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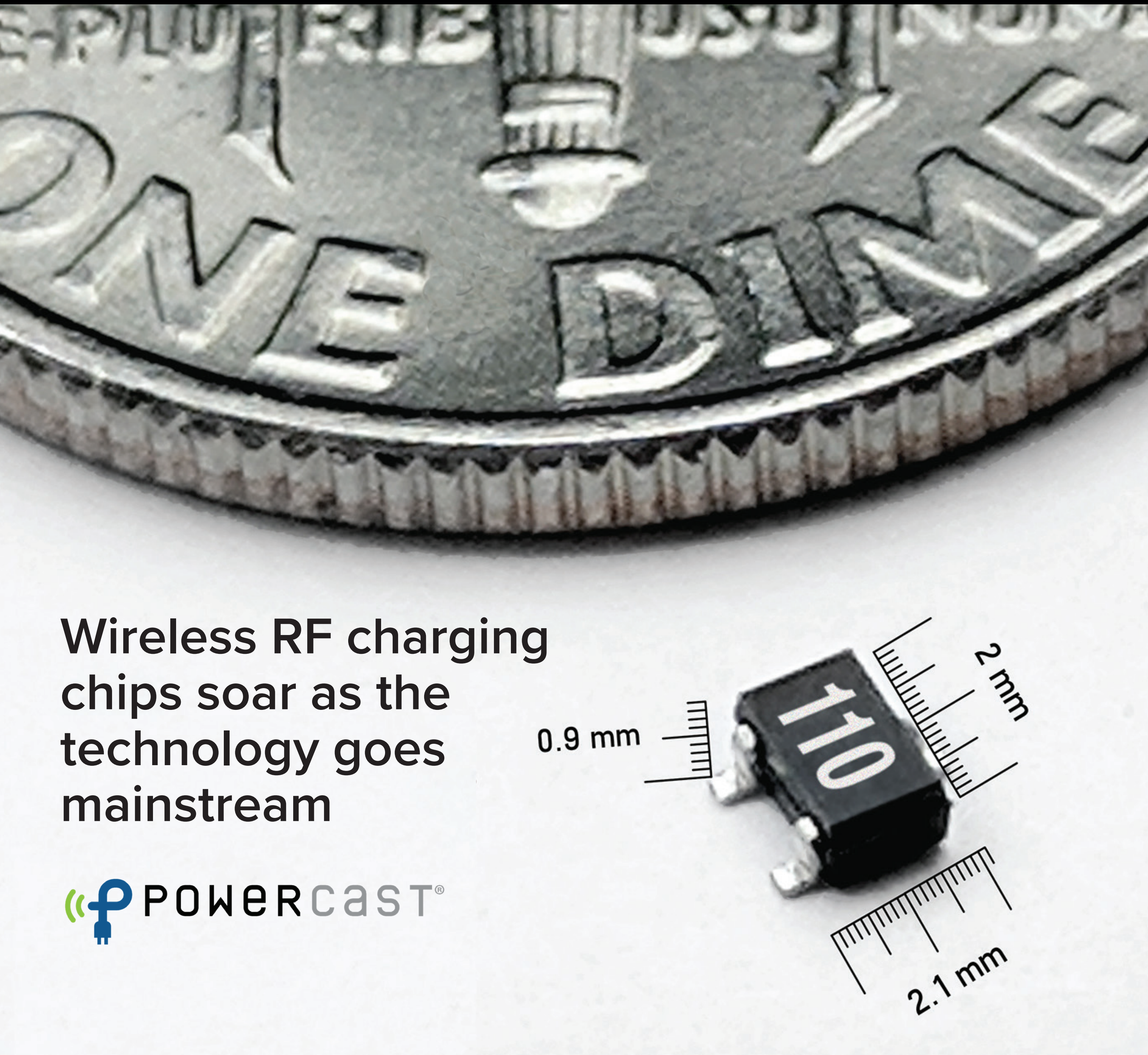

Wireless RF charging chips soar as the technology goes mainstream

POWERCAST

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VIEWPOINT

BY MARK ANDREWS TECHNICAL EDITOR

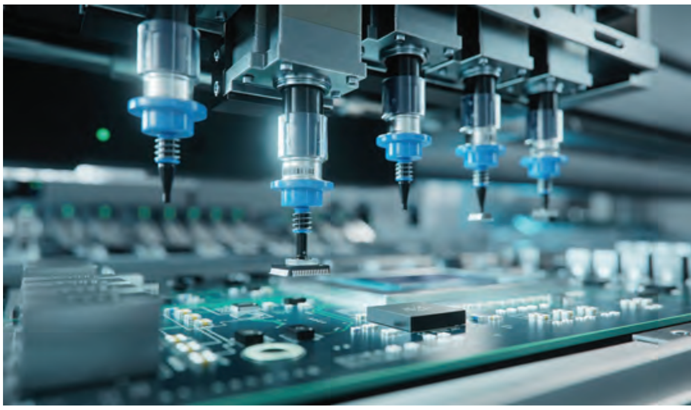
Will Fab spending sprees remedy the power device shortage?

The message came loud and clear: We need more power ICs! The 'we' in this case included major automotive OEMs and anyone trying to buy anything that became unavailable because the product's MCU was sitting in a cargo ship or amongst the backlogged orders at myriad global Fabs.

Once pent-up demand sent shoppers back to auto sales lots beginning in 2020 and throughout 2021 it quickly became clear that demand would continue exceeding supply unless Fab capacity was expanded. Fast-forward to the middle of 2022 and we see shovels hitting sand in 60 new Greenfield projects along with many expansions; there are about 110 global Fab projects of all types/sizes underway as of this writing.

With so many expansions it is natural to wonder: will oversupply trash the market? Investors bank-rolling Fab spending sprees don't think so and neither do IC manufacturers since demand continues to accelerate thanks to transport electrification, the ever-increasing demand for mobile data access and the many more chips needed to manage power in products of all types. Digitization is relentless. The SEMI trade association predicted recently that Fab equipment spending would set a new record this year: $109 billion. As Ajit Manocha, president and CEO of SEMI stated, "The global semiconductor equipment industry remains on track to cross the $100 billion threshold…This historic milestone puts an exclamation point on the current run of unprecedented industry growth."

No kidding. Put another way, 2022 Fab spending is on track to be twice as great as 2019's level.



In this edition of Power Electronics World we examine the impact of pandemic recovery on a sector widely seen as 'most effected' by the power IC shortage: Transport. Strategy Analytics Director Asif Anwar offers insights about current production levels and what is expected for the balance of 2022 and in 2023. We also explore advances being made by Powercast in wireless RF recharging—the company recently reached a new sales milestone, showing that power harvesting is blossoming for sensors, actuators and IoT devices.

We also look to engineering simulation leader Ansys for their insights into ways that advanced multiphysics simulation can speed designs into production.

