at the edge]?" Teig said. "After a couple of years of doing this work, we discovered [there] was and then decided ... we should make a chip that embodies these ideas."

The idea that Teig presented to the Xperi board was to spin out a company to make a chip that could do meaningful inference in edge

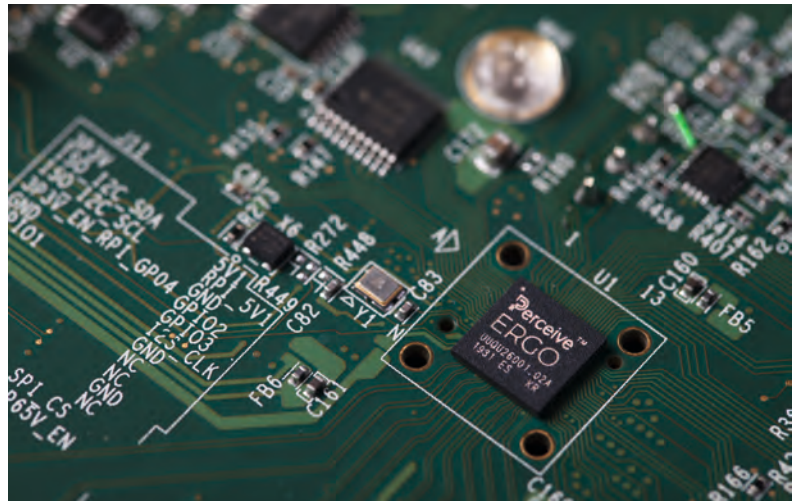


Perceive's Steve Teig

devices with a power budget of 20 mW. The result, a 7 × 7-mm chip named Ergo, can run 4 TOPS without external RAM (in fact, it is running the equivalent of what a GPU rated at 4 TOPS can achieve, Teig said). Ergo supports many styles of neural networks, including convolutional networks (CNNs) and recurrent neural networks (RNNs), in contrast with many solutions on the market that are tailored for CNNs. Ergo can even run several heterogeneous networks simultaneously.

"The only thing that limits how many networks we can run is the total memory that's required for the combination," Teig said, adding that Perceive has demonstrated simultaneously running YOLOv3 or M2Det — with 60 million or 70 million parameters — plus ResNet 28 with several million parameters, plus a long short-term memory (LSTM) network or RNN to do speech and audio processing. In an application, this might correspond to enabling imaging and audio inference at the same time.

Perceive also claims that its Ergo chip is extraordinarily power-



Perceive claims that its Ergo chip's efficiency is up to 55 TOPS/W, running YOLOv3 at 30 fps with just 20 mW. (Image: Perceive)

efficient, achieving 55 TOPS/W. This figure is an order of magnitude above what some competitors are claiming. Perceive's figures have it running YOLOv3, a large network with 64 million parameters, at 30 fps while consuming just 20 mW.

This power efficiency comes down to some aggressive power-gating and clock-gating techniques, which exploit the deterministic nature of neural network processing; unlike other types of code, there are no branches, so timings are known at compile time. This allows Perceive to be precise about what needs to be switched on and when.

"In a battery-powered setting, [the chip] can be literally off — zero milliwatts — and have some kind of microwatt motion sensor or analog microphone to detect something that might be of interest," Teig said. "We can wake up from off, load a giant neural network of data-center class, and be running it in about 50 milliseconds, including decryption. So we leave only about two frames of video on the floor."

But careful hardware design is only part of the picture.

INFORMATION THEORY

"We've come up with a different way of representing the underlying computation itself and the arithmetic that goes with it," Teig said. "We are representing the network itself in a new way, and that's where our advantage comes from."

Perceive started with information theory — a branch of science that includes mathematical ways to distinguish signal from noise — and used its concepts to look at how much computation is required to pull the signal from the noise. Teig uses an object-detection network as an example.

"You hand the network millions of pixels, and all you want to know is: Is there a dog in this picture or not?" he said. "Everything else in the picture is noise, except dog-ness [the signal]. Information theory makes it quantifiable — how much do you have to know [to tell whether there is a dog in the picture]? You can actually make it precise, mathematically."

As Teig describes it, mainstream neural networks are able to generalize based on seeing many pictures of dogs because they have found at least some of the signal in the noise, but this has been done in an empirical way rather than with a mathematically rigorous approach. This means noise is

Startup Reinvents Neural Network Math, Launches 20-mW Edge AI Chip

carried with the signal, making mainstream neural networks very large and making them susceptible to adversarial examples and other tricks.

“The more you can be mathematical about figuring out which parts need to be kept and which parts are just noise, the better job you can do at generalization and the less other overhead you have to carry with you,” Teig said. “I would claim even current neural networks are extracting signal from noise; they’re just not doing it in as rigorous a way, and as a result, they’re carrying extra weight with them.”

This information-theoretic point of view is the basis for Perceive’s machine-learning strategy, which represents neural networks in a new way. “Really, this is a marriage between an information-theoretic perspective on how to do machine learning and a chip that embodies those ideas,” Teig said.

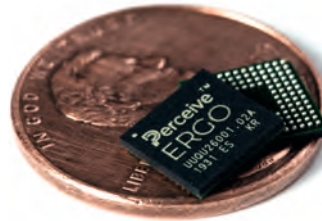
CHIP ARCHITECTURE

With Teig’s background as CTO of Tabula, you might expect hardware based on programmable logic, but that’s not the case here.

“I’ve been strongly influenced by thinking about programmable logic for a decade and how to build rich interconnect architectures to enable high-performance, very parallel computation, because much of what happens on an FPGA is also massively parallel and very intensive in its interaction between computation and memory,” he said. “That work has definitely influenced my work at Perceive, but what we have is not programmable logic per se. It’s been influenced by that way of thinking, but the architecture itself is around neural networks.”

Perceive’s neural network fabric is scalable, with initial chip Ergo having four compute clusters, each with its own memory. While exact details are still under wraps, Teig did say that these clusters are significantly different from anything found in other AI accelerators, which typically use arrays of MAC units to compute dot products of vectors and matrices.

“We are not doing that,” Teig said. “We do not have an array of MACs. As a result ... we are 20x to 100x as power-efficient as anything else on the market. The reason for that is that everybody else is doing the same thing and we’re not. Our representation of the networks is quite new, and that’s what’s allowed us to achieve such great efficiency — that,



Perceive’s technology is based on reinventing neural network math using techniques from information theory. (Image: Perceive)

plus the machine-learning technology that’s able to find this representation of the networks and to train the networks in a way that makes them compatible with what the chip wants to see.”

IMAGE AND AUDIO

Ergo can support two cameras and includes an image-processing unit that works as a pre-processor, handling things like de-warping fisheye lens pictures, gamma correction, white balancing, and cropping.

“It’s not fancy, but the pre-processing that’s obviously useful to do in hardware, we do in hardware,” Teig said. “And we have the audio equivalent, too — we can take multiple stereo microphones and do beamforming, for example.”

There is also a Synopsys ARC microprocessor with a DSP block that can also be used for pre-processing, plus a security block, also from Synopsys.

“One of the things we’ve done is to encrypt absolutely everything in order to maintain a level of security in an IoT setting,” Teig said. “We encrypt the networks, encrypt the code that runs on the microprocessor, encrypt the interfaces, encrypt everything.”

The chip features appropriate I/Os for sensors outside image and audio, and it supports an external flash memory and/or microprocessor, which enables over-the-air updates. This could be used to update the neural networks loaded on the chip or load different networks as required.

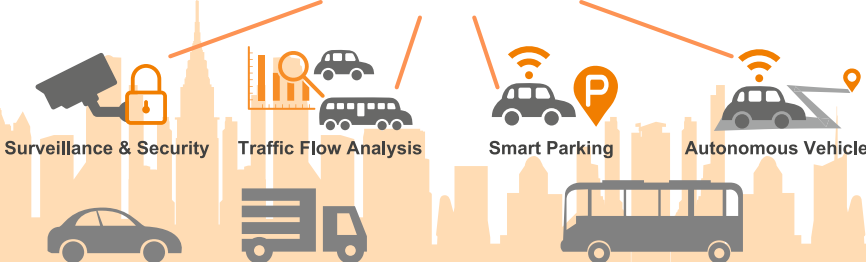
Ergo is sampling now along with an accompanying reference board. Mass production is expected in Q2 2020. ■

Sally Ward-Foxton is a staff correspondent at AspenCore.

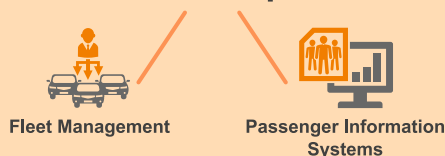


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COVER STORY

The Growing Importance of Innovative MEMS Microphones

By **Julian Kornprobst**, Product Marketing Specialist, Infineon Technologies AG, and **Somu Goswami**, Technical Marketing Specialist, Infineon Technologies AG

Microphone technology is becoming increasingly important as audio applications and features proliferate. Different factors have to be considered for a variety of applications, ranging from audio quality to water and dust robustness to size and cost. Infineon offers a portfolio of XENSIV™ MEMS microphones that ranges from low-cost models to products that deliver the highest performance levels.

The Growing Importance of Innovative MEMS Microphones

Voice is set to replace buttons in the future as a means of intuitively interacting with the environment around us. Reaching beyond conventional audio devices such as phones and recorders, voice control is now being incorporated into billions of other devices. Sensors such as MEMS microphones are key enablers of the trend toward human-machine communication. According to a report published by SAR Insight,¹ nearly 6 billion devices are expected to have voice interfaces supporting features such as voice triggers, voice biometrics, and embedded digital assistants by 2023. The current Covid-19 crisis has highlighted two areas where high-performance microphones can play a key role in developing sophisticated solutions: online meetings with high-quality audio and health tracking.

Many people are working from home because of the coronavirus pandemic. As a result, video conferencing has become the main way for employees to communicate with their colleagues. In these situations, advanced audio features can help reduce the perceived distance between friends and colleagues. Teams all over the world are using advanced video conference systems (Figure 1) to communicate more effectively — something that is particularly important in times when people are not able to meet in person.

High-quality video and audio are vital for ensuring that online meetings are efficient and convenient. If you think back to your last Skype or Zoom video call, what was more important: seeing your colleagues or hearing them? In terms of poor quality, what would bother you more: a blurry image or only hearing a part of each word? Audio often is noticed only when it is poor quality. And once we are used to good quality, nothing else will do. The main goal here is to ensure that each speaker's voice is reproduced as naturally as possible.

A new class of high-performance microphones is paving the way for smarter video calls and a host of other features. Smart cameras can pan and zoom in on people and objects to keep up with the action. They can also automatically pivot to keep everyone in view. Smart sound enhances the voice of the person talking while minimizing background noise. To improve performance levels, high-performance MEMS microphones are increasingly combined with advanced audio processing functions such as blind source separation or beamforming to localize the position of the user and blur out the background sounds. Today's video conference systems are fully integrated units that include a codec, display, camera microphones, and loudspeakers.

RISING DEMAND FOR HIGH-QUALITY AUDIO

High-quality video conferencing is no longer limited to the business world. The need to communicate with family and friends — be it in a “virtual happy hour” or digital Easter celebration — has led to the emergence of a number of new tools. New consumer devices such as Facebook's Portal, which combines video and audio features, all benefit from high-performance microphones that offer a high-quality audio experience. Other new applications are also being developed. Robots that can communicate with people in hospitals or retirement homes, for example, already exist today. Better sensors will make these interactions increasingly natural. In recent years, true wireless stereo (TWS) earbuds have emerged as a new device category in the field of hearables. TWS earbuds are not connected to each other or an audio source



Figure 1: Video conferences benefit from improved audio quality based on high-performance microphones.

by wires. Instead, they are connected over Bluetooth. Like their larger, over-ear cousins, TWS earbuds are equipped with a range of audio features in which microphones, once again, play a key role.

Active noise cancellation (ANC), for example, was originally developed to reduce the static noise of engines on flights. Nowadays, more powerful algorithms and better microphones have pushed ANC beyond the world of travel, enabling users to eliminate background noise and voices in the office or at home. It is even a feature in today's TWS headsets. Beamforming with microphone arrays enables people to have clear conversations, whether they are working from home or in a noisy environment.

Headphones, by design, isolate wearers from the outside world. While this can provide valuable passive isolation from annoying sounds, it is not always convenient. In many situations, we also want to hear what's going on around us without having to remove our devices — for instance, to tune in to announcements in train stations, pick up on surrounding sounds while running in a park, or talk to others. Transparent hearing modes have been developed that enable users to create blended augmented audio experiences by telling their high-performance microphones how much of the outside sound environment they wish to capture. Sound is picked up just before it enters the ears and is altered and played back in real time, creating a transparent, augmented hearing experience. Some manufacturers provide smart features, such as the automatic activation of transparent hearing when the wearer's name is called. In the future, it may be possible for microphones to be activated automatically when they detect an approaching car or a boarding announcement in an airport, for instance.

While transparent hearing is a first step toward emulating human ears, the experience can be taken one step further with 360° audio recordings. This technology involves equipping earbuds with microphones that have a low noise floor. The wearer can then use these earbuds to record sound experiences such as concerts in 360° audio. This creates an immersive experience that can be played back and relived later or shared with friends. The listener feels like they are actually at the concert; without any hiss noise, the recording cannot

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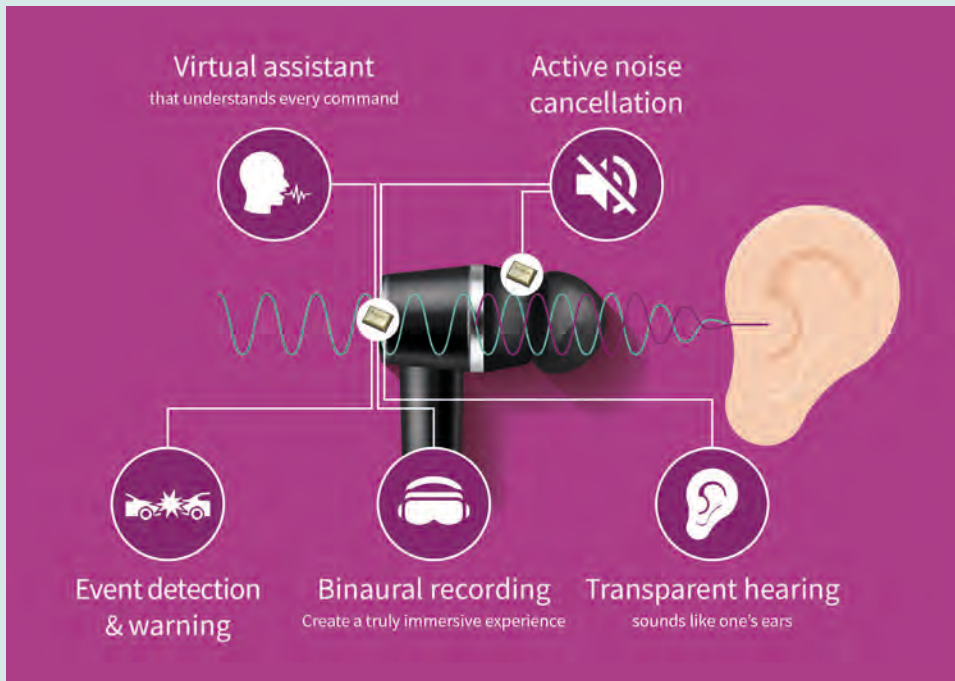


Figure 2: High-performance microphones are vital in a wide range of voice-control features and applications.

be distinguished from the real thing. Microphones are vital for providing the high-quality input that all of the applications mentioned here need in order to deliver an outstanding user experience and excellent audio quality (Figure 2). MEMS microphones with best-in-class audio quality specifications can deliver the required performance.

HEALTH TRACKING

Monitoring vital signs with optical sensors is an established technology. In some instances, however, space constraints limit the use of existing sensors. One way to save space here is to combine several sensors — creating, for example, a microphone that can also monitor body temperature. Health tracking is a growing market for mobile devices. Tracking applications will become more appealing as users become more health-conscious. High-performance microphones with ANC can be combined with body temperature sensors to provide a useful solution for tracking health and detecting a high temperature. A TWS headset with the ability to track the wearer’s temperature and issue a warning at the onset of a fever provides peace of mind; users can rest assured that their health is being monitored. Detecting fevers at an early stage means that treatment can be started promptly. Having a record of a patient’s body temperature can also help with diagnosis and treatment. Infineon has developed an ASIC that features an I²C temperature sensor. Combining this with the MEMS produces a high-performance microphone with temperature-sensing functionality — a solution that saves space by combining the two sensors.

INNOVATIVE APPLICATION EXAMPLE: FLUSENSE

An innovative device invented in the U.S. at the University of Massachusetts Amherst demonstrates the possibilities of using microphones in medical tracking (<https://www.umass.edu/gateway/feature/flusense>). Designed to analyze coughing and detect crowd sizes, the FluSense device is made up of three components: a camera, a microphone, and a computer (Figure 3). The challenge for the developers was to find an early way to predict and monitor the outbreak of influenza-like illnesses — characterized by key symptoms such as fever and coughing — as feeding lab-confirmed cases into epidemic models takes time.

The FluSense solution captures crowd-level non-speech body sounds such as coughs in an unobtrusive and passive manner, combining this data with patient counts estimated using thermal images taken in hospital waiting rooms. Together, these elements provide key predictive information on epidemiological trends for a given demographic. The FluSense platform processes low-cost microphone array and thermal imaging data at the edge using a Raspberry Pi and a neural computing engine (the Intel Movidius). None of the information stored is personally identifiable.

The solution can run deep-learning-based acoustic models and algorithms for estimating crowd sizes based on thermal imaging in real time. The system can detect coughs with an accuracy of up to 87%. The developers now aim to validate the model in non-clinical settings such as restaurants, public transportation, and classrooms. High-performance microphones could increase detection rates further under such conditions.

MICROPHONE PERFORMANCE

Taking a closer look at microphone performance, there are several factors to take into consideration: What are high-performance microphones? Which microphone parameters are important and which ones are relevant for different use cases? Every microphone is capable of recording a range of sound pressure levels (SPLs); this is known as the dynamic range of a microphone. The upper limit of the dynamic range is defined as the acoustic overload point (AOP), while the lower limit is defined by the microphone’s self-noise. A microphone can pick up only signals with an SPL above its self-noise. This lower threshold is known as the “noise floor” of a microphone, and it defines the signal-to-noise ratio (SNR). A microphone cannot record any sound below its noise floor. A microphone with a noise floor of 30 dB SPL, for example, cannot capture a human whisper at 25 dB SPL amplitude. Therefore, microphones with a higher SNR (i.e., a lower noise floor) are well suited to picking up low-amplitude audio signals.

SNR and AOP are important parameters for assessing individual microphone performance. However, most devices today use several microphones in an array. Smartphones, for example, have three or four microphones, while TWS incorporates up to six microphones (three per earbud). The numbers are even higher in conference systems. In short, microphone arrays can contain anywhere from two to 32 microphones. The performance of a microphone array depends on a combination of individual microphone characteristics and combined array characteristics. The individual characteristics include the AOP and SNR, while the combined array characteristics include factors such as sensitivity matching (whether all mics have almost the same sensitivity) and phase matching (whether all mics have a similar phase response). These features combine to improve overall audio capture and to ensure that the array produces higher-quality sound and has lower self-noise levels — comparable in many ways to watching a movie in normal resolution or full HD.

THE IMPORTANCE OF HIGH-QUALITY AUDIO RAW DATA

Virtual assistants like Siri and Alexa are voice user interfaces (VUIs) present in smart speakers. VUIs comprise an array of microphones that are used to capture higher-quality raw audio data as input for the application processor. The raw data input from high-SNR

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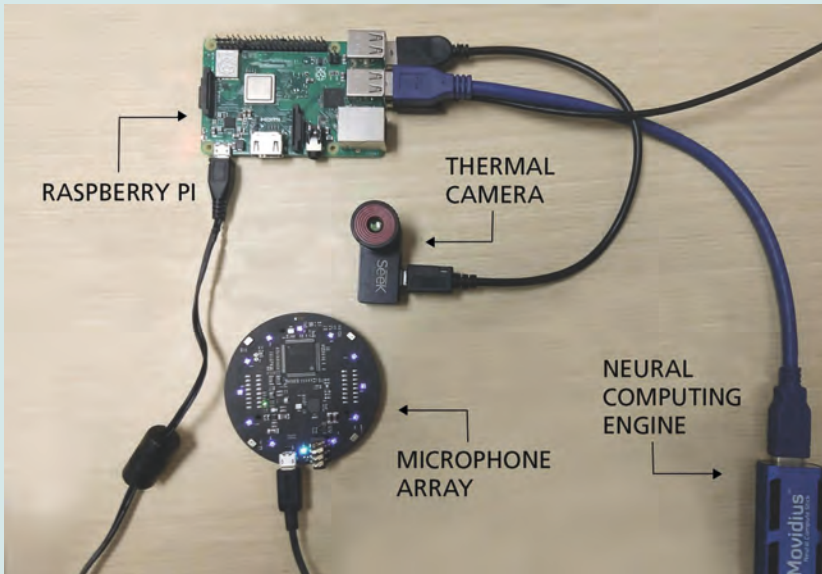


Figure 3: FluSense is an innovative concept for monitoring influenza trends. It combines a microphone array with a camera to analyze coughing and patient counts. (Image: University of Massachusetts)

microphones contains more information and less self-noise, which makes the subsequent processing on the edge processor and in the cloud more efficient. Better raw audio data input results in a higher hit rate, lower false acceptance instances, and, subsequently, a lower error rate for system wakeup. In short, having better microphones in your smart speaker means that the next time you ask it a question, you won't have to repeat yourself.

In general, each acoustic parameter has its own importance and enables certain specific use cases (Figure 4). High SNR, for example, is important for picking up distant and whispered voices in smart speakers, video conferencing devices, and similar far-field applications. A study conducted by Infineon showed that higher-SNR microphones can capture whisper audio 40% better than standard microphones. High

AOP is key for undistorted concert music recordings and echo cancellation when a microphone is placed close to a speaker. Good phase matching is important for microphone arrays and improving the performance of beamforming algorithms. In other words, if you are building a system that has to perform beamforming, pick up audio from a distance, and cancel echoes, you need an array of microphones with all of the above-mentioned features.

In addition to providing all of the audio parameters for the use cases mentioned above, microphones should be robust against water and dust. They must also work within their specifications under variations in temperature, humidity, pressure, and other environmental factors. In an ideal world, microphones would not generate any self-noise at all but would emulate the human ear, which has an extremely low noise floor. In reality, however, there are technical limitations defined by physics. There are typically four noise contributors in MEMS microphone systems: the MEMS itself, the ASIC, the package, and its sound port. The highest noise contributor for state-of-the-art microphones used in smartphones is the MEMS component. Infineon has improved the MEMS component, pushing the boundaries of MEMS microphone performance beyond even the current best-in-class dual-backplate technology. The company's efforts here culminated in the development of Infineon's innovative, patented sealed dual-membrane (SDM) MEMS technology.

A LOOK INSIDE A MEMS MICROPHONE

Before explaining how the new SDM works, it makes sense to take a quick look at the inside of a MEMS microphone and see what challenges the different components have to overcome to deliver the best performance. A typical design combines a MEMS sensor and an ASIC. MEMS microphones extract audio pressure changes as electrical signals. The ASIC then processes these signals either in differential analog or in digital format at the output. The first challenge is handling the pressure levels of loud sounds, as they produce large mechanical movements in

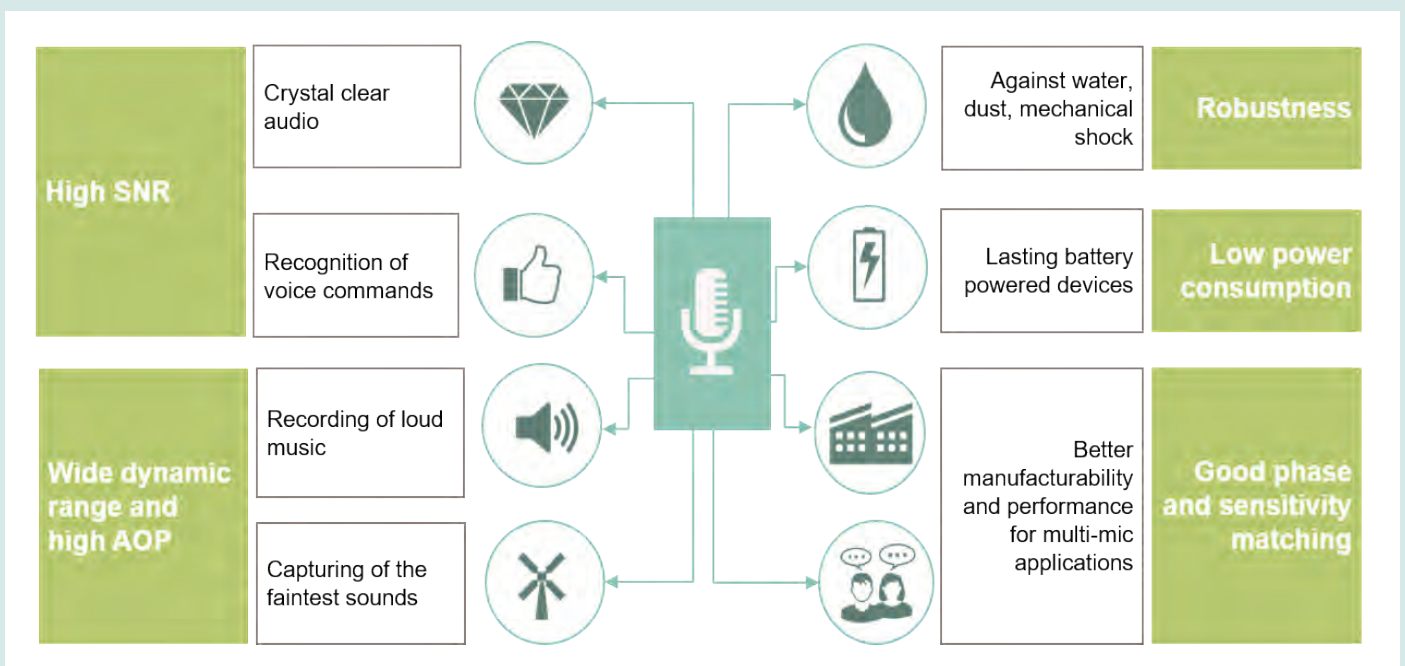


Figure 4: High-performance microphones are characterized by a number of different parameters.

The Growing Importance of Innovative MEMS Microphones

the membrane. These kinds of extreme membrane displacements cause distortion. The second challenge is to design an ASIC capable of handling the large signal that the MEMS element generates. As audio-processing algorithms assume a linear signal, any distortions above 1% can cause a significant reduction of the audio quality on which advanced audio processing relies.

One approach is to implement a MEMS sensor element that places the moving membrane between two capacitor plates (dual backplate, or DBP). A DBP MEMS microphone minimizes distortion due to its symmetrical construction. The same effect is achieved by moving two membranes that sandwich the capacitor plate (dual membrane).

SEALED DUAL-MEMBRANE TECHNOLOGY

The introduction of DBP technology has produced a significant increase in linearity specifications compared with MEMS microphones with a single backplate.

The next evolutionary step is capacitive MEMS microphones with an SDM. Sealing the capacitance area enables practically noise-free audio signal capture. This increases the SNR further, from 70 dB up to 75 dB (Figure 5). The first prototypes have already achieved an SNR of 75 dB and an AOP of 135 dB SPL. The first devices in this new generation have already been used to demonstrate the advanced audio features discussed above. By the end of 2020, Infineon will introduce further shrunk-sealed dual-membrane microphones targeted at space-constrained devices.

