THE **PUBLICATION** FOR **DESIGN ENGINEERS**

DENA

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EDITORS WORD

What a year!

2023 will be a year I'll remember for a long time. Various forms of artificial intelligence (AI) have entered our lives over the past few years, but none have made an impression on the collective consciousness as much as ChatGPT. Even my 93-year-old mother waffles on about it, for goodness' sake.

It's amazing to think ChatGPT was launched in November 2022, which is only one year ago as I pen these words. Since that time, different incarnations of this form of generative AI have popped up all over the place (search Google for "Chatsimple," "GitHub Copilot," and "Metabob," for example).

I was recently talking with the folks at Flux.ai about their Flux CoPilot. This is an AI-powered PCB design tool that can read hundred-page data sheets in seconds, after which it automatically connects the components (microprocessors, sensors, displays…) in the schematic and in the layout in real time while you watch in awe.

I just got off a video call with a friend. We'll call him Joe (because that's his name). Joe told me how he was questioning ChatGPT about an error message he was receiving from his compiler. ChatGPT asked him to share the problem area in his code. When Joe did so, ChatGPT immediately responded with a description of what he was doing wrong and proffered a code snippet to fix the problem.

Now I can't wait to see what 2024 will bring. As always, of course, all of us here at DENA will be here to help guide you on your way.

Max Maxfield

CLIVE 'MAX' MAXFIELD
Editor, DENA

DENA DESIGNING ELECTRONICS NORTH AMERICA

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TOP STORY

Teledyne LeCroy announces 65GHz 12-bit oscilloscope platform

The new WaveMaster 8000HD high-bandwidth, high-definition oscilloscope (HDO) platform has models from 20GHz to 65GHz of bandwidth, 12 bits of resolution, up to 320GS/s of sample rate, and an industry-leading 8 gigapoints (Gpts) of acquisition memory.

The WaveMaster 8000HD retains the unrivaled validation and debug capabilities of its predecessor while adding new SDA Expert serial data analysis software options for testing next-generation serial data technologies, coupled with unique capabilities to meet the requirements of complex link and high-speed embedded system debugging.

www.teledynelecroy.com

Infineon presents intelligent tire pressure sensor

Infineon Technologies AG has combined its automotive expertise with its patented glass-silicon-glass MEMS sensor for the automotive tire pressure monitoring system (TPMS) market to launch the XENSIV SP49 tire pressure monitoring sensor.

The XENSIV SP49 integrates MEMS sensors with an ASIC and provides smart tire features that enable advanced tire pressure monitoring systems. It features a powerful 32-bit Arm M0+ core, a large flash memory and RAM, Low Power Monitoring (LPM), and optimized fast acceleration sensing. The SP49 is ideally suited for intelligent tire functions such as on-tire auto-position sensing, tire inflation assistance, tire blowout detection, and load detection.

www.infineon.com

OKW enhances robust handheld enclosures

OKW's robust DATEC-MOBIL-BOX handheld plastic enclosures are now available in seven versions. Rated IP 65 (optional) for use in harsh environments, the high-performance DATEC-MOBIL-BOX is ideal for mobile data recording and transfer, measuring and control, and stock and sales logging.

All DATEC-MOBIL-BOX enclosures combine comfortable ergonomic curves with flat surfaces for installing interfaces. The top is recessed to accommodate a membrane keypad. Inside, there are mounting pillars for PCBs. OKW can also supply fully customized versions. Services include machining, lacquering, printing, laser marking, decor foils, special materials, RFI/EMI shielding, and assembly of accessories.

www.okwenclosures.com

KYOCERA AVX releases new supercapacitor modules

The new SCM Series double-layer, series-connected electrochemical supercapacitor modules can be used by themselves or in conjunction with primary or secondary batteries to extend battery life and backup time or provide instantaneous power pulses in hold-up, energy harvesting, and pulse power applications in the industrial, energy, telecommunications, automotive, transportation, and medical industries.

The series exhibits very high capacitance, very low ESR, high efficiency, high power density, and excellent pulse power handling characteristics. It also supports active cell balancing and ruggedly withstands high current, high vibration, and frequent charge and discharge cycles.

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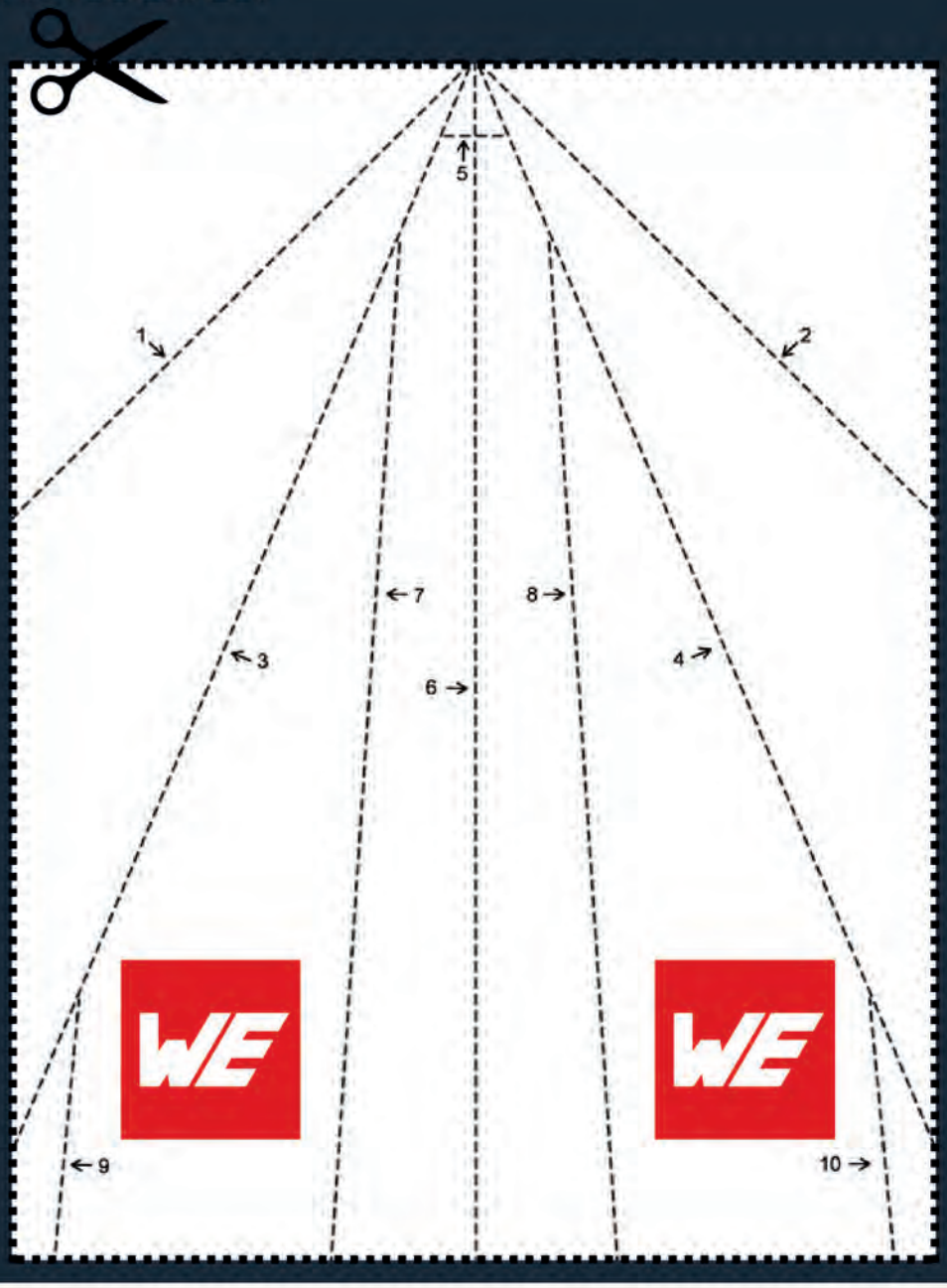

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Spectrum adds new high-speed PCIe digitizers

Spectrum Instrumentation has extended its M5i flagship series of high-speed PCIe digitizers, adding two new models with ultrawide bandwidths that go up to 4.7GHz for -3dB attenuation or even 5GHz for -5dB attenuation. The models M5i.3360-x16 and M5i.3367-x16 provide one and two channels respectively. Each card is capable of sampling at rates up to 10GS/s, with 12-bit vertical resolution, specifically designed to deliver the most accurate acquisition and analysis of signals in the GHz range.

The high bandwidth, combined with fast sampling, allows signals to be analyzed for frequency content anywhere from DC to the Nyquist limit (half the sample rate, or up to 5GHz), making them ideal for working with extremely fast signals in laser systems, semiconductor testing, spectroscopy, reflectometry, and a wide variety of RF applications.

www.spectrum-instrumentation.com

Littelfuse launches world's smallest subminiature flange mount reed sensors

The 59155 and 59156 from Littelfuse are the world's smallest subminiature flange mount reed sensors. The sensors' design provides compact size, contactless activation, and customization options, making them suitable for a wide range of tight-spacing applications across different industries.

www.littelfuse.com

TDK introduces a sample kit for TVS diodes

TDK's sample kit (B74999T9999M099) consists of ten different types of ultra-compact transient voltage suppressor (TVS) diodes. Five belong to the general-purpose GP series, which protects against overvoltage on applications such as smartphones, tablets, notebooks, wearables, and network components; the other five belong to the high-speed ULC series, which are tuned for particularly sensitive high-speed interfaces (e.g., USB-C, Thunderbolt, HDMI, Display Port, MIPI, FireWire, DVI, S-ATA, or SWP/NFC).

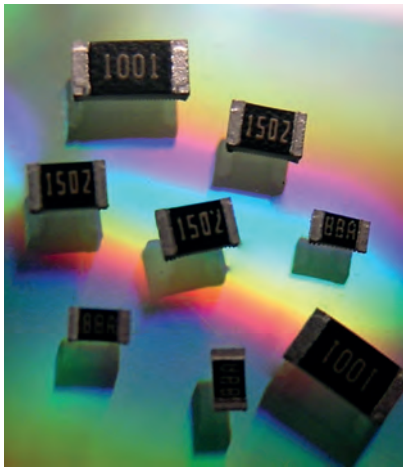
www.tdk-electronics.tdk.com

Stackpole announces RNHT thin film precision resistors

Automotive and industrial applications may have harsh environmental requirements for resistors. When those requirements include high temperature capability and high precision, options are limited.

Stackpole's RNHT thin film precision resistors offer full power capability up to 85°C and operation up to 170°C. The automotive grade RNHT is AEC qualified and offers a wide range of values in sizes from 0402 through 1206 in tolerances down to 0.02% and TCRs down to 5ppm. The thin film RNHT has exceptional long-term stability and reliability inherent in thin film technology.

www.seielect.com



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Innovative analog IP alerts and protects against side-channel attacks

Chris Morrison, Director of Product Marketing, **Agile Analog**

What applications are vulnerable and how can a voltage glitch detector help?

Over the last few years there has been an alarming surge in the number of side-channel attacks (SCAs). Security breaches are becoming increasingly common. Indeed, researchers recently revealed that they had been able to 'jailbreak' features and extract the encryption key of a well-known electric vehicle (EV) using a voltage glitch.

Companies—big and small—should be aware that hackers are finding new ways to exploit security vulnerabilities. It's important to understand the range of applications that are at risk and what counter-measure solutions are available. This article focuses on voltage SCAs and offers examples of how an analog IP voltage glitch detector can help.

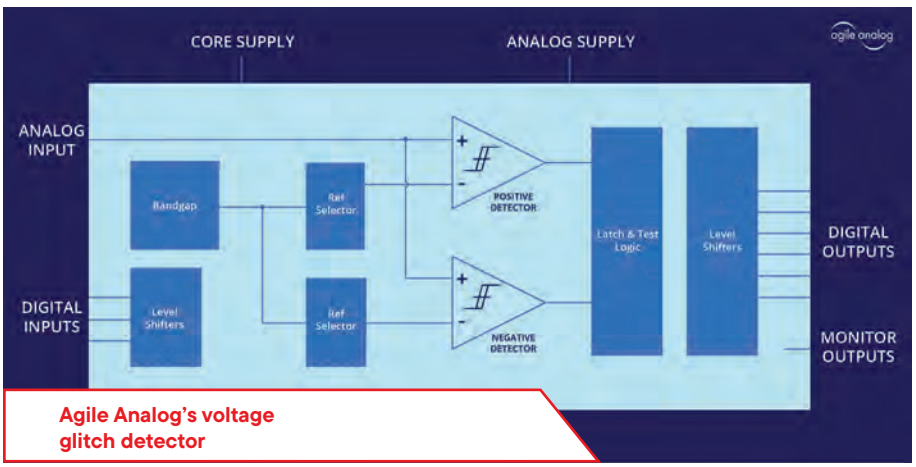
Agile Analog has created a voltage glitch detector IP called agileVGLITCH that can be incorporated into an SoC design. This configurable IP, along with Agile Analog's temperature and clock attack monitor IPs, checks vital parameters like voltage, clock, and temperature for any changes that might point to an attack on the chip, such as supply voltage fluctuations or power supply manipulation. If these occur, the SoC's processor is notified. Some example applications are as follows:

IoT Security Device: Consider a wireless door lock to a home, where a malicious person gains access to the lock and uses voltage glitching to enter the debug mode of the device, reading all the authorized keys for the lock. With agileVGLITCH embedded, the IoT security device can detect and record the voltage glitch, alerting the cloud system of an attack, and noting the date and time, which could help identify the culprit.

Security Camera: A security camera can be compromised using a voltage SCA to bypass the boot-signing sequence, allowing a malicious person to reset the system and then reflash unauthorized firmware. This would enable the hacker to view the video and audio stream content, which could be used for blackmail purposes. When using agileVGLITCH, the system can detect voltage glitch events and terminate any unauthorized activity.