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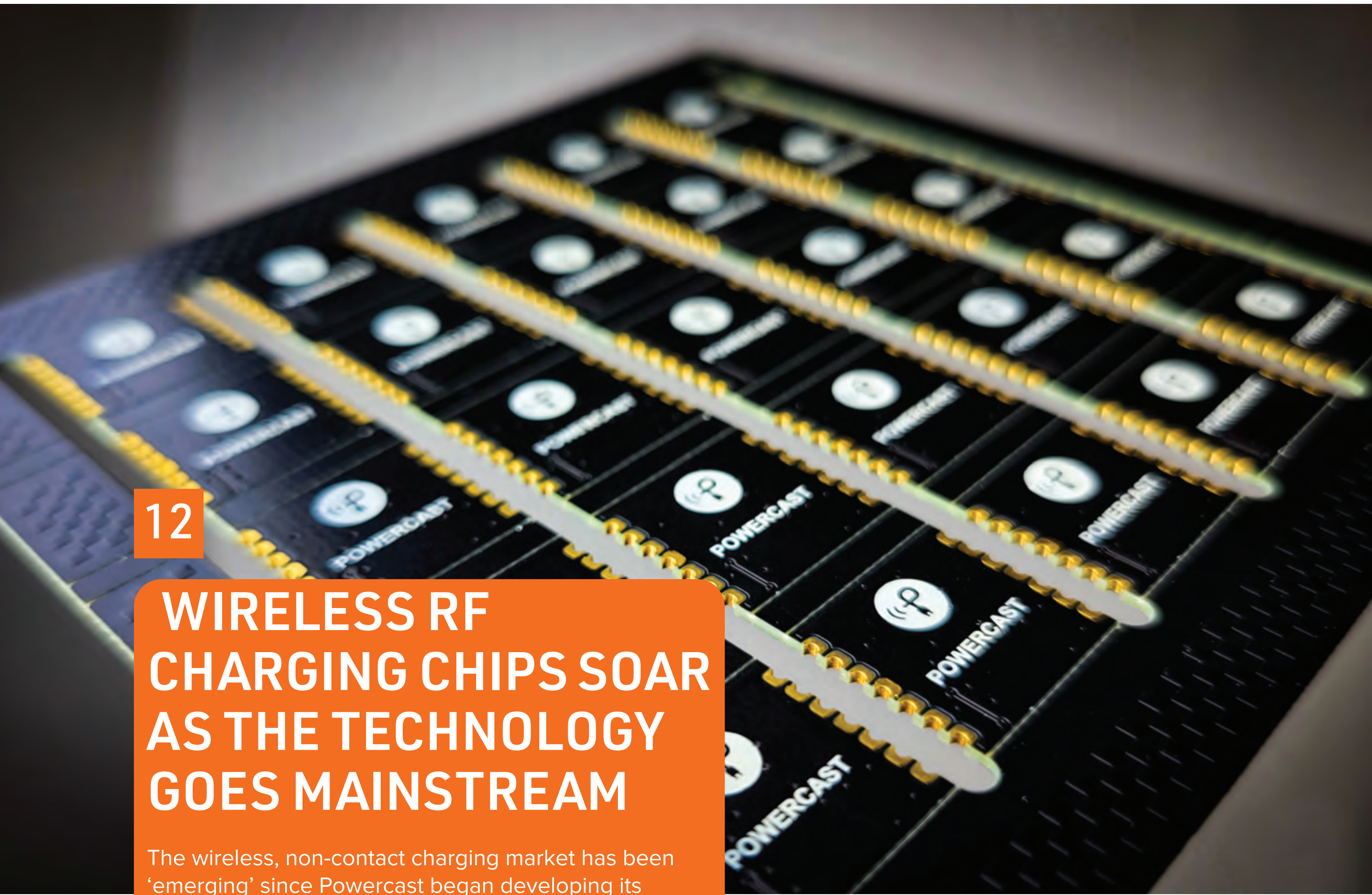

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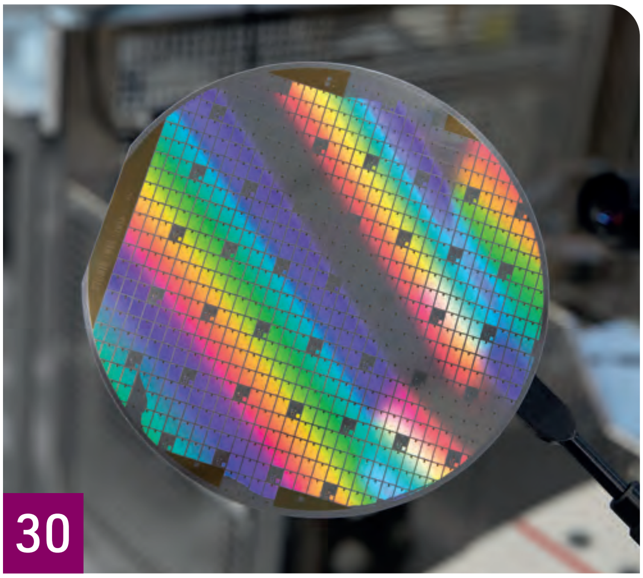

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Toshiba and Farnell extend partnership

Agreement will increase the range of innovative power semiconductors and discrete devices offered by Farnell

TOSHIBA ELECTRONICS EUROPE GMBH has extended its relationship with the distributor Farnell, which trades as Newark in North America and element14 throughout Asia Pacific.

Under this agreement, Farnell will stock more Toshiba products in greater quantities with an increased focus on Toshiba's strengths including power solutions and advanced motor control. Farnell's portfolio will encompass some 800 products by year end and increasing further to 1,000 items during 2023.

The focus will be on Toshiba's optocouplers and relays, low- and high-voltage MOSFETs, discrete IGBTs, small signal diodes and transistors, voltage regulators, logic devices and motor control solutions.

Commenting on the enhanced partnership, Ian Wilson, senior manager - Distribution Sales - at Toshiba Electronics Europe GmbH said: "In these times of global shortage it is important to strengthen our support to meet the product availability and support needs of the engineering community who continue to design, qualify, upgrade and repair with the latest components.

"We are particularly pleased to see some of our more innovative products become available via Farnell." Simon Meadmore, VP of Product and Supplier Management at Farnell added: "Farnell has a successful long-term relationship with Toshiba, and this is the right time to grow our range with this strong, innovative and respected brand. Our customers can now enjoy enhanced availability of Toshiba products coupled with fast access to new-to-market technologies. The new agreement strengthens the overall relationship between Toshiba, Farnell and the Avnet Group. We are committed to regularly launching new devices to enhance our existing portfolio from Toshiba."

GaN Systems and TSMC exhibit Latest Power Electronics

GaN SYSTEMS will show the latest in GaN power electronics innovation at TSMC's 2022 North America Technology Symposium and Innovation Zone at the Santa Clara Convention Center on June 16th, 2022.