CONCLUSION

Microphone technology is becoming increasingly important as the number of audio applications and features rise. Different factors have to be considered for a variety of applications, ranging from audio

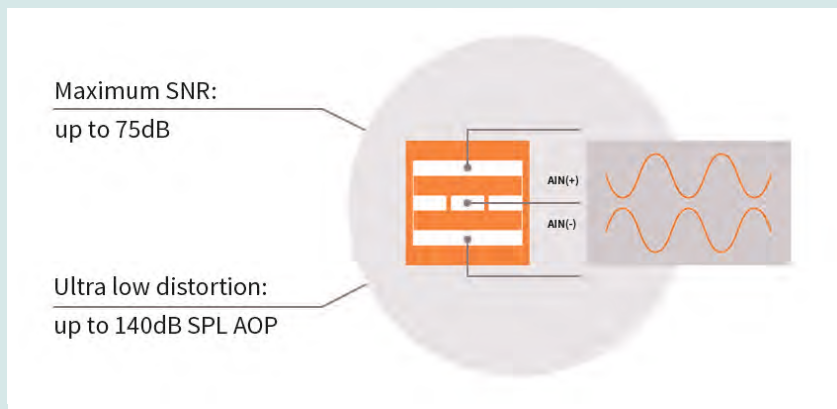


Figure 5: MEMS microphones with robust sealed dual-membrane technology (SDM) set the SNR and AOP benchmarks.

quality to water and dust robustness to size and cost. Infineon offers a portfolio of XENSIV™ MEMS microphones that ranges from low-cost models to products that deliver the highest performance levels. Devices with a single backplate are robust and cost-effective but have limited acoustic performance, whereas MEMS devices with DBP provide improved acoustics. SDM technology combines the highest acoustic performance (SNR up to 75 dB) with high robustness (IP 57). SDM MEMS microphones with best-in-class SNR are robust against dust and water and are the ideal choice for emerging applications such as high-quality video/audio conferencing and medical tracking. ■

REFERENCE

¹Digital and Voice Interface Forecast, October 2018

NEWS

Imagination Inquiry Exposes Wider Risk of IP Sales to China

Imagination Technologies' now-defunct plan to add four Chinese investors to its executive board has touched a raw nerve in the U.K. and triggered a series of events leading to a full-blown government inquiry. In a three-hour hearing before the U.K. Parliament's Foreign Affairs Committee, three Imagination CEOs, past and present, were grilled in a public battle to preserve the IP developer's legacy. The public debate centered on the suitability of Imagination owner Canyon Bridge Partners' recent attempt to add new Chinese directors to the board and the government's role — if any — in protecting home-grown intellectual property (IP).

Tech industry executives watched the live online event as factions within Imagination's past and present senior leadership

defended their business strategies. Imagination's revenue has steadily declined since 2017, and its recovery path has pitted former CEOs Hossein Yassaie and Ron Black, as well as former senior executive John Rayfield, against interim CEO Ray Bingham, who favored the involvement of Chinese backers.

None of the issues were resolved. The committee tried to unravel the drama that sparked the questions — the departure of Black and Rayfield as well as former senior executive Steve Evans — and fears that Imagination would relocate to China.

The bigger picture — IP licensing and security risks represented by China — isn't unique to the U.K. Electronics companies view the lucrative Chinese electronics market as fiscal salvation; governments greet China's foreign-investment plans with suspicion.

IC Unit Shipments Face First-Ever Back-to-Back Decline

Market researcher IC Insights forecasts that worldwide IC unit shipments will register their first-ever back-to-back annual decline in 2020. Prior to 2019, the previous four years that IC unit shipments declined were 1985, 2001, 2009, and 2012. From 2013 through 2018, IC unit shipments were on a respectable growth path, with an 8% increase logged in 2013, a 9% jump registered in 2014, a 5% increase displayed in 2015, a 7% increase shown in 2016, a double-digit growth rate of 15% in 2017, and a 10% increase in 2018.

In contrast to the double-digit increases in 2017 and 2018, 2019 marked only the fifth time in the history of the IC industry that IC unit shipments registered a decline, according to IC Insights.

OPINION | WIDE-BANDGAP DEVICES

SiC Technology for Electric Vehicles

By Maurizio Di Paolo Emilio



There is an opportunity for remarkable growth in the market for hybrid and electric vehicles (H/EVs), but we must innovate our way past some technological barriers on the sustainable-mobility landscape if we hope to see electrically powered vehicles become commonplace on European roads. Much of the public still needs to be persuaded of the efficiency of electromobility. Toward that end, several car manufacturers are working on fast-charging systems aimed at facilitating the use of electric cars. Wide-bandgap semiconductor silicon carbide (SiC) is central to those efforts.

DC fast-charging stations are an interesting field of application for SiC modules. To achieve the ambitious goals on power density and system efficiency that are being set by industries and governments, SiC transistors and diodes are needed. But developers must ensure a correct approach to the fast-charging system, with sufficient insulation and appropriate modularity.

Battery charging is a mostly constant-current application with a low demand for dynamic power. The main trend here is attaining the highest possible efficiency throughout the battery charge cycle. Today, 15- to 20-kW units use discrete components in 19-inch × 3U × 800-mm modules with forced-air cooling. New infrastructure is targeting DC chargers exceeding 350 kW, leading to the use of liquid cooling to enable a power growth increase per sub-unit to 60 to 75 kW in even smaller form factors.

The power supply blocks of the charger consist of an AC/DC front end followed by a DC/DC converter to provide the charging voltage to the battery. The AC/DC section converts the power supply from the distribution network to a useful DC voltage, avoiding ripple fluctuations. The DC/DC converter provides electrical isolation from the vehicle chassis for safety reasons while providing the necessary DC-charging voltage to the vehicle.

By replacing silicon-based designs using IGBTs or MOSFETs in the AC/DC block of the charger with SiC devices, the circuit design is simplified while the power density and, hence, the efficiency are significantly increased, enabling reductions in parts count and in system size, weight, and cost.

With a simple change in the control software, the SiC block can also enable the bidirectionality needed to allow the vehicle battery to become part of a smart grid. Enabling such bidirectionality with a silicon solution would require the use of more hardware in a far more complex circuit design.

Because the TO-247 and TO-220 formats can be used for packaging, SiC devices also enable



IMAGE: SHUTTERSTOCK

rapid replacement of silicon IGBTs and MOSFETs with the new SiC alternatives. In contrast, devices built with another wide-bandgap semiconductor, gallium nitride (GaN), have better results with surface-mount-device (SMD) formats. While SMDs are lighter and smaller, they cannot serve as swap-in replacements, relegating their use to new projects.

Silicon carbide devices can help sell the driving public on the efficiency of electromobility and put more hybrids and EVs on the road.

Infineon offers a pair of power modules that can be used in combination for 50-/60-kW EV charging solutions. The Easy 1B (F4-23MR12W1M1_B11) integrates a four-pack topology for the DC/DC stage of the charging station. The Easy 2B (F3L15MR12W2M1_B69) has a three-stage configuration that is well suited for the Vienna Rectifier, which is common for the power-factor correction (PFC) stage in this application. The modules use Infineon's CoolSiC diodes, rugged and efficient devices that were designed to meet requirements for use in hybrid and electric vehicles. An improvement on Infineon's last-generation Schottky diodes, the CoolSiC diodes have better figures of merit, minimizing power losses.

The use of SiC in the drivetrain also ensures greater efficiency and, by extension, vehicle autonomy. AC Propulsion took advantage of high-performance SiC FETs to hit all the system power targets for an EV traction inverter design. The company designed in UnitedSiC's UF3SC120009K4S, a 1,200-V, 9-mΩ SiC FET delivering improved efficiency over competing SiC devices in three-phase AC traction inverters for EVs. The devices returned >99% efficiency in AC Propulsion's design, even when switching at frequencies of >20 kHz and at 2× the frequency of IGBTs.

The UF3SC120009K4S is packaged in the TO-247 format, making it a cost-effective drop-in replacement for silicon equivalents. Its efficiency allows the use of a self-contained heat sink.

The SiC projects and devices discussed here demonstrate the progress being made on increased efficiency. Over time, such advances will gain consumer confidence for improving EV technology. ■

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

WIDE-BANDGAP DEVICES

SiC MOSFETs for the Next Generation of EVs

By Maurizio Di Paolo Emilio

In their efforts to maximize energy efficiency in electric and hybrid vehicles, designers are focusing on devices in compact packaging and on assembly of high-thermal-reliability, low-switching-loss power electronics modules. Design parameters take into account the power level, conversion efficiency, and operating temperature of the vehicle powertrain system; thermal energy dissipation capacity; and the system package.

SiC VERSUS GaN

The bandgap of a semiconductor material refers to the energy needed to knock an electron of the material from the valence band to the conduction band. Silicon carbide (SiC) and gallium nitride (GaN) are wide-bandgap (WBG) semiconductors, meaning this energy level is higher for those

SiC power electronics for EVs meet the design requirements for high-power applications, thus contributing significantly to system performance and long-term reliability.

materials than it is for silicon (Si): Si's bandgap is 1.1 eV, compared with 3.3 eV for SiC and 3.4 eV for GaN.

Despite the similar bandgaps of SiC and GaN, components based on those materials are not interchangeable, and a designer's choice of material will differ according to the parameters of use for the systems in which the devices will operate.

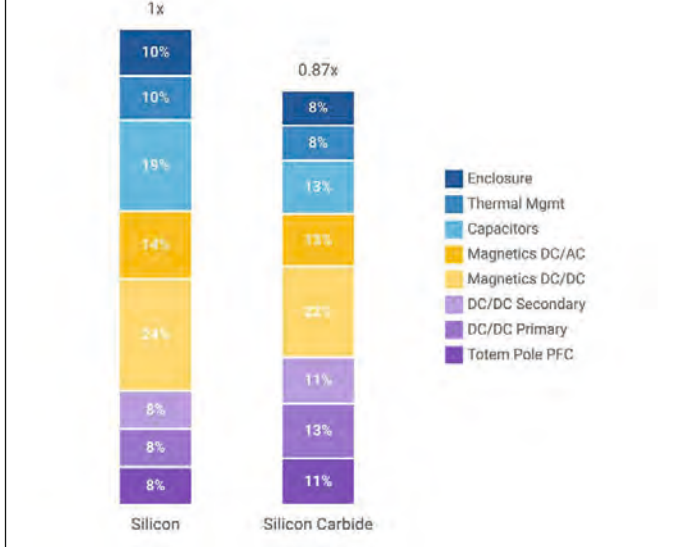
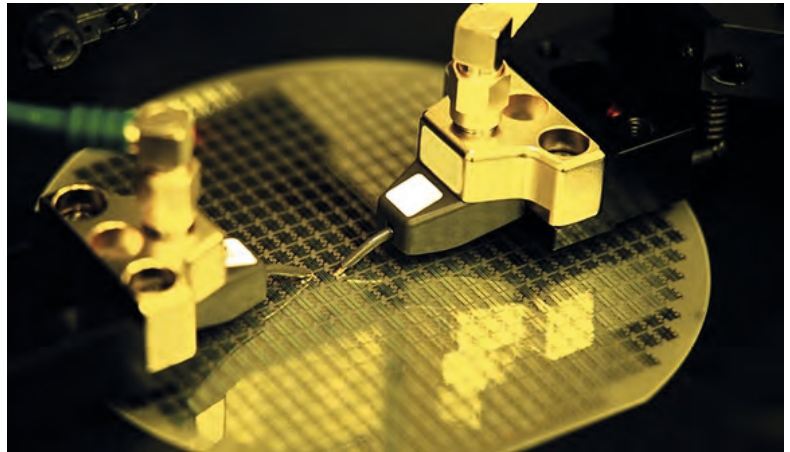


Figure 1: Reducing total system cost in a 6.6-kW bidirectional on-board charger design (Image: Cree/Wolfspeed)



vice president and general manager of Power at Cree. “Global OEMs have announced more than US\$300 billion in EV investments, and we expect a projected 20% of all model types manufactured to be electrified within the next 10 years.”

GaN performance and reliability are related to temperature and the Joule heating effect on the channel. Substrates such as SiC and diamond integrated into GaN can improve heat management, making it possible to lower the operating temperature of the device.

GaN-on-SiC works very well for very high-frequency (RF) applications and thus is expected to serve future devices that will work with 5G. GaN-on-Si, meanwhile, maintains its place in low-voltage (<200-V) products such as compact USB Power Delivery (PD) chargers. In the range between 600 V and 650 V, both technologies work very well in sub-2-kW applications.

Because of its excellent performance in minimizing switching losses, GaN can be the right solution when switching frequencies in the megahertz range are required. But at increased switching frequency and current values, GaN's weak resistance ($2\times$ to $3\times$ greater than SiC's) can limit GaN's application at high temperatures in terms of both device and system cost.

“Due to the massive adoption of silicon carbide in the automotive industry, we see a path for silicon carbide to become the most cost-effective solution in an even wider variety of power supply designs,” said Cameron. “Silicon carbide is a key solution for on-board chargers [OBCs]. The power-density and -efficiency improvements over silicon implementations enable a strong reduction in terms of volume and weight [Figure 1].”

Cree's products “enable bidirectional OBC designs that support the V2x [vehicle-to-vehicle or vehicle-to-grid] trend,” Cameron added. “With our portfolio of devices at 1,200 V and 650 V, we are able to meet the requirements for both 800-V and 400-V electric vehicle architectures.”

CREE'S SOLUTIONS

With the release of its Wolfspeed 650-V silicon carbide MOSFETs, Cree is targeting a broader range of industrial applications. Target markets include EVs, data centers, and renewable energy.

“There is an array of applications that can benefit from Cree's new 650-V MOSFETs,” Cameron said. “Electric vehicles and data centers are two areas that can see huge benefits from the technology that primarily stem from its high-efficiency, high-power-density traits. Compared with silicon alternatives, you can see half the conduction losses, 75% lower switching losses, and 70% greater power density [Figure 2].”

SiC MOSFETs for the Next Generation of EVs

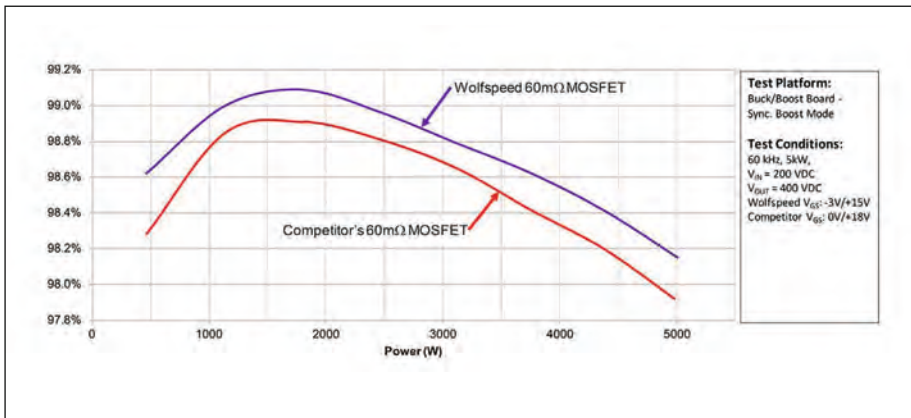


Figure 2: Cree's Wolfspeed 650-V MOSFET is designed to minimize both switching and conduction losses. (Image: Cree/Wolfspeed)

Those benefits are a natural fit for EVs and data centers, as well as telecom power, UPS [uninterruptible power supplies], solar inverters, and others.”

The 15- and 60-mΩ, 650-V, AEC-Q101-qualified devices, using third-generation Cree C3M MOSFET technology, offer lower switching losses and lower on-state resistance than previous solutions. The MOSFETs provide 75% lower switching losses and 50% lower conduction losses than silicon equivalents, resulting in a potentially 300% increase in power density. Increased efficiency and faster switching speeds allow customers to design smaller solutions with higher performance.

“Power supply designers can achieve maximum efficiency in their products when they use silicon carbide, enabling them to get either more power out of the same form factor or the same power out of a smaller form factor, or [they can] maximize power density to reduce size, weight, or cost,” said Cameron. “The properties of the silicon carbide substrate are absolutely critical. For example, as a cousin to diamond — the best heat conductor in nature — silicon carbide has vastly superior thermal performance over silicon. The easier it is to get the heat out, the cooler the device runs, which multiplies the effect of the low on-resistance change over temperature

[Figure 3].”

Full SiC modules are becoming more widely available, both in standard footprints and new module designs optimized around the WBG material.

“Our release of the XM3 family of 1,200-V silicon carbide half bridges shows the improvements possible when packaging is designed with silicon carbide in mind,” said Cameron. “We also actively support module manufacturers in the development of modules based on our silicon carbide die, and they have been able to achieve excellent performance with their innovative designs.”

The strong adoption of SiC solutions has been driven by ever-increasing demands for performance in a range of industrial applications. According to market research, the most profitable markets for new power devices will be electric mobility and self-driving vehicles, in which WBG semiconductors will be used in inverters, OBCs, and LiDAR anti-collision systems. This is no surprise, given that the thermal characteristics and efficiency of the new devices meet demands to optimize the performance of the accumulators. ■

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

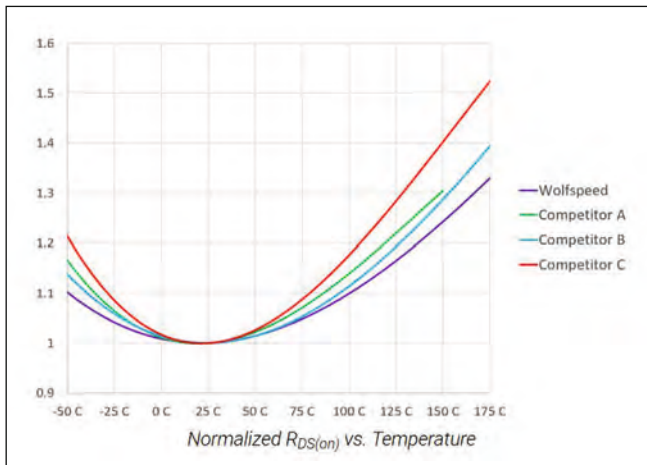


Figure 3: Normalized drain-source on-resistance versus temperature for a range of devices (Image: Cree/Wolfspeed)

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WIDE-BANDGAP DEVICES

GaN HEMTs Outperform MOSFETs in Key Growth Applications

By Maurizio Di Paolo Emilio

Silicon power MOSFETs have not kept pace with the evolutionary changes in the power electronics industry, where factors such as efficiency, power density, and smaller form factors are the main demands of the community. Silicon MOSFETs have reached their theoretical limits for power electronics, and with board space at a premium, power system designers need alternatives. Gallium nitride (GaN) is a high-electron-mobility transistor (HEMT) semiconductor that is adding real value in emerging applications.

For a 48-bus system, a 250-kHz GaN solution with double the frequency allows a 35% size reduction, lowers inductor DCR losses, and cuts system cost by roughly 20%.

GaN transistors are significantly faster and smaller than silicon MOSFETs, enabling efficiency gains that have opened the door to applications not possible with silicon technology. Efficient Power Conversion's (EPC's) eGaN FETs are supplied in low-inductance, low-resistance, small, and low-cost land grid array (LGA) and ball grid array (BGA) packages. The new EPC FETs offer designers best-in-class performance compared with silicon MOSFETs in both hard- and soft-switching applications.

GaN FETs

GaN switching devices are available in two types: enhancement mode (e-GaN) and

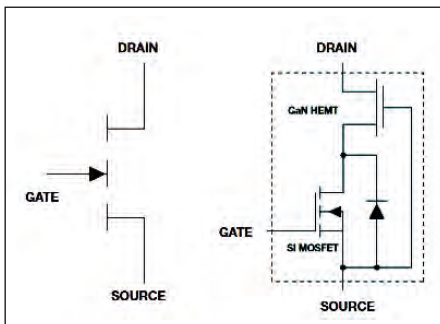


Figure 1: e-GaN (left) and d-GaN configurations (Image: EPC)

cascode depletion mode (d-GaN). An e-GaN transistor works as a normal MOSFET, even with a reduced gate-to-source voltage. It offers a simpler package and low resistance, with a bidirectional channel and without a body diode.

The d-GaN transistor is normally switched on and needs a negative voltage. You can overcome this problem by connecting the HEMT transistor in series with a low-voltage silicon MOSFET, as shown in **Figure 1**.

In contrast, the e-GaN transistor is normally off and is turned on with a positive voltage applied to the gate. Unlike d-GaN, e-GaN devices do not need a negative startup bias; with a zero bias on the gate, the device is turned off and does not conduct current.

The threshold of an e-GaN FET is lower than that of a silicon MOSFET, yielding a very low gate-to-drain capacitance (C_{GD}). The low-capacitance structure permits switching hundreds of volts in nanoseconds at megahertz frequencies. GaN FETs' large gate-to-source capacitance (C_{GS}) relative to C_{GD} gives the devices good dV/dt immunity.

The dV/dt sensitivity of power-switching devices is caused by the various parasitic capacitance and gate-drive circuit impedance levels. The gate-charge (Q_g) parameter, on the other hand, indicates the ability of the device to change states quickly, reaching a higher dV/dt with minimal switching losses. The gate charge of an e-GaN device is $10\times$ higher than for an equivalent MOSFET, while d-GaN devices have about a $2\times$ to $5\times$ higher Q_g than MOSFETs.

To determine the dV/dt sensitivity of a power switch, you can use a figure of merit called the Miller charge ratio (Q_{GD}/Q_{GS}). A Miller charge ratio of <1 will guarantee the theoretical dV/dt immunity. The gate-drive circuit layout is a critical factor in improving dV/dt immunity.

The d-GaN transistor has the gate structure of a low-voltage silicon MOSFET. Therefore, existing commercial MOSFET gate drivers can easily operate d-GaN switches. The downside is that the addition of the silicon MOSFET ignition resistance raises the overall ignition resistance. The increase can be significant for low voltages (<200 V). For higher values (600 V), the additional resistance may be only about 5% of total on-resistance. A d-GaN transistor also has increased packaging complexity. Parasitic inductance and capacitance between the MOSFET and the GaN HEMT may

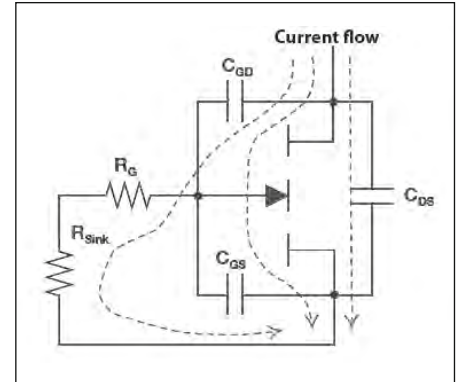


Figure 2: Parasitic capacitance and current flow in a GaN device (Image: EPC)

cause delay during switching transients.

The reverse-conduction characteristics of a switching device are important. In a MOSFET, the voltage drop of a body diode is low and its reverse recovery is very slow, resulting in high switching losses.

GaN devices do not have a reverse body diode; they are able to conduct in the reverse direction because of their physical nature. In the case of reverse conduction, it will be necessary to have dead time. A d-GaN device in cascade has reverse recovery by means of the low-voltage silicon device.

In hard-switching converters, the output charge is dissipated in the FET at each power-on transition. This loss is proportional to the output charge (Q_{OSS}), bus voltage, and switching frequency. GaN FETs have a significantly lower Q_{OSS} than silicon FETs, reducing the output charge loss per cycle and thus allowing higher frequencies (**Figure 2**).

AUTOMOTIVE AND CONSUMER SOLUTIONS

Emerging computing applications demand more power in much smaller form factors. In addition to the expanding needs of the server market, some of the most challenging applications are multi-user gaming systems, autonomous cars, and artificial intelligence.

Automotive systems are increasingly moving toward 48-V devices, driven by the increase in electronically controlled energy-hungry functions and the emergence of autonomous vehicles that create additional demands on the energy distribution system from systems such as LiDAR, radar, cameras, and ultrasonic sensors. These energy-hungry processors represent an additional burden for traditional 12-V power distribution buses in the automotive sector.

GaN HEMTs Outperform MOSFETs in Key Growth Applications

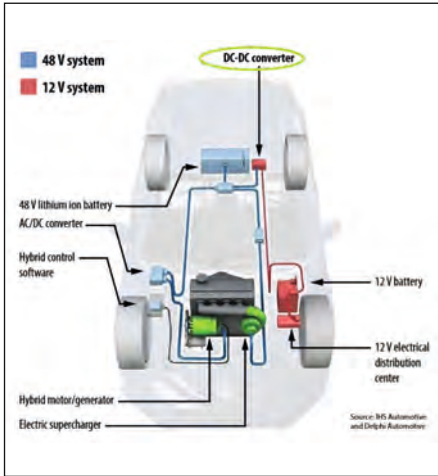


Figure 3: Representation of a 48-V mild hybrid system

For 48-V bus systems, GaN technology increases efficiency, reduces system size, and reduces system cost. A 250-kHz GaN solution with double the frequency allows a 35% reduction in size, lowering inductor DC resistance (DCR) losses as well as cutting system cost by approximately 20% compared with the MOSFET solution. GaN’s exceptionally high electron mobility and low temperature coefficient allow low Q_c and zero reverse-recovery charge (Q_{RR}). The final result is a device that can manage tasks with a very high switching frequency for which a low on time is beneficial, as well as those in which on-state losses dominate.

“High-power EPC eGaN FETs’ lower resistance in the on state, lower capacitance, higher current, and excellent thermal performance characterize these power converters with over 98% efficiency,” said Alex Lidow, CEO and co-founder at EPC. “This family of eGaN FETs halves the drain-source on-resistance to enable high-current and high-power-density applications.”

The latest generation of eGaN FETs also halves the hard-switching figure of merit compared with the previous generation for improved switching performance in high-frequency power conversion applications.

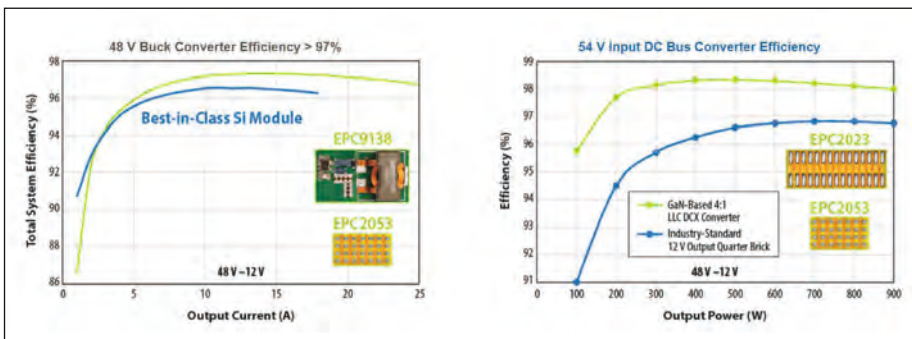


Figure 4: Efficiency versus current (Image: EPC)

An increase in performance to 30 V enables GaN to be used to build high-power DC/DC converters, point-of-load (PoL) converters, and synchronous rectifiers for isolated power supplies, PCs, and servers.

The smallest, most cost-effective, and highest-efficiency non-isolated 48-V to 12-V converter, suitable for high-performance computing and telecommunication applications, can be achieved by employing eGaN FETs such as the EPC2045, according to EPC. The EPC2045 has an operating temperature of -40°C to 150°C with thermal resistance of 1.4°C/W . The drain-source on-resistance ($R_{DS(on)}$) is $5.6\text{ m}\Omega$ typical (Figures 3 and 4).

In the consumer market, portable solutions are becoming increasingly energy-hungry. Efficiency and thermal management are critical in small platforms with minimal cooling solutions. The need for fast and efficient chargers has led the consumer market toward GaN solutions (Figure 5).

LIDAR

The eGaN FETs and integrated circuits are the logical choices to use when turning on a laser in a LiDAR system because FETs can be activated to create high-current pulses with extremely short pulse widths. “The short pulse width leads to higher resolution, and the higher pulse current allows LiDAR systems to see further,” said Lidow. “These two features, together with their extremely small size, make GaN ideal for LiDAR.”

EPC provides various development boards for its eGaN FETs. The EPC9144 is mainly designed to drive high-current laser diodes with high-current pulses at a total pulse width of 1.2 ns and current up to 28 A (Figure 6). The board is designed around the 15-V EPC2216 eGaN FET, which is automotive-qualified to AEC-Q101. The EPC9126 and EPC9126HC development boards are primarily intended to drive laser diodes with high-current pulses and total pulse widths as low as 5 ns (10% of peak). They are designed with the 100-V EPC2212 and EPC2001C enhancement-mode eGaN FETs, capable of 75-A and 150-A current pulses, respectively.