Satellite TV: Consider the case where a hacker plans to remove digital rights management (DRM) from films broadcast over a satellite channel to resell the films. This can be achieved by installing a voltage glitcher on the HDMI controller supply to a satellite receiver with a valid subscription. By these means, the hacker can reset the HDMI output to be non-HDCP validated. Decrypted HD content can be streamed out to a non-secure device, which then re-encodes the content without protection. The agileVGLITCH IP can detect voltage glitching and prevent this from happening.

Automotive: An automotive supply regulator may have an undetected minor manufacturing flaw that causes a gradual increase in power supply resistance. When under heavy load, this could cause the voltage to fall below accepted safe levels. The agileVGLITCH sensor can identify voltage degradation that occurs over time. The system can relay this information back to the car manufacturer, which can identify vehicles that need correcting.



Agile Analog's voltage glitch detector

Conclusion

Side-channel attacks are increasing in frequency and severity. Companies must wake up to the fact that they need to take preventive action. Fortunately, there are advances in technology that can help to offer protection against a variety of different security vulnerabilities.

www.agileanalog.com

THERE'S A KEYSTONE IN EVERY GREAT INVENTION.

VR HEADSETS & THEIR ELECTRONICS

Featuring SMT Board-to-Board Edge Connectors

Virtual reality, or VR, has exploded in recent years. In VR, the user is immersed in a 3D environment generated by computers that mimic reality. In the most advanced VR experiences the users can move in a digital environment, hear sounds and with special hand controllers, simulate touch.

VR is transforming the space program and how astronauts train for missions. It is also transforming healthcare by allowing doctors to practice complex surgeries in a virtual setting before performing the surgeries on live patients. Industries presently using VR are auto, architecture, construction, tourism, and aerospace.

You'll find many of our products in modern VR systems such as our featured SMT Board-to-Board Edge Connectors, as well as • LED Spacers & Lens Caps • Metal Key-Pad Dome Switches • Pins, Plugs, Jacks & Sockets • Battery Clips, Contacts & Retainers • Test Points & Terminals

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Foundational elements for signal integrity

Knowing the fundamentals isn't enough; a foundational understanding is required

It is done. We graduated and are ready to conquer the world of high technology. We are emboldened by the fundamentals of electromagnetics, linear circuits, and RF/Microwave. We know Green's functions and advanced math. But six months into the new job, signal integrity issues are coming faster than we can fix them. What has gone wrong?

Designs that include functions like optical modules, supercomputing elements, and 400-800Gb Ethernet drive design complexity and signal integrity challenges exponentially. Knowledge of the fundamentals won't solve today's signal integrity issues. They require more—a foundational understanding of signal integrity methodology that only evolves through experience. Foundational elements for signal integrity include the following:

- Benchmarking 3D field solvers—simulation to measurement.
- Making quality measurements (TDR and VNA).
- Advanced understanding of non-simple crosstalk propagation.
- Understanding laminate systems.
- Ability to optimize electromagnetic structures using EDA tools.
- Ability to read both S-parameters and TDR as working languages.
- Creating sound stack-ups.
- Dynamic power delivery.
- And yes, all the fundamentals!

In the past, basic crosstalk over lower speeds and reflective loss were considered "the" challenges. Not so at today's performance levels. High-speed digital components, including optical modules, switch and routing ASICs, SerDes IP, and AI accelerators transmit high-speed data over long distances. These long reaches and tight timing margins require minimized reflection and resonance. Impedance mismatch can come from anywhere. The unit interval—the time region that everything needs to happen for high-speed digital—is working down to less than 18ps!

Specialized companies focus on signal integrity analysis tools. It's important to note that even with the best signal integrity analysis and test software available, nothing beats experience. In the rush to find and hire the smartest and most talented engineering grads from the best schools, recruiters, executives, and investors overlook one fundamental principle: staff with foundational experience matters. There is a rush for super-computer and AI development with huge capital investment, and those companies are staffed with droves of PhD folks with a finely tuned understanding of fundamental concepts, but no working knowledge. They cannot simply step into 112G PAM4 optical module design and expect to be successful. It's not about being smart enough.

Those of us with signal integrity analysis expertise have lived through wild successes and epic failures that helped us to learn and develop expertise. It took years of practical experience to hone. We are already seeing the impact of low foundational skills. The result is that many super-computer and AI start-ups will fail. Where is the problem?

I'm afraid my take is that a lot of very clever people are ignorant with respect to the need of foundational mastery, and this is coupled with a lack of humility. The moral of this story is to determine what you don't know and create a plan to address the gap between the fundamental understanding you have and the foundational knowledge you need.

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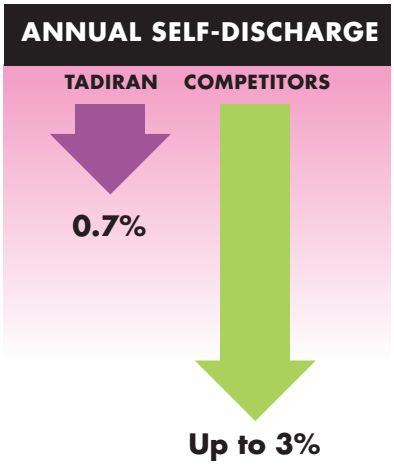

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Revolutionizing battery measurements

Introducing a non-destructive method to estimate the SoH and SoC of a battery

Dr. Gerald Morrison, CTO, **SigmaSense**

Battery measurements are crucial for energy storage, consumption, and transportation. Accurate and efficient techniques are essential for ensuring quality, estimating state of health (SoH) and state of charge (SoC), and predicting and preventing dangerous battery failures.

Electrochemical impedance spectroscopy (EIS) is a non-destructive method that can estimate the SoH and SoC of a battery without disassembly while under actual operating conditions. EIS is considered the gold standard for analyzing batteries and helps predict and prevent dangerous battery failures by measuring specific characteristics of a battery's impedance and internal state.

EIS measurements and today's limitations

EIS measurements supply valuable insights to manufacturers and system designers into the complex electrochemical nature of batteries. However, the widespread adoption of EIS is hindered by the limitations of traditional laboratory-based potentiostats, which are bulky, expensive, and not workable for wide-scale, in-the-field measurements.

The future of in-situ EIS lies in the development of semiconductor chips. A detailed article on the advantages and the reality of this future is found in the article *From Lab to Field: Scaling EIS Technology with Semiconductor Chips for Battery Systems* (https://bit.ly/3riVgMN).

How EIS works

EIS works by applying a small perturbation AC current (or voltage) to a battery and measuring the resulting AC voltage (or current) over a range of frequencies, typically from 0.01Hz to 8kHz. Small perturbation currents are preferred as some electrochemical systems, like batteries, can become non-linear at high currents, invalidating the analysis of certain parameters.

According to Ohm's law, the ratio of voltage to current at each frequency is impedance. For batteries, this is a complex number. Impedance data is plotted in several ways, such as Nyquist plots or Bode plots. This data can be used to find equivalent circuit models with quantitative parameters representing the battery's components and interactions, further aiding in understanding battery dynamics.

Nyquist plots and EIS analysis

The Nyquist plot is a preferred way of representing battery impedance data as it offers several practical advantages over other visualization methods, such as Bode plots. Some reasons include:

- Sensitivity to changes, making it easier to detect variations in the impedance data.
- Simplified interpretation of data, as some parameters can be read directly from the plot for certain equivalent circuit models.
- Evaluation of various phenomena in different parts of the battery through detailed analysis.

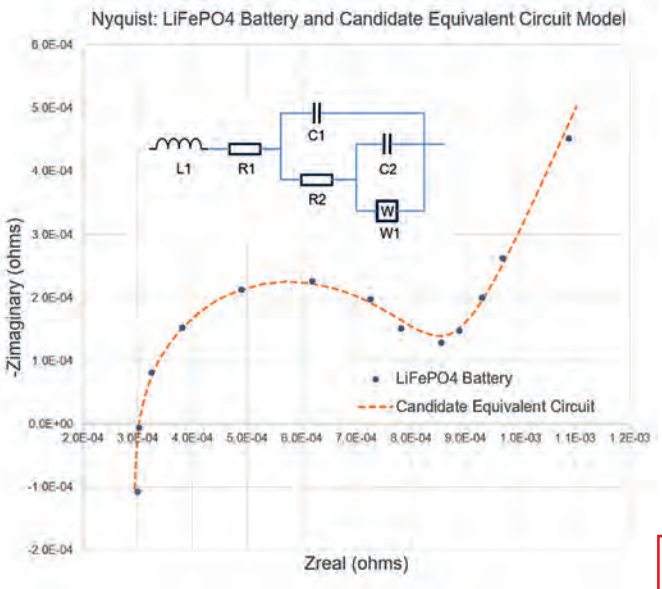
A real-world example of a Nyquist plot and a fitted candidate equivalent circuit model is shown in the figure. This data was collected from a SigmaSense EIS chip measuring an exceptionally low impedance 230Ah LiFePO4 battery.

The future of EIS and battery technology

EIS is a powerful, non-destructive method for estimating the SoH and SoC of batteries, as well as predicting and preventing dangerous battery failures. It provides valuable insights into the complex electrochemical nature of batteries, making it an essential tool for the development of sustainable battery storage systems.

With the development of semiconductor EIS chips, in-situ EIS measurements are now a reality. As the demand for efficient and reliable energy storage solutions continues to grow, the integration of EIS semiconductor chips into battery systems will play a crucial role in advancing the field of battery technology.

www.sigmasense.com



Real-world example of a Nyquist plot and a fitted candidate equivalent circuit model

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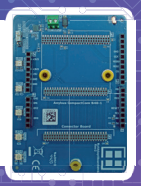

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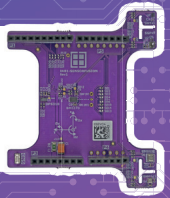

RAB2 – CO2 sensing

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How antenna advancements impact smart cities

Introducing the world's smallest ceramic chip antenna

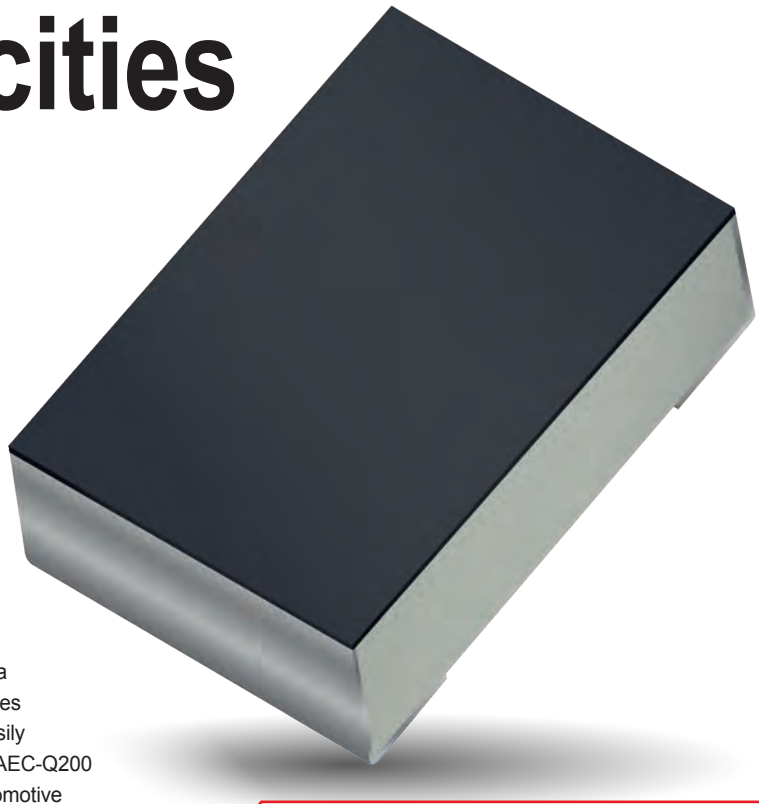
In the previous issue of DENA (September/October 2023), we talked about how oscillator advancements impact smart cities. Consistent timing and frequency behavior is critical for many applications, but for smart cities they will also need to be small and reliable for a long time and in harsher conditions than the average electronic component.

Similarly, antennas will need to be small and reliable, but their design criteria will be based on parameters like gain, bandwidth, radiation pattern, and efficiency. Among the latest advancements of antenna technology include the smallest ceramic chip package for Wi-Fi, Bluetooth, UWB, and GNSS. These devices maintain typical ceramic and LTCC antenna performance but in a much smaller size, meaning reduced keep-out areas allowing for compact RF modules. Compact is convenient and allows for finesse or aesthetic solutions in general, but being compact may determine viability for smart city applications specifically.

Smart cities require many wireless nodes in highly variable environments, so they'll need to be durable. However, circuits will also need to be installed in space-constrained or ergonomic designs as the number and complexity of smart city applications grow. Passive components take up a large portion of PCB area, but antennas with large keep-out areas can make it feel especially challenging for RF designers. Off-board antennas will save PCB space of course, but these aren't always viable. For small low-profile circuits, on-board antennas are preferred.

On-board antennas can be tricky though, sometimes requiring major circuit layout, housing, or position changes if designed in late or as an afterthought. In the absence of a dedicated antenna design team, it may be worthwhile to consider ease-of-implementation as a parameter when shopping for antennas.

Kyocera-AVX Components pioneered ceramic passive electronic component technology, so it's no surprise they have recently released the world's smallest ceramic chip antenna. The 9001978 (Wi-Fi, BT, UWB) and 9002137 (GNSS, L1, L2, L5, L6) both have a length and width of 1mm × 0.55mm respectively, with a height of only 0.4mm. The ceramic body lends itself to a wider temperature range (–55°C to +125°C) than other antenna packages and easily meets AEC-Q200 for automotive applications. In addition, full ceramic manufacturing capability was employed for the active elements within the ceramic body to avoid simple monopole or PIFA (Planar Inverted-F Antenna) designs to ensure high gain and multi-band efficiency regardless of position and surroundings. This makes implementation and meeting regulatory specifications easier, ultimately reducing time-to-market.