GaN Systems will exhibit innovations across consumer, data centre, industrial and automotive markets. Additionally, a GaN Systems charging station will invite attendees to charge their phones, tablets, and laptops and gain real-world experience with fast-charge GaN AC/DC chargers.

GaN Systems CEO, Jim Witham, will provided his perspective on the power market with a presentation titled "Transforming the World with Smaller, More Efficient, More Reliable, Cost-Effective Power Electronics," highlighting the long-standing GaN Systems and TSMC partnership.

"GaN power semiconductors are becoming the transistor technology of choice in many major markets," said Stephen Coates, general manager of GaN Systems Asia. "Our ongoing collaboration with TSMC is reinforced by our joint commitment to innovate and push GaN technology to higher performance continuously. In partnership with TSMC, we have brought the promise of GaN from concept to high volume production and experiencing the greatness of GaN in the power market."

GaN Systems' has a long-standing partnership with TSMC, its primary and long-time foundry partner. The GaN Systems Taiwan campus is walking distance from TSMC in the Hsinchu Science Park and has enabled constant collaboration between the two companies.

"We are truly honoured to be among the select TSMC customers invited to participate in TSMC's Technology Symposium Innovation Zone," said Jim Witham, CEO GaN Systems.

"For over a decade, our partnership with TSMC has supported our strategy to deliver the most extensive and highest performance power semiconductors. Together, TSMC and GaN Systems will continue to fuel new products of importance in our increasingly electrified world."

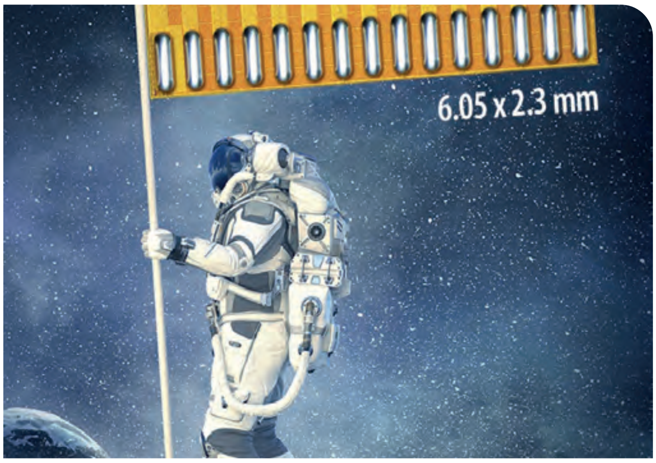
EPC announces rad hard 100V GaN FET

Offers lowest on-resistance for demanding space applications

EPC has expanded its family of rad-hard GaN products for power conversion solutions in critical spaceborne and other high-reliability environments with a 100V device that is believed to offer the lowest on-resistance of any 100 V rad hard transistor on the market.

The EPC7018 is a 3.9 mΩ, 345A Pulsed GaN FET in a 13.9 mm2 footprint. It has a total dose radiation rating greater than 1 Mrad and SEE immunity for LET of 85 MeV/(mg/cm2). The EPC7018, along with the rest of the rad hard family, EPC7014, EPC7007, EPC7019, comes in a chip-scale package, the same as the commercial eGaN FET and IC family. Packaged versions will be available from EPC Space.

Applications benefiting from the performance and fast deployment of the EPC7018 include DC-DC power, motor drives, lidar, deep probes, and ion thrusters for space applications, satellites, and avionics.



"The EPC7018 offers designers a high power, ultra-low on-resistance device enabling a new generation of power conversion and motor drives in space operating at higher frequencies, higher efficiencies, and greater power densities than ever achievable before", said Alex Lidow, CEO, and co-founder of EPC

The EPC7018 is available for engineering sampling and will be fully qualified for volume shipments in December 2022.

Magnachip unveils a new 650V IGBT for solar inverters

MAGNACHIP SEMICONDUCTOR has announced that the company has unveiled a new 650V insulated-gate bipolar transistor (IGBT) for solar inverters.

As environmental impacts from climate change are becoming more severe, the use of renewable energy like solar power continues to expand globally to reduce carbon emissions. Omdia, a global market research firm, estimates that the global market for IGBTs in the renewable energy sector will grow 15% annually from 2022 to 2025.

In March 2022, Magnachip developed a new 650V IGBT built with advanced "field stop trench technology" for fast switching speed and high breakdown voltages and the company will begin mass production of it this month. The current density of this new 650V IGBT was improved by 30% compared to the prior generation by adopting the latest technology. This IGBT is also designed to provide a minimum short-circuit withstand time of 5µs and it is optimized for parallel switching because of its positive temperature coefficient. The parallel switching of this IGBT will increase the load current and thus the maximum output power.

In addition, the 650V IGBT features anti-parallel diodes for fast switching and low switching loss, while guaranteeing a maximum operating junction temperature of 175°C. Based on standards issued by the Joint Electron Device Engineering Council (JEDEC), this new IGBT can be widely used for applications requiring strict power level and high efficiency, such as solar boost inverters and converters, uninterruptible power supplies and universal power inverters.

"Magnachip's first IGBT was introduced in 2013, and since then, we have been committed to developing high-efficiency products for a variety of markets, while strengthening our presence around the world," said YJ Kim, CEO of Magnachip. "With this new product, we are expanding our efforts to deliver high-performance products for the eco-friendly renewable energy market."

Power Electronics market to reach $43.7B by 2031

Market growing at 5.1 percent CAGR, says Allied Market Research

ALLIED MARKET RESEARCH'S recently published a report on the power electronics market reveals that the power electronics industry was $26.6 billion in 2021 and is expected to reach $43.7 billion by 2031, growing at a CAGR of 5.1 percent from 2022 to 2031.

Increase in use of power electronics in several applications and need for power management devices in automotive, consumer electronics, and energy & power industries are driving the growth. However, complex integration process for advanced electronics devices hinders the market growth.

By device type, the power module segment held the largest share in 2021, accounting for more than two-fifths of the global power electronics market, due to unmatched efficiency and durability. However, the power discrete segment is expected to register the highest CAGR of 6.5 percent during the forecast period, owing to their faster switching.

By end user, the energy and power segment held the lion's share in 2021, contributing to nearly one-fifths of the global power electronics market. However, the automotive segment is estimated to manifest the highest CAGR of 7.6 percent from 2022 to 2031, due to rise in demand for electric and hybrid vehicles and growth of electro-mobility and photovoltaic inverters market.
By region, the global power electronics market across Asia-Pacific dominated in 2021, holding around half of the market, due to increase in investment by prime market players in emerging technologies. However, the market across LAMEA (Latin America, Middle East and Africa) is projected to portray the highest CAGR of 6.1 percent during the forecast period.