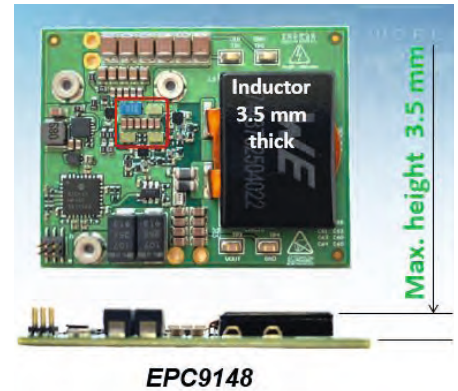


Figure 5: EPC9148 GaN transistor board for consumer applications (Image: EPC)

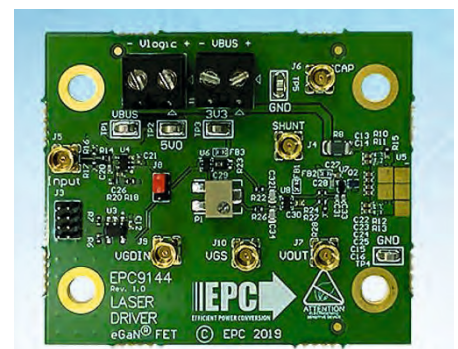


Figure 6: EPC9144 development board (Image: EPC)

Cepton Technologies’ Helius LiDAR solution, based on the EPC technology, delivers advanced object detection, tracking, and classification capabilities to enable applications for smart cities, transport infrastructure, security, and more. It combines industry-leading 3D LiDAR sensing powered by Cepton’s patented Micro Motion Technology (MMT), edge computing for minimum data burden and maximum ease of integration, and built-in advanced perception software for real-time analytics.

“LiDAR has become a very significant market,” said Lidow. “It is probably most recognized as the solution for autonomous cars. However, a faster-growing market is for short-range LiDAR, which is being used for things like robots that only need to see a few feet, drones for collision avoidance, and driver-alertness systems.”

“Short-range LiDAR systems do not require as much current as long-range LiDAR systems. But seeing [over a] short distance means you need an even faster pulse, because if you’re measuring something that is 1 meter away, [for example], the return signal will come back in just nanoseconds. We’ve demonstrated systems for short-range LiDAR that have pulse widths less than 1.2 ns.”

GaN HEMTs Outperform MOSFETs in Key Growth Applications

Maximum Ratings			
PARAMETER		VALUE	UNIT
V_{DS}	Drain-to-Source Voltage (Continuous)	100	V
	Drain-to-Source Voltage (up to 10,000 5 ms pulses at 150°C)	120	
I_D	Continuous ($T_A = 25^\circ\text{C}$, $R_{\theta JA} = 44^\circ\text{C/W}$)	1.7	A
	Pulsed (25°C , $T_{PULSE} = 300 \mu\text{s}$)	2.4	
V_{GS}	Gate-to-Source Voltage	6	V
	Gate-to-Source Voltage	-4	
T_J	Operating Temperature	-40 to 150	°C
T_{STG}	Storage Temperature	-40 to 150	

Thermal Characteristics			
PARAMETER		TYP	UNIT
$R_{\theta JC}$	Thermal Resistance, Junction-to-Case	14	°C/W
$R_{\theta JB}$	Thermal Resistance, Junction-to-Board	79	
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient (Note 1)	100	

Figure 7: EPC2037 enhancement-mode power transistor (Image: EPC)

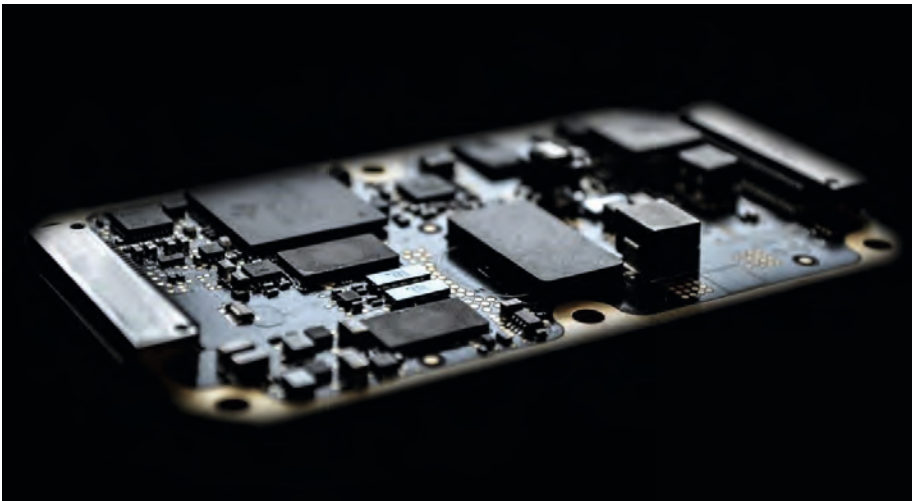


Figure 8: Isolated power-conditioning unit, the Cesium PCU-1C28, designed with EPC devices (Image: EPC)

WIRELESS POWER

“Wireless energy is ready to be incorporated into our daily lives,” Lidow said. Transmitters can be placed in furniture, walls, and floors to power or charge electronic and electrical devices efficiently and economically over large areas and across multiple devices.

Wireless energy transfer has been studied for more than 100 years; in fact, the concept dates back to the invention of the Tesla coil. A key factor in making viable wireless energy transmission systems viable is efficiency: To define such a system effectively, a large portion of the energy transmitted

by the generator must reach the receiving device. Magnetic resonance technology is the linchpin to ubiquitous implementation, enabling transmission over large areas, spatial freedom for positioning reception devices, and the ability to power multiple devices simultaneously.

EPC offers a full range of transmitter and receiver reference designs from single device charging to multiple devices powered simultaneously across a large surface area. GaN enables high efficiency for both the low-frequency (Qi) and high-frequency (Air-Fuel) standards, supporting a lower-cost,

single-transmit amplifier solution that can wirelessly charge devices regardless of the standard used in the receiving device. Wireless charging systems that rely on the Qi standard operate by inductive coupling at frequencies in the 100- to 300-kHz range.

AUDIO APPLICATIONS

The lower power dissipation of Class D audio systems produces less heat, saves space and costs for printed circuit boards, and extends battery life in portable systems. Now that GaN-based HEMT devices with much better physical properties have become a reality, a leap in Class D amplifier performance is on the doorstep. The low resistance and low capacitance of eGaN FETs offer low transient intermodulation distortion. Fast switching capability and zero reverse-recovery charge enable higher output linearity and low crossover distortion for lower total harmonic distortion.

“The first Class D amplifiers were designed for cars, because they wanted to have more speakers and more power in cars,” said Lidow. “Class A amplifiers were just too big to produce more than about 25 W and still fit in the dashboard. Class D was first introduced in the 1980s and enabled cars with 16 speakers and 250 W of power. Its sound quality, however, was never as good that of a Class A amplifier. That’s because MOSFETs can’t switch fast enough, and therefore, the relatively low switching frequency means relatively poor-quality reproduction. And with GaN devices, of course, you can go to much higher frequencies.”

SPACE APPLICATIONS

Enhanced-mode GaN is widely used in device development for space applications. Commercial GaN power devices offer significantly higher performance than traditional radiation-hardened devices based on silicon technology. This allows the implementation of innovative architectures with applications on satellites, data transmission, drones, robotics, and spacecraft.

Smaller than equivalent MOSFETs, eGaN FETs provide radiation tolerance, fast switching speed, and improved efficiency, leading to smaller and lighter power supplies (smaller magnets and reduced heat sink size or even elimination of heat sinks in many cases). Faster transient response can also reduce capacitor size. Using these FETs, power supply designers have the choice of increasing the frequency to allow smaller magnets, increasing efficiency, or designing a satisfactory balance of both. ■

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

WIDE-BANDGAP DEVICES

Reliable and Efficient Control of SiC MOSFETs

By Maurizio Di Paolo Emilio

Demand continues to grow rapidly for silicon carbide (SiC)-based devices to maximize efficiency and reduce size and weight, enabling engineers to create innovative power solutions. Applications that leverage SiC technology range from electric vehicles (EVs) and charging stations to smart power grids and industrial and aeronautical power systems.

New digital programmable gate driver solutions help accelerate the process from design to production. The higher electric field strength of SiC substrates permits the use of thinner base structures. Silicon carbide is also excellent in its voltage resistance but not very good in standup short-circuit conditions. The new gate drivers have been designed to address problems such as system noise, short-circuits, over-voltage, and overheating.

SiC TECHNOLOGY

SiC technology is now widely recognized as a reliable alternative to silicon. Many manufacturers of power modules and power inverters have laid the foundations for SiC use in their product roadmaps.

“The [market] growth in silicon carbide power semiconductor devices has doubled over the last three years,” said Orlando Esparza, strategic marketing manager at Microchip Technology. “There’s a lot of optimism in the market that it will reach up to US\$10 billion within the next seven to 10 years. We are seeing rapid adoption [for SiC], and we are working on a large number of opportunities globally.

“These opportunities span across many different types of applications within indus-

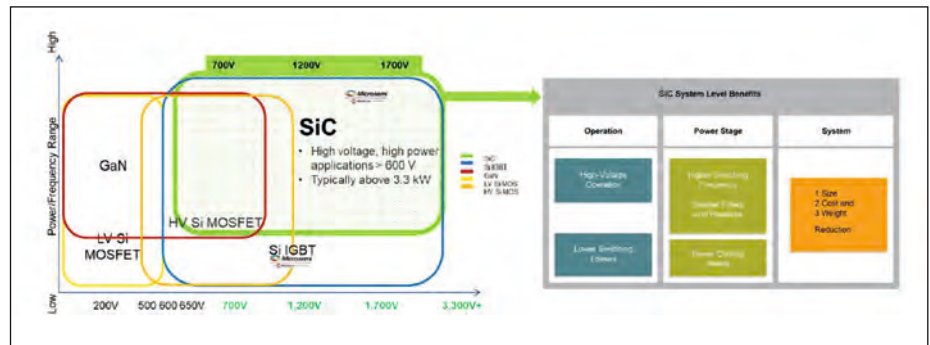


Figure 1: What’s driving the adoption of SiC in power electronics?

(Image: Microchip Technology)

trial, automotive, medical, aerospace and defense, traction or train, and more.”

SiC power technology allows EV and other high-power switching applications to achieve maximum efficiency, said Esparza. “Silicon carbide serves the needs of applications requiring system voltages of 600 V and above. We’re seeing a lot of opportunity for our 700-V and 1,200-V devices within electric-vehicle applications that have either a 400-V or an 800-V bus, [as well as in] industrial medical equipment that is in the higher-voltage range.”

System designers are adopting SiC solutions to overcome the efficiency limitations of traditional, silicon-based devices, he added. “Silicon carbide allows their systems to be smaller and lighter-weight, and the overall system cost is actually lower.”

Microchip’s new power modules include commercially qualified Schottky barrier diodes (SBDs) at 700, 1,200, and 1,700 V to maximize switching efficiency, reduce heat

gain, and reduce system footprint. Available topologies include dual diode, full bridge, phase leg, dual common cathode, and three-phase bridge, and multiple current and package options are offered.

The addition of SiC SBD modules in designs maximizes switching efficiency, reduces thermal gain, and allows for a smaller system footprint. High device performance enables system designers to minimize the need for snubber circuits by leveraging the stability of the diode body without long-term degradation (**Figure 1**).

Microchip offers several reference designs to accelerate design development. The MSCSICSP3/REF2 reference design provides an example of a highly isolated SiC MOSFET dual-gate driver for the SiC SP3 phase leg modules (**Figure 2**). It can be configured by switches to drive in a half-bridge configuration with only one side on at any time and with dead-time protection. The low-inductance SP6LI driver reference design

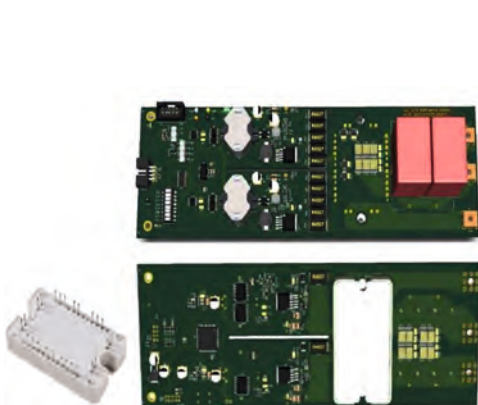


Figure 2: MSCSICSP3/REF2 reference design (Image: Microchip Technology)

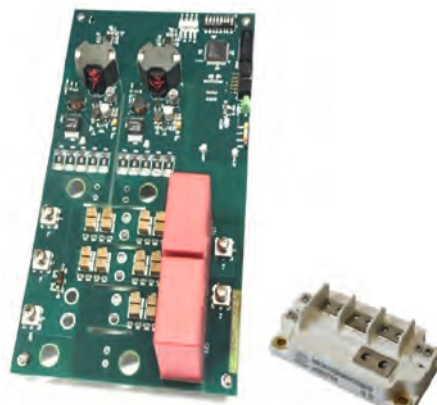


Figure 3: Low-inductance SP6LI driver reference design (Image: Microchip Technology)



Figure 4: MSCSICPFC/REF5 is a three-phase Vienna PFC reference design. (Image: Microchip Technology)

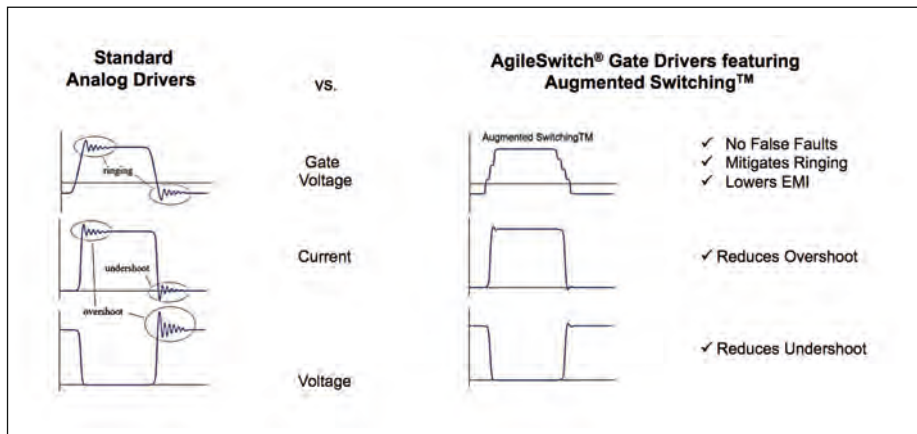


Figure 5: Digital gate driving is superior to analog driving. (Image: Microchip Technology)

implements a half-bridge driver up to a 400-kHz switching frequency (Figure 3). The MSCSICPFC/REF5 is a three-phase Vienna power-factor-corrected (PFC) reference design for hybrid EV/EV chargers for 30-kW applications (Figure 4).

The Vienna 30-kW three-stage PFC, the SiC, and the SP3/SP6LI modules drive reference projects and boards that provide system developers with tools to reduce development cycle time. Power-factor correction is critical in addressing the sources of potential loss and should be implemented accordingly.

DIGITAL GATE DRIVERS

Microchip's AgileSwitch digital gate drivers effectively reduce EMI problems and switching losses by up to 50% (Figure 5). Digital solutions are designed to address the critical challenges that arise in operating SiC and IGBT power devices at high switching frequencies. They can switch at up to 200 kHz and provide up to seven different failure conditions and monitoring conditions.

"Our gate drivers were designed to address all of these issues such as noise in the system, short-circuit overheating, and overvoltage," said Rob Weber, product line director for AgileSwitch at Microchip Technology. "We put in a lot of functionality with regard to these critical issues that emerge when you're trying to drive silicon carbide."

The drivers feature Microchip's Augmented Switching technology and robust short-circuit protection and are fully configurable via software. They are optimized for transportation and industrial applications, including inverters and induction heating.

Figure 6 shows the stylized waveform of turning on and turning off the switch. "We turn the switch on and off in steps where we modify the voltage and the time at the different voltage level for the both the turn-on and the turn-off," said Weber.

Microchip provides numerous development

kits for productive development with digital gate drivers. The 62-mm Electrical Master Plug and Play SiC Gate Driver is optimized for traction, heavy-duty vehicle, and induction heating applications. The Augmented Switching Accelerated Development Kit (ASDAK) includes the hardware and software elements required for rapid optimization of SiC module and system performance, giving system designers the flexibility to adjust system performance through software updates using the Intelligent Configuration Tool (ICT). The ICT offers configuration of several drive parameters, including on/off gate voltages, DC link and temperature failure levels, and increased switching profiles.

Digital programmable gate drivers have been designed to address problems such as system noise, short-circuits, overvoltage, and overheating. SiC MOSFET modules can be operated closer to their rated specifications.

By reducing turn-off spikes and ringing, under normal operation as well as under short-circuit (DSAT) conditions, SiC MOSFET modules can be safely operated at higher frequencies that enable dramatic increases in power conversion density. This allows SiC MOSFET modules to be operated closer to their rated specifications, resulting in size, cost, and performance improvements. ■

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

NEWS

AI Chip Market Will Hit US\$70B in 2026

The worldwide market for AI accelerator chipsets is predicted to grow from US\$8 billion in 2019 to US\$70 billion by 2026, according to a new report by analyst Global Market Insights. This represents a remarkable uptake in the technology from its present position — a compound annual growth rate of 35%.

The growth is due in part to the increase in popularity of e-commerce platforms that use AI-based recommendation engines housed in the cloud. The growing acceptance of cloud-powered virtual assistants that use AI to understand speech is also driving demand. Financial services companies are also extensively adopting AI to improve fraud detection and better calculate lending risks.

The European market is expected to experience a surge in demand due to the region's many companies working on systems for autonomous driving. Autonomous vehicles use AI chipsets to interpret data from cameras and combine it with information from other sensors such as LiDAR and ultrasound to build up a picture of their environment. According to the report, the European market will grow 33% between 2020 and 2026, driven by autonomous-vehicle development activity.

Arm Offers Free Upfront Access to Small Startups

Arm is expanding its Flexible Access program to offer new startups the most conducive initial licensing terms possible: free. The new initiative, Flexible Access for Startups, offers access to some of Arm's most valuable intellectual property at zero initial cost to companies with US\$5 million or less in funding.

Arm introduced Flexible Access last June with a flat-fee approach to licensing that the company devised to minimize both the cost and bureaucratic barriers to designing with its products. The terms included a fee of US\$75,000 a year for one tape-out annually or US\$200,000 a year for unlimited tape-outs. But that's still too dear for the innumerable tiny startups looking to demonstrate that their proposals have merit in order to earn a next round of funding.

Early-stage startups now can access a range of Arm IP at no cost, allowing them to experiment, design, and prototype with various Arm solutions throughout the product development cycle, the company said.

PACKAGING

Wanted: Process Engineers Versed in Packaging

By Junko Yoshida

The new frontier of leading-edge IC design is packaging, according to Arijit Raychowdhury, an expert in digital and mixed-signal design who teaches VLSI courses at the Georgia Institute of Technology and who received the 2018 IEEE/ACM “Innovator Under 40 Award” at that year’s Design Automation Conference.

Integration is the holy grail of VLSI design. Next-generation IC design lives or dies on the next feasible advance in integration. Historically, the VLSI community has depended on progress in process node technology to overcome the next fast-approaching bump on the road toward higher integration. But times are changing.

The chip industry understands that scaling in accordance with Moore’s Law has been slowing. The industry appears reluctant to confront an imminent upheaval in chip integration — an unmistakable transition from process to packaging technologies.

Raychowdhury is one of a rarified few who have zeroed in on this trend. Citing Advanced Micro Devices’ Zen and Intel’s Lakefield processors, he told EE Times Europe that packaging is an area that process engineers must understand. Intel is using an advanced package integration technology called Foveros for its Lakefield chips, Raychowdhury noted. “AMD is using similar integration technology to combine 7-nm CPU with 10-nm I/O using package-level integration. It helps improve system yield for them. Their flagship product for this is Zen 2.”



Georgia Tech’s Arijit Raychowdhury
(Image: University of Notre Dame)

Others are notably taking similar approaches for package-level integration. “Apple, Qualcomm are all pursuing this, and they are at different levels of maturity,” said Raychowdhury. Put simply, leading CPU vendors looking to the future are “all about heterogeneous integration of the package.”

The emphasis on leading-edge IC design is shifting from the process to the packaging. The problem is that “there is very little understanding, at least in the U.S., about how this transition is going to happen,” according to Raychowdhury. He singled out TSMC as a company “doing a better job” of letting the industry know “what is on-die versus what is on-package.”

During our interview, Raychowdhury stressed the importance of “connecting the dots” in the engineering world. Linking theories learned at school

with designs in the real world is one obvious example. Knowing how the business of technologies connects with Wall Street valuation is another. While technical papers submitted at ISSCC or VLSI Symposia inform engineers about cutting-edge technology, there is a huge middle ground that must be explained between advanced tech papers and books that teach engineering basics.

Our conversation covered challenges in teaching EE courses in the pandemic era, transistor scaling, new fields of expertise for next-generation VLSI designers to master, and what sort of engineering students are most likely to succeed in the real world.

TEACHING IN THE PANDEMIC ERA

EE TIMES EUROPE: I see you’re at home. Is school still in session?

Arijit Raychowdhury: We just got done [for the semester] a day before yesterday. We moved to online classes in the middle of March; it’s been almost six weeks of online classes. We have students from all over the place — you know, from China, from Vietnam — so it’s crazy to hear from a student from the West Coast saying, “Oh, it’s a lot of work.”

EETE: How do you teach online?

Raychowdhury: We video-record the lectures ahead of time and post them online. Then during normal class hours, we just log into Blue Jeans, Microsoft Teams, or some other video conference system. Then we do a little more of a Q&A. I answer students’ questions and all that, as opposed to going through the entire lecture. It has been OK. I mean, I wouldn’t say it’s that bad, but it’s been OK.

But I think now you’re seeing lots of students who don’t have proper internet connections. This could be a struggle even within this country right here. There are students in rural areas, and they don’t have a stable internet. And you know, we already had tornadoes a couple of weeks back. And there were students in southern Georgia whose houses

suffered some damage and power outages. It’s just a mess.

EETE: So despite all the advances in technology, we are still at the mercy of nature. Is that right?

Raychowdhury: In all sorts of ways. Yes.

INFORMATION GAP

EETE: Over here at AspenCore, we are on a mission to discern a gap between what our readers thought they’d already learned in school and what they have to do on the job. From your viewpoint as an instructor, are you getting feedback from students such as, “Gosh, I wish I’d learned that in school!”?

Raychowdhury: That’s one thing students always mention, and this can be very specific to certain instructors as well. Students are always interested in understanding how things they’ve learned in class apply to the real world — which products use which fundamental techniques and [apply] what they’ve been taught. This is what we hear often in academia.

Some academics have moved to academia from the industry. They have a better understanding of what’s going on. I think students — undergraduates particularly — enjoy taking courses that have more implications [in terms

of] on what the industry is doing and whether they can get jobs. Then there are some courses that are fundamental; we can’t stop teaching them Laplace or Fourier transform.

EETE: So these must be taught.

Raychowdhury: Right. But [students] sometimes find it hard to connect them to real-world applications. They are always looking for how the theory connects to practice.

You asked me about my connections with [EE Times sister site] EDN. I’ve been reading EDN since, I don’t know, 2001. I used to work at Texas Instruments long back before I went to grad school. So, the first design that I did at TI actually got this EDN Innovation Award. It was back in 2003. It wasn’t just me; our whole team got that award. Because it was the first award I actually got in my life, that was cool.

SETUP AND HOLD

EETE: Speaking of EDN stories, one of the most popular articles is about “setup and hold time.” Consistently, the basics of setup and hold time have been very popular. So where could we get more of that kind of stuff out there?

Raychowdhury: I think that’s a perfect question. I agree. These days, in our VLSI course, I spend about 20% of my time just talking about

Wanted: Process Engineers Versed in Packaging

setup and hold time. I did not understand how complex that was before I started working in the industry. And if you really want to understand what hold time is, and if you design a flip flop and how you clock the two stages of a flip flop so that you can get the best hold time ... these are the things that you only learn by building it and seeing how it works and then deploying it in millions and billions. We need to get someone to write about it. I think you need someone who, first, [knows] the theory but also understands what's going on in practice. This is exactly the kind of thing missing in books. It's missing in most articles as well.

2D, 2.5D, AND 3D INTEGRATION

EETE: In the academic world, it takes time for a book to be published. It takes time for a course to be developed to cover a technology. Are there things you see that you wish you had an opportunity to create a course for?

Raychowdhury: For example, look at technology today, and people are saying that transistor scaling probably is coming to an end, whatever it means. Technologically speaking, maybe scaling isn't going as fast as we would want. But in terms of memory technologies, for example, or back-end-of-line transistor technologies, I think there are lots of new things happening. The industry is moving very fast in that particular domain. And there are no good books, because these are all the black magic that the industry talks about.

Another trend that I see, which is not covered in books as well as it should be, is integration — 2D, 2.5D, and 3D. We all wonder: What does it mean, then, and what are the different implications?

But [discussions about it in the industry are] optimistic. They talk about layers and layers of transistors, which is never going to happen. Even if it's technologically feasible, it's just economically not feasible. Even for the short-term means of getting there — like the chiplet technologies that Intel has been working on. I don't think there are good books on [that].

TRANSITION FROM PROCESS TO PACKAGING

EETE: Are there emerging technologies that we ought to be highlighting or we should be bringing to people's attention or getting them prepared to be able to use? There's a lot of excitement about things like quantum computing, but in reality, quantum computing is a decade away. [Are there] things that are a little closer so that we might say, "Hey, you know, in the next year or two, you might be called upon to work in this area, and here's some background information to get you started"?

Raychowdhury: I think one of those areas would be that process engineers now need to understand packaging. The way I look at that trend now, if you look at what AMD is doing with the Zen processor or what Intel is doing with Lakefield, you see it's all about heterogeneous integration of the package. A lot of back-end engineers in these companies are now going to use their skills to build dense packages. I can see that happening.

Many of our research programs [at Georgia Tech] are industry-funded. So I can see that those in the industry are asking us to look at these kinds of things — work from a design perspective as well as from a processing perspective.

There is very little understanding, at least in the U.S., about how this transition is going to happen. TSMC is probably doing a better job of making sure that people can understand that this is a smooth transition between what is on-die versus what is on-package. And I think this would be one area where I would suspect people need to be ready very soon.

MOST LIKELY TO SUCCEED

EETE: As a professor, when you see a student start work at TI, for example, what general knowledge do you think he or she should have? What are the basics — other than a personal specialty — that he or she should absolutely know or seek to know? Any advice?

Raychowdhury: I feel like people who do well in the industry eventually have a broad understanding. Today, I tell my students to take courses all across the board, not just courses in your area of research. A good example would be people who are doing process technologies. They need to understand physics and chemistry really well.

Device people really need to understand materials. If they don't, it's a problem. It's harder for materials people to understand devices and technology. I think understanding how basic chemistry works helps. Because as we change the paradigm, we are looking at new materials.

Similarly, I feel like a lot of circuit designers, particularly analog designers, who go into the industry do not have or have forgotten basic math. So I think they have to relearn those things once they go to TI or whatever company.

Sometimes they have the skill sets, but they do not necessarily have a broader, general understanding of engineering — including math, physics, and chemistry, which are often required.

EETE: When you showed up at the doorstep at TI, you were the young guy. Did you already have a Ph.D. at that time?
Raychowdhury: No.

EETE: So when you showed up, what things did you wish you had studied before joining the company?

Raychowdhury: I had all the background knowledge, but what I was missing was, I didn't know how to connect the dots. How is this particular subject material connected to that subject material?

I think that's something that you don't learn in college, because you're learning all these courses in separate semesters. At some point, all of these things need to click together. My first six or eight months at TI were essentially spent trying to understand how these different components are connected.

Universities now are trying to do more hands-on design-based courses in the senior year and even for graduate students, which I think will help a lot.

Some people have the natural ability to hack things and write software and break things and put them back together. I think they are better engineers. They will be able to connect better when they enter the workforce. So I think more vertically integrated projects and courses are important.

NEW COURSES

EETE: As you develop new courses for the next year, what are the things that you think will be must-teach topics?

Raychowdhury: I teach circuit courses. From a circuits perspective, I think a lot of students have gone down to the deep end. They're just interested in, you know, understanding how EDA tools work. Like, how do you know the different new options that Synopsys has come up with or new back-end tools Cadence is producing? And they want to just do projects and get the skill set.

I'm actually taking the fall semester off and trying to build a new course I can use in the spring when I go back. I want to teach the fundamentals. When grad students — and I mostly teach graduate students — graduate without having a good understanding of signal and noise, that's a problem. And these are circuit designers.

In the VLSI space, we don't have a lot of good fundamental courses. That's mostly because of demand from the students. Students mostly want things that can help their skill set. They don't really understand that it doesn't take long to pick up those skills after you graduate. They need more of a fundamental understanding.