Depiction of 9001978 (Wi-Fi, BT, UWB) and 9002137 (GNSS, L1, L2, L5, L6) chip antenna

Smaller smart city electronics will undoubtedly lead to unique solutions, but just as important are adoptable solutions for asset tracking, smart grid, and healthcare among others. The number of remote IoT nodes is projected to increase dramatically over the next decade, and reducing the footprint of remote IoT nodes has direct environmental and energy consumption benefits, which will help proliferate smart cities.

Responsible use of resources is becoming increasingly scrutinized, even in the Solar and EV sectors, and advancements like the smallest chip antenna discussed here will help accomplish this for smart cities without sacrificing performance.

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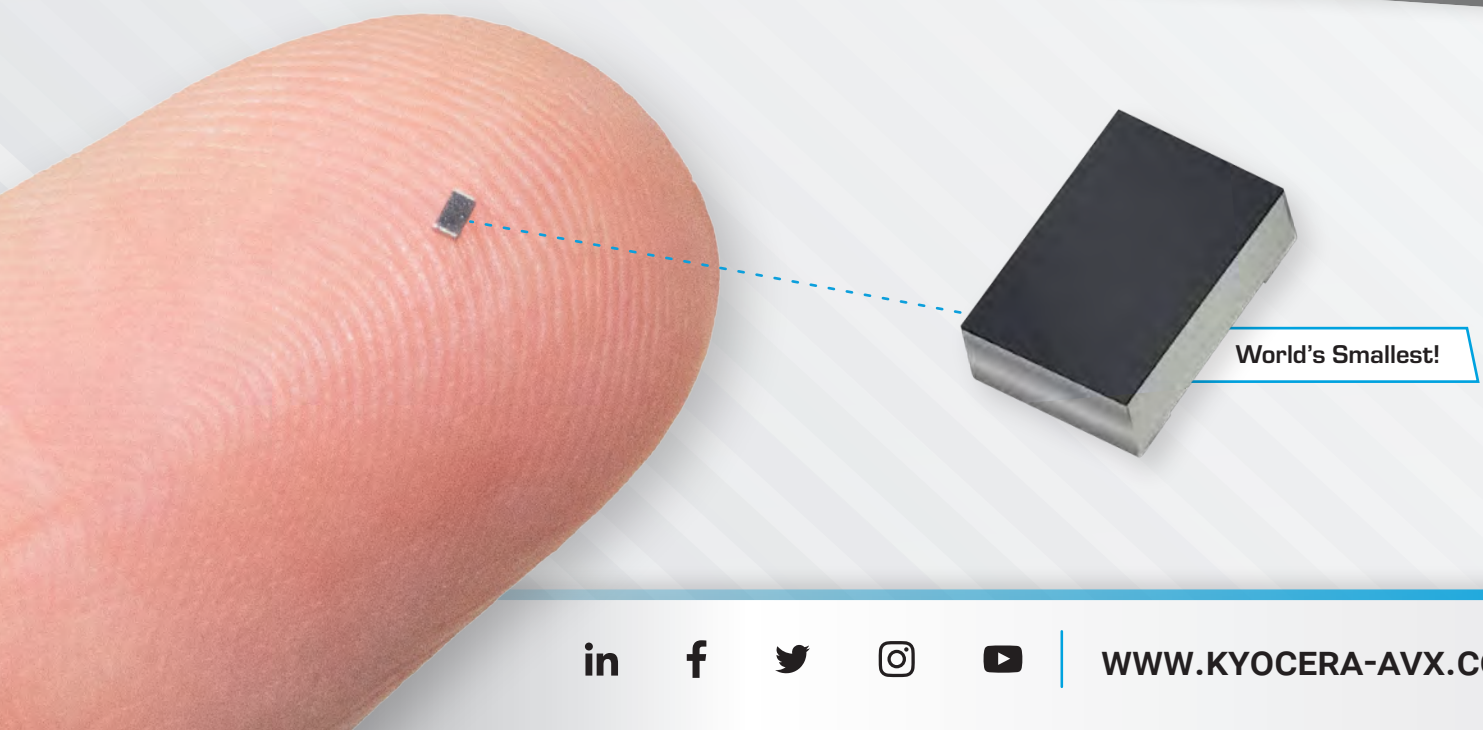

WWW.KYOCERA-AVX.COM

Diversity in your design and supplier

Engineers must select parts that are resilient to market changes and disruptions

In the realm of manufacturing, meeting supply chain disruptions can be a daunting challenge. When production shortages loom, the pursuit of a swift and effective design solution becomes paramount. The urgency escalates when a single part threatens to halt the entire production line. It is in these critical moments that product availability takes center stage, serving as the focus in selecting a viable replacement or alternative that can used as a drop-in replacement.

For engineers tasked with resolving such predicaments, it is essential to have a comprehensive understanding of the market dynamics surrounding a particular part before incorporating it into a prototype or gaining approval for production use. After all, if the product in question is already scarce, it is unlikely to provide immediate relief to the pressing issues within the design, supply chain, or production processes.

Perfect Parts Corporation steps into this arena as a valuable resource. With access to an extensive inventory of over twenty million components in its supply chain, coupled with robust design chain engineering solutions, Perfect Parts Corporation offers a lifeline to professionals seeking quick, reliable, and well-informed solutions.

Our team of experts is well-equipped to guide customers through the intricate process of selecting alternatives, understanding drop-in replacement options, exploring similar components, and assessing market inventories. We recognize that in today's complex manufacturing landscape, securing components through dependable sources is fundamental to ensuring their availability at a cost that aligns with production requirements and design specifications.

Perfect Parts Corporation takes pride in its status as a disabled-owned, women-owned, small, disadvantaged, minority business. Our suite of services goes beyond mere component sourcing. We excel in cross-referencing parts, finding suitable alternatives, conducting component testing, facilitating kitting, managing distribution, raw materials, and orchestrating reverse logistics, among other supply chain solutions.

Diversity suppliers like us bring invaluable advantages to our clients' supply chains and engineers alike. Our offerings extend to cost-saving opportunities, alternate parts, cross-referencing services, and insights into emerging products and services. We offer fresh perspectives and enhance a company's ability to navigate the ever-changing landscape of market disruptions.

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How to specify secure power for critical building automation systems

Don Baldwin, Technical Support Manager – Power, **Sager Electronics**

There are a range of global standards related to security and safety

Secure power is an essential element in building automation systems like fire protection, security and access control, emergency lighting, critical communications, and server closets. The wide range of systems require an equally wide range of highly efficient power supply types like open frame, enclosed, and DIN Rail from 35W to 600W. Those power supplies can be required to meet a range of global standards related to security and safety like the following:

- ANSI/CAN/UL 2524 Standard for In-building 2-Way Emergency Radio Communication Enhancement Systems in North America.
- EN 54-4 Fire detection and fire alarm systems—Part 4: Power supply equipment in Europe.
- GB 17945 Fire Emergency Lighting and Evacuate Indicating System, in China.

What do the standards cover?

Emergency Responder Radio Communication Systems (ERRCS) are an example of critical communications that require reliable power. First responders rely on wireless communications being available under all circumstances, and the National Fire Protection Association (NFPA) in the US requires that ERRCS meet UL 2524. The standard covers the radio base station, repeaters, transmitters, receivers, signal boosters, power supplies, and battery charging systems.

Early detection of fires can save lives and minimize property damage. EN 54 is a family of European standards that includes product standards and application guidelines for fire detection and alarm and ventilation control systems. This EN 54-4 standard covers control panels and power supplies, including back-up batteries and chargers.

Rapid evacuation of buildings during emergencies also protects lives. Fire emergency lighting and evacuation indicating system components—such as luminaries, control panels, main power supplies, and standby power sources, including back-up batteries and chargers—are required to meet GB 17945 in China. This includes specific requirements for charging batteries. These systems typically combine a central control system with distributed controllers and power for location emergency lighting and emergency luminaire fixtures.

Functions like network connectivity for condition monitoring and control of power supplies and battery chargers and fault indicators for critical faults like AC-OK, DC-OK, Batt-low, and No-batt, plus a variety of interfaces like LED indicators, audible alarms, Form C relay, and TTL outputs can also be important considerations when meeting the various standards.

The standards cover a wide range of equipment types with power requirements from a few watts to hundreds of watts. All the power supplies must meet strict efficiency, no load power consumption, electromagnetic compatibility (EMC), and safety requirements, as well as be rated for operation in harsh environments like –10 to +60°C or –30 to +70°C depending on the application.

Conclusion

To achieve powering requirements and navigate the tangle of global standards, building automation system designers can turn to MEAN WELL for secure power supplies with a wide variety of options. These options include integrated battery chargers, uninterruptible power supply (UPS) capabilities, monitoring functions like AC-OK, DC-OK, Batt-low, and No-batt, interfaces including LED indicators, audible alarms, Form C relays, and TTL outputs and communications like Modbus, CANBus, and Universal Asynchronous Receiver/Transmitter (UART). They are available in open-frame, enclosed, and DIN Rail packages and can deliver up to 600W.

www.meanwell.com

"Power supplies can be required to meet a range of global standards related to security and safety"

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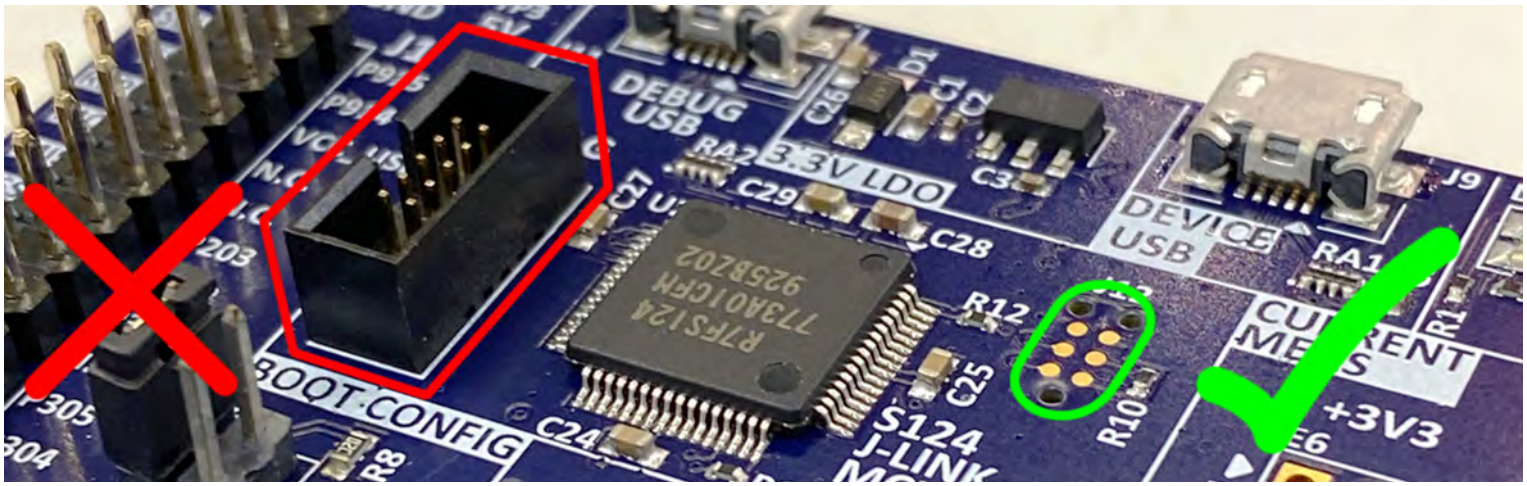

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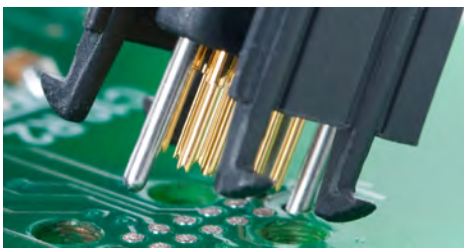

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Fighting software piracy

Using the SEMI license server certification protocol to combat software piracy

Paul Cohen, Senior Manager,
The Electronic System Design Alliance, a SEMI Technology Community

In September 2023, SEMI announced plans to begin licensing its server certification protocol, an industry-developed solution to combat software piracy, which is a growing and costly concern for software vendors and their users.

This three-year project was managed by the Electronic System Design Alliance (ESD Alliance), a SEMI Technology Community, with Cadence Design Systems, Siemens EDA, and Synopsys participating in the development effort to provide strong protection against piracy. The protocol was reviewed and approved by an independent group of semiconductor companies that rely on EDA tools in their business operations, thereby giving it a user seal of approval.

Unauthorized use of licensed software—more commonly known as software piracy—is a problem that impacts both providers and users of licensed software. Industry reports estimate unauthorized access to software costs the industry billions of dollars annually. The Software Alliance—the leading advocate for the global software industry whose members create software solutions that help businesses modernize and grow—estimates that unlicensed and counterfeit software costs companies nearly $359 billion per year. Of course, unauthorized compliance covers a range of piracy, from malware and ransomware to other critical security threats. Unlicensed software is estimated to cost companies nearly $46 billion a year in revenue.