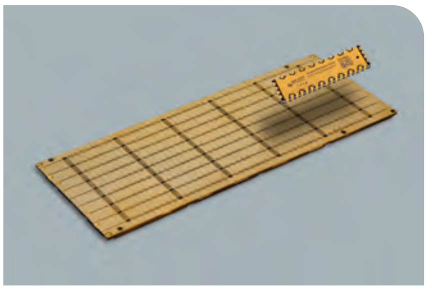
The full report is titled 'Power Electronics Market by Device Type (Power Discrete, Power Module, Power IC), by Material (Silicon Carbide, Gallium Nitride, Sapphire, Others), by Application (Power Management, UPS, Renewable, Others), by End Use (Telecommunication, Industrial, Automotive, Consumer Electronics, Military and defense, Energy and Power, Others): Global Opportunity Analysis and Industry Forecast, 2021-2031'

Vicor opens power module 'fab'

VICOR has opened a new power module manufacturing facility in Andover, Massachusetts. Described as the world's first ChiP (Converter housed in Package) fabrication facility, or 'ChiP fab', it will enable scalable, automated, cost-effective manufacturing of power modules in the United States.

With its new ChiP foundry, Vicor says it has takes a major step toward realising its vision to enable high-performance, modular power system solutions capable of satisfying demanding power requirements.

"Our new ChiP fab integrates all of the process steps necessary to manufacture high-density power modules in wafer-like panels with short cycle time and flexible capacity," said Mike McNamara, Vicor VP of operations. The new, vertically-integrated ChiP fab is said use patented fabrication processes that differentiate Vicor power modules by enabling the most power-dense and energy efficient solutions. The ChiPs are manufactured in panels (see above) using process steps analogous to semiconductor wafer fabs.



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Hitachi Energy

Power GaN: the next wave...

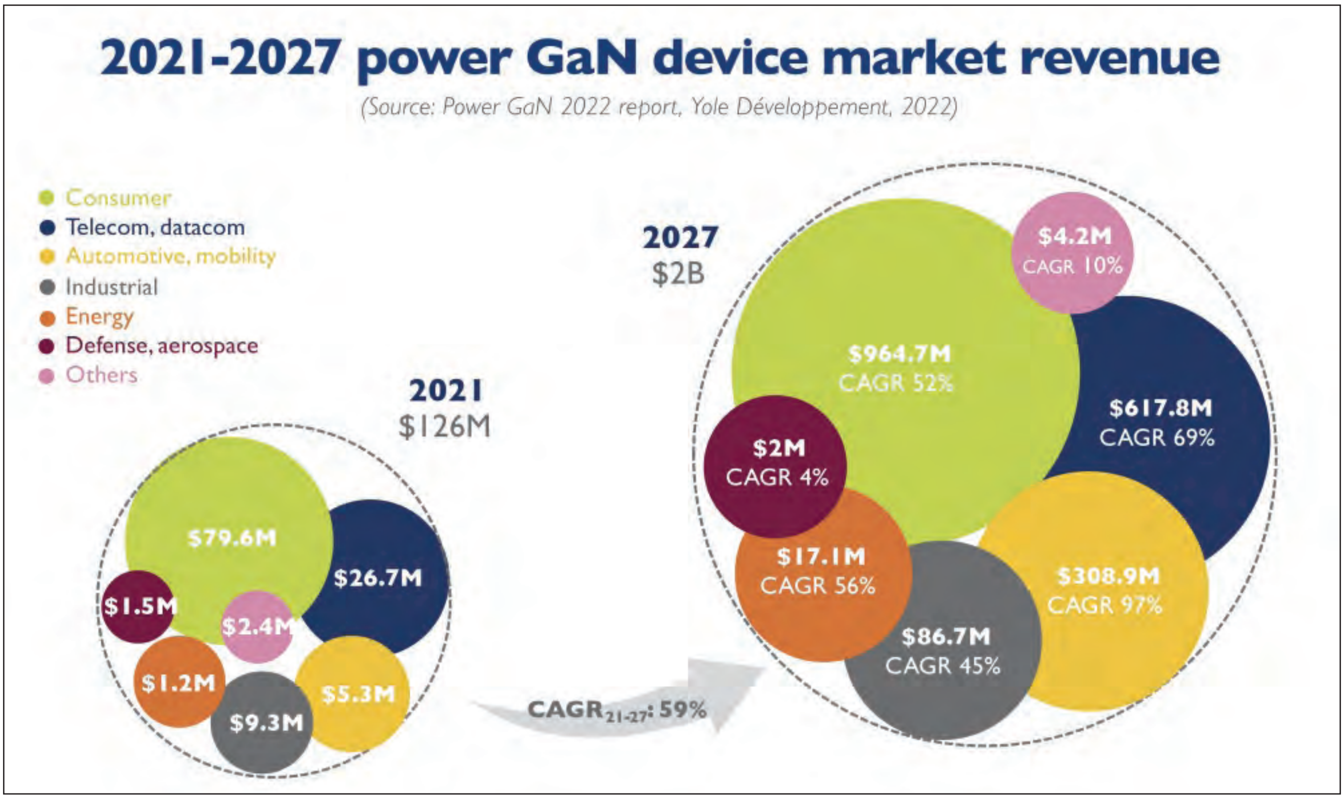
Comms and cars will drive the next power GaN wave, says Yole

YOLE GROUP forecasts that the power GaN market will reach $2B in 2027. In its latest annual report, Power GaN 2022, Yole details the penetration of GaN devices in different applications from the system point of view.

The consumer power supply market will be worth more than $915.6 million by 2027, with a 52 percent CAGR between 2021 and 2027. Yole forecasts an increase in the mid term of GaN penetration in datacom/telecom as regulations become stricter. The interest in adopting 48V-Point-Of-Load systems in data centres to reduce power consumption and cabling volume will favour GaN for low-voltage applications. An increasing number of power suppliers are adopting GaN in their systems. Transphorm, EPC, Texas Instruments, Infineon, and GaN Systems have all announced several design wins. Therefore, the GaN market for datacom/telecom is expected to have a 69 percent CAGR over the forecast period, to more than $617.8 million in 2027. At a lower penetration level, automotive DC-DC converters and OBCs will be part of the next wave of growth during the forecast period. There are ever more collaborations between GaN device players, who are accelerating the automotive qualification of their products, and the Tier-1 and OEMs , who are evaluating automotive GaN solutions. The GaN automotive market is expected to exceed $227 million by 2027, with a 99 percent CAGR between 2021 and 2027.

In its Power GaN 2022 report, Yole's analysts also highlight the dynamic supply chain with new entrants and significant investments. Indeed, since the release of the 2021 report, the market research & strategy consulting company has witnessed the entry of new players into the supply chain. Notably, Rohm is offering a 150V GaN product for telecom/datacom applications. BelGaN, a new GaN foundry based in Belgium, has recently acquired Onsemi's fab. And on the fundraising front, Navitas went public through a SPAC business combination after an agreement valued at $1.04 billion with Live Oak Acquisition Corp.