If you look at the VLSI curriculum — and this is common across the entire country — none of the schools are teaching fundamental VLSI circuit design. ■

Junko Yoshida is global co-editor-in-chief at *AspenCore*.

WIRELESS

How to Get Better Wireless Performance for Mobile Devices with Small PCBs

By Geoff Schulteis

The demand for smaller wireless devices is growing, for use in consumer applications such as wearables, medical devices, and trackers as well as in industrial applications such as lighting, security, and building management. It follows that smaller electronic devices will require smaller PCBs, meaning the antennas must work with shorter ground planes; if they are battery-operated, power is also a factor because the device must not consume too much power.

This presents quite a challenge for the product designer. The end design will need to be submitted for formal network and government approval before the new product can be used on the carrier networks, and the design is likely to fail if the antenna doesn't perform correctly or if the device creates radio interference by re-radiating noise. It follows that it is even harder to get carrier approval for a smaller product because it is more difficult to achieve wireless performance that is good

The design challenge is to give enough space for the antenna to perform correctly and still fit all the components into a smaller PCB.

enough to pass minimum transmit and receive levels. This is particularly true in the U.S., where a design must meet strict criteria to gain network approval. It is a fact that for electrically small antennas to operate at frequencies below 1 GHz, they ideally need ground plane lengths of 100 mm or more to achieve good performance and efficiency. If the antenna efficiency should drop, it will cause issues with power consumption and achieving network approval for the finished product. This means that the challenge for a product designer is to create a design in which there is enough space for the antenna to perform correctly and still fit all the components into a smaller PCB.

This is especially true for antennas operating at frequencies below 1 GHz, which are typically used for products such as internet of things devices, product trackers, fitness devices, and similar small devices.

Wearable devices and medical devices that are used close to the human body present a special challenge. The human body restricts RF signals, so the designer should consider how the antenna will radiate and be certain to place the antenna in such a manner that the human body will not obstruct the signals. Wearable devices can be as small as 50 mm or even less. And some of them may use more than one antenna.

There are several factors that affect the performance of the antenna in a small device, and this article will address them in turn. The first and most important is the ground plane, which, in many cases, is essential for the antenna to radiate. But this is not all; the designer should place the antenna correctly and consider the other components and the position of these in relation to the antenna to ensure that nothing noisy or metallic lies in the antenna's path. Finally, the casing for the device can make a difference, and we will outline the main materials to avoid.

EMBEDDED ANTENNAS: HOW THEY WORK

A dipole antenna uses two radiators to operate, but an embedded chip antenna has only one. For an embedded antenna, a surface of the PCB becomes the second radiator. This explains why, if the length of the

PCB is too short, the antenna will not operate efficiently.

The resonance of an antenna is directly related to its wavelength. The antenna must resonate at whole-number multiples or fractions of the wavelength, with the shortest resonant length being a quarter of the wavelength.

A full-wave antenna at the 916-MHz frequency would need to be approximately 327 mm long, which is not practical for an embedded antenna, but a quarter-wave version is practical at a ground plane length of 87.2 mm. This will be coiled up across the copper traces and layers that are hidden within a tiny surface-mounted chip antenna.

Antenna designers get around this limitation by using the ground plane as the missing half of the half-wave dipole, so a quarter-wave monopole antenna radiates against the ground plane. Therefore, the most popular embedded antennas in small wireless devices tend to be quarter-wave monopole antennas.

GROUND PLANE LENGTH

For an embedded antenna to work efficiently, the ground plane must be at least a quarter-wavelength of the antenna at its lowest frequency. Accordingly, at lower frequencies, the design will be much easier when the ground plane is 100 mm or greater.

The performance of an embedded antenna is directly related to the length of its ground plane, so allowing for the ground plane to be the correct length is the greatest challenge for smaller designs. **Figure 1** shows the tradeoff between ground plane length and antenna efficiency from 794 MHz on the left to 2.69 GHz on the right.

These results show clearly how the antenna efficiency drops for small ground planes at frequencies below 1 GHz. The results were

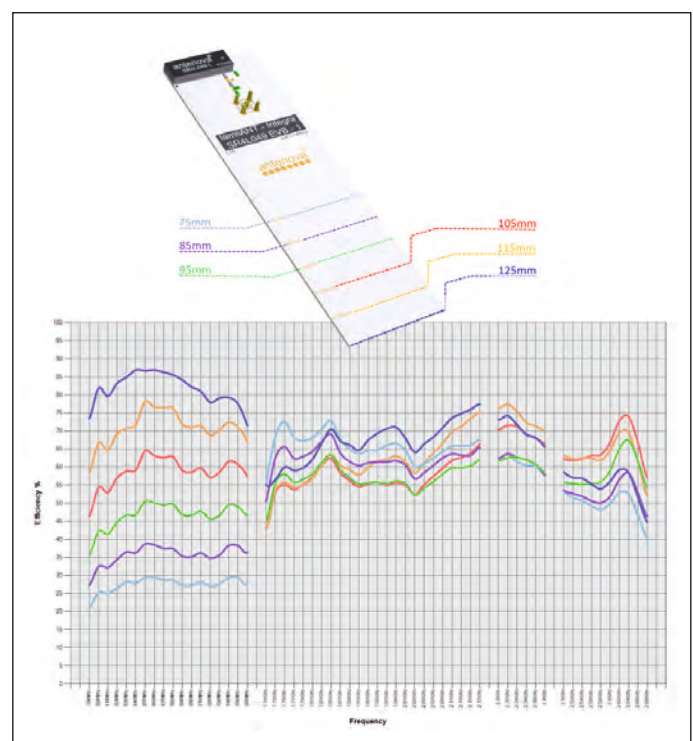


Figure 1 (Image: Antenova Ltd.)

How to Get Better Wireless Performance for Mobile Devices with Small PCBs

for a 3G/4G chip antenna operating at frequencies of 791–960 MHz, 1,710–2,170 MHz, 2,300–1,400 MHz, and 2,500–2,969 MHz.

Generally, the ground plane would need to be 100 mm or more for a device using the frequencies below 1 GHz. In the U.S., the 4G frequencies use bands as low as 698 MHz or even 617 MHz, as with T-Mobile's B71 band, requiring a ground plane even longer than 100 mm.

POSITIONING THE ANTENNA ON ITS PCB

Next, we should consider the position of the antenna on the PCB and its placement in relation to other components. The antenna should be placed in the best position in the overall RF layout and PCB stackup to allow it to radiate effectively.

Each individual antenna is designed to work efficiently in a few places on a PCB. This is often the corner or an edge; however, each antenna is different, so it is important to select an antenna that fits into the design and place it according to the manufacturer's recommendation for that antenna.

Figure 2 shows how the antenna is placed with its clearance area in a small device such as a wearable product or watch. **Figure 3** shows a suitable antenna placement for a watch design. The design maintains the recommended clearance specified above and below this antenna, which is shown in red.

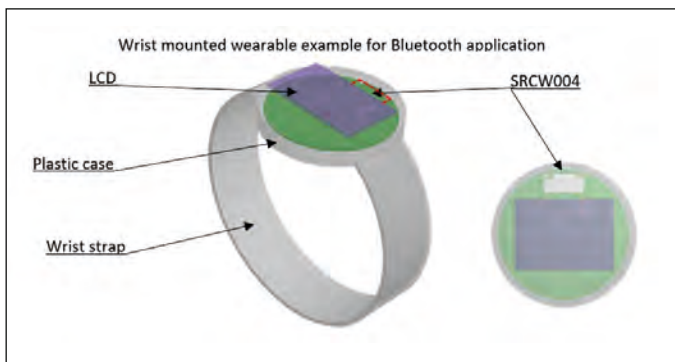


Figure 2 (Image: Antenova Ltd.)

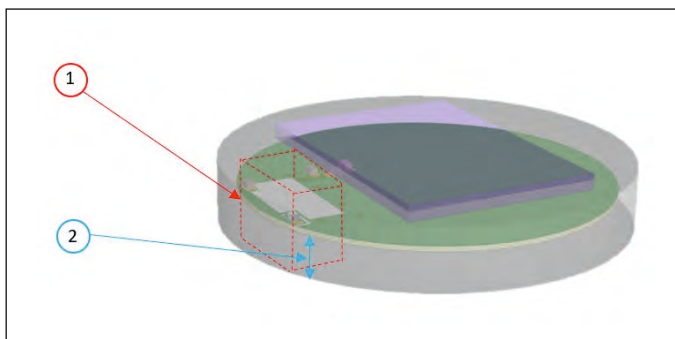


Figure 3 (Image: Antenova Ltd.)

Do not place noisy components, such as a battery or an LCD, close to the antenna section. Antennas are passive components that receive energy and will pick up noise radiated from the noisy components and transfer that noise to the radio, degrading the received signal. The antenna should also be placed away from the human body to improve RF performance; this is the distance marked in blue in **Figure 3**.

The arrangement of the RF feed and the ground connections are critical to the function of the antenna. With small embedded antennas in small PCBs, the copper tracks etched on the PCB may form an integral part of the antenna, so care should be taken to follow the manufacturer's specification or reference design.

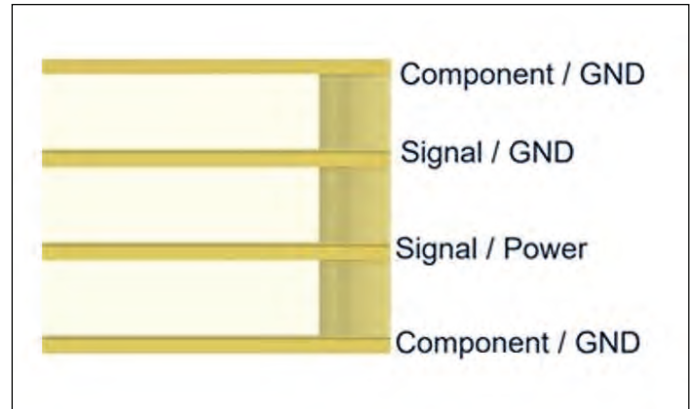


Figure 4 (Image: Antenova Ltd.)

OVERALL RF LAYOUT AND PCB STACKUP

You can maximize the performance of the antenna by giving careful consideration to the layout of the RF elements in the design. The copper ground plane should not be cut up with traces or arranged over more than one layer; then the ground plane portion of the antenna will be able to radiate more effectively.

It is essential to keep components such as LCDs or batteries clear of the antenna area in the PCB layout, as these can interfere with the way the antenna will radiate. For multiband frequencies, we suggest a PCB layout with a minimum of four layers. **Figure 4** shows how the top and bottom layers provide ground planes, while the digital signals and power, which need to be away from the ground plane, run in the space between these.

TUNING THE ANTENNA FOR PERFORMANCE

For those cases in which the ground plane is shorter than ideal, a designer can look at other techniques to increase the performance of an embedded antenna.

One way is to tune the antenna for its country of operation. The 4G frequency range is a wide one, spanning from 698 MHz to 2,690 MHz, but each world region uses just a portion of this band, and an antenna can operate on only one frequency at a time. This means that when a product is to be used in one geographical region, it can be tuned to

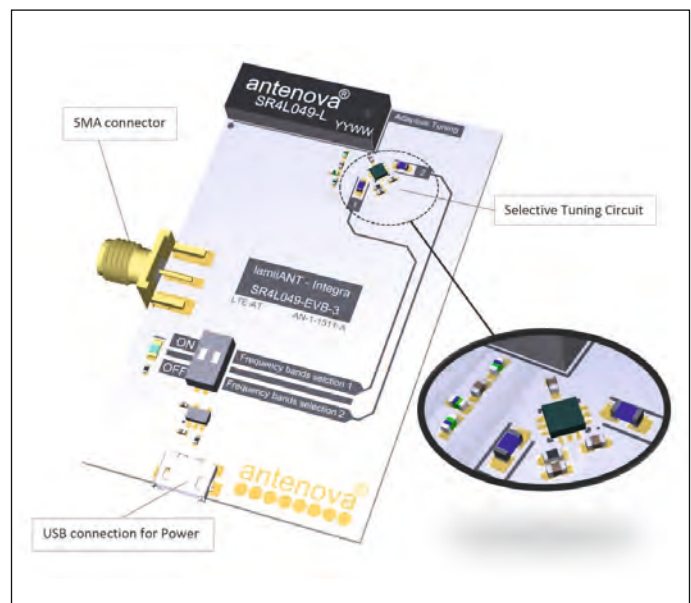


Figure 5 (Image: Antenova Ltd.)

operate in a narrower section of the frequency band. This will boost the performance of the antenna.

Another technique is to include an active tuning network — effectively an additional RF switching circuit, which will help to get over the bandwidth reduction caused by a smaller ground where the host PCB is less than 75 mm. A PI matching circuit is added close to the antenna feed point to fine-tune the antenna and boost performance. The design of the matching circuit will usually need some assistance from an RF specialist. **Figure 5** shows a matching circuit on an antenna evaluation board.

DESIGNING THE TRANSMISSION LINE

Once the material for the PCB has been chosen and its thickness and dielectric constant are known, a co-planar transmission line can be designed using one of the commercially available RF trace design software packages. This will use the PCB thickness, copper layer separation, and substrate dielectric constant to calculate the optimal width for the transmission line and the appropriate gaps on either side to achieve a co-planar transmission line of 50 Ω .

All transmission lines should be designed to have a characteristic impedance of 50 Ω , and the other parts of the RF system, such as transceivers or power amplifiers, should also be designed with an impedance of 50 Ω . Antenova offers a free RF transmission line calculator tool to help designers determine the size of the transmission line.

OTHER FACTORS

There may be more than one antenna on the same board, operating at different frequencies but placed in proximity on the PCB. If an antenna is a receive-only system, such as a GPS receiver, it could be de-sensed by a nearby transmit antenna such as a 4G radio, reducing the accuracy of the GPS system. Care must be taken to separate these antenna systems either by physical distance between the antennas — making sure the antennas are orthogonal to each other — or by notching the ground plane to remove the ground currents shared between the antennas.

In multiple-input, multiple-output (MIMO) systems, the design

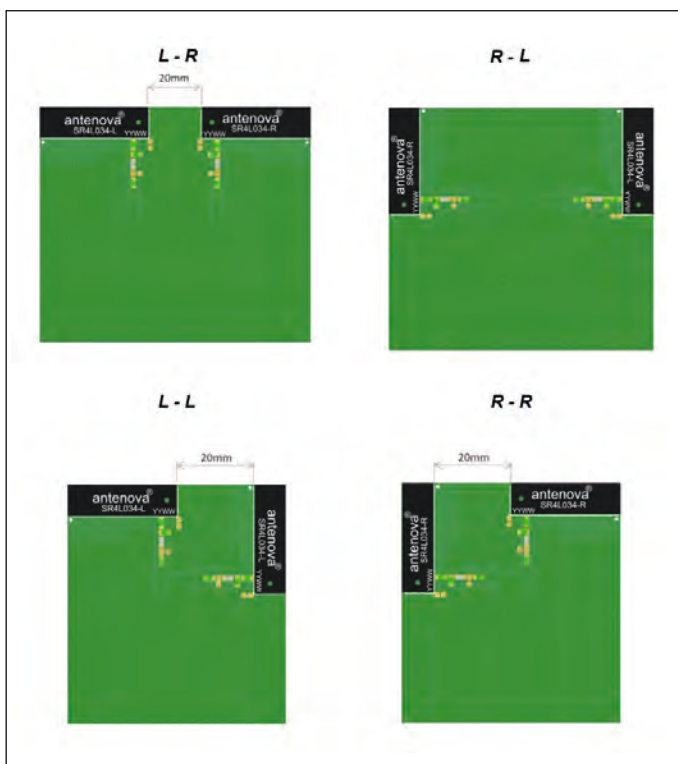


Figure 6 (Image: Antenova Ltd.)

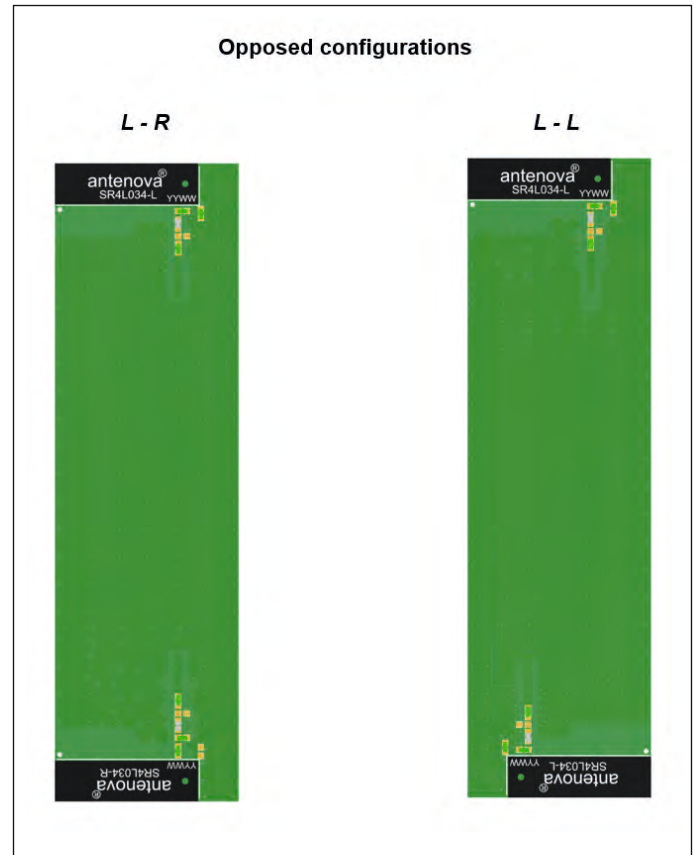


Figure 7 (Image: Antenova Ltd.)

will require more than one antenna, which should be placed with one relative to the other so that they can coexist. Then they can be matched to the same frequencies. It is imperative that the antennas be placed to ensure that the isolation and cross-correlation are within acceptable limits. As mentioned above, care must be taken to separate the antennas in the device. **Figure 6** shows proximity configurations for diversity, while **Figure 7** shows opposed configurations for diversity.

The outer case should not contain metal close to the antenna, but certain metalized coatings are acceptable because they do not conduct energy effectively. Metal objects near the antenna can cause the frequency of the antenna to shift lower in frequency. It can also reduce the amount of bandwidth the antenna is designed to operate with. Another issue with metallic objects near the antenna is that the metal objects block the signal in the direction the metal is placed, reducing the overall radiation pattern and possibly causing the signal to degrade enough to lose connection with the base station.

CONCLUSION

If the product design is to include an antenna, especially if it is using a small PCB, we would recommend selecting the antenna first and placing this first on the PCB. It is easier to do it this way than to slot an antenna into an otherwise-finished design. Thinking about the antenna first is usually the fastest way to achieve a design in which the RF element performs as it should.

This will increase the chance of obtaining network approval for the device. The antenna needs to operate efficiently if it is to gain approval, and the rules are tough. However, AT&T did make allowances for devices smaller than 107 mm and lowered the threshold of efficiency for these smaller devices. ■

Geoff Schulteis is senior antenna applications engineer at Antenova Ltd.

POWER ELECTRONICS

The Rise of the 48-V Robots

By Ali Husain

Industrial robots are an important element of the Fourth Industrial Revolution, and as these devices become connected to systems and remote sensors, they form a significant subsection of the internet of things: the industrial IoT (IIoT).

According to the International Federation of Robotics, or IFR (www.ifr.org), there were almost 2.5 million industrial robots deployed in 2018, and this number is growing at more than 400,000 units annually. The industrial, automotive, and electrical/electronic sectors account for more than half of total deployments, with the metal and machinery,

Solutions based on 48 V reduce the need for system protections and reduce the size of conductors, thereby reducing system weight and cost as well as power losses.

plastics and chemical, and food and beverage industries being significant users as well. Approximately 75% of all industrial robots are deployed in China, Japan, the United States, South Korea, and Germany.

The rapid adoption of robots is not confined to the industrial sector; 250,000

professional service robots were deployed by 2018, a total that represents a staggering increase of more than 60% over the prior year. Two out of every five service robots deployed are classified as autonomous guided vehicles (AGVs) used primarily in logistics and manufacturing. The personal- and domestic-robot market grew similarly (60%) and now comprises about 16.3 million units, used for tasks ranging from vacuuming to education and research.

48 V AND ROBOTICS

Designers are adopting 48-V power sources for a range of applications, in part because 48 V is the highest safe voltage in common use. Solutions based on 48 V reduce the need for system protections compared with mains-powered devices and reduce the size of conductors compared with 12-V-powered products, thereby reducing system weight and cost as well as power losses. Motors that are powered directly by 48 V are also generally smaller, allowing for smaller and lighter robotic joints and thereby increasing machine efficiency, dexterity, and reliability



while reducing weight and cost. This opens up more potential opportunities for robot use to improve the automation of processes in all industries.

Modern applications in which 48-V power is increasingly popular include automotive, where it is rapidly becoming preferred over 12 V for many on-board devices, and cloud computing, where 48-V power distribution is used for server backplanes, cooling fans, and other telecom-related applications. This prevalence means that devices and subsystems for 48-V power are commonly available, increasing the range of options available to designers and lowering costs through economies of scale.

Robots are fairly complex systems; depending upon the application and functionality, they will comprise a number of functional elements, including connectivity, image sensing, position sensing, and motor control. There are also power subsystems to consider, including AC/DC conversion, battery management, DC/DC conversion, multiphase converters, point-of-load (PoL) conversion, linear regulation, and motor drivers. Each of these areas requires an efficient solution for the robot to operate as the designer intended.

If we were to look at similar functional block diagrams for automotive or cloud computing systems, we would find a significant number of similarities with the robot block diagram. This presents opportunities to cross-pollinate power solutions from other applications to robotics. As an example, electronic fuses are used extensively in cloud computing to allow for hot-swapping of storage media and cooling devices such as fans. However, in a robotics application, the same e-fuses could be used to introduce modularity, thereby permitting functional blocks (such as tool pieces) to be exchanged

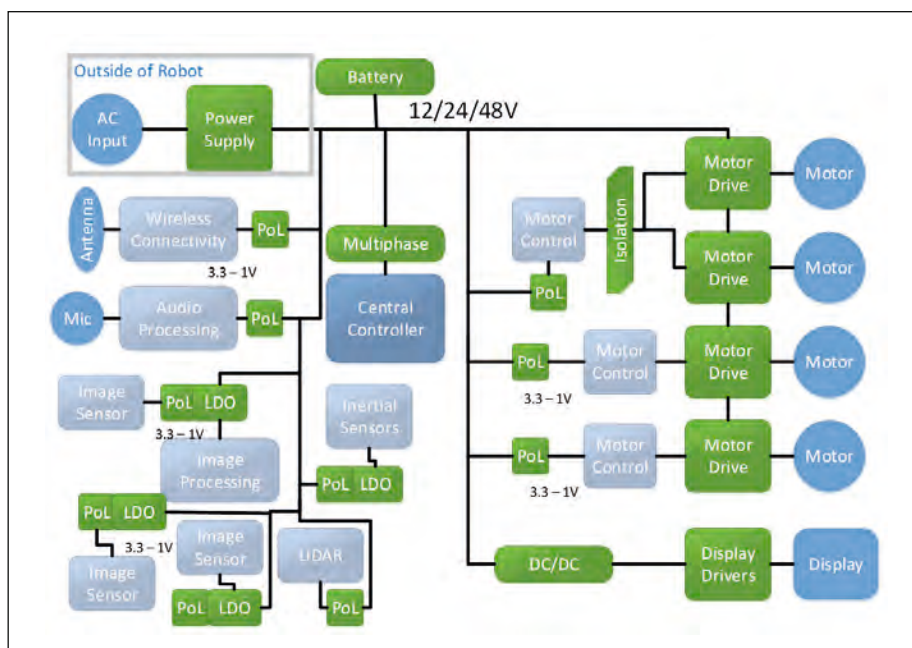


Figure 1: High-level block diagram (including power system) of a typical robot

(Image: ON Semiconductor)

The Rise of the 48-V Robots

by the robot itself — even in the middle of an operation, depending upon the task at hand.

DELIVERING POWER SOLUTIONS FOR 48-V ROBOTICS

Many modern robotics applications use a 48-V bus to transport power around the system. Compared with a typical 12-V bus, 48 V offers 1/16 of the losses or allows thinner and lighter cables to be used. In fixed robot installations, the 48 V will be generated by a mains-fed power supply that will incorporate a power-factor-corrected (PFC) front end. Mobile robots, such as drones and care assistants, will have an on-board battery that is replenished periodically from a mains-powered adapter.

Few semiconductors are able to work directly from 48 V, generally requiring voltages of 5 V down to the sub-volt level. The non-isolated PoL converter plays an important role here, converting a higher voltage to the level that the IC requires. In some cases, an intermediate bus voltage (typically 12 V) would be created by using an intermediate bus converter (IBC) that is loosely regulated with the PoL converter converting the 12 V to the IC supply voltage. Increasingly, single-stage conversion is preferred, and many PoL converters are now available to convert directly from the 48-V rail to the IC supply voltage.

As with every power solution, the power architecture for a robotics application is required to be efficient and reliable, as well as offer high levels of power density so that the robot can be small and nimble enough to perform its function(s) well. Key to achieving this is to select the right semiconductors to form the various power functions within the robot.

SEMICONDUCTOR SOLUTIONS FOR ROBOTIC POWER APPLICATIONS

ON Semiconductor has applied its expertise and resources to offer a wide range of devices and power products that let designers create high-performance power solutions for robotics applications.

One of the most common devices used in almost all power solutions is the MOSFET. ON Semiconductor's extensive range includes superjunction MOSFETs with multiple versions for different switching types and applications. The company's FAST devices offer high efficiency in hard-switching topologies, while its Easy Drive devices are suitable for both hard- and soft-switching applications, where they ensure low electromagnetic interference (EMI) and reduced voltage spikes.

Complementing the MOSFET offering is a wide range of high-voltage gate drivers that allow a microcontroller or other logic circuit to control MOSFETs directly. Depending on the circuit configuration, a simple non-isolated driver (such as ON Semiconductor's NCD570x series) may be used, or a more sophisticated, isolated solution or high- and low-side driver may be needed.

Highly integrated solutions such as intelligent power modules and automotive power modules bring a number of benefits. Typically, these will integrate multiple MOSFETs for multi-phase motor driving along with the necessary driver devices. These modules offer better thermal performance than discrete solutions because all devices are mounted on the same substrate. They are also able to handle higher current levels while improving EMI and providing a solution that is smaller and lighter than discrete equivalents.

Alongside these solutions, ON Semiconductor offers a complete portfolio for robotic power applications including electronic fuses, PFC ICs, rectifiers, current sensors, and switching devices for providing auxiliary power rails. This portfolio is complemented by the industry's lowest-power Bluetooth module for communications and a wide range of image sensors for advanced machine vision. ■

Ali Husain is senior manager for corporate marketing and strategy at ON Semiconductor.

NEWS

SD Storage Workloads Get a Special Processor



Even as demand for data storage skyrockets thanks to big data, artificial intelligence, the internet of things, and 5G, more data is moving to SSDs, notes Pliops president Steve Fingerhut. Indeed, data center SSD usage is forecast to grow a hundredfold in the next decade. "SSDs have a lot of great qualities, but the primary one is performance over hard drives," said Fingerhut.

Over the past 10 years, the cost of SSDs has dropped while their performance has improved, and capabilities have expanded thanks in large part to the rise of NVMe, he said. What's not keeping up, however, is processor performance, and the result is a bottleneck, as companies such as Intel and AMD keep adding cores, which add cost and power with diminishing returns. "As you add more and more cores, you're sharing the same memory bus," said Fingerhut. "That's a big problem."

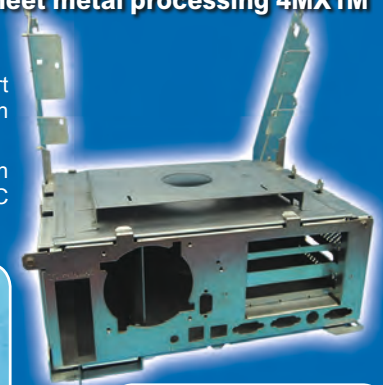
All this growing data is getting stored on fast SSDs, "but it's all being driven through a processor, which isn't really evolving all that quickly." Pliops's solution to these "storage stack inefficiencies" is data-acceleration technology geared for specific workloads within databases and software-defined storage, which the company estimates is about half the spend in an enterprise and data center infrastructure. The Pliops storage processor is a key-value-based storage hardware accelerator that enables cloud and enterprise customers to offload and accelerate data-intensive workloads so that data centers can continue to scale while reducing computational load and power.