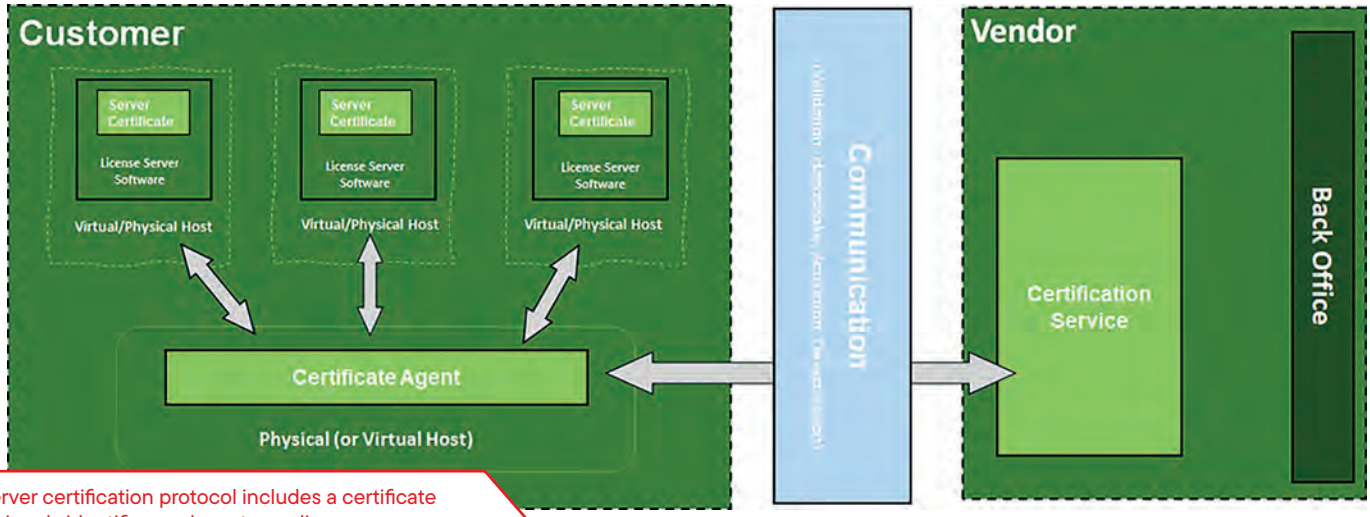
A growing concern

Piracy is a growing concern for all software providers. Unauthorized use deprives them of revenue needed to continue to enhance their products and develop new software tools required by the end users for their product development. It also puts the legitimate end users of the tools at a disadvantage, as they will be competing in the marketplace against companies that did not make a similar investment in the same software.

Many high value software applications such as engineering design software rely on a license manager to authorize the use of the software per the license agreement with the software vendor. Such agreements often include the number of simultaneous users for each software product. For each use, the application contacts the license server software to determine if a license is currently available and, if so, allows the software to run. Previous license manager solutions used specific information derived from the physical machine hosting the license server software (often the MAC address) to prevent unauthorized use. However, that identifier can easily be duplicated or cloned, allowing activation of multiple unauthorized servers, which can then allow additional, unauthorized copies of the application software to be used.

Virtualization adds to the problem

The current trend toward virtualization technologies can make license server identifiers even easier to clone. Even



The server certification protocol includes a certificate that uniquely identifies each customer license server

where the physical machine information is available to the virtual host (which is not always the case), multiple virtual machines may share the same physical host, thus allowing multiple license server instances to have the same identifier. The protocol addresses this concern by uniquely identifying each customer license server, regardless of whether it is physical or virtual.

Locked and floating certificates

To address the trend toward virtual hosts, the SEMI server certification protocol includes two types of certification certificates. First is a locked certificate, which can only be used on a specific host. This is like the previous methodology which relied on a specific license server host machine. With the recent trend towards virtualization, the protocol development team added a floating certificate, which can be used on many hosts, and which includes a methodology to assure only one authorized server is active at a time.

The locked certificate is similar to the current license server methodology in that it requires a machine specific identifier, or "fingerprint." This fingerprint is based on a variety of machine characteristics, sufficient to make each fingerprint unique and difficult to reproduce (clone). The machine data collected is not proprietary, and the details are included in the protocol specification. As part of the protocol review, major design software customers have reviewed and approved the fingerprint contents.

The floating certificate cannot rely on a specific machine fingerprint, since there may not be a specific machine hosting the license server. Thus, the floating version of the protocol relies on a handshake with the vendor to assure only one instance of an authorized server is active at any given time.

Addressing customer concerns

It is common for larger design companies to employ multiple license servers which may be in different geographic locations. The protocol does continue to support multiple, authorized license servers.

A key concern of semiconductor companies is the high availability of license servers since machines can and do occasionally fail or need to be updated. While the protocol addresses unauthorized use, it also supports the use of authorized backup license servers.

Another concern of software customers is the actual usage of the licensed software applications, as this information could affect future negotiations between the vendor and customer. It is important to note that the protocol only authorizes the license server software to issue usage licenses and does not track which software licenses are subsequently used. Thus, no information about actual software use is included in the handshake.

It is also important to note that while the protocol was developed by companies in the electronic design automation (EDA industry), it is not industry specific and can be employed for use with any license management system for high-value software products. The protocol simply provides the ability to uniquely identify each customer license server, independent of the licensed software itself.

Credit where credit's due

Much of the credit for the protocol development effort goes to the ESD Alliance's License Management/Anti-Piracy (LMA) Committee. This highlights how an industry organization like SEMI has the ability to gather industry players to work together to solve critical problems.

New solutions such as this will enable other segments of the software industry to combat piracy, providing a secure license infrastructure compatible with diverse tool environments. Deployment of this capability will increase confidence that all licenses used are fairly acquired, making it harder for unethical players to gain competitive advantage through the theft of licenses, and allowing software suppliers to continue to develop innovative products.

semi.org/en/communities/esda

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Today's market shortages and lead-times of over 52 weeks make it clear that no one's supply chain is safe. Given major constraints that are being experienced by both design and supply chain departments, many OEMs are realizing that partnering with the right distributor is the missing link in their supply chain. Partnering with a distributor that knows reverse logistics, has global reach, a good reputation, and third-party testing capabilities to ensure that your products meet your end user requirements is needed in order to be successful.

Sourcing from the open market can be daunting with counterfeit parts and sub-standard materials posing as a constant threat to your supply chain. Material procured from the open market that is improperly tested can cause loss of relationships, increased liability, major delays, and line down situations. Many distributors test material in house or not fully leaving your supply chain exposed. Perfect Parts works with 3rd party fully accredited test labs which are specialized in performing comprehensive testing including those which are for high reliability applications. By utilizing third party laboratories you can rest assured that there is no conflict of interest when testing material for your supply chain.

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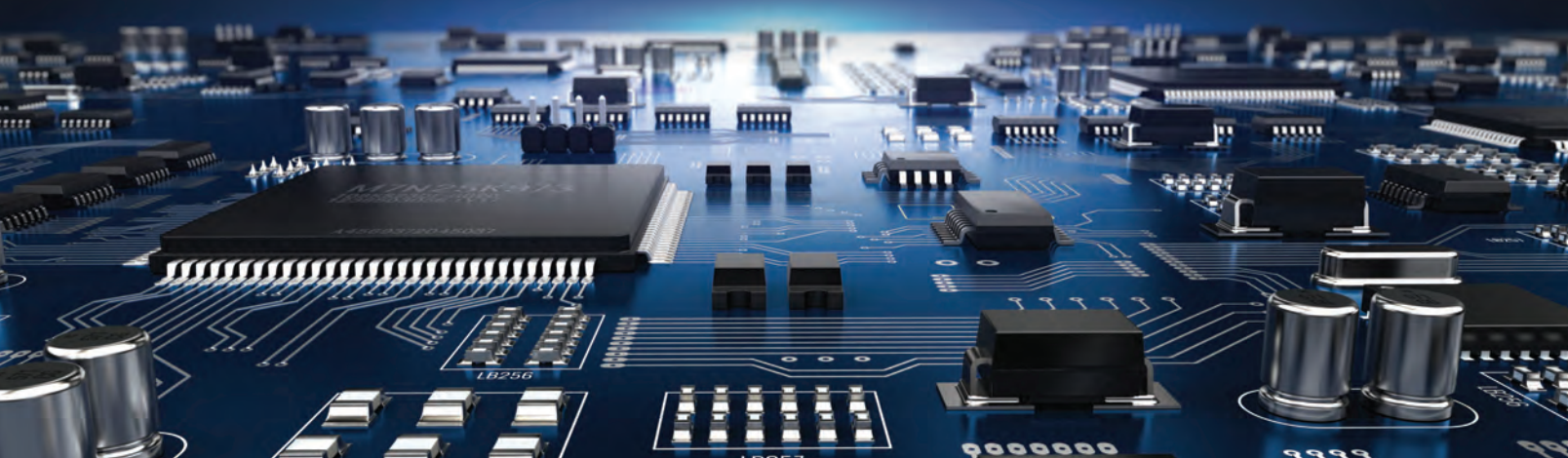

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Next-generation MEMS speakers for wearables

Smaller, lighter, lower-power speakers offer an enhanced audio experience

SonicEdge is an Israeli company that is revolutionizing the audio industry by developing a unique speaker based on micro-electro-mechanical-systems (MEMS) technology. The company was founded in 2019 and has rapidly expanded worldwide, with an office at Technical University, Denmark. The SonicEdge speakers use active ultrasound modulation, a patented technology that generates sound in a completely novel way.

The SonicEdge speakers provide enhanced audio at low frequencies and extended operation across the full audio range and beyond. In addition to being smaller than other speaker technologies, these speakers are vibrationless, have a reduced back cavity, are easy to use and integrate, and can be manufactured with high uniformity, similar to semiconductors. SonicEdge's initial focus is on the true wireless stereo (TWS) and hearable markets, where its speakers enable smaller, more comfortable, and better sounding earphones.

The SonicEdge MEMS speaker is expected to revolutionize the audio industry similar to how LED technology transformed the lighting industry, MEMS microphones changed the microphone industry, and digital transistors revolutionized electronics in the 1960s. The SonicEdge MEMS speaker has several advantages over existing technologies, including the following:

Miniaturization: The first SonicEdge speaker (SE1000) has a footprint of only 4.0mm × 6.5mm, which can easily fit into the ear canal, thereby providing freedom to the earphone designer.

• **Scalability:** The SE1000 MEMS speaker consists of about 400 identical cells (which will be described later in this article). This allows the freedom to increase the sound pressure level (SPL) by increasing the number of cells. Similarly, if it is desired to decrease the SPL, this can be achieved by reducing the number of cells. Additionally, using lots of small cells allows the shape of this MEMS speaker to be customized, but the same SPL will be maintained so long as the number of cells is identical.

Wide Frequency Response: The SonicEdge speaker covers a wide range of audio frequencies, from low to high. The SE1000 covers the full range of frequencies and enables enhanced active noise cancellation (ANC) performance as it provides extra SPL in the lower frequencies.

Durability and Reliability: The SonicEdge speaker is made of robust and durable materials that can withstand mechanical stress, temperature variations, and other environmental factors. This makes it suitable for various applications, including those in harsh environments.

Integration with Other Components: The SonicEdge speaker can co-exist with other sensors, such as microphones, accelerometers, and gyroscopes on a shared PCB since it generates minimal mechanical vibrations. This opens up possibilities for advanced audio systems, sensor arrays, and MEMS-based smart devices.

Chipset: The SE1000 is a chipset of two components: the MEMS chip and the electronic driver chip. Having two individual chips allows design freedom with respect to the end-application. For example, the MEMS speaker can be located in the ear canal without considering the location of the electronic driver chip.

Purely Digital Solution: The audio interface is purely digital, accepting an I²S or pulse-density modulation (PDM) signal.

Ultrasound active modulation

One of the unique features of the SonicEdge MEMS speaker is ultrasound active modulation. The speaker consists of two active membranes: one generating a pure ultrasound signal (the carrier frequency), and another membrane that modulates the sound frequency on the same carrier frequency. By mixing these two signals, the speaker produces audible sound frequencies. For example, to generate a 1kHz tone with a carrier frequency of 400kHz, the first membrane would generate a 400kHz frequency, and the second membrane would generate 401kHz (the modulated frequency of 400kHz + 1kHz). The resulting sound would be the 1kHz signal actively demodulated by this mixer. This principle creates a **constant volume velocity source** or a pump, which explains the pressure build-up at lower frequencies.

The speaker resonance frequency is at the ultrasound regime, which makes it simpler to design acoustic structures to manipulate the

Ari Mizrachi, COO, **SonicEdge**

SPL response. For example, a cavity with a tube in front of the speaker will introduce a resonance to enhance a range of desired frequencies (say 3-5kHz).

Since the SonicEdge speaker's operation principle is a pump, it isn't subject to the non-linearity of traditional speakers for different dBFS (dB Full-Scale), which means the spectrum response of the speaker is linear from 0dBFS to –70dBFS. This, together with the fact that the speaker resonance is not in the audio range, allows an application sound engineer to design a simple (linear) equalizer.

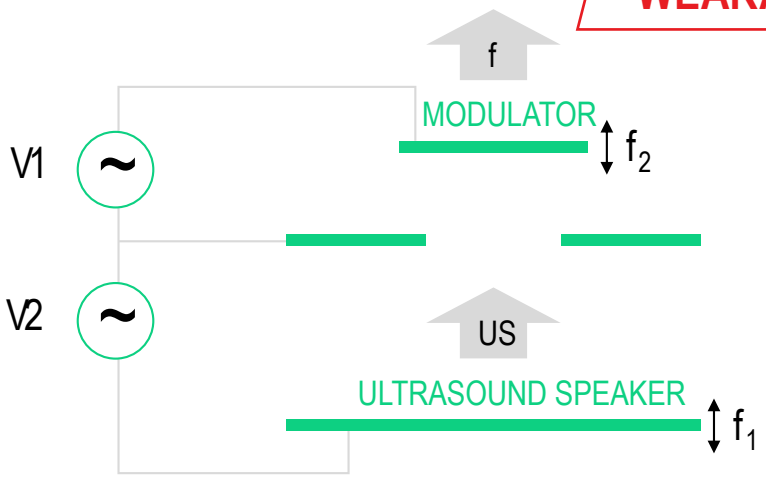
Another significant advantage of the SonicEdge MEMS speaker is its minimal phase delay (or group delay) compared to existing technologies like voice coils. This advantage refers to the speaker's ability to maintain precise phase alignment between the input audio signal and the generated sound waves. Sound waves radiated from the MEMS speaker can recreate the spatial cues and imaging captured in the original audio signal to enhance the listener's experience by providing a more realistic and immersive soundstage. By reproducing sound signals accurately, SonicEdge MEMS speakers achieve superior sound quality and enable advanced signal processing techniques such as ANC. Additionally, this minimal phase delay preserves the timing and coherence of the audio signal, allowing the speaker to faithfully reproduce complex audio waveforms.