Focusing on the Chinese ecosystem, the government has supported more investments from GaN players. Innoscience, for instance, is investing more than $400 million to expand its 8-inch wafer capacity from 10k to 70k wafers per month by 2025. A domestic supply chain for GaN power is well developed, especially for the consumer market. The transition to the 8-inch platform and the consolidation of the supply chain with more players at each level are driving lower manufacturing costs, especially at the epitaxy step, which constitutes the most significant part of a GaN device's cost structure.



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MEMS & SENSORS EXECUTIVE CONGRESS
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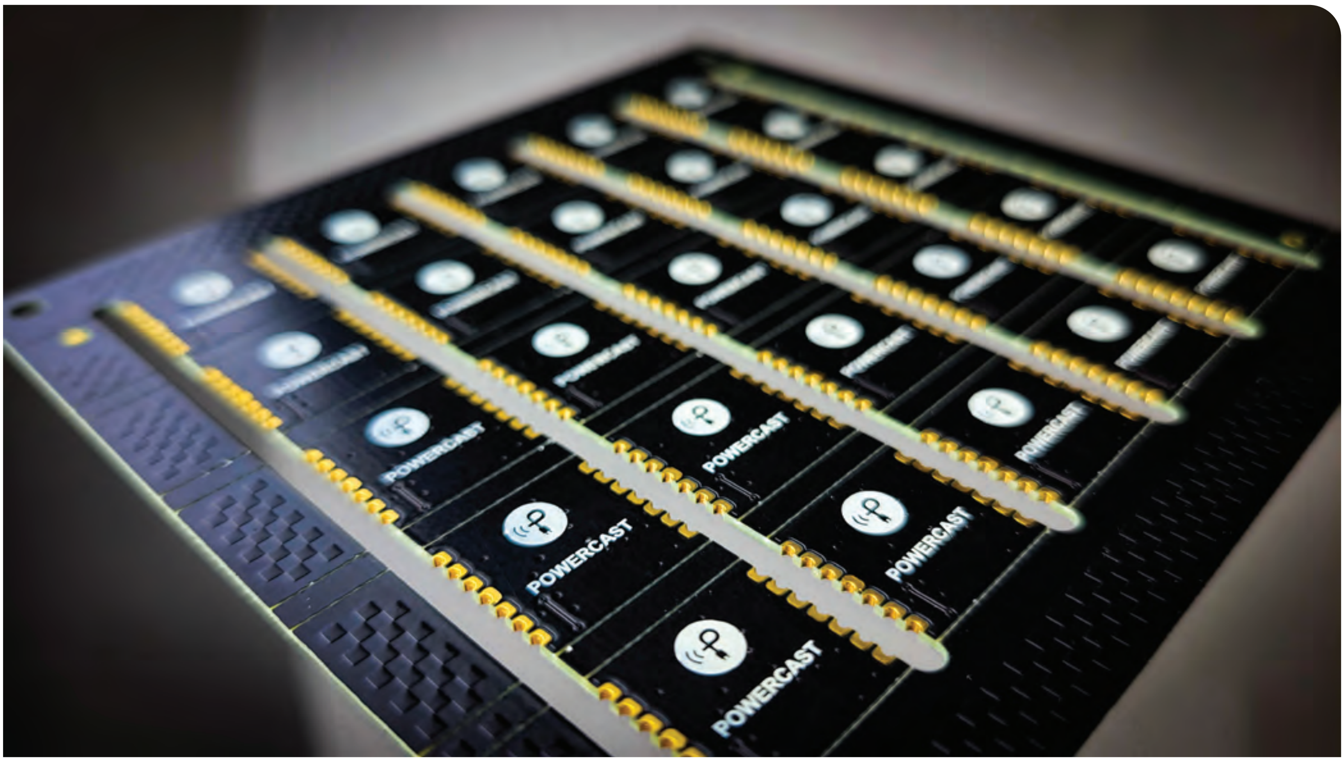


Wireless RF charging chips soar as the technology goes mainstream

The wireless, non-contact charging market has been 'emerging' since Powercast began developing its RF-based chips in 2003. In March this year the company announced shipping 10 million over-the-air Powerharvester chips in two years with 2022 orders at three-times their 2021 level. Power Electronics World spoke with Powercast's Charles Greene, PhD, chief operating and technical officer (COTO), about surging demand and prospects for a cord-free charging future.

A DESIGN ENGINEER once remarked that there can be a Grand Canyon-size gap between 'possible' and 'practical' when it comes to creating new consumer products. His point was that great ideas—like charging batteries wirelessly—remain ideas until all that is needed to turn them into products are in place. Until that happens, even the best ideas remain a glimmer in the eye.

For years, RF engineers understood it was possible to derive direct current (DC) energy by placing any one of a number of concept 'collectors' or 'harvesters' within range of the RF source. But development of the idea into even proof-of-concept devices tended to lag for a number of reasons including poor efficiency, materials limitations, the changeable nature of ambient RF energy levels and other impediments. Yet as often happens when technologies, material sciences, techniques and processes are refined across industries over time, what was once an obstacle paves the way for opportunity.

In the case of wireless RF charging, the idea-into-product transformational process was at least partly aided by the fact that by the early 2000s, a growing number of electronic products, or product sub-systems, were becoming more efficient. Battery technology was also evolving, including the advent of lithium chemistries (Li-ion, emerging Lithium-Iron, and others) that had much greater power density and suffered no memory effects like those seen with nickel-cadmium cells. Lithium cells could also be much smaller than other battery types with comparable outputs; they could also retain energy longer while idle.

Powercast's founders began their journey to capitalize on the potential of RF charging while other companies went different directions, such as those whose technological approach (Qi, for example,) led to the now familiar charging pads and surfaces targeting the mobile device market. Power Electronics World Technical Editor Mark Andrews spoke with Powercast's Charles Greene, COTO, about their developmental history of energy harvesting and how the company's recent sales milestones point to rapid growth within the RF portion of the wireless charging sector.

MA: How has energy harvesting technology progressed from its earlier incarnations (the tech from 3-5 years ago, for example) to the point where sizeable commercial orders are now being placed?

CG: First, a little history about Powercast. Powercast traces its start to a 2003 coffee shop meeting between several University of Pittsburgh wireless and RF (radio frequency) engineers. After that meeting, a small team set out to develop true wireless power solutions that could both eliminate batteries, and enable completely untethered devices that need no wires or charging surfaces. The team knew that if it could deliver long-range, power over distance that could remotely charge enabled devices, it would be a game changer for many industries and products. The team spent several years refining its over-the-air RF wireless charging technology that transmits a radio frequency (RF) whose energy can be 'harvested' to power devices embedded with a small receiver. They entered the market at CES 2007 where Powercast won CNET's Best of CES for Emerging Technology. Powercast has since amassed about 20 awards over the years: https://www.powercastco.com/company/awards/ Our over-the-air wireless power system has two parts – a transmitter and a receiver. Manufacturers embed Powercast's tiny Powerharvester® PCC110 receiver in their devices, which then harvests RF energy sent over the air from either an RF transmitter, an RFID reader, or other RF source. The Powerharvester then converts the RF to DC (direct current) to directly power a battery-free device, or recharge a device's batteries.