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POWER ELECTRONICS

Inaugural PowerUP Virtual Expo Convenes on June 16

By Maurizio Di Paolo Emilio



There's still time to register for AspenCore's PowerUP Virtual Expo, a three-day virtual conference and exhibition focusing on power electronics. Slated for June 16–18, the PowerUP Expo will operate like a live exhibition and conference, providing fairgrounds, an exhibition hall, and a conference area. Exhibitors will present their products and solutions, and chat rooms will allow for direct communication between visitors and exhibitors — all without the need for travel and at the fraction of the cost of a physical event.

The all-virtual conference, which will be available 24 hours a day with live presentations each day from 14:30 to 17:30 CEST (8:30 a.m. to 11:30 a.m. EDT), is an opportunity to exchange ideas and get product and technology updates on three key power electronics topics: motor control, wide-bandgap semiconductors, and smart and renewable energy. The exhibition will feature three panels highlighting the conference topics, with the participants available to answer your questions. Visitor registration is free; for information and to register, go to powerup-expo.com.

THE POWER MARKET

Power semiconductors have historically been based on silicon substrates. Silicon is an excellent general-purpose semiconductor but has well-documented limitations when dealing with high voltages. As power demands rise, the industry is shifting from silicon toward wide-bandgap (WBG) semiconductor materials, which can operate at higher switching frequencies while keeping losses at manageable levels.

While silicon semiconductors will remain a mainstream solution for many years, there are certain applications in which customers can leverage WBG semiconductor characteristics, including improvements in bandgap (eV), breakdown field (MV/cm), thermal conductivity

(W/cm-K), electron mobility ($\text{cm}^2/\text{V-s}$), and electron drift velocity. Without getting into the semiconductor-physics details, suffice it to say that these improved parameters make WBG semiconductors suitable for high-voltage, high-switching-frequency applications while improving power density and heat dissipation.

Advantages of WBG semiconductor power switches include high current density, faster switching, and lower drain-source on-resistance ($R_{DS(on)}$). These device performance improvements lead to significant system-level benefits from an end-customer perspective. In real-life applications, customers can achieve high-temperature operation, along with overall system size and weight reductions.

Gallium nitride (GaN) and silicon carbide (SiC) WBG power semiconductors will emerge as a means to enhance power supply efficiency across industrial environments, while complementing the expansion of the renewable energy segment. Alternative energy sources require adequate control and power processing to be safely connected to a smart grid or even to be directly connected to local loads. The energy flowing needs to be correctly converted before it is delivered to users. The goal is to create control systems capable of flexibly responding to the energy requirements for real-time recharging and discharging.

Two of the most lucrative applications for SiC and GaN are electric vehicles and hybrid electric vehicles (EVs and HEVs). They operate at higher voltages and temperatures, are more rugged, have longer lifetimes, and switch much faster than conventional semiconductor devices. SiC has been adopted in several applications, particularly e-mobility, to meet energy and cost challenges in the development of high-efficiency and high-power devices. GaN is finding use in automotive designs; a number of companies have qualified products for low- and high-voltage EV/HEV applications.

Inaugural PowerUP Virtual Expo Convenes on June 16

Controlling a motor's speed and direction requires the operating system and a range of techniques that will vary with the motor type and the application requirements. Power semiconductors can improve positioning, torque, and efficiency in motor drive and power control applications.

CONFERENCE DETAILS

Bolaji Ojo, group publisher and global co-editor-in-chief at AspenCore, and Maurizio Di Paolo Emilio, editor-in-chief of Power Electronics News and EEWeb, will open the conference on Tuesday by discussing the importance of new strategies to support the power electronics ecosystem.

June 16: Motor Control

The first day of the conference will be devoted to motor control topics. Infineon Technologies, in its opening paper, will provide an analysis of motor inverter trends and solutions. Infineon optimized its TRENCH-STOP IGBT7 technology for motor inverters, enabling low conduction losses. Meanwhile, for integrating the inverter into the motor, Infineon's CoolSiC MOSFETs are a good choice because of their low switching losses and low-ohmic-loss behavior during conduction.

Power semiconductors are a key component of every electric-motor inverter because they make it possible to control both speed and torque. Power semiconductor controlling and sensing are also important motor inverter functions.

Analog Devices' keynote will offer insights into motor control design. Synchronization in motor control applications directly relates to process and production efficiency and quality. It is a multilayered requirement, starting with the alignment of the motor phase-current-sensing methodology with the motor actuation via the power inverter and continuing through the interconnect between motion axes and between networked nodes. The keynote will highlight the value and importance of tight synchronization in networked and multi-axis motion control applications for industrial automation.

After that, Maxim Integrated will analyze the challenges of intelligent motion control and the technology's impact on Industrial 4.0. Industrial convergence is driving discussions in the automation industry about the need for more intelligence at the edge. A new way of thinking is needed to translate semiconductor solutions into products that provide better real-time information so that AI algorithms can be used to optimize an entire factory as well as its individual machines.

To accomplish this level of automation and flexibility, every aspect of the equipment needs to evolve. In the area of motion control, there is a need to develop smart actuators that can provide the necessary control of the flow and the speed with which a product is moved through its operations. Because all applications require their own unique set of motion control and motor drive, these smart actuators will need to provide higher efficiency to limit power dissipation and enable smaller sizes, better control of positioning and torque, and the ability to self-tune and optimize their performance while in operation. This combination of smart integration will enable a new class of products to meet the demands of Industry 4.0 and beyond.

After these speeches, a panel titled "Motor Control Solutions for Any Power Requirements" will feature panelists from major participants in the sector, including Infineon, Maxim Integrated, Power Integrations, Texas Instruments, and Trinamic.

A series of technical talks will follow, covering motor control topics including microstepping control solutions and noise reduction in stepper motors. Analog Devices will present a talk on slew-rate control. Slew-rate control of the inverter switch node provides a degree of control over conducted electromagnetic interference (EMI) in a motor control system. This can help reduce requirements on input and output filters, which are often designed around light-load, worst-case EMI. By contrast, full-load efficiency requirements are generally better met by faster switching of the inverter node. A dual-mode slew rate control gate driver will be presented, and its benefits in motor control systems from this perspective will be outlined.



Inaugural PowerUP Virtual Expo Convenes on June 16

June 17: WBG Semiconductors

Wide-bandgap semiconductor technologies provide implementation opportunities ranging from universal wireless charging to power converters. With all sectors striving for higher efficiency, SiC and GaN power switches will help enable next-generation renewable power solutions across many applications, such as data centers, renewable energy for the green grid, and electric-vehicle (EV) chargers.

Efficient Power Conversion (EPC) will deliver the opening talk, titled “Update from the Front Lines in GaN’s Assault on Silicon Power MOSFETs.” GaN devices offer the best performance in the smallest size to increase the efficiency, shrink the size, and reduce the system cost

Don’t miss this opportunity to exchange ideas and get product and technology updates on motor control, wide-bandgap semiconductors, and smart energy. Visitor registration is free. Go to powerup-expo.com for information.

for 48-V power conversion. EPC’s eGaN FETs and ICs for 48-V applications have seen rising adoption volumes in high-density computing and automotive designs.

After the opening presentation, STMicroelectronics will deliver a keynote on the impact of power wide-bandgap semiconductors in improving the efficiency of on-board chargers, DC/DC converters, and traction inverters in EVs. As GaN devices become available and with SiC shipments growing quickly, WBG devices are making inroads into industrial applications and even some consumer devices. ST will explain why WBG devices represent a paradigm shift for efficiency and how SiC and GaN can help make next-generation smart-industry, smart-driving, and personal-electronics systems more powerful, useful, and convenient.

Next, in a talk titled “Enabling Superior Power Conversion Efficiency with State-of-the-Art SiC Devices,” ROHM Semiconductor will survey the latest technology and performance features of SiC MOSFET and diode products. SiC semiconductors are driving power electronics innovation in multiple industries across the globe. Combining low energy losses, high switching frequencies, and superior reliability, these devices will dramatically improve power converter efficiency and enable system benefits at increasingly competitive costs.

After these speeches, a panel titled “Are You GaN or SiC?” will host experts from major players in the sector such as Analog Devices, Infineon, Power Integrations, GaN Systems, Wolfspeed/Cree, and UnitedSiC. Technical talks will follow, covering the emerging market opportunities for WBG semiconductors, SPICE models for GaN and SiC, and GaN devices in LiDAR systems design.

June 18: Smart/Renewable Energy

With a large number of countries racing to build reliable and long-term-sustainable alternatives to curb fossil fuel emissions, wind energy and solar photovoltaic (PV) installations have recorded unparalleled growth over the past decade. Power semiconductor manufacturers believe GaN- and SiC-based devices hold the key to addressing a primary hurdle for the expansion of renewable energy: the lack of affordable and scalable power conversion and storage solutions. When developing energy systems, cybersecurity, interoperability, control, optimization, virtualization of network functions, and digital management of distributed energy resources (DER) can all represent development challenges. The infrastructure will have the objective of distributing energy — in combination with grid edge technologies, such as microgrid and intelligent buildings — and inte-

grating it into smart grids in order to fully exploit the flexibility of electric mobility while yielding a more stable energy system.

Texas Instruments will deliver the opening paper, “Paving the Way for Next-Generation Systems.” As electrification and data connectivity needs continue to rise, it’s becoming clear that semiconductors will play a key role in creating a better world by making electronics more efficient and more affordable. However, consumers’ expectations will also rise, and electronics and their resulting semiconductors must become more robust. Managing efficiency, cost savings, and robustness will be the goal for manufacturers, and a divide will become apparent between technologies that are good at most of these and those that are great at all of them.

After Texas Instruments, Analog Devices will deliver a keynote on the latest energy solutions. And before the panel convenes, Yole Développement will provide an analysis on the market aspects with a talk titled “Opportunities for Power Electronics in Renewable Electricity Generation.”

When considering the sustainable development of new electricity generation capability and the advantages and drawbacks of different renewable electricity sources, PV and wind energy are today viewed as the most promising choices. Although PV and wind are already quite mature technologies, there is still a large untapped potential to increase their performance, reliability, and lifetime while decreasing the cost of their power electronic components. Yole analysts will present PV and wind inverter market forecasts and discuss technology and supply chain trends. The technology and business synergies among PV, wind, and stationary battery energy storage markets will be analyzed.

After these speeches, a panel titled “The Future of Energy” will host major players in the sector, including ADI, Infineon, STMicroelectronics, LF Energy, Texas Instruments, and Yole.

A series of technical talks on various motor control topics will follow, and some of the topics covered will include “EV Smart Charging Solutions,” “The Future of Smart Energy Development,” and “Making Smart Power a Reality.”

EV smart charging is a system capable of monitoring, using, and limiting the use of charging devices to optimize energy consumption. These systems can be managed by the user (user-managed charging, or UMC) or by the supplier (supplier-managed charging, or SMC). In UMC, the owner of the electric vehicle chooses the recharging time based on the price of energy and the user’s own requirements. In SMC, the energy supplier intervenes directly on the management, via vehicle-to-grid (V2G) technology, regulating the charging and discharging of the vehicle in real time, on the basis of the state of the grid, local power consumption, and information on the EV charging state.

Industry 4.0, smart industry, and smart power are common buzzwords, but what do they really mean for a power designer? Since the early days of the power conversion, when it moved from 50-Hz linear conversion to switching and later to MOSFET technology, power designers have permanently faced challenges. With the demand for lower energy consumption, rising levels of systems integration, and the increased availability of wide-bandgap semiconductors, today’s power designers confront more decisions and more pressure, forcing changes in the way the industry works toward solutions.

In a talk that will close out the conference, LF Energy, a coalition launched last summer by the Linux Foundation, will present a new technology that can accelerate decarbonization by enabling the digitalization of energy. Open-source technology allows vendors, suppliers, and their customers to jointly invest in and work to build the grid of the future. This is the “Power of Together,” as LF Energy describes it. ■

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

MOTOR CONTROL

Gate Driver Solutions Proliferate for Motor Control

By Maurizio Di Paolo Emilio

Electric motors convert electrical energy into mechanical energy that can be used for the movement of the articulated mechanisms to which they are connected. The electric motor must be able to develop a significant torque starting from zero speed and must be highly efficient across the full load range. Ideally, it also needs to have a simple driving and control system.

DC motors use electrical energy in a continuous form. They are generally low-power and are particularly suitable for applications requiring low driving torque and a

Electric motors need to be able to develop a significant torque starting from zero speed, be highly efficient across the full load range, and, ideally, have a simple driving and control system.

certain flexibility of operation. AC motors can be synchronous or asynchronous and use single-phase or three-phase alternating current. In particular, synchronous motors have rotation speeds rigidly connected to the frequency of the sinusoidal current.

Before choosing the ideal motor, engineers need to know the weight and size of the load and at what speed it will move. The working area of the motor under load must fall below the torque curve of the motor. A standard method of sizing a motor is to assume “limit” situations — in other words, to determine the peak values required by the application for torque and speed — to ensure a fair margin of operation.

AC MOTORS

Reliable AC motors are essential to many industrial production processes, from ventilation to fluid- and solid-material transport. AC motor drive designers are constantly striving for energy savings and size reduction. Power Integrations’ gate driver solutions offer outstanding efficiency and an unrivaled level of integration for compact, standard, and premium AC motor drives,

according to the company.

Power Integrations offers several gate driver solutions. The SID11x2K family comprises single-channel IGBT and MOSFET drivers in a standard eSOP package. Reinforced galvanic isolation is delivered using Power Integrations’ solid-insulator FluxLink technology. Output drive current of up to 8 A (peak) enables the products to drive devices up to 600 A (typical) without requiring additional active components.

The SID1183K family is a similar gate driver solution based on eSOP-packaged single-channel IGBT and MOSFET drivers. Features include short-circuit protection (desaturation detection) with advanced soft shutdown (ASSD), undervoltage lockout (UVLO) for primary-side and secondary-side control, and rail-to-rail output with temperature- and process-compensated output impedance to guarantee safe operation even in harsh conditions.

The SID1183K offers a low, 260-ns propagation delay time and propagation delay jitter of ± 5 ns with high common-mode-transient immunity. FluxLink technology enables safe isolation between the primary side and secondary side.

DC MOTORS

Brushless DC motors (BLDCs) offer greater efficiency and reliability than brushed motors and are finding increased application in household appliances and consumer electronics. As efficiency standards for those

applications continue to strengthen, better power conversion technology is also needed to minimize total power losses and simplify the design.

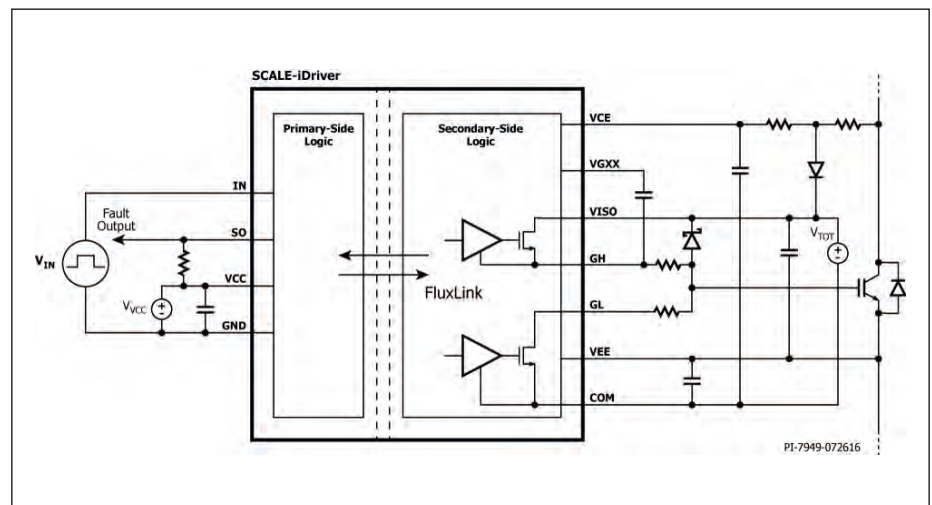
The driver is a basic element of BLDC control. It is a power amplifier that produces a voltage output to drive the high-current high-side and low-side IGBT gates of the H-bridge circuit. To meet rapidly rising demand, Power Integrations has released a new BridgeSwitch family for BLDC engines up to 400 W. These high-voltage half-bridge motor drivers are 99.2% efficient, require no heat sink, and reduce software certification time and expense, according to the company.

The BridgeSwitch driver family features advanced fast-recovery-diode field-effect transistors (FREDFETs) with integrated lossless current sensing. The superior efficiency, combined with the distributed thermal structure of the integrated half-bridge (IHB) driver, reduces both the weight and cost of the system. The integrated lossless current detection system, bus voltage detection circuitry, and system-wide thermal detection circuitry make this family of devices ideal for BLDC motors used in household appliances.

INDUSTRIAL MOTORS

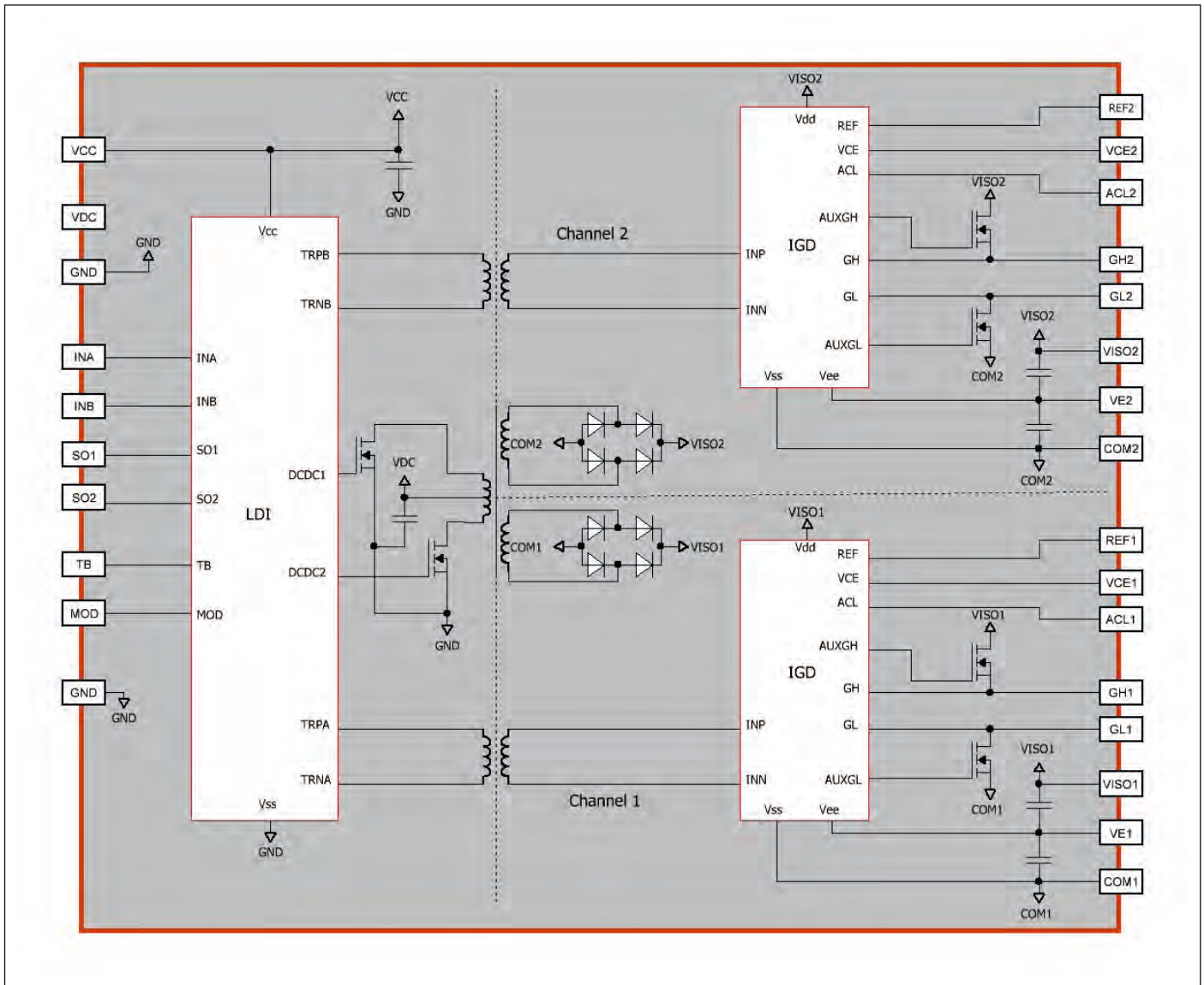
Industrial motors and medium-voltage drives (MVDs) must be made to last, ensuring high reliability and availability that can withstand harsh environmental conditions. Power Integrations offers robust gate driver solutions for industrial motors, supporting multilevel topologies as well as H-bridge series connection MVDs.

The 2SC0435T is a compact driver for industrial applications offered by Power Integrations, with a footprint of 57.2×51.6 mm and a 20-mm profile. The SCALE-2+ chipset reduces the number of



Typical application schematic for the SID11x2K and SID1183K (Image: Power Integrations)

Gate Driver Solutions Proliferate for Motor Control



Block diagram of the 2SC0435T (Image: Power Integrations)

components by up to 85% compared with conventional solutions, increasing reliability and reducing costs. The device offers a complete two-channel driver core with all the required drive elements, including an isolated DC/DC converter and short-circuit protection as well as supply voltage monitoring. Each of the two output channels is electrically isolated from the primary and the other secondary channel.

SERVO MOTORS

The operating principle of servo motors is similar to that of stepper motors, but there are some fundamental differences to take into account. In conventional servo systems, the controller sends signals to the motor drive via pulse/direction or analog position, speed, or torque commands. Next-generation controllers use a fieldbus structure. The drive then sends the right amount

of current required for each motor phase. The motor feedback returns to the drive and, if necessary, to the controller. The drive uses this information to switch the rotor correctly and send reliable data about the position of the moving shaft. For this reason, servo motors are considered “closed loop” and incorporate an encoder (feedback) that continually sends the position to the controller.

Power Integrations’ 2SC0106T dual-channel gate driver core, equipped with the new SCALE-2+ chipset, is a high-performance two-channel IGBT/MOSFET gate driver core for 1,200-V IGBTs in the 37- to 110-kW power range. The 2SC0106T drives 600- to 1,200-V IGBTs with collector currents up to 450 A and switches at frequencies up to 50 kHz.

The 2SC0108T is a new SCALE-2 dual-driver core that combines compact design and high reliability with broad applicability.

It drives typical IGBT modules up to 600 A, 1,200 V or 450 A, 1,700 V. The 2SC0108T combines a complete two-channel driver core with all of the elements required for driving, such as an isolated DC/DC converter and short-circuit protection as well as supply voltage monitoring. Each of the two output channels is electrically isolated from the primary side and the other secondary channel.

Power Integrations’ broad portfolio of highly reliable gate driver products, from ICs and driver cores to plug-and-play drivers, provides a high level of integration along with enhanced safety features and certified isolation capabilities. ■

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

OPINION | CHIP MANUFACTURING

Seeing Moore's Law with 2020 Vision: Less Is Now Moore

By Syed Alam



For more than five decades, companies have relied on technological advancements from Moore's Law to drive manufacturing profitability. It was simple, yet brilliant, and it worked. Computers steadily became smaller and more powerful as transistors on integrated circuits became more efficient. Semiconductor companies reaped the rewards because their chips, when manufactured on more advanced technology nodes, actually cost less.

Now let's fast-forward to 2020 and examine whether this same principle still holds true. The market dynamics have changed substantially over the course of 50 years, prompting concerns that doubling the number of transistors every one to two years might not be the right approach anymore.

LET'S DO THE MATH

As the industry has transitioned to newer nodes, design costs have grown exponentially. To put that in perspective, the annual design costs for 65-nm chips were well below US\$50 million back in 2016.¹ However, today, the design cost for a 5-nm device ranges from US\$210 million to US\$680 million, and for a 3-nm device the cost ranges from US\$500 million to US\$1.5 billion.² That is a 3,000% increase as we go from 65 nm to 3 nm. With such skyrocketing costs, it now

Companies have relied on technological advancements from Moore's Law for decades to drive manufacturing profitability. Does this principle hold true today?

makes "Moore" sense for semiconductor companies to realign their long-term goals to identify additional opportunities for older, more economical technologies. While moving to advanced nodes may deliver growth in certain sectors, it will not necessarily deliver profit.

This current situation is in stark contrast to what semiconductor companies have been used to. In the past, they could justify high initial design investments because the cost of designing and manufacturing newer nodes came down over time as yield and production quality ramped up. Each successive generation of technology took advantage of lower manufacturing costs than the previous generation.³

However, because nodes in the 28-nm to 14-nm range are already so densely packed, it's much harder

and more complex to reduce the critical dimensions of transistor components any further. Creating the next generation of ultra-dense chips requires more manufacturing cycle time, additional manufacturing steps, and additional headcount. In addition, there has been significant capital investment required through various stages in semiconductor history: transitioning from 200-mm to 300-mm wafers, automating material-handling systems, and upgrading equipment, particularly in photolithography.

Today, there is no guarantee that the rewards associated with advanced chip development will outweigh the costs.⁴ Semiconductor companies must think carefully about where — and whether — to invest in advanced chip production.⁵

IMPLICATIONS FOR 2020 AND BEYOND

Clearly, semiconductor companies will continue to leverage their vast expertise to innovate and drive new technological capabilities for a very long time. However, the decades-old mandate to double wafer capacity no longer carries the advantages it once did. As a result, chip companies need to pursue opportunities that are aligned to a viable business strategy as well as to their growth and profitability objectives. That means they need to make smart choices with their R&D wherein they really think about the costs, benefits, and requirements of moving to the more



advanced nodes — and whether there is a market opportunity on which to capitalize.

Semiconductor companies should also make sure they are generating as much value as they can out of their existing investments in older nodes. Many of these older nodes are so established that they still have many years of life left to offer growth and profitability. Instead of jumping to the next node because that is what semiconductor companies always did, they need to step back and see if customers are even asking for it or will need it in the near future.

In summary, the end of Moore's Law doesn't mean that semiconductor companies will innovate any less. In fact, they may innovate more by doing less. This may not always mean an automatic jump to the newest, most advanced process node available. Instead, companies will look to new doors for innovation that they may not have thought of previously. The industry is going to be just as exciting, just in a different way than what was originally defined by Moore's Law. ■

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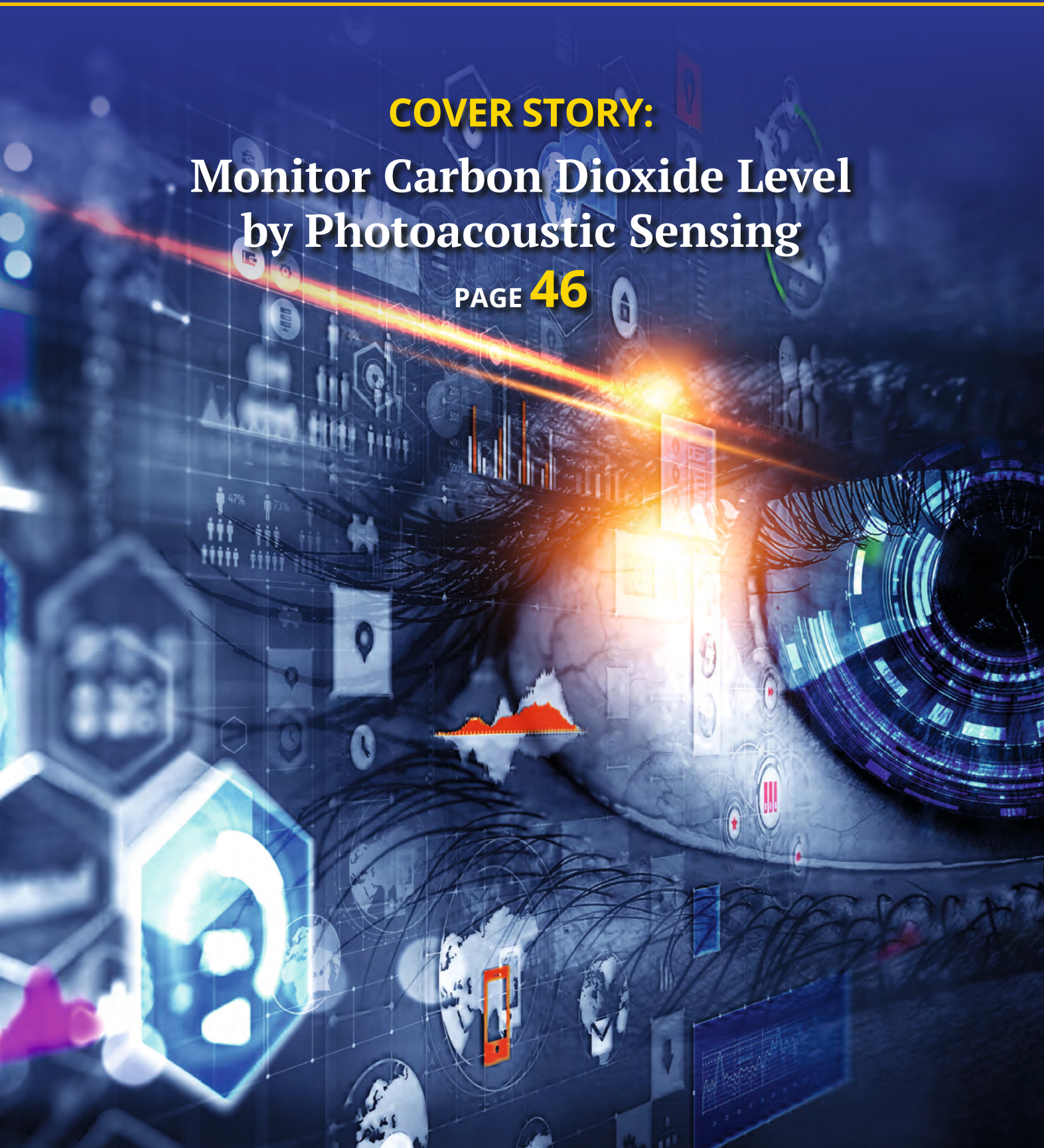
SENSOR TECHNOLOGIES

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COVER STORY:

Monitor Carbon Dioxide Level by Photoacoustic Sensing

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OPINION | NEUROMORPHIC VISION

Europe Still the Focal Point for Neuromorphic Vision

By Anne-Françoise Pelé



Neuromorphic vision is the intersection of biology, computer science, electronic engineering, and physics to form artificial neural systems inspired by biological structures. It fosters knowledge transfer and sharing. It brings a perspective on perception.