Other markets

The SonicEdge speakers are also suitable for free field applications, such as augmented reality (AR) and virtual reality (VR) glasses, mobile phones, automotive, and others. For supporting those markets, SonicEdge has plans to introduce suitable products in the future.

The unique features presented here make SonicEdge MEMS speakers an innovative solution in the audio industry that offers superior performance and quality compared to traditional speakers.

www.sonicedge.io



AI is Forcing Design and Structural Changes at Chipmakers

The mouthwatering prospect of a new artificial intelligence market running into trillions of dollars has triggered massive operational changes at semiconductor suppliers seeking a piece of the AI pie

The aura of artificial intelligence has exploded over the technology world. The chip sector and design engineers are certainly not immune to its effects. Every company is now offering AI-related products and services or developing one. That is the case in the semiconductor industry where many chipmakers are rebranding themselves as AI focused enterprises. New marketing slogans about their AI capabilities are cropping up and products aimed initially at traditional PC, consumer electronics, medical and industrial sectors are getting tagged as AI-ready. The composition of design engineering teams is also changing across the industry. It is now compulsory, it seems, for companies to let customers know of groups within their enterprises that are devoted to AI development.

AI is changing more than the marketing landscape of the semiconductor industry, however. AI, the technology behind Chat-GPT, is transforming how semiconductor enterprises operate, market themselves and relate with customers. AI is forcing deeper structural changes across the industry, especially in how companies operate, liaise with customers and suppliers, manage manufacturing systems and the entire supply chain. For engineers, the realignments of operations have had deeper implications. Design engineering systems are being impacted as companies explore opportunities for synergies across their operations, including between internal units and customers and in how technical staff manage their workflow. AI is "being built into every product," and services as Intel Corp. CEO Patrick Gelsinger noted while presenting the company's latest results.

The numbers involved are huge. Just for the semiconductor market alone, artificial intelligence is expected to drive sales of more than $600 billion within years, observed industry sources. Chips and systems alone will account for approximately half of this with the rest split equally between generative AI software and omniverse enterprise software, said Manuvir Das, vice president of enterprise computing at Nvidia Corp., speaking at the Goldman Sachs' annual 'Communacopia' tech conference. "It's not just about the chips, it's about the whole stack," Das said. The entire ecosystem will be impacted, added Das. "

That outlook resonates at Intel where the company insists it is infusing all its products with AI as part of its plans to register a bigger presence in the market. With pressure piling on everywhere, Intel is trying to put a spark in its computing business and

Lisa Su,** president and CEO, **Advanced Micro Devices

make its offerings more compelling to customers that rivals like Nvidia are luring away with the concept of "accelerated computing."

Towards $1 trillion

Industry sources say the market for AI will help the chip industry easily achieve its goal of reaching $1 trillion in sales by the end of this decade. Demand for AI-related services is expected to soar to nearly $2 trillion by 2030, from a projected $207 billion in 2023, according to data compiled by Statista. With the explosion in demand has also come increased interest in AI startups. Investors are pouring $5 billion annually into AI startups, Statista said, with a large chunk of the investment going to companies focused on machine learning and chatbot.

The huge growth experienced by AI chip and software market leader Nvidia explains why other semiconductor manufacturers are pouring into the sector. Nvidia's sales in its current fiscal year are expected to more than double to $54.6 billion, from $27 billion, in the prior fiscal year. The sales growth pace will slow down modestly in the next fiscal year when Nvidia's sales are projected to top $81 billion, growing nearly 49 percent, according to the average estimate of analysts who track the company. Other AI chip vendors are racing to catch up with Nvidia but many of them started well behind. Their strategy involves customizing existing products for AI and developing new ones to address future market needs. Advanced Micro Devices Inc., for example, supplies graphics processing units – just like Nvidia. It is not seeing similar growth, however, although the company has changed its trajectory to point operations at the AI market.

The result of AMD's laser focus on AI was evident in the second quarter when it accelerated the introduction of new devices and secured engagement with leading OEMs and cloud services providers. "In AI, we made strong progress in the second quarter as we met key hardware and software milestones to address the growing customer pull for our data center AI solutions," said Lisa Su, president and CEO of AMD, during the company's recent conference call with analysts. "Our AI strategy is focused on three areas: first, deliver a broad portfolio and multi-generation road map of leadership GPUs, CPUs, and adaptive computing solutions for AI inferencing; second, extend the open and proven software platform we have established that enables our AI hardware to be deployed broadly and easily; and third, expand the deep and collaborative partnerships we have established across the ecosystem to accelerate deployments of AMD-based AI solutions at scale."

Expanding roles

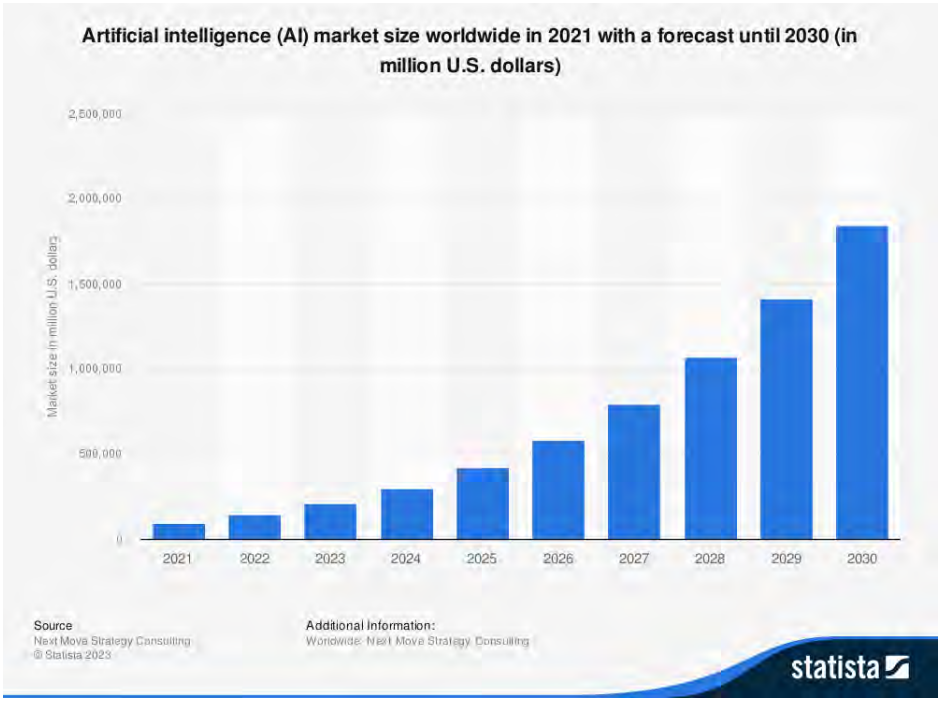
In today's AI dominated marketplace, even regular semiconductor vendors have discovered the need to repackage and rebrand themselves as players in the AI business. Many have dramatically changed their offerings and debuted products targeted directly at the AI market. Companies like AMD and Intel are in this category. The two companies remain committed to their microprocessor business and have positioned their offerings to boost data center sales while avoiding the cannibalization of their desktop PC and notebook business. Intel's Gelsinger, for example, has spoken about the fact that not everyone would be able to access or afford conducting AI activities in the cloud. Customers in this category are usually regular consumers and enterprise PC buyers who use generative AI for basic search and other functions.

This class of users would benefit from offerings that are not cloud-based, Gelsinger noted. "You can't roundtrip to the cloud. You don't have the latency, the bandwidth, or the cost structure to roundtrip, say, inferencing at a local convenience store to the cloud. It will all happen at the edge and at the client," he said.

Then there are companies whose offerings have not changed much but which see opportunities for cross-selling into the AI market. They include companies that are deeply embedded in the supply chain and whose products are needed across the industry. Companies like Texas Instruments, for example, have processors and products that are being either modified or redesigned for customers' AI needs. In March, TI rolled out a new group of Arm Cortex-based vision processors, which it said, "allow designers to add more vision and artificial intelligence (AI) processing at a lower cost, and with better energy efficiency, in applications such as video doorbells, machine vision and autonomous mobile robots."

TI calls its artificial intelligence offerings "Edge AI" noting that these depend on its embedded processors. The processors are handy tools in helping companies benefit from the innovations taking place in the semiconductor market, said TI. To introduce its AI-related offerings, TI launched what it described as Edge AI Studio. It offers "a 'low-code' experience that allows designers to develop and test AI models without writing code, instead using GUI-based tools to extend the promise of artificial intelligence to non-experts," TI said, in a statement.

That strategy is working for many chipmakers which provide the backbone but that are not directly involved in the development of AI chips. The list, according to observers, is long and growing. Even foundry market leader Taiwan Semiconductor Manufacturing Co. Ltd., a chip contract manufacturer that emphasizes not competing with its customers, is benefiting from the AI explosion. The company is seeing rising demand for its services from clients like Nvidia, but it is also leveraging AI in internal operations and design support offered to customers. It's a win-win for everyone.



Fab renovation: A blue CHIPS investment

Prolonging production in existing fabs while new fabs come online

With the CHIPS and Science Act providing $52.7 billion for American semiconductor research, development, manufacturing, and workforce development, companies like Intel, Micron, Samsung, and TSMC have already unveiled plans for new US-based fabrication plants. However, meeting the demand spurred by the CHIPS Act will require more than just building new fabs—it will also require extending the longevity of current facilities.

The dilemma is that new factory construction can take several years to complete and typically costs $10 to $20 billion. This means existing semiconductor fabrication plants will need to update their aging fab tools to keep up with production demand.

Rebuilding aging fabs and getting them back online presents challenges. Since many 150mm and 200mm wafer fabs are still using tools that are up to 20 years old, the equipment is nearing the end of its usable life without aftermarket renovation.

Semiconductor fabs also require computer hardware and peripherals, such as keyboards, monitors, and mice, to monitor and control processes such as wafer lithography, deposition, surface conditioning, dicing, bonding, metrology, and packaging.

Fab tools designed 10 to 20 years ago may still use operating systems such as DOS and Windows XP. Due to the vast differences in operating systems that emerge over time, there can be significant compatibility issues when interfacing with modern computer hardware.

In response, some leading industry experts are providing computer hardware that is compatible with these early operating systems to effectively prolong the life of fab tools. The effort is not only helping to meet demand, but also enabling American facilities to take advantage of CHIPS and Science Act incentives, dramatically boosting the bottom line.

"Given the current market demand and chip shortage, the ability to maintain fab tool uptime is more important than ever today," says Paul Shu, President of ARISTA Corporation, a global provider of computing platform and Key Performance Indicator (KPI) visualization products for production automation in numerous industries.

As a resource for semiconductor plants, ARISTA has created a Longevity Task Force. This task force is a team of specialized technical professionals focused on increasing the longevity of wafer fabrication tools to optimize production and increase productivity.

ARISTA's Longevity Task Force has successfully provided fabs with computer hardware that is compatible with early operating systems for tools designed up to 20 years ago. This enables the fabs to either keep building new tools or rebuild the existing tools. The company provides computer hardware used in a full spectrum of front-end and back-end fab equipment.

Shu notes that the team has devoted considerable time to finding credible replacement parts for aging systems in addition to working with fabs to verify the compatibility of the parts.

For new fab construction, the company also offers state-of-the-art technologies designed to improve productivity and process automation. This includes visualization display products, thin clients, keyboard video mouse (KVM) extenders, ruggedized equipment, and audiovisual solutions.

With chip demand already high today, it will only increase as connected devices, emerging technologies, digital transformation, and industrial applications drive growth in the semiconductor market. In this market environment, the fabs that effectively maintain their legacy computer systems and tools will gain both a productivity and profitability edge, even with the construction of new facilities.