Powercast cut its teeth helping commercial and industrial customers power their wireless sensor networks (WSNs), waterproof designs, RFID tags, military devices and other designs ever since its initial RF transmitter, Powercaster®, was FCC approved in 2010. Then in 2017, Powercast entered the consumer electronics market when its new PowerSpot® RF transmitter got the FCC nod. Now, demand has grown so much that the company has shipped 10 million Powerharvester PCC110 chips in the last two years alone.

MA: *Has the device you are shipping now changed much since it first went to market?*

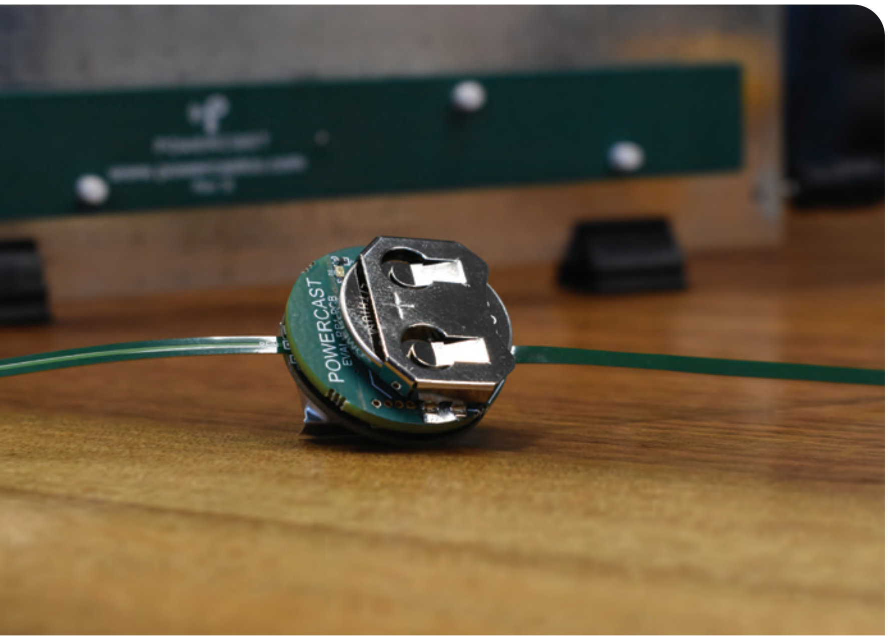
CG: Our Powerharvester PCC110, a tiny but powerful RF-energy-harvesting chip, has not changed in the past few years because it continues to be the most efficient and cost-effective power harvesting solution in the market. However, we are continuing to invest in research and development and are targeting new transmitters with even lower price points to enable more consumer electronics applications. The general awareness of RF wireless power/wireless charging and harvesting is increasing, which is driving more applications; more applications bring a reduction in price points for components and that opens more opportunities in the consumer electronics market.

MA: *Device sales in the millions are always noteworthy. How large is the market now and are we entering a new phase as IoT and other sensor-enabled products are becoming more common?*

CG: Due to the proliferation of IoT and low-power devices, we believe the TAM is easily in billions of units per year within the next couple years. Powercast sees the energy-harvesting market as 'Aggressively growing' every month/year, due to global organizations' increase in demand for untethered devices that are freed from wires, batteries, and placement restrictions. Powercast has been profitable since 2012, and we are seeing about a 50% growth per year for the last two years.

We not only see the existence of a viable energy-harvesting platform, but we also invented it. Our transmitter and receiver RF energy-harvesting system continues to be the most affordable and widely used to transmit and harvest RF signals. As we explore different harvesting frequencies, we confirmed the PCC110 receiver chip's ability to harvest ambient energy from Wi-Fi routers, and we see some energy harvesting all the way to the 28GHz (5G) range. We are expecting strong growth as consumer electronic devices using RF wireless harvesting are starting to be released to the public.

Powercast's Wireless Charging Grip for Nintendo Switch Joy-Con Controllers is the first gaming product that charges over the air without wires or mats.



➤ Powercast's smart-watch sized flex circuit recharging board (EVAL-FLEX1-PCB).

MA: *What sets Powercast technology apart from other wireless charging systems?*

CG: Firstly, we need to review the major methods of harvesting wireless energy and then I can better show what makes the Powerharvester different. Let's briefly look at the following:

- **Vibration** is the concept of converting vibration energy to electrical energy. This method is only ideal for machinery that vibrates.
- **UV/IR** energy must have direct line of sight between the transmitter and the receiver for it to work properly; any obstructions result in no power reaching the receiver.
- **Qi,** which is inductive charging requiring direct contact with a pad or other charging surface, is useful for high-power applications like phone charging that require Watts of power, but device alignment is quite restrictive as the transmitter and receiver must align a few millimeters apart.
- **Solar and wind,** in most cases, must be outdoors and therefore can be costly to build and can also be a bit limited in capabilities.
- **Radio frequency (RF)** does not require direct line of sight, is free of device placement restrictions, can deliver power into waterproofed enclosures, is low power (microwave to millimeter wave) and is more versatile than the processes previously mentioned.

One of the reasons we focus on RF-based harvesting is that radio frequency energy is all around us every day, everywhere we go. From the RFID networks in our stores and manufacturing facilities to the Wi-Fi routers keeping our devices online, to the signals constantly pinging our cell phones, RF is always working behind the scenes to keep us connected. While harnessing these existing RF signals (ambient harvesting) is technically possible, implementing dedicated RF transmitters is the more reliable option.

While there are several options for over-the-air power, RF is among the most dependable and scalable forms of wireless power transfer for both indoor and outdoor environments. In general, wireless power is more reliable than ambient RF harvesting, as it's identifiable and predictable. It's also easy to integrate RF wireless charging technology as it's not restricted by movement or exact placement allowing it to accommodate devices that induction cannot.

Some observations about Qi (pad charging) vs. contactless (over-the-air) charging: To begin, Powercast is not competing with Qi, and believes there is a need for both technologies. Qi is useful for high-power applications like phone charging that require Watts of power, while RF over-the-air wireless technology is appropriate for low power (microwave to millimeter wave) devices. Powercast believes that wireless power, whether contact-based Qi, or over the air, will only get bigger and more ubiquitous.

Consider this future scenario: Software will inform devices on what source to charge from – Qi if in contact and RF when further out. There will come a day when the charging and seamless handover from the blended platforms will make charging automatic. Tomorrow's users will enjoy devices that are always charged without thinking about it.

MA: *Since RF wireless charging is unlike technologies requiring coils and pads or the wired connection to an energy source that is common to Qi, how does Powercast compare to closer competitors?*

CG: Powercast's RF-to-DC power harvesting products have been in the market since 2007, and have been available through distribution since 2010, and are currently available globally through our distributor, Arrow Electronics. Powercast is the only RF wireless power company with product in the market at any significant scale, having shipped over 10 million chips in the past two years.