Journalists work in the present to prepare for the future. We delve into the past, in search of context, explanations, and references.

As part of my research into the concept and application of neuromorphic engineering, I once interviewed Pierre Cambou, principal analyst for imaging at Yole Développement (Lyon, France). After

paying a vibrant tribute to Carver Mead, the Caltech professor who is acknowledged as the father of neuromorphic computing, Cambou mapped the geography of research and development activity. “The image-sensing efforts come mostly from Europe and Israel,” he said. “The memory ecosystem is almost 100% in the U.S., while the computing ecosystem is more balanced between Asia, Europe, and the United States.”

I was struck by the correlation of “image sensing” with “Europe.” Cambou’s observation deserves more attention, especially in light of a few recent events: Samsung sealed a deal with Zurich-based startup iniVation, and Sony quietly acquired Zurich-based Insightness and co-presented with Paris-based Prophesee a new, stacked, event-based vision sensor at the International Solid-State Circuits Conference. What’s up with neuromorphic sensing in Europe? Why here?

THE WINDOW TO THE SOUL

“The sense which is nearest to the organ of perception functions most quickly; and this is the eye, the chief and leader of all others,” wrote Leonardo da Vinci.

Vision is a sensory experience. Understanding vision is one of the central goals of neuromorphic research and development. Had da Vinci not observed light rays, examined the optic nerves, and dissected eyes, he would not have fostered the development of the camera obscura. Had Eadweard Muybridge not developed an interest in human locomotion and animal motion photography, he would not have devised the zoopraxiscope, a forerunner of motion pictures. Had the Lumière brothers not been interested in seeing life’s moments unfold on a big screen, they would not have invented an early motion-picture camera and projector called the Cinématographe. And had Misha Mahowald not been fascinated by the structure of the eye and brain and how they work together, she would not have invented the silicon retina in 1991.

Mahowald lived and breathed the technology and was determined to accomplish her mission. “I think that it’s going to take a lot of effort to demonstrate that engineering can bring specific understandings to biological systems, and perhaps even more work to demonstrate that understanding biological systems can give rise to new engineering solutions,” she once said. “But there is no proof like demonstration, so I just need to do it.”

A Ph.D. student at Caltech under Mead’s tutelage, Mahowald moved to Oxford in the early 1990s to work with Kevan Martin and Rodney Douglas on analog VLSI models of the microcircuits of the visual cortex. In 1995, she established the Institute of Neuroinformatics at the University of Zurich and ETH Zurich to identify the computational principles of the brain and implement them in artificial systems that interact intelligently with the real world. “The brain is imagination, and that was exciting to me; I wanted to build a chip that could imagine something,” she said.

The silicon retina not only offered the promise of restoring sight but illustrated how the convergence of multiple scientific disciplines — biology, electrical engineering, and computer science — can generate synergies.

THE FOCAL POINT

Mahowald paved the way for further critical work on neuromorphic vision as she inspired the next generations of researchers. For decades, Europe has been draining a steady flow of students and researchers from all over the world. Some came here after earning their degrees and never left.



Shih-Chii Liu received her Ph.D. in 1997 from Caltech’s Department of Computation and Neural Systems. A year later, she joined the Sensors Group at the Institute of Neuroinformatics. Tobias Delbrück, the inventor of the Dynamic Vision System, received a Ph.D. from Caltech in 1993 and moved to the Institute of Neuroinformatics in 1998. Liu and Delbrück now co-lead the Sensors Group. Kenan Eng came to Zurich in 2000 to pursue his Ph.D. at the Institute of Neuroinformatics. Twenty years later, he is the CEO of iniVation and chairman of aiCTX and QuantActions. He is also a board member at iniLabs and an adviser for Karuna VR and We Are Play Lab.

“In the early ’90s, researchers worked on how to construct equivalences of neurons and neural circuits in silicon,” said Eng. “The principles we are seeing in operations now are basically the same as those built back then. In fact, some of the features were removed to make the systems more buildable from an engineering sense, but those ideas are still influential in both research and the long-term product roadmaps of companies coming out.”

The Institute of Neuroinformatics has become the center for neuromorphic sensing research, as well as the center of attention and discussion. “Everybody would basically come, visit, and bring their ideas,” said Eng. It is also involved in two international workshops every year: one in Italy, one in the U.S.

“We were, and still are, in a unique position of being a focal point for all this research worldwide,” said Eng. “This is about having a mix of people locally plus acting as a hub for the global community in this research field.”

The concept has been so successful that it is being replicated in other parts of the world. Australia has just set up the International Centre for Neuromorphic Systems, and China has similar plans. “We take this as a compliment,” said Eng.

A compliment, and concrete evidence of the efficiency of open collaboration. ■

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

MICROELECTROMECHANICAL SYSTEMS

MEMS Multi-Sensor Kit Targets IoT Developers from Novices to Pros

By Maurizio Di Paolo Emilio

STMicroelectronics' STEVAL-MKSBOX1V1 SensorTile.box wireless multi-sensor development kit lets users design IoT and industrial applications based on wearable, environmental, and remote motion sensors. The SensorTile.box builds on the experience ST has gained since its 2016 release of the SensorTile module and associated SensorTile Curriculum, an open-source, university-level introductory course developed in collaboration with the University of California, Los Angeles (UCLA) and still available today.

ST's stated aim for the SensorTile modules and classes are twofold. The first is to support students around the world in learning about the broad applications of sensors in everyday life through IoT technology. The second is to develop the modules further to enhance power and ease of use in order to bring more devices to the internet of things. SensorTile.box (Figure 1) thus takes a leap forward over its predecessor.



Figure 1:
The SensorTile.box
development board (Image: STMicroelectronics)

SensorTile.box lets developers of all skill levels, including home hobbyists, easily experiment with designs for IoT applications. Starting from a small, 5 × 3-cm board, you can design and program an IoT solution to perform a range of practical tasks and procedures. For example, you could monitor a child sleeping in the next room with the digital microphone, check the temperature and humidity in the home environment, or assess the working conditions of a machine by monitoring its vibrations.

The STEVAL-MKSBOX1V1 IoT node is ready for immediate use. It is delivered with a 500-mAh lithium battery and an 8-GB microSD board already installed. The integrated sensors leverage ST's extensive and proven set of microelectromechanical system (MEMS) devices. SensorTile.box fits into an IP54 plastic enclosure measuring 57 × 38 × 20 mm (Figure 2).

Connections are made via Bluetooth.

Because SensorTile.box supports



Figure 2: The box
(Image: STMicroelectronics)



Figure 3: Application possibilities (Image: STMicroelectronics)

many predefined IoT applications (Figure 3), non-professional programmers can use it to create wireless IoT projects and wearable sensor applications quickly and easily. When connected to a smartphone via Bluetooth Low Energy, the IoT plug-and-play module lets users observe and calculate the data detected by the sensors, including step counts, trajectory, speed and distance traveled, and environmental monitoring data such as altitude, humidity, temperature, and pressure. For more experienced designers, SensorTile.box offers a development model that allows sophisticated applications to be created using graphical wizards, along with the ability to write custom embedded code.

THREE USAGE MODES

The development kit can be used in entry, expert, or pro mode to accommodate the full range of potential user groups.

Entry mode, as the name implies, is for non-experts. The simple and intuitive graphical interface allows activation and reading of various sensors and applications, including step counting, vibration monitoring, audio recording, a compass, and a baby monitor.

Expert mode does not require knowledge of integrated development environments (IDEs) or C language programming. It allows you to create applications by selectively activating some of the available sensors and to use machine learning to generate inferences. Sensors available in expert mode to achieve more complex implementations include a digital temperature sensor, six-axis inertial units, three-axis accelerometers, three-axis magnetometers, altimeters, pressure sensors, audio sensors, and humidity sensors. It is an interesting opportunity for those who want to start using IoT platforms.

Pro mode is for experienced professionals who want to program applications within an IDE. SensorTile.box includes an interface for firmware programming and debugging that allows professional users to develop complex software for powerful applications. The STM32 open development environment (STM32 ODE) is used for this purpose.

MEMS Multi-Sensor Kit Targets IoT Developers from Novices to Pros

The ODE includes a function library for artificial intelligence with a neural network.

The STEVAL-MKSBOX1V1 is equipped with a wide range of low-power intelligent MEMS sensors from ST. There are also three buttons and three LEDs, an STM32L4 microcontroller to manage sensor configuration and output data, a micro-USB battery-charging interface, and a BLE module from ST for wireless communication with a BLE-enabled smartphone.

SensorTile.box lets developers of all skill levels experiment with designs for IoT applications.

APPLICATION DETAILS

The board is ready to operate immediately. Simply download the free ST BLE Sensor app on your smartphone (Figure 4) and start operating your device right away with one of these apps:

- The compass allows you to configure and use the LSM6DSOX accelerometer and gyroscope and the LIS2MDL magnetometric sensors to monitor the tilt sensor data and feedback diagram in real time.
- The step counter lets you configure and use the LSM6DSOX accelerometer to monitor steps and speed, tracking valuable information over time.
- The data logger and app allow tracking of vehicles via environmental and motion sensors in order to record the transport and storage conditions of selected objects.
- The barometer lets you configure and use the LPS22HH pressure sensor, HTS221 humidity sensor, and STTS751 temperature sensor to monitor real-time environmental information on your smartphone or to collect and graphically represent data in the time domain on your screen.
- The vibration tracker allows the LSM6DSOX accelerometer to be configured and the board to be trained to monitor the operation of domestic or industrial motorized equipment in the form of vibration and thus implement abnormal vibration control for predictive maintenance purposes.
- The baby monitor allows you to configure and use the MP23ABS1 microphone audio sensor to detect the sound of a human voice, such as a child's cry. The detection sends a warning to a user's smartphone and illuminates an LED diode on the sensor board.
- The compensated magnetometer lets you create additional apps at the output of the magnetometer with external magnetic-field noise compensation.

The additional flexibility in professional developer mode enables you

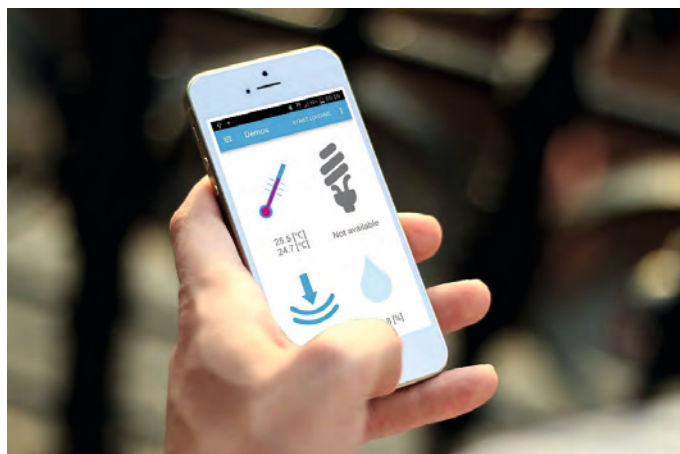


Figure 4: The free ST BLE Sensor app (Image: STMicroelectronics)

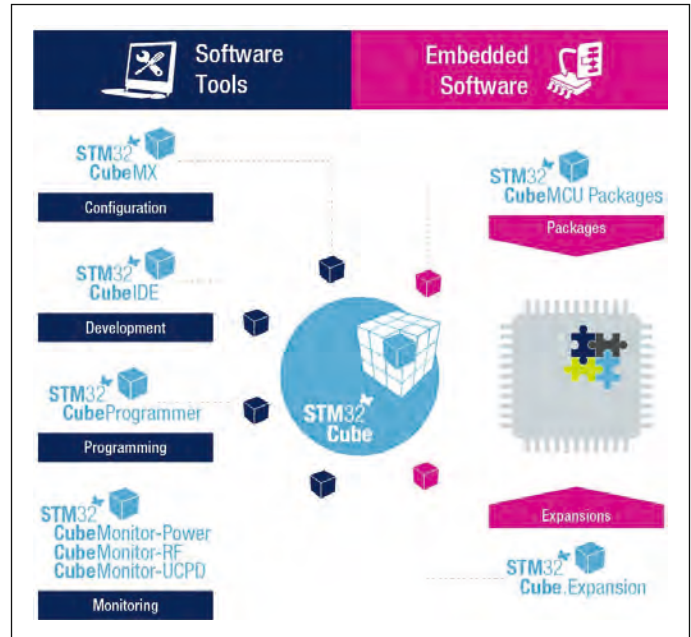


Figure 5: The STM32Cube toolset (Image: STMicroelectronics)

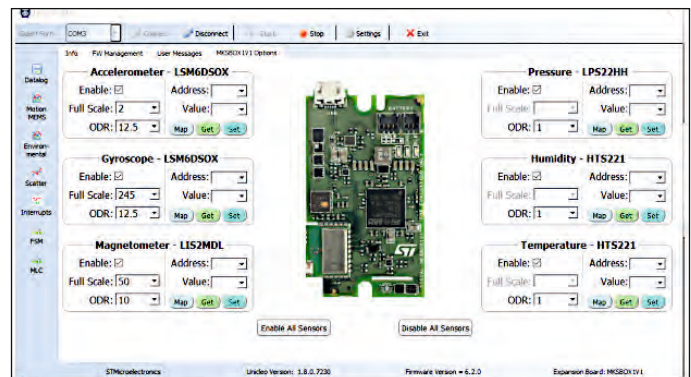


Figure 6: Sensor setup (Image: STMicroelectronics)

to activate or exclude sensors individually in order to optimize energy consumption. You can also combine data acquired from multiple sensors, use sensor-fusion technology to improve the overall accuracy of the results, and calibrate the sensors individually after final assembly.

AI AND RAPID DEVELOPMENT

Using the LSM6DSOX Machine Learning Core and AI extensions to the STM32Cube development ecosystem (Figure 5), professional developers can deploy neural networks to enable highly sophisticated pattern recognition and classification functions (audio and motion). Professional users also have the ability to develop powerful applications quickly and efficiently within the STM32 ODE, using the STM32CubeMX configurator and code generator and the ST-Link V3 programmer and debugger.

The board will not be sold online but will be offered through ST Partners to advance ST's aim of allowing the platform to reach a broad base of users and meet more needs (Figure 6). Additional releases beyond SensorTile.box are planned. ■

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

MICROELECTROMECHANICAL SYSTEMS

AAC Banks on Edinburgh's Talents, Opens MEMS Microphone Design Center

By Anne-Françoise Pelé

Microphones are ubiquitous in all aspects of the entertainment industry, and their penetration is largely due to the steady demand for smartphones, wearables, hearing aids, AR/VR headsets, and other consumer electronics devices. Seizing the opportunity, AAC Technologies Holdings (Shenzhen, China) has opened a microelectromechanical systems (MEMS) microphone design center in Edinburgh, Scotland.

The Edinburgh center completes AAC's global network of R&D activities with a primary focus on MEMS microphones. In the short term, "our objective is to develop a family of microphones that can meet the demanding specifications of smartphones," said Colin Jenkins, R&D director and on-site lead. "The initial microphone we are working on is a very high-performance digital microphone. The entire IP [intellectual property] of the microphone is owned by AAC, and it will probably be ready for production before the end of this year."



AAC's Colin Jenkins

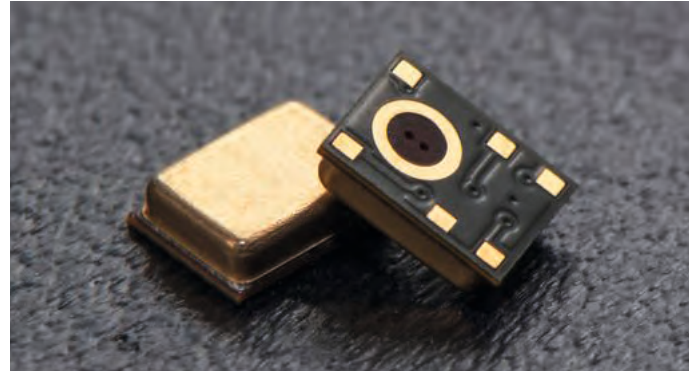
The center aims to strategically position AAC at a time when voice-controlled artificial intelligence applications are becoming increasingly central to the smartphone and mobile user experience. It will focus on high-end MEMS microphone devices with smaller physical dimensions, better signal-to-noise ratio (SNR), lower power draw, and improved ruggedness and reliability. With such features, MEMS microphones can be used in devices that offer improved keyword detection, user recognition, multi-language recognition, and custom wake-up words.



AAC's David Plekenpol

"The added value of AI is for the natural-language processing," said Dimitrios Damianos, technology and market analyst in the photonics and sensing division at Yole Développement (Lyon, France). "The voice is a more natural way to interact with the machine. You don't have to use a keyboard. You don't have to use your hands. You just use your voice." But understanding a speaker's intent — not just detecting language but grasping context — requires a lot of processing. "AI is adding the value of decoding and helping our communication with our devices," Damianos said.

AAC will work to optimize the signal pathway and to achieve power savings by limiting the need for a power-hungry DSP to process audio signals. The company will focus on a more system-level approach to



AAC's MEMS microphone (Image: AAC Technologies Holdings)

building microphone solutions, including the processing inside the microphone. "We will move in that direction soon," said chief strategy officer David Plekenpol.

FAST-MOVING MARKET

The microphone market continues its upward trend. For the 2018–2024 period, Yole predicts a compound annual growth rate of 3%, from US\$1.7 billion to US\$2 billion.

The MEMS microphone market, which now represents about 70% of the total, will grow from US\$1.2 billion in 2018 to US\$1.6 billion in 2024. Key driving markets include smartphones, smart speakers, and hearables, such as wireless earbuds. "In the last couple of years, the smart-speaker and hearable markets have experienced explosive growth," said Damianos. In volume terms, MEMS microphones in smart speakers will grow at a CAGR of 13% to 1.2 billion units in 2024. In wireless earbuds, they will expand at a CAGR of 29% to 1.3 billion units in 2024.

To reap the benefits of the ever-growing trend, MEMS companies are trying to move up the value chain and become more vertically integrated. "The ASIC, the transducer, and the packaging [constitute] the MEMS microphone, and if you have two out of three, then you rely on an outside partner to build, for example, the transducer," said Plekenpol. "Our intention is to have all three pieces basically coming from AAC. That's an ever-present roadmap of development for high-SNR microphones."

Recently, Infineon AG has shifted its business model from selling microphone dies to players such as AAC to selling complete packaged MEMS microphones, and it has expanded beyond MEMS microphone manufacturing to become an integrated provider that handles manufacturing, packaging, testing, and sales of the devices. When asked about this, Plekenpol said he understood Infineon's logic, because that's the way to go "if you want to develop a complete solution — not only [building the] ASIC, transducer, and packaging but actually building a system-level solution."

He added, "If you have the resources and the talent to build all those elements on your own, then you have a more integrated product and, I think, a better financial performance."

EUROPE'S WEALTH OF TALENT

AAC intends to leverage R&D resources and pursue its expansion in Europe over the next three to five years. "Not that we can't find [talent] in Asia, and more specifically in China, but I suppose that for a global

AAC Banks on Edinburgh's Talents, Opens MEMS Microphone Design Center

company like AAC, one might be benefiting from a global reach, both in the U.S. and in Europe, to attract the best talent,” said Plekenpol. “There is a huge wealth of technical talent that we can tap in Europe, so we will be increasing our presence in Europe — not by tenfold, but I am in a hunt for at least three other locations in Europe and in North America.”

Edinburgh was a clear choice because “it’s a very easy place to do business, as we were able to set up a company in less than a week,” said Plekenpol. Edinburgh is also “a magnet for talent,” he said, celebrating the access to university resources as well as the vitality and cost structure of the Scottish city. “There is a pocket of expertise in MEMS microphone development,” which AAC is planning to grasp and extend to other MEMS disciplines. When you build a competency in MEMS, he said, there is an opportunity to leverage it into new markets, “and our intention is to extend it to accelerometers and other sensors that can

target vertical markets like automotive, IoT, and AR/VR.” AAC’s Edinburgh center, which is expected to employ six MEMS designers in June and up to 30 people in the next four to five years, will collaborate with the company’s design centers in Denmark and Finland, both focused on optics and camera design.

“AAC is not an acquisitive company,” Plekenpol said. “It is not about acquiring companies but identifying people who have been in the industry for a long time, are looking for a shift in their career, and are excited about our company and the integration of microphones, acoustics, haptics, and optics sensors in smartphones.”

Today, AAC’s suite of MEMS microphone solutions is used by OEMs such as Samsung, Amazon, Xiaomi, Vivo Communication Technology, and OPPO. ■

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

ENVIRONMENTAL

Monitor Carbon Dioxide Level by Photoacoustic Sensing

By Maurizio Di Paolo Emilio

As modern construction techniques and materials yield buildings that are increasingly airtight, carbon dioxide sensors play an essential role in the monitoring and management of indoor air quality. Sensirion has designed a miniaturized CO₂ sensor device around photoacoustic sensing principles to enable a packaging size of only 10 × 10 × 7 mm, targeting new integration and application possibilities in the internet of things, consumer electronics, appliances, and HVAC markets.

Fitting into a space of just 1 cubic centimeter and able to measure temperature and humidity as well as CO₂ concentrations, the SCD40 is particularly suitable for high-volume, cost-sensitive applications, according to Sensirion.

THE CO₂ FACTOR

Excessive levels of carbon dioxide in indoor environments compromise human health, comfort, and productivity. High indoor CO₂ concentrations typically are the result of human presence; because we breathe in oxygen and emit CO₂, the latter can accumulate to dangerous levels in indoor environments that are not properly ventilated.

The dense thermal insulation of modern buildings indirectly contributes to CO₂ pollution indoors. Thick windows and doors help modulate indoor temperatures, thereby reducing energy consumption and cost, but they do so at the cost of reduced exchanges of indoor and outdoor air.

Carbon dioxide concentrations above 1,000

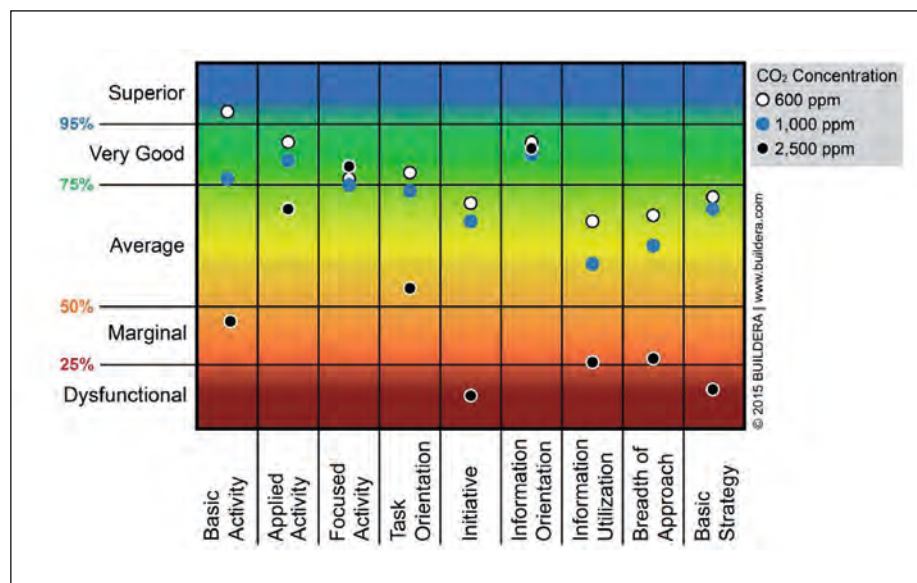


Figure 1: Impact of CO₂ on human decision-making performance

(Image: “Is CO₂ an Indoor Pollutant?” Environmental Health Perspectives, 120 (12), 1627-a475. December 2012)

parts per million can cause drowsiness; at 2,000 ppm, some people start to get headaches. Consider that in a closed room, such as a crowded classroom, levels can rise to 5,000 ppm. The New York Times last year reported on the effect of CO₂ on cognitive functions such as the ability to concentrate. It cited one study in which subjects answered test questions under varying CO₂ levels. According to the article, the study found that “the higher the carbon dioxide, the worse the test-takers did; at 2,500 ppm, their scores were generally much worse than at

1,000 ppm.” Moreover, “Without a specialized sensor, you can’t realistically know how much carbon dioxide is building up while you hunker down in a small room for a long meeting.”

Ventilation systems are therefore required in modern buildings. Air exchangers and intelligent ventilation systems in the commercial and residential sectors use CO₂ sensors to regulate ventilation in the most energy-efficient and human-friendly way. CO₂ sensors can also be integrated into purifiers, intelligent thermostats, and other smart-home products.