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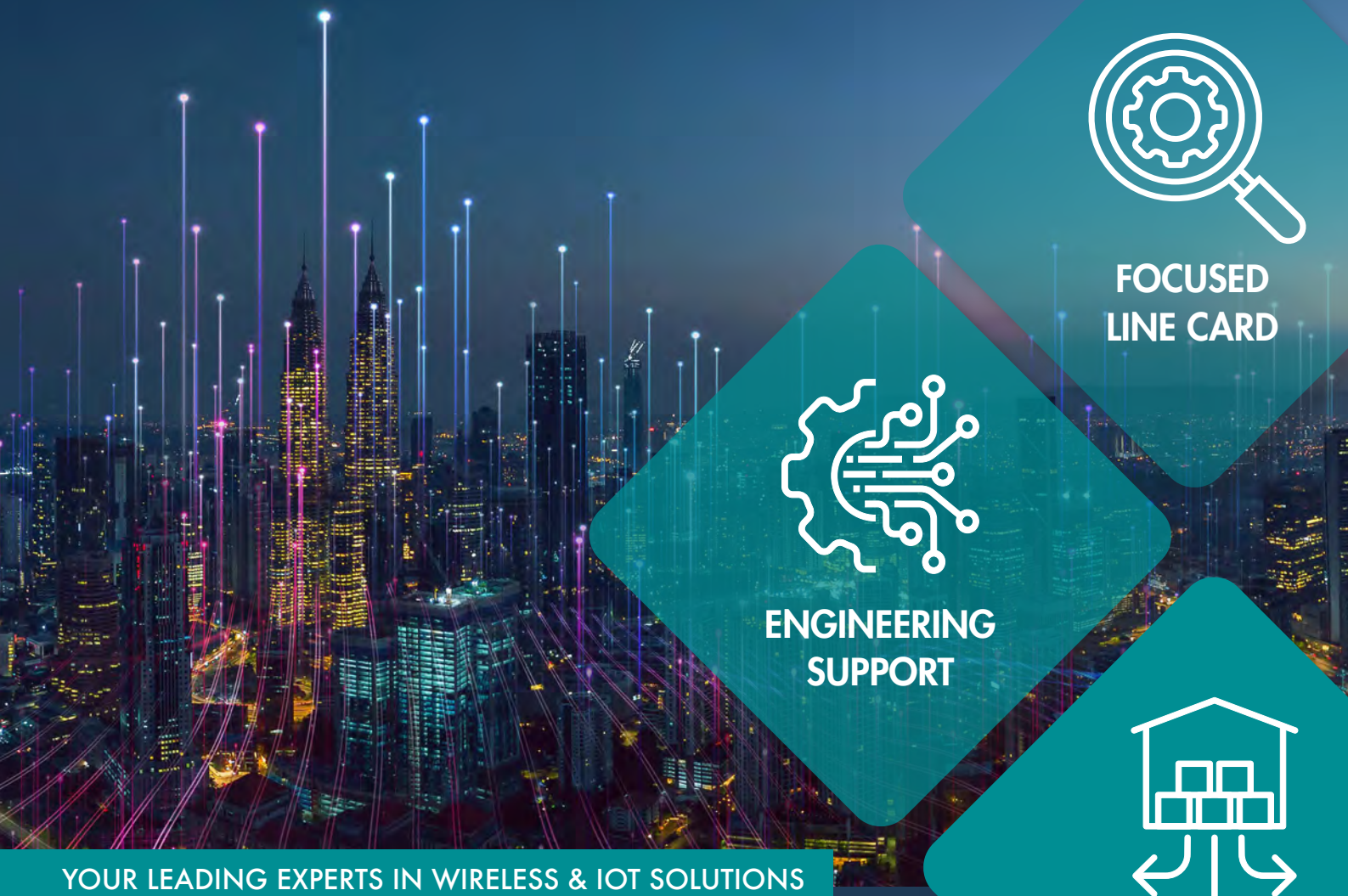

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Fast roll-off filters: Are they the best choice?

Picking the right ADC/DAC filters and sample rates for your audio design

Michael Chandler-Page, Systems Engineer, **Cirrus Logic**

The selection of interpolation and decimation filter options in audio analog-to-digital converters (ADCs) and digital-to-analog converters (DACs) is an often-misunderstood aspect of audio systems design. Selecting a fast roll-off filter to give the widest audio bandwidth isn't always the best choice for sound quality. Filter selection is a trade-off between key performance aspects, including interaction with the analog signal path design. Listening tests suggest that selecting a filter for the best impulse response can significantly improve perceived audio quality of the system, especially at higher sampling rates.

Decimation and interpolation filters

Modern high-performance oversampling ADCs initially convert the analog input to a low-resolution, high sample rate digital signal. A digital "decimation" filter converts this signal to the digital audio output at a typical sample rate (for example, a 24-bit, 96 kHz sample rate).

Similarly, high-performance oversampling audio DACs convert a low-resolution, high sample rate signal to analog. They use a digital "interpolation filter" to convert a digital input signal (for example, a 24-bit, 96 kHz sample rate) to the low-resolution high sample-rate input required by the delta-sigma DAC stage.

The characteristics of these filters can make a great deal of difference in the measured and subjective audio performance of the converter. The best choice of filter may depend on the application, the external analog design, and the preferences of the designer. For this reason, many ADC and DAC ICs provide multiple selectable options for the filters.

Making the right choice

Start with the following questions to help identify the best choice for your application:

1. At what sample rate(s) will the product operate? This limits the scope of the plots and specs to review. Operating at a higher sample rate comes at a high cost in resources but enables fundamentally better sound quality by relaxing the trade-offs in the interpolator/decimator filter, achieving a better impulse response for a given passband width and stopband attenuation specification.
2. What flat passband does the product need? Unless your high sample-rate product objectively requires spectrally flat reproduction of ultrasonic audio, consider limiting the upper frequency of your passband spec to 20kHz. This will enable the other performance aspects to be improved, which can better improve the audio performance of your product.
3. Does your application face EMI challenges requiring higher stopband attenuation to avoid impairment in the audible band caused by out-of-band signal folding? Enhancements to your analog design to better filter out-of-band signal content may allow the use of a filter with less stopband attenuation, which may improve audio performance, especially impulse response.
4. Can you choose a filter with a better impulse response? This can make a highly audible improvement to the perceived audio quality.

With these answers for your application in mind, we can explore how they affect filter choices.

Ideal filters meet the real world

Ideally, the decimation or interpolation filter would have a flat frequency response up to the Nyquist frequency (half the sample rate and the theoretical maximum bandwidth of the sampled signal) and then complete attenuation of all higher frequencies. Also, the time domain characteristic would be perfect: an impulse input resulting in a one-sample impulse output with no ringing.

The problem is that digital filter theory makes this impossible. Real, implementable digital filters are a trade-off between different aspects of their performance, and enhancing any one of these aspects degrades one or both of the others. These aspects include:

- Flatness of the passband and the upper frequency limit of the passband relative to the Nyquist frequency.
- How much the stopband is attenuated, and the lower frequency limit of the stopband relative to the upper limit of the passband.
- How much ringing there is in the impulse response.

The wider the frequency range between the upper frequency limit of the passband and the Nyquist frequency, the less

severe these trade-offs may be. It follows that for audio, where for practical purposes the upper frequency limit for the passband may be 20kHz, higher sample rates such as 192kHz may enable better-performing decimation and interpolation filters.

Understanding the trade-offs

What do these trade-offs mean and how do they affect the audio quality of the system? The passband flatness and extent are the easiest to understand. A flat frequency response means an authentic, high-fidelity tonal balance to the sound. Humans typically cannot hear above 20kHz, but if your application requires high-fidelity reproduction of ultrasonic audio, then you may need to prioritize extending the passband beyond 20kHz.

The stopband attenuation determines how well the ADC or DAC rejects spurious high-frequency content above half the sample rate. This prevents it from aliasing into the audible passband, where it degrades the distortion performance of the signal path. This may have audible effects, such as impairing clarity and stereo positioning.

For an ADC, this can be mitigated by enhancing the analog filter design on the input signal path to reduce the level of out-of-band content in the analog input signal from sources such as RF transmitters or switching power supplies. This enables selection of a decimation filter with less stopband attenuation. Conversely, if the ADC input is susceptible to high-frequency interference, then a filter with more stopband attenuation may be required.

For a DAC, it may be feasible to select an interpolation filter with less stopband attenuation if the analog output signal path has enough bandwidth to maintain linear operation in the presence of out-of-band signal energy. Conversely, if the DAC output path is more susceptible to out-of-band energy, it may be prudent to select an interpolation filter with more stopband attenuation.

The impulse response characterizes how accurately the converter handles transients, especially those with high-frequency content such as high-hats or plucked instruments. Human hearing seems surprisingly sensitive to the temporal quality of transients. It has been observed that selecting a filter with minimal impulse response ringing gives a distinct subjective impression of immediacy and realism with musical content, as compared to a filter with more impulse response ringing.

Filtering for best sound quality

It can be tempting to view filter response plots in terms of "more bandwidth sounds better," and then select the filter with the greatest flat passband. In reality, however, given a flat passband up to 20kHz, the best perceived audio quality is usually obtained by selecting the filter with the best impulse response and enhancing the analog design to improve filtering of and immunity to out-of-band content.

DACs and ADCs that feature multiple filter options—such as Cirrus Logic's high-performance Pro Audio Family of converters that are optimized individually for each sampling rate—give the best possible impulse responses for a wide range of applications. With multiple filter options to choose from, designers can significantly improve the measured and perceived audio quality of their system.

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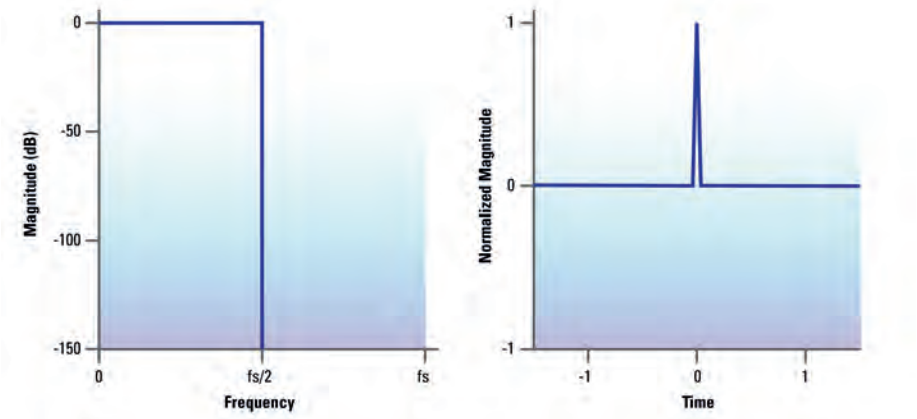

Fig 1. Frequency response and impulse response of an idealized decimation/interpolation filter

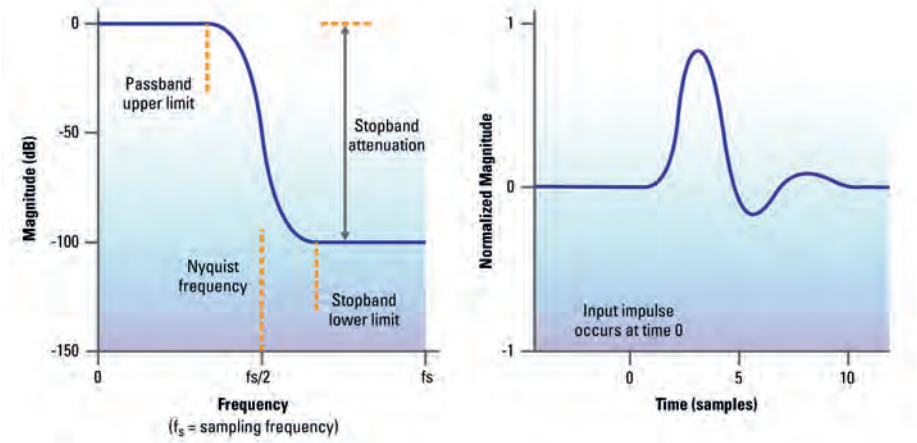

Fig 2. Frequency response and impulse response of a real-world decimator/interpolator filter

Driving smart city, transportation, and communications innovations

Jonatan Aronsson, President and Founder, **CEMWorks**

Welcome to vehicle-to-vehicle (V2V) and vehicle-to-everything (V2X) communications

System-level electromagnetic (EM) simulation is becoming an increasingly important technology for the design of next-generation smart cities, transportation, and global communications systems. These sectors demand innovative, automated tools for EM simulation.

Let's step inside the world of EM simulation to understand the scale of smart city complexity it needs to address today. For example, EM plays an important role in determining antenna placement. The simulation must consider all the antennas, how they interact with each other, and how they interact with their surroundings, including potential interference from other on-board or nearby communications systems.

Another example is the push toward self-driving cars, a communications application that requires EM analysis for internal communications of critical vehicle functions such as steering, motor control, and braking, along with vehicle-to-vehicle (V2V) and vehicle-to-everything (V2X) communications services.

More systems are coming online that need to communicate. It used to be that a car would have a global positioning system (GPS). Now, this has evolved to GPS coupled with radars and communications between vehicles. New vehicles are likely to have V2V communication whereby vehicles can exchange sensor information. One vehicle may notice an obstacle and transmit that information for other vehicles to pick up. Or V2X where vehicles can communicate directly with traffic lights, for example. Of course, if all vehicles support this type of communication, then traffic lights won't be needed because the vehicles could synchronize between themselves.

In these advanced cases, communication link reliability becomes critical, particularly when there's no line of sight. An intersection with skyscrapers at each corner and no clear line of communication means the vehicle must rely on communication signals that bounce off the buildings. Analyzing how these signals propagate and how to control them is a complex challenge that needs to be solved.

5G cellular communications with its push toward millimeter wave frequencies is another increasingly complex area. Millimeter band electromagnetic waves don't travel as far and are easily obstructed by buildings, trees, vehicles, and even pedestrians. At lower frequencies, they can penetrate through buildings and bounce around corners. This means antenna placement for base stations becomes more critical. It also explains why 5G networks typically rely on small cells for adequate coverage that can be mounted on existing structures like light posts and traffic signals.

Beamforming might be used to track a pedestrian. With traditional antennas, energy radiates in all directions. For millimeter wave 5G networks, the energy needs to be concentrated and it's challenging to figure out where to direct the beam. The introduction of Reconfigurable Intelligence Surfaces (RIS) adds yet another layer of complexity. Operators must simultaneously and in real-time configure both the beamforming antenna and the RIS. They must determine the direction of the focused beam while also providing instant updates for RIS configuration changes. These changes to the RIS can be extremely energy-efficient by only toggling diodes on and off.

Looking ahead, 6G with frequencies ranging from 28 to 300 gigahertz will pose new challenges. Semiconductor systems capable of handling these high frequencies are under development. Traditional simulation methods, like component-level SPICE models, lack the required accuracy for such high-frequency applications.

In summary, EM simulation is an indispensable tool for solving complex computational problems in smart city, transportation, and communications systems. The growing complexity and high-frequency nature of these systems make it imperative to develop more advanced EM simulation tools.

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Remote IIoT connectivity requires advanced lithium batteries

by Vitaly Milner,
Product Manager,
Tadiran Batteries

Bringing digital connectivity to remote sites and harsh environments

Choosing the right battery for a remote IIoT application is essential to reducing ongoing maintenance costs and the replacement of failing batteries.

The choice of power source is increasingly complex for remote wireless devices operating in hard-to-access locations, where extreme temperatures can reduce battery performance and hard-wired power is either inaccessible or cost prohibitive. Common applications include industrial robotics, SCADA, process control, asset tracking, safety systems, tank level and flow measuring, environmental monitoring, AI, M2M, and wireless mesh networks, to name a few.