There are several competitors who have recently begun developing concepts to enter the RF-based over-the-air wireless power market. Their stories are creating a lot of interest which is helping drive the industry's thirst for over-the-air wireless charging, but these newcomers aren't shipping product into the market like Powercast is.

We have the most efficient energy receiving chip on the market, converting RF to DC with up to 75 percent efficiency. We believe we have competitively priced products already, but are still actively working on driving down the price of RF transmitters so that they can become ubiquitous and become the standard for charging low-power consumer devices.

There is significant market potential. As mentioned before, we believe RF energy harvesting and RF wireless power/charging is easily billions of units per year within the next couple years.

MA: *What role does energy harvesting play (or could play) in aiding global economic recovery following the COVID-19 pandemic?*

CG: Over-the-air RF wireless power and energy harvesting can help the economic recovery after the COVID-19 pandemic in many ways, from enhanced device functionality, to increased automation that could help alleviate the global labor shortage. Examples include:
- Medical and other devices with embedded RF power harvesting technology can be completely sealed and therefore waterproof, allowing easier cleaning.
- RF-powered wireless devices can use either rechargeable batteries, or no batteries at all, helping with the global labor shortage by removing the need to replace batteries.
- RF-powered wireless devices can automate certain functions to deal with staffing shortages.

An example is robots fitted with RFID readers that can change prices on electronic shelf labels (ESLs) as the robots roam by them in a store, instead of an associate having to physically change paper price labels.

Additional practical applications include battery-free sensing in hazardous material chambers or storage containers where it's dangerous for individuals to be around, and vaccine temperature tracking using existing RFID equipment.

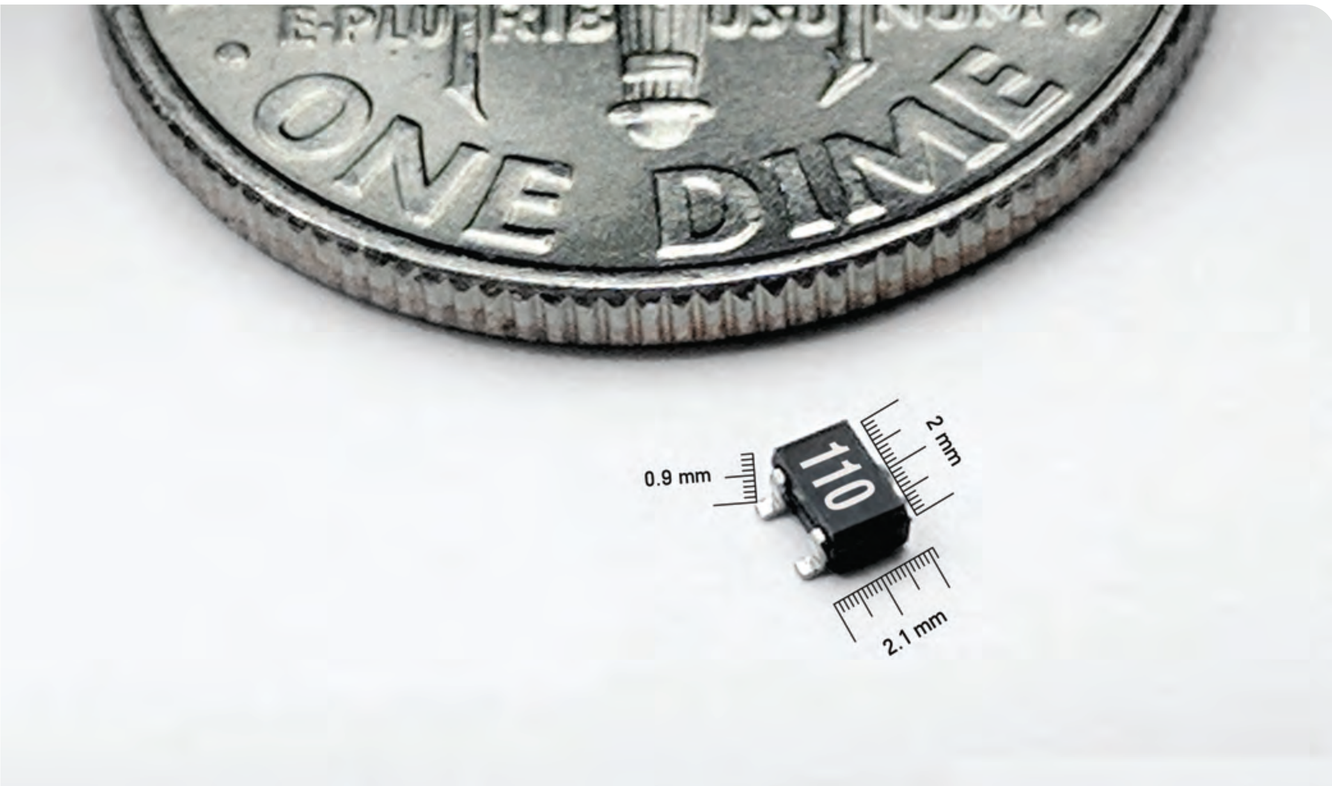
MA: *Sensors and power for IoT/IIoT devices have long been touted as key markets for energy harvesting. Are you seeing other application trends? Where may the future lead?*