Monitor Carbon Dioxide Level by Photoacoustic Sensing

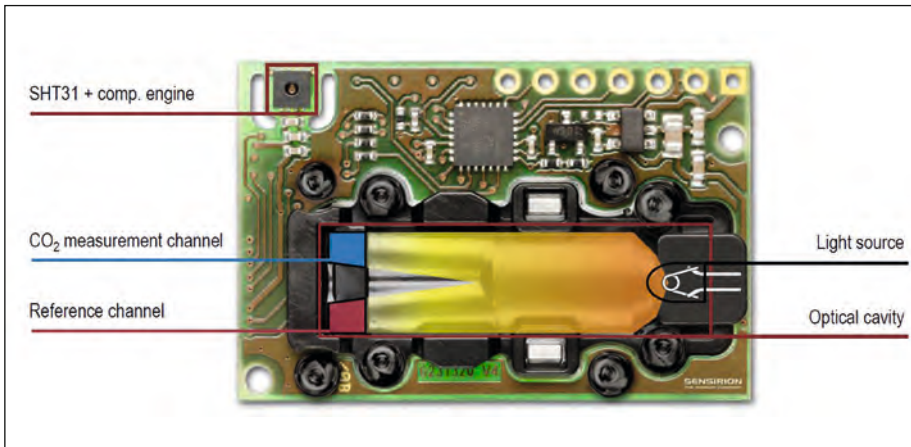


Figure 2: SCD30 technology (Image: Sensirion)

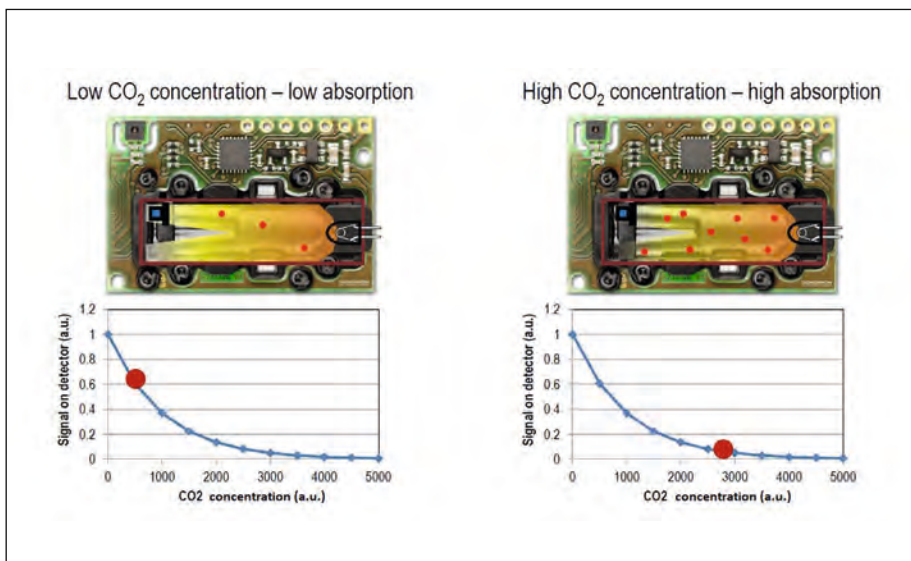


Figure 3: NDIR principle (Image: Sensirion)

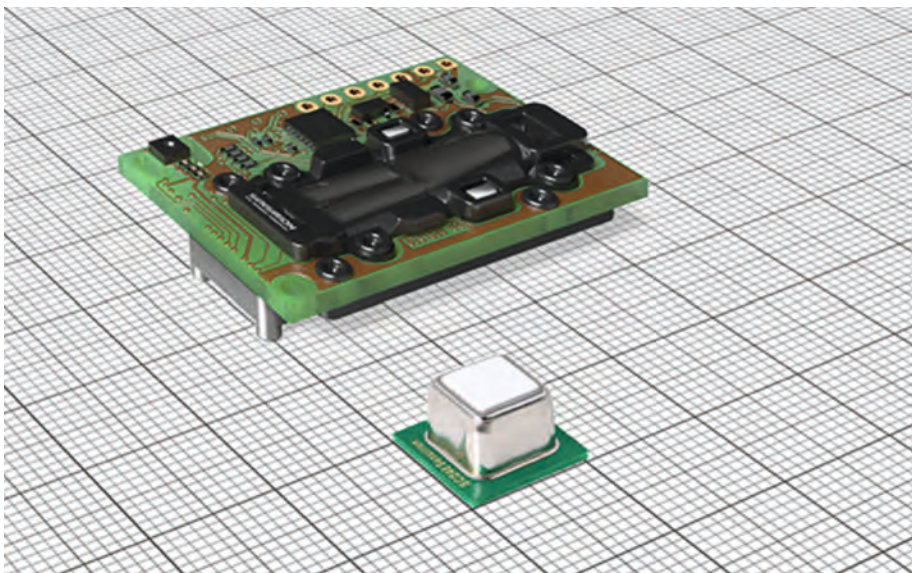


Figure 4: Size comparison of the SCD30, based on NDIR, and the SCD40, based on PASens Technology (Image: Sensirion)

Public awareness of the negative cognitive effects of CO₂ pollution is growing, said Marco Gysel, product manager for CO₂ sensors at Sensirion (Figure 1). As a result, “there is an increasing number of initiatives from the public and private sector to monitor and counteract high CO₂ concentrations,” he said. “Most initiatives focus on classrooms, universities, and commercial office buildings, but there is an increasing demand for CO₂ sensing for residential apartments as well.”

PHOTOACOUSTIC DETECTION VERSUS NDIR

Sensirion’s previous-generation sensor, the SCD30, was based on the non-dispersive infrared (NDIR) optical detection principle. The size and cost of NDIR sensors have restricted their use to a few applications. For the SCD40, Sensirion used the photoacoustic detection principle to reduce the size of the optical cavity without compromising performance. The new device is smaller than its predecessor by a factor of 7. The company is betting that its miniaturized CO₂ sensor will create the basis for a range of new sensing applications.

NDIR-type sensors are frequently used in gas analysis. The main components are the infrared source with a wavelength filter, a sample gas chamber, and an IR detector (Figures 2 and 3). By illuminating an infrared beam through a sample cell containing CO₂ and measuring the amount of infrared absorbed by the sample at the required wavelength, an NDIR detector is able to measure the volumetric concentration of CO₂ in the sample.

The sensitivity of a sensor based on the NDIR principle is directly proportional to the optical beam path. A large reduction of the path leads to a compromise of its performance, which limits the miniaturization potential of this technology. The size, structure, and large number of discrete components required for NDIR sensors result in a bill-of-materials (BOM) cost that is beyond the reach of many applications.

“Sensirion is always aiming at disrupting sensor markets by making components smaller and more price-effective without compromising performance,” said Gysel. “For CO₂ sensing, we identified photoacoustic technology as the most promising approach. In addition to reducing the size and the cost of CO₂ sensors, this technology allows for SMT [surface-mount technology] assembly to replace arduous through-hole soldering. These three factors combined have the potential to open up new CO₂-sensing markets. Personally, I believe that photoacoustic technology has the potential to replace NDIR as the standard CO₂-sensing technology over the next five to 10 years.”

Monitor Carbon Dioxide Level by Photoacoustic Sensing

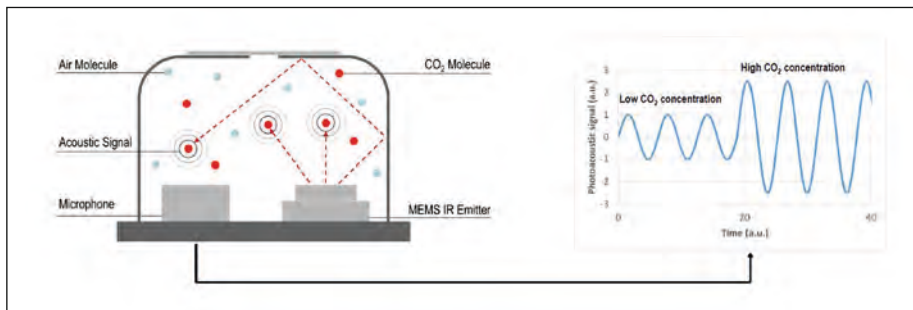


Figure 5: Functioning of PASens Technology. There are dust filters on the top of the sensor. (Image: Sensirion)

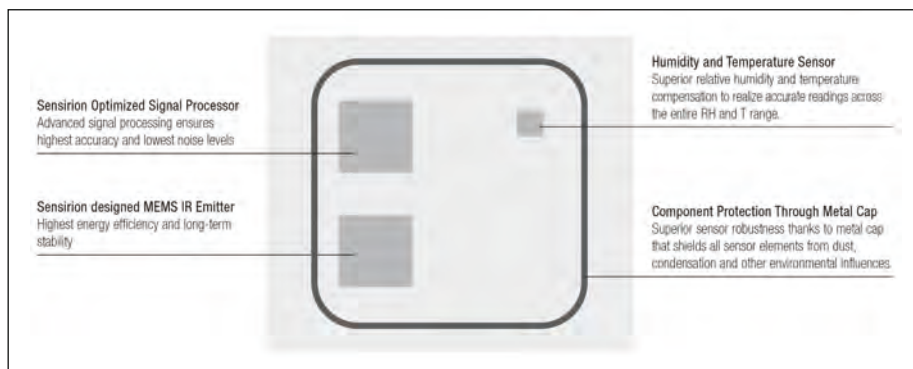


Figure 6: SCD40 sensor features (Image: Sensirion)

With a photoacoustic detection approach such as Sensirion’s PASens Technology, the sensitivity of the sensor is independent of the size of the optical cavity. Sensirion combined that approach with its CMOSens Technology for miniaturization to create a new type of sensor (Figure 4).

The photoacoustic principle is relatively simple. A modulated narrowband light signal at 4.26 μm , corresponding to the absorption bands of CO_2 molecules, is emitted in a small,

enclosed space. The CO_2 molecules in the measuring cell absorb part of the irradiated light. The absorbed light excites molecular vibrations. The result is an increase in translational energy that causes a periodic change in pressure in the measuring cell. The change can be measured with a microelectromechanical system (MEMS) microphone to calculate the CO_2 concentration (Figure 5).

Gysel described the process as it relates to the PASens Technology: “Upon absorption,

the energy of the photon is first transferred to the CO_2 molecule and subsequently to the surrounding molecules. The absorbed energy results in a microscopic pressure increase. Since millions of absorption events take place inside the optical cavity, the pressure increase becomes a macroscopic phenomenon. By modulating the IR emitter, we induce a pressure increase and decrease with a well-defined frequency, which is nothing other than an acoustic sound wave. While the frequency of the sound is given by the IR-emitter modulation frequency, the amplitude of the sound is proportional to the CO_2 concentration.

“This amplitude of the photoacoustic signal can be measured with a MEMS microphone. The CO_2 concentration is then calculated using the built-in processor by means of advanced signal-processing algorithms.”

The SCD40 represents a combination of sensing and MEMS technology by combining minimum size and maximum performance, according to Sensirion (Figure 6). The SCD40 offers a measurement range of 0 ppm to 40,000 ppm, fully calibrated and linearized output, and a digital I²C interface.

“Maybe the biggest asset with the SCD40 is that we design and produce all the critical components in-house,” said Gysel. “This allows us to realize highest performance while keeping a cost-effective BOM structure. For example, the actively regulated IR emitter, which is based on our CMOSens technology, ensures the highest long-term stability and is significantly more cost-effective than existing off-the-shelf products.”

Sensor accuracy “enables our customers to design products with superior performance” and allows customers in certain sectors to meet industry norms and standards, he added. Standards compliance “is very critical in the HVAC market, for example,” he said.

Sensirion specifies the accuracy of the SCD40 as ± 30 ppm (+3% of reading), which Gysel said “is among the best accuracy that can be found on the market. Rated sensor lifetime is 10 years.”

The CO_2 problem is very much felt. According to the World Health Organization, more than 5.5 million people worldwide die from air pollution each year. Many cities have integrated sensors to map air quality into existing infrastructures. Indoor air pollution can have negative consequences on economic health as well as human health. To keep the concentration of contaminants low, even the most airtight buildings must swap out stale air and bring in fresh air. Intelligent indoor and outdoor sensors are critical components in this effort. ■

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

NEWS

New Technique Embeds Sensors in Clothing for Vital Sign Monitoring

Researchers at the Massachusetts Institute of Technology (MIT) have developed a technique to embed sensors into stretchy clothing fabric, paving the way to monitor vital signs such as temperature, respiration, and heart rate as you go about your day. The form-fitting, sensor-embedded garments are machine-washable. Researchers said that the garments could be used to remotely track a patient’s health, ranging from checking in on those ill at home or in a hospital to monitoring an athlete’s physical activity. It can also be useful for telemedicine, which is particularly useful now, during the Covid-19 pandemic, for doctors who are increasingly connecting with patients remotely. “We can have any commercially available electronic parts or custom lab-made electronics embedded within the textiles that we wear every day, creating conformable garments,” said Canan Dagdeviren, the LG Electronics Career Development assistant professor of Media Arts and Sciences at MIT, in a statement. “These are customizable, so we can make garments for anyone who needs to have some physical data from their body like temperature, respiration rate, and so forth.”

BIOSENSORS

MEMS Foundry Rogue Valley Thinks Globally, Acts Locally

By Anne-Françoise Pelé

After decades of watching companies move production to regions with low labor costs, the Covid-19 pandemic is compelling governments to see manufacturing in a new light and consider improving domestic sourcing of microelectronics. For entrepreneurs who had chosen to set up their foundries locally, this long-awaited change in perception is music to their ears.

Rogue Valley Microdevices Inc., a micro-electromechanical systems (MEMS) foundry located in Medford, Oregon, has been playing a strategic role in the scramble to develop Covid-19 diagnostic tests. EE Times Europe spoke with Jessica Gomez, the company's co-founder and CEO, about the rationale for having domestic production capabilities and how to support the establishment of more domestic companies like hers.



Rogue Valley's Jessica Gomez

RIGHT PLACE AT THE RIGHT TIME

When Rogue Valley opened its doors in 2003, it was the first and only microelectronics manufacturing facility in Southern Oregon. Considered a daring endeavor by some, it was a calculated risk for its founders. Since then, the company has grown to more than three times its original size.

A full-service precision MEMS foundry, Rogue Valley specializes in MEMS device fabrication and silicon wafer services, including low-pressure chemical vapor deposition (LPCVD) nitride, oxide, metal, and resist spray

coat. With experience in biomedical-device manufacturing, the company has been solicited to cope with the exponential rise in demand for diagnostic tests for Covid-19.

"We have definitely seen a big shift as a manufacturing company," said Gomez. When companies working on Covid-19 tests approached Rogue Valley with requests to be made a top priority, Gomez would answer "No problem." But inevitably, "that created a general shift in where our focus was, and it definitely had an impact on where we put our resources, what our schedules are, who we have doing what."

Responding to the global emergency, many biomedical companies have indeed adapted their existing technologies, originally used for cancer and other diseases, to detect Covid-19 infection or antibody responses. For instance, Maryland-based Hememics Biotechnologies Inc. recently received a grant from the U.S. Department of Health and Human Services to speed development of its lateral flow biosensor, which detects SARS-CoV-2 and associated antibodies from nasal swabs or white blood cells. Each biosensor, which comprises 17 sensors in a multiplexed sensor array, includes a multilayered chip from Cypress Semiconductor, a Bluetooth LE radio, and a MEMS die made by Rogue Valley.

The Hememics tool, Gomez said, "is quick, not overly sophisticated, meaning that it is not going to give you tons of information, but it will give you an answer, one way or the other."

The World Health Organization has been advocating the need to "test, test, test" to

control the spread of the virus. MEMS manufacturers have a prominent role to play in that effort. "It's one thing to develop a technology, but in order to use it, you have to manufacture it," said Gomez.

In general, the U.S. and Europe are lacking some manufacturing infrastructure. "You can get all the FDA [U.S. Food and Drug Administration] approvals that you want, but if you can't make [your product], it's not helping anyone," said Gomez. "We need to start thinking how we are going to deliver this technology because once commercialization

happens, we cannot have this dead space where there are very little resources on the manufacturing side."

Describing her company as a shop for microelectronics, Gomez said, "We have the basic building blocks to make all kinds of devices." This has proved to be a definite advantage as transportation restrictions during the pandemic have squeezed the supply chain. "Part of our business is supporting other manufacturing facilities, so we have been working with other foundries and universities and supporting them when they have had a missing capability," said Gomez.

PREVENTION BETTER THAN CURE

Bringing production back is a recurring topic, but this pandemic could serve to make it a priority. As Gomez explained, when China — "which is responsible for 80% of the supply chain" — came to a standstill early in the pandemic, the downside of relying on Chinese manufacturing hubs to "feed the rest of the world with parts" became clear.

Gomez stressed the importance of diversifying the supply chain to limit or contain vulnerabilities. "We need to diversify those manufacturing centers so that we have consistency, we maintain a robust supply chain, we are not vulnerable to natural disasters, and we have the ability to shift things around as needed."

Part of that is a policy discussion about taxes "and how we manage tariffs that encourage companies to manufacture in particular parts of the world," she said. A tradeoff must be found to allow supply chain diversification and mitigate risk. "When things go fine, everyone makes money, but when the political situation is tricky, when we have a pandemic, a number of things that happen at large scale get disrupted. And we are so connected now that it has a much bigger impact." Thinking about how to rebalance the supply chain, especially in the microelectronics supply chain, is going to be an important discussion, said Gomez.

Another trend to watch is investors' interpretation of and reaction to the current situation, she said. In the early 2000s, investors identified small companies developing technologies for the telecom industry and invested heavily in them. Those companies brought their own R&D and manufacturing capacity to the table, but when the economy collapsed, "investors realized it was a big waste of money [to have everything in-house] and required these companies to outsource." Some of those facilities transitioned to a foundry model; many others completely disappeared.

That's where we are now, and Gomez wonders what comes next. "Are we going to see some sort of hybrid model? Are investors going to invest in companies and tell them

MEMS Foundry Rogue Valley Thinks Globally, Acts Locally

to go find a partner and pass the dollars on to them to secure the supply chain without having to put \$20 million in an R&D facility?" Clearly, she said, "it is something people are thinking about in Month Two of not having access to those resources they are reliant on."

OPEN DIALOGUE AND COLLABORATION

Prior to founding Rogue Valley, Gomez worked for Standard Microsystems Corp. (Hauppauge, New York) and held positions at Integrated Micromachines and Xponent Photonics. After her experience in the semiconductor industry, she said she has developed a different philosophy. "Large semiconductor companies

were very hesitant to share information, even basic information," said Gomez. The nature of MEMS manufacturing differs, and she tries to engage in open dialogue with her customers.

MEMS manufacturing processes are unique, but that is no reason to get proprietary. According to the company, "We share engineering-level data with our customers, freeing you to bring up a process at Rogue Valley that you will later use for high-volume production at a larger fab." Elaborating, Gomez said, "When we work with customers and we come to the table, we are there to support the technology getting to market, through its commercialization and out to the world."

It is a different way of collaborating and building relationships with other foundries. Every time Gomez interacts with her counterparts at foundries such as Canada-based Micalyne Inc., they discuss how they can work together and support their customer base so that they can make sure they have enough capacity to deliver, she said.

"MEMS has been such a slow-growing piece of the industry," said Gomez. "This is really challenging, and without collaboration, we are not getting anywhere." ■

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

BIOSENSORS

Goodix's CEO Scans the Future of Biometric Sensing

By Anne-Françoise Pelé

With mobile devices now used to conduct transactions such as bill payments, online shopping, and banking, in-display fingerprint sensors for authentication have proven their security and convenience benefits. Founded in 2002, Goodix Technology (Shenzhen, China) provides fingerprint sensors for some of the world's largest smartphone companies, including Samsung, Xiaomi, Huawei, Lenovo, OnePlus, ZTE, and Vivo. And with bezel-less smartphones becoming the norm, Goodix has put its fingerprint sensor underneath the screen. Its optical in-display fingerprint sensor started with 18 adoptions in 2018, its first year of commercialization, and has now been used in more than 100 smartphone models.

EE Times Europe spoke with David Zhang, founder and CEO of Goodix, to learn more about the company's vision for biometrics and how it is preparing for 5G.

EE TIMES EUROPE: Goodix recently released an ultra-thin in-display fingerprint sensor designed for 5G devices. What does 5G impose in terms of security/biometric authentication? What are the main challenges?

David Zhang: As the industry and global consumers call for continuous enhancements in mobile experiences, premium features such as higher transmission rates, multiple cameras, seamlessly smooth display performances, and batteries with ultra-long standby time are introduced to global consumers via premium 5G devices; yet these upgrades require additional space for larger modules and complex 5G antenna designs.

Overcoming this rising challenge, Goodix introduced the ultra-thin optical in-display fingerprint sensor as the answer.

We used to think that a below-0.3-mm in-display fingerprint sensor was a fantasy, but we have turned this fantasy into reality. After dozens of various designs and countless tests, we achieved the breakthrough by implementing a micro-optics design in the innovative, ultra-thin optical in-display fingerprint sensor. The compact design in module size not only frees up excess space for hardware optimizations in 5G devices, such as more powerful cameras or higher-capacity batteries, but also extends flexibility in the fingerprint module location to complement smartphone manufacturers' different advanced user interface designs.

To complement the design with an advanced manufacturing process, Goodix and partners joined forces in reconstructing the supply chain, overcoming the technical diffi-



Goodix's David Zhang

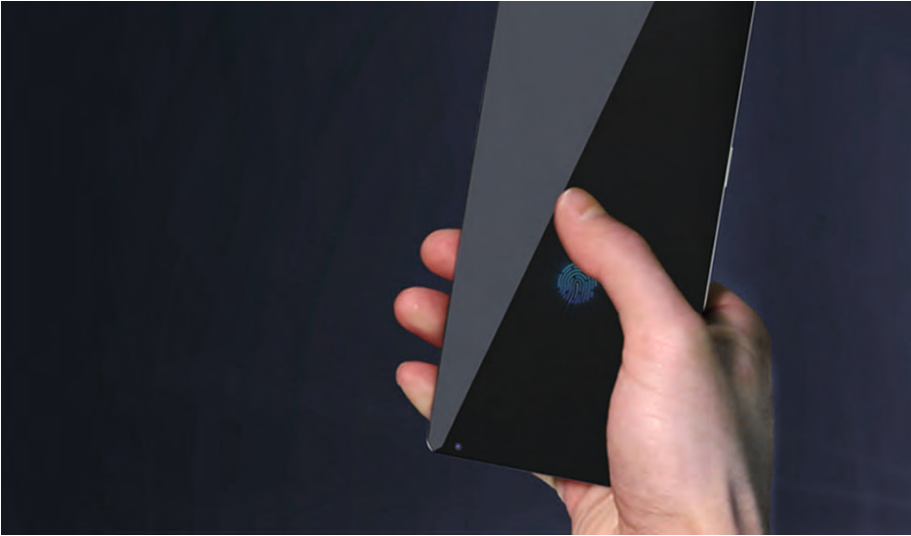
culties in manufacturing the microlens while ensuring high yield and scale of its production. The solution is ideal for manufacturers, as the module delivers outstanding anti-electromagnetic-interference performance and doesn't need to be laminated to the screen.

EETE: Is 5G one of Goodix's priorities for 2020? If yes, what will Goodix do to be at the forefront of biometric authentication in the 5G era?

Zhang: With six years of dedication and devotion in R&D, we drive the development of optical in-display fingerprint authentication technology from its creation to continuous breakthroughs. 5G is bringing a smarter life to the world, and Goodix's ultra-thin optical in-display fingerprint sensor is serving as a key component of the premium mobile experiences in the 5G era. Accommodating the demands of the market and from our customers, we will also speed up the commercialization of our optical in-display fingerprint solution for LCD panels by optimizing its performance.

EETE: In February, Goodix completed the acquisition of NXP Semiconductors' Voice and Audio Solutions [VAS] assets to extend its biometric capabilities to the voice channel. What are your ambitions?

Goodix's CEO Scans the Future of Biometric Sensing



Goodix's in-display fingerprint sensor (Image: Goodix)

Zhang: The acquisition of NXP's VAS allows us not only to open up more business opportunities and cooperation potentials with our customers but also to gain an industry-leading R&D team and predominant patented technologies in the audio field, [thereby laying] a solid foundation for the development of new products. In the future, we will build up unique technical advantages step by step to provide customers with audio products and services for mobile devices, earphones, smart homes, and even automotive electronics.

EETE: Are you envisioning other R&D directions?

Zhang: We already have products that combine a heart-rate detector with a fingerprint sensor: Our Live Finger Detection, a winner of CES Best of Innovation, Edison Gold, and Computex d&i awards in 2017, features a compact chip design with a built-in heart rate sensor.

In the fields of touch controllers, the debut of an upgraded touch control solution supporting both flexible and rigid OLED displays will be expedited. We will also broaden the horizon of our touch control solution applications in mobile devices, automotive electronics, and smart homes.

Building on years of experience in optical studies, we will roll out our ToF [time-of-flight] solution in 2020, targeting achievement of commercialization by offering differentiating values. And with the completed acquisition of VAS, we will gear up for a wider range of partnerships with customers based on a richer product portfolio in the newly established audio product line.

In the meantime, we will continue investing in research and development of technologies utilized in mobile devices and [internet of

things] applications, as well as improving the performance and expanding the categories of our wearable sensors. We will launch and commercialize a new-generation heart-rate sensor with heart-rate detection, blood oxygen [saturation monitoring, and] ECG functions for wearables this year.

EETE: With the explosion of IoT, security risks will increase, and people will be more and more vulnerable to security threats. Securing the IoT is indeed fundamental to the well-being, privacy, data security, personal safety, and security of everyone and everything across nations. In your opinion, what kinds of innovations are needed for IoT security?

Zhang: From our understanding, IoT is not a new object. [Rather,] it includes "things" from the known internet that connect physical objects in our life to formalize a mega network and enable data communication between humans and objects or between objects and objects. Such a combination extends the traditional, virtual internet world to our physical world. Potential security risks also expand from conventional cybersecurity to endpoint terminal security due to the network scope expansion.

Therefore, more perspectives have to be considered when mentioning IoT security — for example, whether the data uploaded to the cloud from the terminal is trustworthy and not manipulated, whether the command from the cloud down to the terminal is authentic and available all the time, and whether the data transmitted between terminals has integrity and confidentiality guarantees.

Security is a relative concept; there is

no absolute security, especially in the IoT domain. We'd better talk about security in particular scenarios and deliver to customers an optimized security solution under the circumstance of not sacrificing user experience or product performance. Such principles bring challenges in areas like basic security theory, security algorithms, secure protocols, secure hardware/software/system architecture, and security evaluation; [these] are, on the other hand, motivations and missions of innovations by Goodix.

Goodix's IoT portfolio covers different layers in IoT and utilizes security concepts for commercialized products, from endpoint sensors to transmit-layer Bluetooth LE or NB-IoT and data-processing-layer Secure SoC. Our security experts, cryptographers, and vulnerability analysis team have been closely working with each product engineering team to deliver innovative and secure IoT solutions.

EETE: What will shape the future of biometric sensing? And what role will Goodix play to make this possible?

Zhang: As the most popular option among biometric authentication solutions, fingerprint sensors have been widely utilized in daily applications. Mobile payments represent the next frontier in seamless e-commerce experiences and demand a high level of security. Peer-to-peer payment apps, retailer apps, platform apps like Alipay, WeChat Pay, Google Pay, etc., all support fingerprint authentication, realizing customized, data-driven user experiences. The future of biometric sensing calls for one-touch, convenient authentications with a high level of security.

In terms of application scenarios, Goodix's solution offers large-area in-display fingerprint solutions for various displays — smartphone, tablet, even wearables such as smart watches — to meet the different customization needs of smart-device manufacturers.

We believe other biometric technologies will coexist with the current options as supplement methods. Thus, we've been investing in R&D of various biometric technologies, such as 3D structured light and ToF, and will plan for commercialization based on our customers' needs.

We will broaden the horizon of our biometric-authentication solution applications in mobile devices, automotive electronics, and smart homes. Our innovative fingerprint solution for automotive, for example, is expected to introduce a brand-new smart driving experience, with its leadoff commercialization in a prominent automobile brand soon. ■

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

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TRENDS TO WATCH

Neuromorphic Chips Mimic the Human Brain

By Maurizio Di Paolo Emilio



IMAGE: CERYX

The electrical properties of biological cells have long been studied to understand intracellular dynamics. The difficulty of measuring microscopic parameters that control the dynamics of ionic currents and the nonlinearity of ionic conductance have hindered efforts to construct quantitative computational models. The growing attention paid to implantable bioelectronics for the treatment of chronic diseases is driving technology toward low-power solid-state analog devices that accurately mimic biological circuits.

The human brain processes information and stores it instantly through more than 100 billion neurons. The neurons communicate with each other through more than 100 trillion synapses that are connected in parallel, allowing the network to perform memory, computation, reasoning, and computing simultaneously at low power (about 20 W).

Many researchers and analysts believe that neuromorphic chips are likely to be the future not only for AI but also for developing low-energy cryptographic evaluation systems.

Neurons determine signals as part of networks that produce collective oscillation patterns that are extremely sensitive to the neurons' properties. One objective of neuromorphic chips is to be able to integrate nonlinear electrical characteristics and offer shallow power with the ability to process a considerable volume of signals in real time.

Solid-state neurons implemented through a microelectronic layout respond almost identically to biological neurons under stimulation from a wide range of current injection protocols. The optimization of nonlinear-equation models demonstrates an effective method for programming analog electronic circuits. This approach offers a way to

repair diseased biocircuits and emulate their function with biomedical implants that can adapt to biofeedback.

Neuromorphic chips represent a promising technology for implanted brain-machine interfaces, with many research projects now under way. An application example includes solutions to improve visual prosthetic systems or deep brain stimulation settings. "Neuromorphic chips are low-power and compact, and they potentially can adapt, through on-chip online learning circuits, to the changes that the body undergoes with time," said Giacomo Indiveri, director of the Institute of Neuroinformatics at the University of Zurich and ETH Zurich. "Typically, neuromorphic chips are designed to couple to the neural circuits they are being interfaced to by using the same dynamics and then detecting anomalies in the activity of the neural populations they are talking to" — for example, to detect the onset of a seizure.