Ultra-long-life lithium batteries enable low-power devices to improve operational efficiencies, track assets, optimize supply chains, reduce environmental impact, initiate cost-saving predictive maintenance programs, and more. The vast majority of these devices draw average current measurable in micro-amps with pulses in the multi-amp range, making them ideally suited for primary (non-rechargeable) lithium batteries. There are also niche applications that draw higher amounts of average current measurable in milli-amps with pulses in the multi-amp range, often better suited for energy harvesting in conjunction with an industrial grade rechargeable lithium-ion (Li-ion) battery to store the harvested energy.

To address the unique requirements of energy harvesting applications, an industrial grade Li-ion battery has been developed that can last up to 20 years, endure 5,000 full recharge cycles, and be recharged and discharged at temperatures down to –40°C.

Ultra-long-life lithium batteries

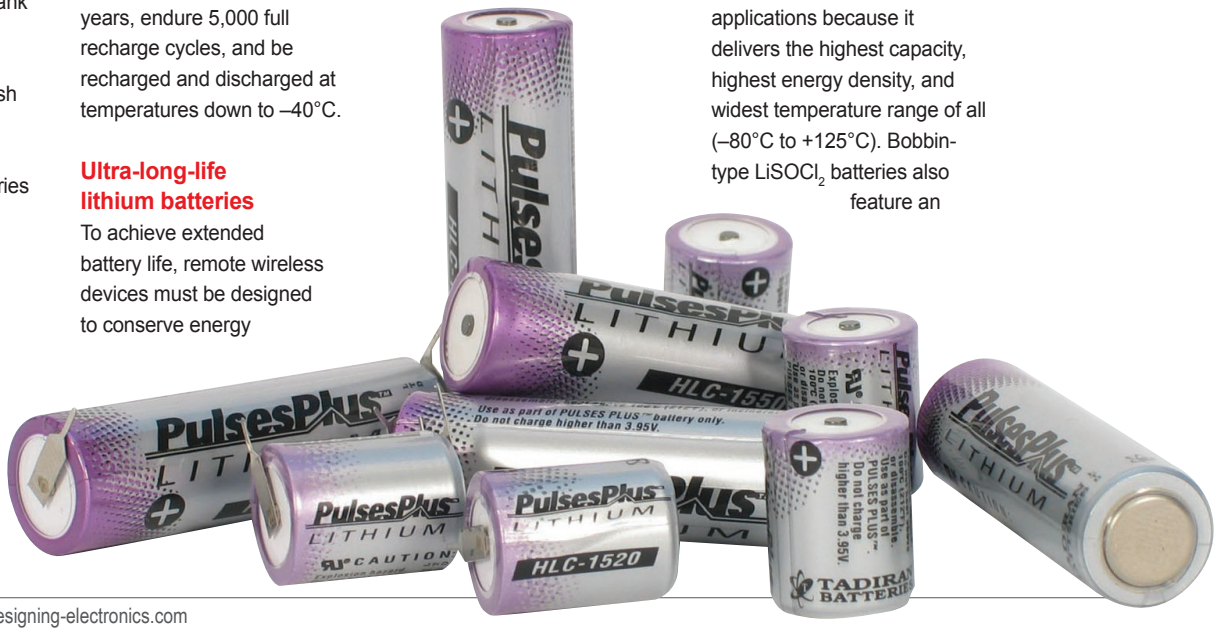
To achieve extended battery life, remote wireless devices must be designed to conserve energy wherever possible, mainly using low-power chipsets, low-power communications protocols (e.g., WirelessHART, ZigBee, LoRa), and proprietary techniques to minimize energy consumption during 'active' mode. While valuable, these energy-saving techniques are often far less important than the choice of battery.

Numerous primary (non-rechargeable) battery chemistries are available for low-power devices. Least expensive is the ubiquitous alkaline cell, which delivers high rates of continuous current with the trade-off being a high self-discharge rate of up to 60% per year, making them ill-suited for long-term deployments. Alkaline cells have very low capacity and low energy density, which may result in added size and bulk. In addition, alkaline cells use a water-based chemistry that is prone to freezing.

On the opposite side of the spectrum are the lithium-based chemistries used in industrial applications. As the lightest non-gaseous metal, lithium features an intrinsic negative potential that exceeds all other metals, delivering the highest specific energy (energy per unit weight), highest energy density (energy per unit volume), and higher voltage (OCV) ranging from 2.7V to 3.6V. Lithium cells are also non-aqueous and less prone to freezing than alkaline cells.

Bobbin-type $LiSOCl_2$ chemistry

Among primary lithium chemistries, bobbin-type lithium thionyl chloride ($LiSOCl_2$) chemistry is widely preferred for remote wireless applications because it delivers the highest capacity, highest energy density, and widest temperature range of all (–80°C to +125°C). Bobbin-type $LiSOCl_2$ batteries also feature an



extremely low self-discharge rate as low as 0.7% per year, enabling certain cells to last up to 40 years.

Achieving lower self-discharge

Self-discharge is common to all batteries. Chemical reactions reduce the energy stored in the cell without any connection between the electrodes and any external circuit. Remote wireless devices often lose more energy annually to self-discharge than is required to operate the device.

Bobbin-type $LiSOCl_2$ cells can minimize self-discharge by harnessing the passivation effect, whereby a thin film of lithium chloride (LiCl) forms on the surface of the anode to separate it from the electrode, thus limiting the chemical reactions that cause self-discharge. When a current load is applied to the cell, the passivation layer causes initial high resistance and a drop in voltage until the discharge reaction begins to dissipate the passivation layer: a process that repeats each time a load is applied.

The amount of passivation can vary based on numerous factors, including cell construction, current discharge capacity, the length of storage and storage temperature, discharge temperature, and prior discharge conditions, as partially discharging a cell and then removing the load will decrease the passivation effect over time.

Experienced battery manufacturers harness the passivation effect through proprietary cell design and construction, including the use of higher quality raw materials. A superior grade bobbin-type $LiSOCl_2$ battery can achieve a self-discharge rate as low as 0.7% per year, able to retain 70% of its original capacity after 40 years. By contrast, an inferior quality bobbin-type $LiSOCl_2$ cell can have a self-discharge rate as high as 3% per year, exhausting 30% of its available capacity every 10 years, making 40-year battery life impossible.

A hybrid approach

High pulses of up to 15A are required to initiate two-way wireless communications. Standard bobbin-type $LiSOCl_2$ cells cannot deliver such high pulses due to their low-rate design but can be modified with the addition of a patented hybrid layer capacitor (HLC). This hybrid approach uses the bobbin-type $LiSOCl_2$ cell to deliver low-level background current during 'standby' mode, while the HLC delivers the high pulses required during 'active' mode. The patented HLC features a unique end-of-life voltage plateau that can be interpreted to deliver 'low battery' status alerts for predictive maintenance programs.

Supercapacitors can also store high pulses but are mainly limited to consumer electronics due to serious drawbacks that do not allow for the use of all available energy, low capacity, low energy density, and high self-discharge rates of up to 60% per year. Supercapacitors linked in series require the use of bulky cell-balancing circuits, which adds expense and drains additional current to further shorten their operating life. However, supercapacitors can be utilized in conjunction with bobbin-type $LiSOCL_2$ cells to enhance voltage response.

What to look for

The ideal power source should last for the entire lifetime of the device, thus reducing or eliminating the need for costly battery changeouts. Unfortunately, a superior grade battery can be difficult to distinguish from an inferior grade cell because annual capacity losses may take years to become fully measurable. Additionally, the algorithms and theoretical models used to calculate battery life expectancy tend to underestimate the passivation effect as well as long-term exposure to extreme temperatures.

Since theoretical models tend to inaccurately predict expected battery life based on short-term data, careful due diligence is required to specify the ideal battery. To properly evaluate competing battery brands, potential suppliers should be required to provide fully documented test reports, including theoretical models verified by historic data, as well as in-field performance data from similar devices operating under comparable loads and temperatures.

Identifying the ideal battery based on application-specific requirements will serve to maximize product performance while reducing the long-term cost of ownership.

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System-on-module in industrial embedded systems

There's an imperative for SoMs with a focus on enhanced WiFi and the IoT

The digital landscape of the 21st century is profoundly interconnected, driven by the relentless growth of the IoT and ubiquitous wireless access. As the industrial sector races towards a future dominated by smart devices, machinery, and digital interfaces, the demand for embedded systems—particularly those employing system-on-module (SoM) / computer-on-module (CoM) solutions—with advanced WiFi connectivity, has surged. The significance of these components is irrefutable.

SoMs with advanced WiFi connectivity play a pivotal role in this transformation. Prominent industrial use cases include smart manufacturing, energy management, logistics and fleet management, smart building and warehouse management, operational surveillance, remote process control, and more. They are complete computing systems interfacing into a carrier board that reduce development complexities and accelerate time-to-market. They are preferred for many industrial applications because of their compactness, flexibility, and scalability.

Driving connectivity in industry 4.0

The dawn of Industry 4.0—often characterized as the Fourth Industrial Revolution—heralds an era where factories, machinery, and production lines are interconnected. The mainstay of this revolution is robust wireless connectivity as industries rely on an array of sensors, actuators, and other smart devices. These elements provide real-time feedback, optimize operations, and forecast maintenance needs. To function cohesively, next-generation WiFi connectivity such as WiFi 6, facilitated by modern SoMs, becomes indispensable.

The benefits of enhanced connectivity

As newer WiFi standards like WiFi 6 and WiFi 6E emerge, they bring improvements in speed, latency, and device handling capabilities. An upgraded SoM equipped with the latest WiFi technology ensures the following:

Faster Data Transfer: Enhanced speed ensures that the vast amounts of data generated by industrial processes are transmitted without delays, enabling swift decision-making.

Concurrent Device Support: Advanced WiFi standards can handle a multitude of devices concurrently. In an industrial setting with hundreds of connected entities, this capability is invaluable.

Reduced Latency: For processes that require immediate feedback—like certain automation tasks—reduced latency can make a significant difference in efficiency and safety.

Recent developments in the embedded systems market have underscored the criticality of next-generation WiFi capabilities. A case in point is the recent announcement by Variscite, a global SoM designer and manufacturer. Recently, the company announced the availability of its first WiFi 6-enabled SoM, the VAR-SOM-MX93, which is based on the NXP i.MX 93 platform.

The VAR-SOM-MX93's extended bandwidth and improved range provides simultaneous streaming, reduced latency, and optimal power management. Integration of the NXP IW611/IW612 WiFi 6 modules ensures a certified, dual-band WiFi 6 (802.11ax/ac/a/b/g/n) with 802.15.4, BT/BLE 5.3. This solution aligns with the evolving demands of the IoT, as evidenced by its full support for the new Matter standard. This SoM encapsulates energy flex architecture for efficient processing and is an excellent fit for industrial embedded computing systems.

Challenges and considerations

While the need for SoMs with enhanced WiFi is clear, the transition isn't without some issues that may slow progress. Industries need to consider compatibility concerns, investment costs, and the requirement for skilled professionals to integrate and maintain these new systems.

As the industry gears up to embrace the vast potentials of Industry 4.0, the underpinning factor remains robust, secure, and efficient wireless connectivity. SoMs with upgraded WiFi stand at the forefront of this transformation. By integrating these advanced systems, industries can hope to fully harness the power of the IoT, portability, and the interconnected digital ecosystem.

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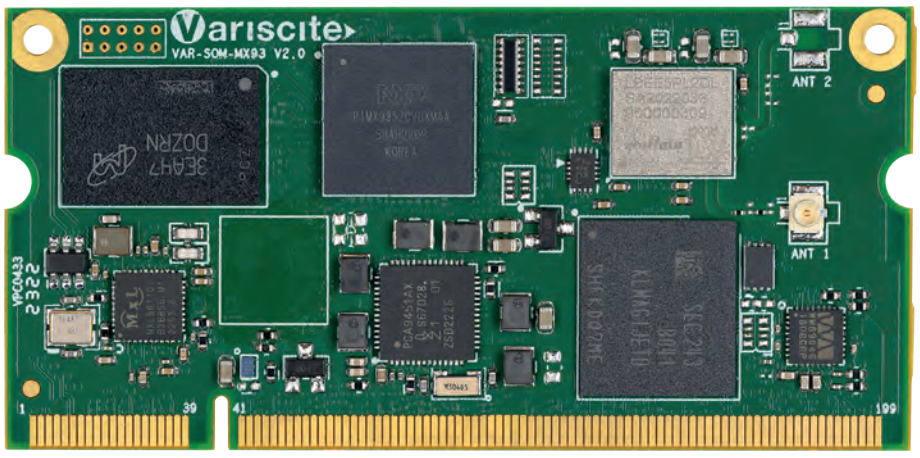


Why software is eating hardware

Lauro Rizzatti, Business Advisor to **VSORA**

What it is going to take to deliver on the promise of generative AI

In 2011, venture capital investor Marc Andreessen wrote an opinion piece for *The Wall Street Journal* titled "Why Software Is Eating the World." As part of this, he noted that it took 10 years after the wide adoption of the internet—and the dot-com economic bubble—for the new technology to bear fruit and suggested that this timeframe could be applicable to similar technological developments.

In his opinion piece, Marc proposed that software was in the process of revolutionizing the entire human experience. The following 10 years showed how prescient he was. During the decade following Marc's article, many established industries were disrupted by software. The laggards were replaced. Financial, industrial, agricultural, medical, entertainment, retail, healthcare, education, and defense were all touched and permanently changed by software.

Software was indeed eating the world.