Neuromorphic chips work similarly to the human brain, conserving energy and working only when needed. Many researchers and analysts believe that these chips are likely to be the future not only for artificial intelligence but also for developing low-energy cryptographic evaluation systems.

"The chips would meet the needs of [patients with] degenerative neuron disease by substituting diseased biocircuits with synthetic ones," said Alain Nogaret, a professor of physics at the University of Bath. Nogaret is part of a research team that worked with cardiologists to show that "neuron chips can reverse the effects of heart failure by restoring the function of ... respiratory neurons" at the base of the brain.

In a paper¹ on their findings, the authors state their reluctance to extrapolate the results to other diseases, "as the only extensive trials we have conducted on animal models of disease so far are animal models of heart failure." But according to Nogaret, "diseases that come to mind" as candidates for the approach include "Alzheimer's disease and diseases of ion channels in the neuron membrane (channelopathies). Epilepsy [patients] could also benefit, as some forms of epilepsy

Neuromorphic Chips Mimic the Human Brain

reported in the literature are associated with specific ion channels.”

Indiveri said, “Another application area in this domain that is more mature is cochlear implants. The main advantages of neuromorphic chips are their lower power consumption, their compactness, and their potential for ‘speaking the same language’ [as the] spiking neurons they are being interfaced to, i.e., that of action potentials and neural dynamics.”

Neuromorphic chips could also be used to listen to motor neuron activity and to decode the expected muscle-activation pattern (e.g., for control of a prosthetic device).

The chips are analog devices, typical of nonlinear dynamic systems. This means they read raw nerve signals and output neuron oscillations as analog voltages. “No ADC/DAC is needed,” said Nogaret. “Asynchronous chips can thus integrate complex, noisy synaptic inputs in real time. The main difficulty lies in conditioning the chip — through its parameters, gate biases, etc. — to respond identically to a specific type of biological neuron. This is the purpose of the parameter estimation methods that our lab and others are beginning to develop.”

The chip must be minimally invasive in terms of biocompatibility, adapting to signals with virtually zero power consumption by maximizing the use of energy-harvesting sources. The design constraints are the same as those imposed on the electronic circuits and systems currently being used in implants such as cardiac pacemakers. “To a large extent, these conditions are already accessible, thanks to the 60-or-so years’ experience we have in producing VLSI circuits,” said Nogaret. “The challenge of optimizing these chips further to optimize bioimplants will be met through incremental engineering progress and feedback from targeted trials.”

VLSI circuits realized with CMOS technology are a strategic technology for the development of digital systems; continual increases in microelectronics integration have enabled systems of rising complexity.

The development of VLSI systems has resulted in highly specialized technologies. Integration at the packet and chip level is more practical for the implementation of VLSI systems because of their compact size and short signal interconnection. The growing complexity of chips creates a need for improved design methodologies and more powerful CAD environments.

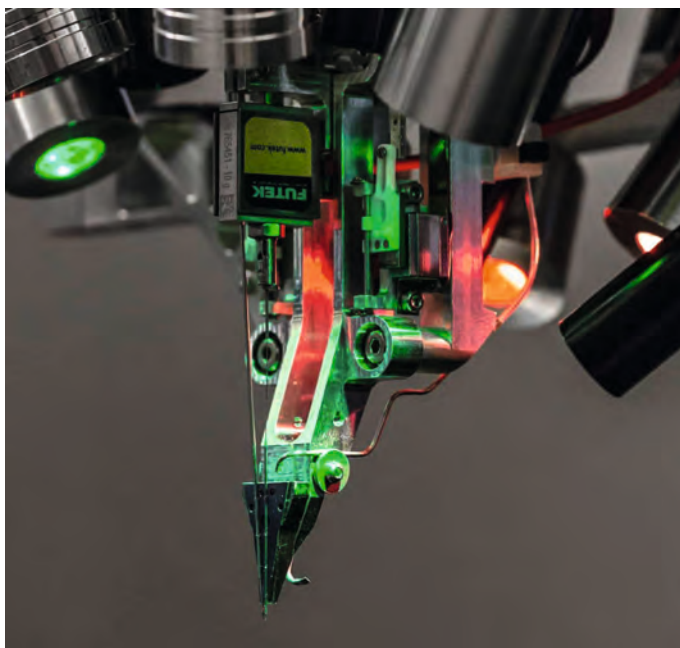


Figure 1: This sewing-machine-like robot inserts electrodes into the brain. (Image: Neuralink)

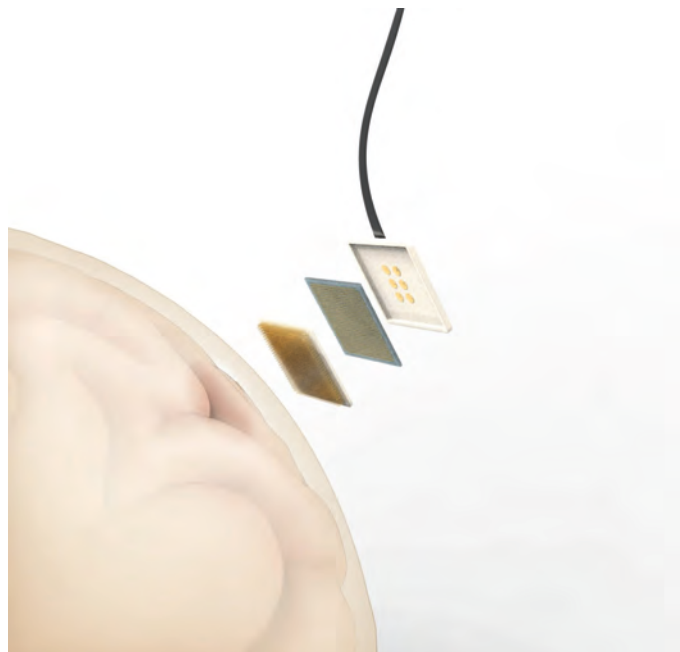


Figure 2: The Paradromics system (Image: Paradromics)

Further research and development are required before complete adoption is possible, however.

Among the companies working on application cases, Ceryx Medical is developing bioelectronic central pattern generators (CPGs) to imitate the body’s nerve centers. CPGs produce rhythmic outputs in the absence of rhythmic inputs. In medical applications, the devices could help control involuntary and voluntary rhythmic processes such as peristalsis, heart rate, and even gait, restoring proper functioning when natural rhythmic processes have been impaired by disease or injury.

Startups Neuralink and Paradromics are also working to optimize neuromorphic solutions. Neuralink is building an implantable wireless system that has far more electrodes so that it can record signals from more neurons (Figure 1).

Paradromics is bringing to market the first high-data-rate brain computer interface (Figure 2). The implantable system can be used for practical health-care applications by vastly increasing data rate, portability, and durability. The startup is focused on enabling an even higher density of probes over the face of its neural implant by integrating more, smaller electrodes.

Future challenges for neuromorphic devices are to increase the efficiency of the response and the improvement of the model through deep-learning tools, with the aim of transforming the brain into an increasingly digital one. The key application for such solutions is a digital cure for Alzheimer’s disease and other cognitive disorders.

A neuromorphic chip can mimic the brain to process data effectively, far surpassing existing machines, which struggle to accommodate the demands of big data, AI, and machine learning. Neuromorphic chip processing is also expected to play a crucial role in non-medical areas, including voice/face recognition and data mining, learning accurately from evolving data. ■

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TRENDS TO WATCH

Microfluidic Technologies Diagnose World's Return to Normal

By Anne-Françoise Pelé and Maurizio Di Paolo Emilio

As countries work to contain the Covid-19 pandemic, the need for effective diagnostic testing has been front and center. Accurate, accessible testing is a precondition for the population's gradual return to normal — or, most likely, a new normal.



Yole Développement's
Sébastien Clerc

Diagnostics companies have mobilized their resources and readied tens of tests, sometimes within weeks. In the face of the health emergency, the U.S. Food and Drug Administration and other regulatory bodies have lowered their standards and granted "Emergency Use Authorizations" for some of the tests. Since mid-March, companies including GenMark, BioFire, Cepheid, and Mesa Biotech have received approvals for their microfluidic-based rapid molecular testing for SARS-CoV-2, the pathogen that causes Covid-19.

A new dynamic of innovation is emerging around the world, and it seems obvious that there will be a before and after Covid-19. "The pandemic will certainly leave its mark on the way we work, produce, and live in society," Sébastien Clerc, technology and market analyst in microfluidics, sensing, and actuating at Yole Développement (Lyon, France), told EE Times Europe. The structure of the diagnostics industry will change as it intensifies its R&D activity and continues to consolidate. Overall, the microfluidics market will grow at a CAGR of 11.7% to US\$17.4 billion in 2024, Yole predicts.

MICROFLUIDICS EXPLAINED

The Covid-19 test protocol includes a real-time reverse-transcription polymerase chain reaction (RT-PCR) test of a person's saliva or nasal sample and may currently take several

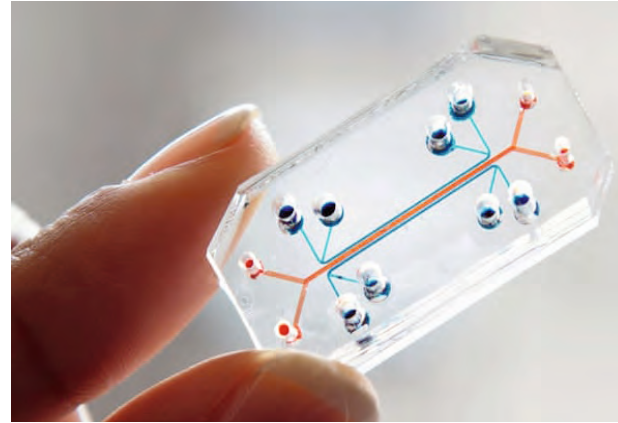
days to yield results. A rapid test can help contain the number of unnecessary visits to health clinics and save lives by reducing the spread of the virus. Researchers are looking to apply microfluidic chips in coronavirus test protocols.

Microfluidics is a multidisciplinary field involving engineering, physics, biochemistry, and nanotechnology. It deals primarily with the behavior, precise control, and handling of geometrically confined fluids on a small (typically sub-millimetric) scale, in a context in which capillarity governs mass transport.

Microfluidic technology thus proves to be very suitable for the definition of the test structure used in many fields of biological research and has the potential to offer rapid diagnostic tools.

In a typical approach using a microfluidic chip, a small volume of fluid is injected in micron-scale channels by using a pump, allowing precise control of the microenvironment to reduce mass and heat transfer times. It thus requires smaller samples and less reagent, enabling greater efficiency at a lower cost compared with conventional methods.

Different types of pumps precisely move liquid inside the chip at a rate of 1 μL /minute to 10,000 μL /minute. The form factor is usually transparent and measures 1 cm to

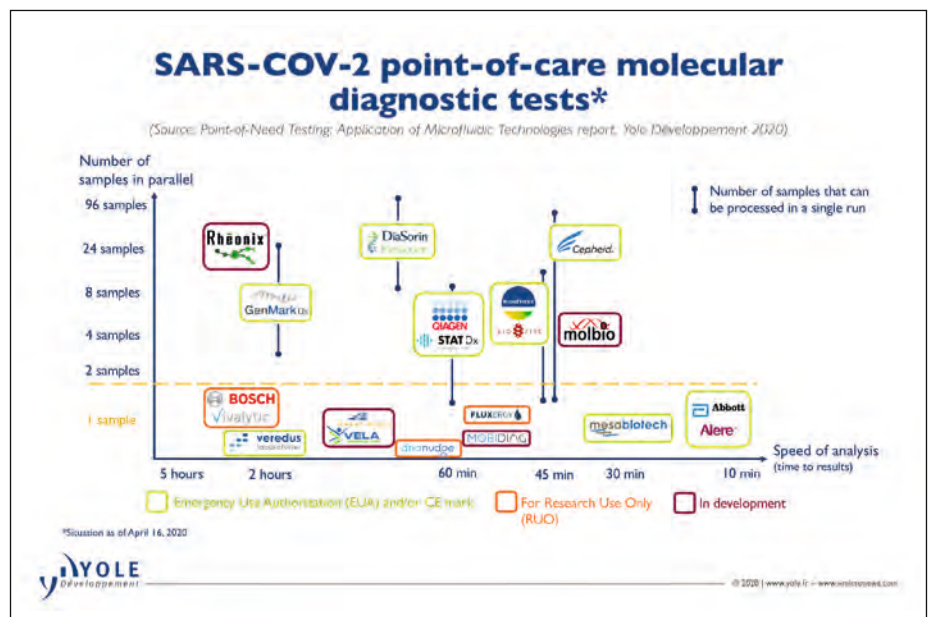


Microfluidic chip (Image: darwin-microfluidics.com)

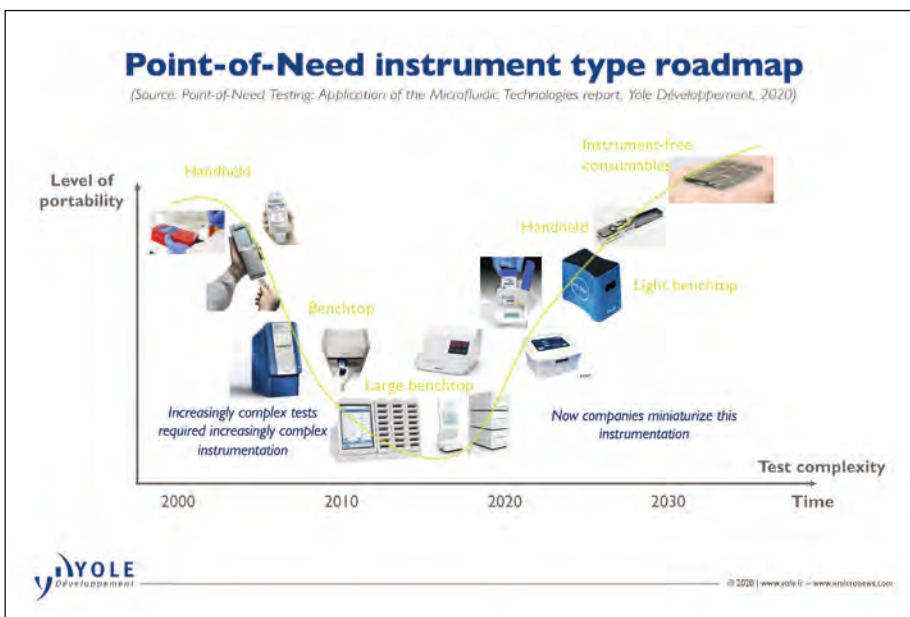
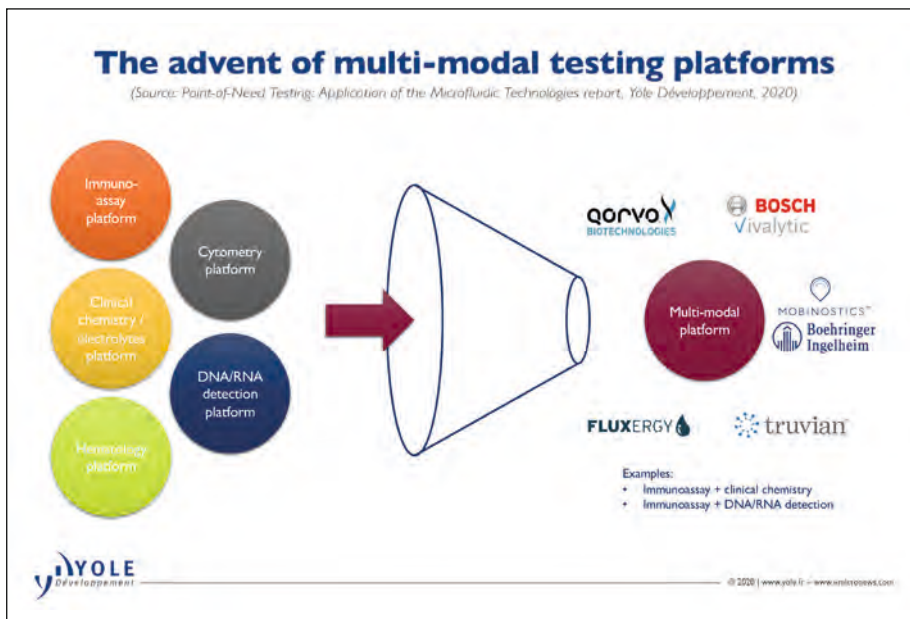
10 cm in length. The thickness ranges are from about 0.5 mm to 5 mm.

The flow of liquids through the channel network can be induced by various systems, such as pressure regulators, syringes, and hydrostatic pressure. Microfluidic units are used to measure molecular diffusion coefficients, fluid viscosity, pH, and required chemical coefficients. Microfluidic PCR chips have already been used to detect viruses and bacteria and could offer excellent functionality in the RT-PCR workflow for diagnosing Covid-19.

Microfluidic approaches have several advantages over other conventional solutions: faster reaction times, higher sensitivity, better temperature control, automation, and easier parallelization with microelectromechanical system (MEMS) solutions.



Microfluidic Technologies Diagnose World's Return to Normal



The choice of materials and manufacturing methods for microfluidic devices is determined by their final applications. The first material used for microfluidics was silicon, with chips built using the established processes of the microelectronics industry, but silicon was quickly replaced by glass and then polymers. Polymers offer the right solution because they are cheaper, are robust, and involve faster fabrication processes. Polydimethylsiloxane is the most common material used for microfluidic devices because of its optical transparency, biocompatibility, elasticity, and simple manufacturing process (soft lithography).

LIFTING THE LOCKDOWN

The sooner a patient is taken care of, the better the chances of recovery. Given the

virulence of Covid-19, those battling the pandemic are in a race against time, and companies have mobilized resources to cut the time to diagnostic test results from days to hours to minutes, all while increasing throughput. Abbott Laboratories' ID Now, Roche Molecular Systems' Cobas, and Cepheid's Xpert Xpress are rapid point-of-care (PoC) molecular assays for Covid-19 detection. Cepheid's test has the capacity to process multiple samples simultaneously; the Cobas and ID Now platforms can handle only one sample at a time.

"The problem with PoC platforms is that the throughput of patient tests is very low," said Clerc. "These platforms can handle between one and eight samples at a time. Even though tests are ultra-fast, [yielding results] in 15 to 30 minutes, only a few

patients can be tested per hour." Lifting the lockdown, however, requires a massive testing program "on the order of hundreds of millions of tests per week." Supplementing the molecular tests will be serological tests to verify the presence or absence of SARS-CoV-2 antibodies in blood samples.

A key challenge in the exit plan will be to identify people who have had an asymptomatic or mild form of the virus. In those cases, molecular tests aren't needed, said Clerc. "If the patient has contracted the virus but is in remission or has fought it, the molecular test will not be able to detect it. A serological test will be needed to measure the response of the patient's immune system to the virus." Those tests are simpler and do not necessarily require microfluidic technologies.

Complicating matters, it is not yet known whether immunity to the virus lasts weeks, months, or years. "It's too early to tell," said Clerc, "but we do know that patients develop immunity, and if we can detect it through mass screening of the population, we'll be able to ease restrictions."

PREPARING FOR THE AFTER-CRISIS

The availability of established technologies has helped companies move faster with Covid-19 diagnostic testing. Lessons learned from the 2002 SARS outbreak have guided the development of Covid-19 identification and detection solutions. Lessons learned during the Covid-19 outbreak will result in a call for more versatile diagnostic solutions to prevent and manage future epidemics.

Tools that provide accuracy, ease of use, and automation are essential for health professionals. The holy grail for diagnostics, Clerc noted, would be a small box capable of performing any kind of test in minutes. Such multimodal platforms could address immunoassays, clinical chemistry, cytometry, and molecular diagnostics with the same instrument, at the point of care.

Portability and affordability are also important. Only one instrument would be purchased to run hundreds of different tests, in parallel or not, on that platform. "Consider a doctor's office or a pharmacy; there is usually not enough room for several instruments," said Clerc. Extending the subject to pandemics affecting developing countries, he added that "it is not convenient to transport multiple machines and install them under a tent to perform different types of tests." Companies such as Qorvo Biotechnologies, Bosch Healthcare, Truvian Sciences, and Boehringer Ingelheim Mobinostics are working on solutions to address those scenarios.

Once an automated platform has been developed, the next challenge is designing a cost-effective microfluidic cartridge able to run various types of tests on the same

Microfluidic Technologies Diagnose World's Return to Normal

footprint. “A microfluidic cartridge is dedicated to one type of test, and different types of tests need to be developed,” said Clerc. “A company can develop two to three tests per year, but there are hundreds to develop.” That’s where collaborations and acquisitions make sense.

FOSTERING RELATIONSHIPS

In the health-care industry, barriers on the road to success are high, and acquisitions are often the best solution to remain competitive. In the past decade, large diagnostics companies such as bioMérieux, Roche, and Qiagen have acquired promising microfluidic technologies through the purchase of small or

mid-sized companies. Market consolidation has accelerated to the extent that a group of about 15 players now accounts for more than 75% of the market. “Large companies do not take the risk of technical development and prefer to invest in already-developed technologies,” said Clerc.

At the same time, an acquisition by a larger company can provide startups with an established distribution network and improved logistics support. IQuum (Roche), BioFire Diagnostics (bioMérieux), and STAT-Dx (Qiagen) are good examples of microfluidic technology developers whose approaches took off once the companies were acquired.

But collaboration remains the fastest way

to develop microfluidic tests. Bosch Health-care, for instance, has teamed with Randox Biosciences and R-Biopharm to develop tests to implement on its Vivalytic platform.

“If we look ahead two or three years and if we reach a dozen partnerships, that’s potentially two or three additional tests per partnership per year,” said Clerc. “This is starting to provide an extended range of tests for users.” ■

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SPECIAL REPORT: NEUROMORPHIC COMPUTING

The Slow but Steady Rise of the Event Camera

By Tobi Delbrück

Roughly a billion dollars of investment in CMOS image sensors (CIS) over the past 20 years has led to the current market, where these beautiful imagers are produced by the billions each year. As CIS became a commodity, neuromorphic silicon retina “event camera” development languished, gaining industrial traction only recently, when Samsung and Sony put their state-of-the-art image sensor process technologies on the market.

Our event camera, introduced at the 2006 International Solid-State Circuits Conference (ISSCC), included huge, 40- μm pixels using a 350-nm process. Even then, CIS pixels were down by about a few microns. In 2017, Samsung published an ISSCC paper on a 9- μm -pixel, back-illuminated VGA dynamic vision sensor (DVS) using their 90-nm CIS fab. Meanwhile, Insightness announced a clever dual-intensity + DVS pixel measuring a mere 7.2 μm .

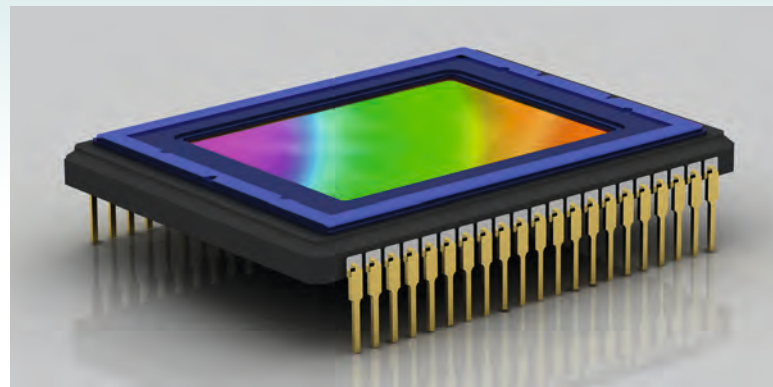
Both Samsung and Sony have built DVS solutions with pixels under 5 μm based on stacked technologies in which the back-illuminated 55-nm photosensor wafer is copper-bumped to a 28-nm readout wafer.

Amazing increases in event readout speed have also resulted from industrial development. These clever designs are bringing DVS pixels down to the sizes of standard global-shutter machine-vision and automotive camera pixel sizes. It means that DVS has a fighting chance to establish itself as a viable mass-production vision-sensor technology in the same “megapixel race” that has consumed CIS for decades.

The development of neuromorphic silicon retinas is a great example of faith meeting practical reality. The development of silicon retina event cameras goes back to 1989 with Kunihiko Fukushima’s Reticon and the work of Carver Mead and Misha Mahowald at Caltech in the early 1990s.

I joined this effort as a graduate student at Caltech with Mahowald and Mead as mentors. We neuromorphic engineers believed we could build a camera that worked like the biological eye. The reality after a decade of early work was that our “silicon retina” pixels were vastly too big (i.e., expensive) and too noisy (i.e., they made terrible pictures). Just as important, they didn’t offer sufficient advantage over CIS.

All this early development was taking place concurrently with the constant improvement of CIS. A breakthrough of sorts occurred during our work on the European project called CAVIAR, when Patrick Lichtsteiner and I came up with the DVS pixel circuit. Anton Civit



assisted me in building the first USB DVS camera. We sold several hundred 128 × 128-pixel DVS cameras to neuromorphic community early adopters who were not ASIC developers. This pixel architecture is the foundation of all subsequent generations from all the major players (even when they don’t say so on their websites). The DVS brings a “unique selling proposition” over previous silicon retinas and standard cameras, owing to its sparse, quick spiking output that responds reliably to low-contrast natural scenes while offering great dynamic range and speed. Early DVS cameras allowed neuromorphic researchers to play with the technology to determine its potential.

A decade later, conventional machine-vision and robotics researchers did the same. This would not have happened without my students Patrick Lichtsteiner, Raphael Berner, and Christian Brandli, who now lead several startups. The other key was long-term support from UZH and ETH for basic technology development and funding from the European Commission’s Future and Emerging Technologies initiative.

GROWING ECOSYSTEM

Similar to what occurred with CMOS image sensors, event camera startups such as Insightness (recently acquired by Sony), iniVation (which carries on the iniLabs mission), Shanghai-based CelePixel, and well-heeled Prophesee are established, with real products to sell. Others will surely follow.

Recently, mainstream computer-vision researchers introduced to event cameras (mainly via academic collaboration or through our

The Slow but Steady Rise of the Event Camera

neuromorphic workshops) have published compelling results derived from event cameras. DVS with event-based sensitivity to changes in brightness has become synonymous in these communities with “event cameras.”

That’s the case even though the original neuromorphic definition included a much broader class of vision sensors capable of mimicking the computational power of biological retinas.

The past 30 years have seen steady development of event camera technologies. If the fallout from Covid-19 does not delay further research, we may see mass production of these sensors in the next few years (consumers can find Samsung DVS products on store shelves already).

Along the way, we have had lots of fun playing with DVS at many levels, ranging from

device physics and CMOS circuit design to complete robotic systems driven by AI.

I now think of DVS development as mainly an industrial enterprise, but it was the heavy focus on sparse computing that has led us over the past five years to exploit activation sparsity in hardware AI accelerators. Like the spiking network in our brains, these AI accelerators compute only when needed. This approach — promoted for decades by neuromorphic engineers — is finally gaining traction in mainstream electronics.

The fundamental neuromorphic organizing principle (as Carver Mead might put it) is to compute only where and when needed. ■

Tobi Delbrück is a professor of physics and electrical engineering at ETH Zurich in the Institute of Neuroinformatics, University of Zurich and ETH Zurich, Switzerland.

NEWS

Upgrading Electrical Systems with Digital Electronics — Finally

Both residential and commercial properties are ripe markets for intelligent systems, smart security systems, and other automation solutions, but old electrical infrastructure is pervasive and can sometimes stand in the way. Taking this into account, startup Amber Solutions has created a series of solid-state electrical solutions for smart outlets, circuit breakers, and more. Built-in software management provides an intelligent control base within the electrical wiring endpoints of buildings for use by third-party security and automation providers.

Government safety regulations have helped motivate circuit breaker suppliers to include new protection functions. Wall receptacles and switches have taken a similar technological path. The vast majority of receptacles are simple mechanical structures without electronics or advanced capabilities. Nowadays, more advanced receptacles include a ground-fault-detecting circuit interrupter (GFCI) to prevent electric shock, particularly in wet areas such as kitchens, bathrooms, and garages. Similar to ground-fault-detection switches, these GFCI outlets include sensitive electronics to detect a fault condition but continue to rely on the electromechanical architecture of the 1950s to open and close circuits.



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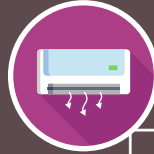
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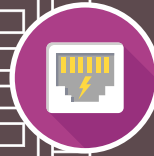


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