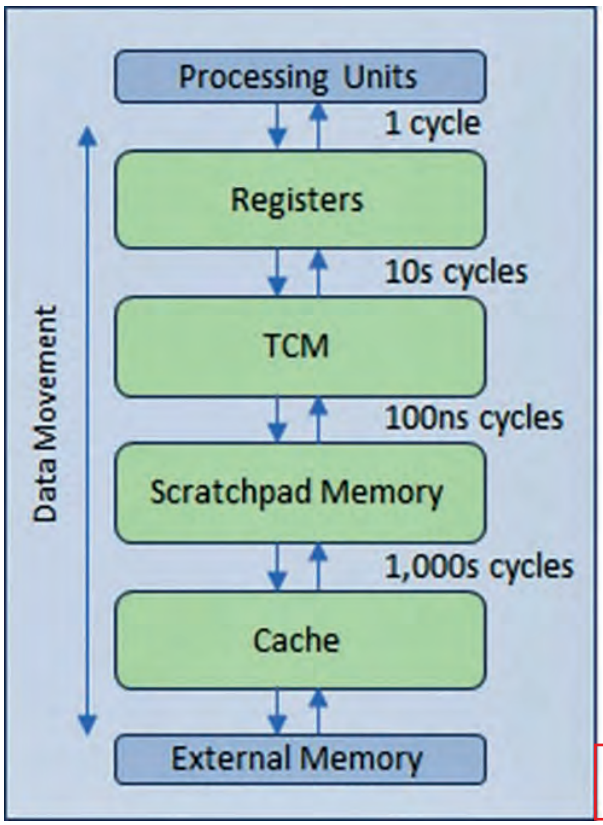
The reaction to the adoption of various forms of artificial intelligence (AI) today leads us to predict a second revolution. According to McKinsey, Generative AI (GenAI) could add the equivalent of $2.6 trillion to $4.4 trillion annually across all industry sectors. "Generative AI is going to be as fundamental as the creation of the microprocessor, the personal computer, the internet, and the mobile phone," says Microsoft Founder Bill Gates.

Marc's prophetic headline was soon expanded to: "Software is eating the world, hardware is feeding it, and data is driving it." Now, software is eating the hardware.

AI is built on complex algorithms whose execution is dominated by data movement, not by data processing that heavily taxes data throughput. The latest types of algorithms implemented in dense or large language models (LLM) called transformers consist of neural networks capable of learning context by tracking relationships in sequential data like the words in a sentence.

Initially, transformers were favored by car manufacturers for designing autonomous driving (AD) algorithms because of their ability to track and learn multiple complex interactions between the environment and the AD vehicle. Today, they are the foundation of GenAI technology.

Caution prevails. GenAI needs vast amounts of processing power and substantial data communication throughput that must be supported and delivered by the underlying hardware infrastructure. These demanding requirements are necessary to process billions of parameters on every clock cycle.



A multi-level hierarchical memory cache alleviates data traffic between the main

ChatGPT is living proof with more than 100 million users signed on in less than a year after launching. The number of parameters in the current GPT-4 generation is estimated to have increased to more than one trillion from the previous generation of 175 billion. This means that AI hardware accelerators must scale to handle anywhere from 175 billion to over a trillion parameters stored in memory to execute each user query.

Computing architectures currently in use are not designed to handle this amount of data traffic between processor cores and memories that are typically implemented outside the computing cores. Central processing units (CPUs) are inadequate for the task. Graphics processing units (GPUs) have the performance but not the implementation efficiency.

In fact, almost all computing architectures are inadequate. They force processors to idle while waiting to receive data, especially with GPT-4 where idling is higher than 97% of the time. To put this another way, their efficiency is lower than 3%. A processor with a nominal computing power of one PetaOPS—10^{15} or 1,000,000,000,000,000 operations-per-second—at this efficiency level produces only about 30 TeraOPS of performance.

The root of the problem sits on the memory bottleneck commonly called the "memory wall," which suggests improvements in processor performance far exceeds those of the memory. To address this bottleneck, the semiconductor industry devised a multi-level hierarchical memory cache that reduces data traffic with the slower main and external memories.

LMM model training and inference are typically handled by large and expensive computing farms that run for days, consume massive amounts of electric power, and generate voluminous amounts of unwanted heat. Inference processing on edge devices, a potential market for an unlimited number of applications, is further hindered by inadequate bandwidth, insufficient computational power, long latency, and excessive energy consumption.

As was noted earlier, ChatGPT-4's model size has pushed into trillion+ parameters that must be stored in memory, causing the memory size requirement to move into terabytes territory. These parameters must be accessed simultaneously at high speed during training/inference, pushing memory bandwidth to hundreds of gigabytes or even terabytes per second. Processor efficiency of data transfer bandwidth between memory and processor is almost non-existent.

Power consumption is another consideration. Algorithms are executed on high-performance computing clusters, each consuming several kilowatts of power. The actual power consumption required to perform ChatGPT-4 user queries on a large-scale overloads power generating plants and overstresses energy distribution networks.

Obviously, investment in the hardware infrastructure has not kept up with ChatGPT or its energy consumption. Based on current purchasing options for processors, an estimate of the acquisition cost for a GPT-4 processing system running 100,000 queries/second—a benchmark established by Google search—would be in the ballpark of several hundred billion dollars. Meanwhile, the energy costs of running the hardware would be in the range of several hundred million dollars per day. Back-of-the-envelope calculations would lead to a cost per query of about ¢10 vis-à-vis ¢0.2 in a Google search.

As a result, any promise of unparalleled productivity from Generative AI is dashed with the current limitations of the hardware infrastructure costs.

A semiconductor industry call to action

The semiconductor industry has an opportunity to challenge the status quo with an improved hardware infrastructure built on an innovative processing architecture that needs to scale to accommodate a broad range of today algorithms and to be able to address future LLMs enhancements. Such an architecture ought to possess the following capabilities:

- More than one petaflop of processing power per device.
- Processing efficiency of 50% under massive workloads.
- Latency of less than two seconds per query.
- Power consumption of less than 50 watts per device.
- Costs of less than $100 per device.

This architecture should also adopt the latest manufacturing advancements, including the lowest process technology nodes and multi-chip stacking.

In summary, the cost effectiveness of an economically sustainable, energy-efficient processing system must increase by at least two orders of magnitude. Lowering the annual cost to run 100,000 queries per second on a GPT-4-type system from hundreds of billions of dollars to fewer than $10 billion will deliver the promise of GenAI and keep it from consuming its feeder.

www.vsora.com

"The cost effectiveness of an economically sustainable, energy-efficient processing system must increase by at least two orders of magnitude"

Innovation Will Continue to Amaze

Jeff Newell, Senior Vice President of Products, **Mouser Electronics**

The innovation we are seeing today in new products continues to amaze. It certainly is an exciting time. Today's manufacturers continue to introduce smaller, faster, and more powerful semiconductors with more capabilities. As the industry's new product leader, we make it our mission to bring these new technologies to market for engineers and buyers.

Mouser is stocking the world's leading products from over 1,200 manufacturer brands. Whether it's new quad-channel analog-to-digital converters from Analog Devices or mixed-signal microcontrollers from Texas Instruments, engineers and buyers can count on Mouser as a trusted, go-to source for authentic components and technical support. Our technical teams can provide in-depth understanding of the latest solutions, providing customers with valuable guidance and advice.

In 2024, key technology drivers, such as 5G, IoT, AI, and electric vehicles, will continue to accelerate overall consumption and demand. The automotive industry is estimated to drive 20% of overall chip demand and the wireless communication industry is projected to drive 25% of growth by the year 2030.

At the same time, the industry can expect to see new investment. The Semiconductor Industry Association predicts that increased investments, both private and government, will lead to more domestic semiconductor production, which can help avert future chip shortages and ensure the industry meets the growing need from sectors like the automotive, data storage, and wireless connectivity industries.

All of this bodes well for the electronic components industry.

www.mouser.com

Anticipating Technological Marvels

Daniel B Lynch Sr., General Manager, **Memory Protection Devices Inc.**

As we bid adieu to the whirlwind of innovations that characterized 2023, we find ourselves standing on the cusp of another thrilling year in the realm of electronic product design. The astonishing strides made over the past year have transformed our lives, propelling us into an era of unprecedented connectivity and convenience. Yet, as we peer into the future, the question beckons: what marvels lie ahead in 2024?

The past year was a testament to the relentless pursuit of excellence within the electronic industry. Designers, engineers, and visionaries collaborated to orchestrate a symphony of ingenuity, introducing a dazzling array of new components, tools, and technologies. From the integration of AI-powered assistants into everyday devices to the expansion of 5G networks that united us in a digital embrace, 2023 painted a vivid canvas of technological possibilities.

As we stand at the precipice of a new year, the curtain rises on a stage set for technological marvels that defy our imagination. Just as 2023 surprised us with its cascade of innovation, 2024 holds the promise of even more extraordinary breakthroughs. From the symphony of 5G connectivity to the ballet of AI's interaction with reality, the unfolding narrative of electronic product design beckons us to embrace the unknown with open arms.

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The Demand for SWaP-C Solutions

Jessica Knight,
VP of Sales, Americas, **Harwin**

The electronics industry is characterized by a never-ending search to deliver improved performance while reducing system size, weight, and power (SWaP). First used in the security and aerospace industries, this acronym—and its successor, SWaP-C (size, weight, power and cost)—is now common parlance for engineers in all areas of the sector.

In 2024, pressure on these engineers to deliver SWaP-C-optimized solutions will increase thanks to 'megatrends' that include extended deployment of AI and the unstoppable growth of industrial and consumer IoT applications (and the convergence of the two in so-called 'AI-at-the-edge'). In tandem, sustainability concerns, environmental legislation, and challenges to energy security and cost will further push efficiency up the design agenda—especially as we create ever-more-power-hungry systems ranging from the chips that power the generative AI revolution to the charging and powertrain platforms essential to electric vehicles.

Also in 2024, we will see the ongoing growth of the commercial space industry as it heads towards what, according to McKinsey & Company, could be a $1 trillion market by 2030. In turn, 'NewSpace' organizations seeking competitive advantage through shorter development times and lower costs will increasingly seek out 'off-the-shelf' components that address the challenges of space operation but don't limit them to using only those older products that have gone through a lengthy and expensive qualification process.

www.harwin.com

Accelerating Innovation

Sean Bailey,
President, **OKW Enclosures**

At OKW Enclosures we are forecasting an exciting 2024 with demand driven by the accelerating pace of innovation—especially in the IIoT and Industry 4.0.

OKW is well placed to capitalize on this, having enjoyed an exceptional 2023. Judicious purchasing of raw materials enabled OKW to support its customers through the COVID crisis and post-pandemic shortage of components. As a result, OKW saw a growth in export orders and rising demand for its in-house enclosure customization services.

Now, OKW is targeting further opportunities in the lucrative Industry 4.0/IIoT sector with new enclosure introductions and development. Last year the global IIoT market was valued at $101.45 billion, with a compound annual growth rate (CAGR) of 20.5% from 2022 to 2030, according to analysts at Coherent Market Insights.

Meanwhile, OKW's work on medical projects has virtually doubled, while measurement continues to be extremely buoyant. Both represent key areas of enclosures expertise and experience for the Pittsburgh, PA company.

OKW President Sean Bailey said: "I feel very positive about 2024. These are exciting times. It feels as if there is pent-up demand. Our existing customers are staying with us longer and ordering more because we are there to support them through challenging times. And the technological innovation we're seeing in markets such as Industry 4.0 and measurement bodes well for new inquiries," he added.

www.okwenclosures.com

Accelerating Efficiency

Ron Demcko, AVX Senior Fellow,
KYOCERA AVX Components Corporation

From a passive component point of view the theme of efficiency will accelerate in 2024. The exact meaning of efficiency varies greatly by sector. Examples include the following:

Consumer: SMT MLCC capacitors are a high runner in consumer electronics. There's no better example than a smart phone, which might employ 1,000 MLCCs in its design. Ongoing materials and manufacturing programs in MLCC manufacturers have created both high value MLCCs in larger case sizes as well as ultra-miniature cases, which are a fraction of the size of a grain of salt, thus enabling size and weight reductions in portable/handheld electronics.

Telecom & Communication: Both inductive and resistive parasitic losses are present in all modern-day capacitors. Manufacturers are rapidly minimizing those 'loss' features and creating ideal components that reduce power consumption and operate at higher frequencies. This allows faster communication and processing networks to be built that carry more data.

Automotive & Transportation: Self-healing power capacitors, flexible capacitors, and enhanced reliability capacitors are all making a mark on automobiles, resulting in higher safety and enhanced auto performance.

Data Center: Micro-miniature heat 'pipes' have been developed that transfer heat while not conducting electrical signals. This has resulted in the ability to directly add supplemental cooling to hot IC pins and enhance both IC reliability and processing capability.

High Reliability & Aerospace: New materials and processing have created multiple families of miniature, lightweight, highly reliable capacitors that enable higher efficiency to power conversion in next generation spacecraft electronics.

www.kyocera-avx.com

Innovation and Growth

Dave Doherty,
President, **DigiKey**

DigiKey has seen a huge amount of innovation in 2023. In the past year alone, there has been a surge in new product introductions in every industry from automotive to medical, industrial automation to consumer devices, and everything in between, driving business across the board. We expect that innovation and growth to continue into 2024.

Industrial automation and automotive should continue to perform very well in the Americas and EMEA. In Europe, we're also seeing strong demand for green technology, enabling the transition to reduce carbon footprints.

We expect wireless connectivity, smart sensors, cross architecture solutions, and rapid prototyping will all be key driving trends in the year to come. In addition, we're keeping an eye on the market demands that are shifting as the needs for AI and machine learning technology increase, including supercomputers and AI chips.

To support the innovation growth and accelerate progress for engineers and designers, DigiKey will continue to make investments in more robust and predictive web search functionality, higher inventory levels, and increased automation in the DigiKey warehouse, which all benefit procurement professionals by providing an easy and efficient research, shopping, and delivery experience.

By offering the newest technologies and components used to build machines and devices, along with robust online tools and resources, DigiKey helps propel industries like healthcare, automotive, energy, 5G, and IoT into the future.

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