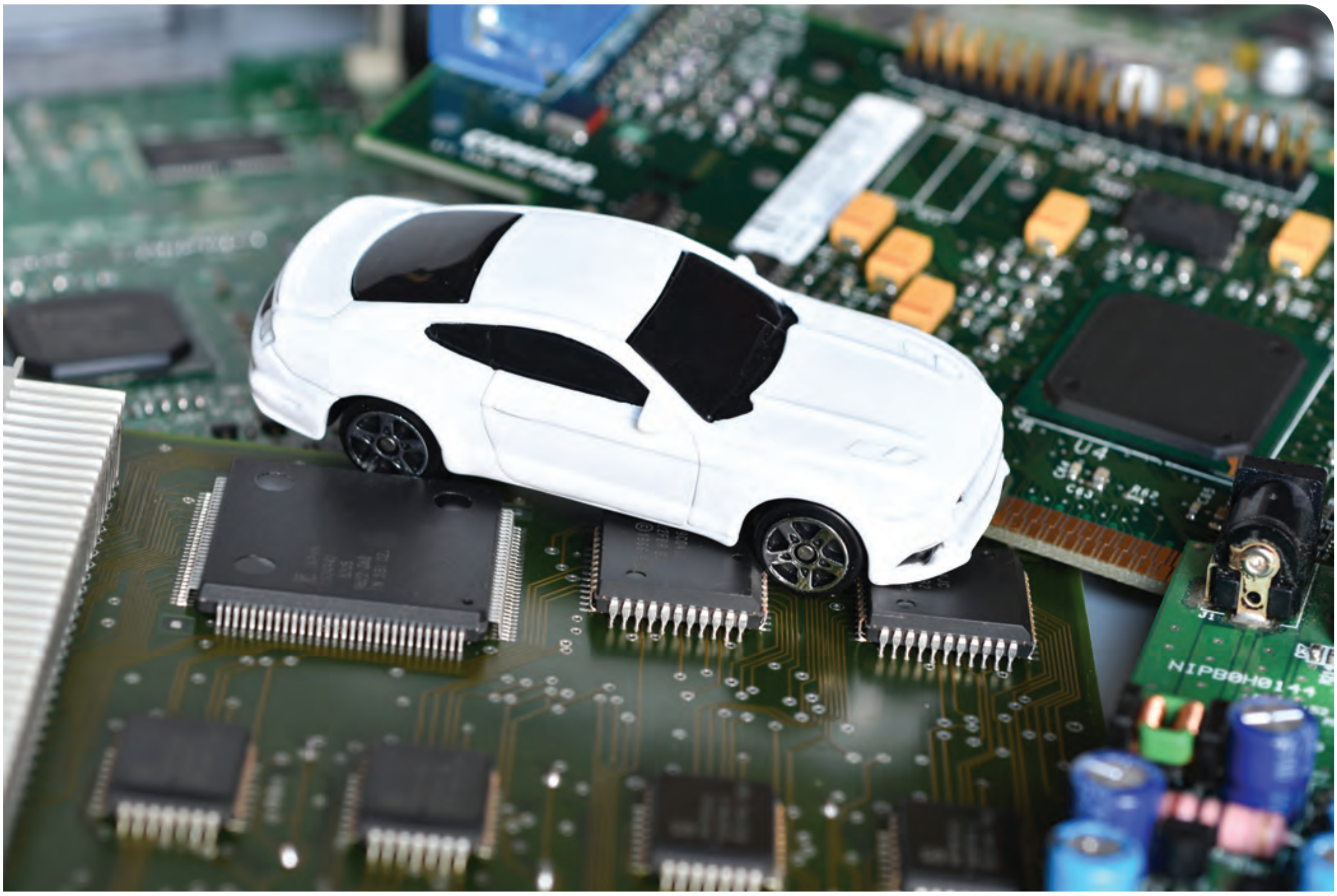
CG: One of Powercast's visions is to make disposable batteries obsolete and keep them out of landfills. Hence, the company helps its customers create environmentally-friendly RF-powered devices using either rechargeable batteries, or no batteries at all. The company's technology won a 2021 Sustainability Award for reducing battery e-waste.

In some cases, like a small powered device near a router or a transmitter, Wi-Fi could potentially power the device by harvesting nearby RF signals. By eliminating the need to replace batteries you also remove device downtime as employees service or replace the batteries. Without wires or the need to replace batteries, companies can deploy devices such as IoT sensors in remote locations where it was previously impossible.

Powercast's 'Powered by Powercast' video series shows real-world examples of over-the-air RF wireless charging technology in action, demonstrating how it can:
- Save time and money,
- Enable new functionality, and,
- Reduce battery e-waste.

> Powercast's tiny PCC110 RF-to-DC converter chip.





Strategy Analytics examines the on-going automotive power IC shortage

Shortages of automotive semiconductors including power electronics component-level devices and SoCs led to production shortfalls, idled workers, price hikes and empty sales lots throughout 2021—issues that persist into 2022. Power Electronics World asked Strategy Analytics' Asif Anwar to offer a second quarter update and explore the latest developments that continue to affect global transport markets.

BY ASIF ANWAR, DIRECTOR, PBCS, STRATEGY ANALYTICS

SEMICONDUCTOR SUPPLY was constrained in 2021 as the automotive industry competed with sharp increases in demand from mobile, consumer electronics and other end markets. The semiconductor shortage was further impacted by several other events including an earthquake in Japan, snowstorms in Texas, a fire at a Renesas facility and a severe drought in Taiwan.

Despite these challenges, front-end semiconductor production started to normalize, but the second half of the year was characterized by headwinds at backend processing facilities as a resurgence in COVID-19 cases there and at R&D operations in Malaysia, India and Taiwan hampered the ability of the automotive semiconductor industry to meet ongoing demand.

The combined impact of semiconductor shortages in general, combined with several other events (snowstorms, droughts, fires) served to limit the much-vaunted recovery in light vehicle production. Major OEMs steadily increased the frequency at which they reported adjustments to their production schedules during 2021, citing the ongoing impact of semiconductor shortages. Even those companies that were initially better prepared, e.g. Toyota, have continued to regularly advise of adjustments to their production lines because of the semiconductor shortage and other material constraints. The situation in Japan was also recently impacted because of an earthquake on March 16 which reportedly impacted the operations of a range of companies including Toyota, Nissan, Kioxia, and Renesas.

The frequency of announcements related to production adjustments declined as OEMs adjusted to the supply constraints. Alongside this was also an acknowledgement that OEMs did not fully appreciate the intricacies of the semiconductor supply chain. This has led to major OEMs publicly announcing deals with major semiconductor suppliers.

The stunted growth for global vehicle production in 2021 because of these semiconductor shortages has been in sharp contrast to the robust financials being reported by automotive semiconductor suppliers through 2021. This is reflected in rising backlogs with suppliers continuing to run at capacity to fulfil the robust growth in automotive semiconductor demand. The combination of strong demand and constrained supply also translated into semiconductor pricing increases. Current modelling predicts a slowing down in price increases from 2023 onwards with ASP year-on-year declines starting to see normalized rates of decline from 2028.

This will be tied with COVID-19 impacts lessening as more of the global populace is vaccinated and an assumption that further variants will have less of an impact on those vaccinated, easing the pressure on hospitals and reducing the requirement for lockdowns. On the other hand, it is to be noted that China is still maintaining a ‘zero tolerance’ approach, which at the time of writing has resulted in major cities, e.g. Shanghai, being put into lockdown; this is having an impact on vehicle production with more notable effects being reported in the second quarter of 2022.

It is notable that there are other challenges that will impact vehicle production in 2022, not least of which is the Russia-Ukraine conflict. As well as the effect on global vehicle production because of OEMs pulling out from Russia, the automotive semiconductor supply chain is having to deal with other factors. This includes the sourcing of raw materials such as iron and steel, the production and supply of wire harnesses, and the production of noble gases used in semiconductor manufacturing will also pose broader challenges to vehicle production. We believe these effects will be temporary as the OEMs, Tier 1s, automotive semiconductor suppliers and the rest of the supply chain adjust their sourcing arrangements. However, this will be coupled with a drop in consumer confidence as inflationary pressures bite into vehicle sales. This will translate into a slower recovery trajectory in 2022.

Semiconductor shortages will continue into the second half of 2022, but there is an inherent assumption that supply-demand dynamics will start to normalize towards the end of the year. While noting the potential for excess inventory build, most automotive semiconductor suppliers have entered long-term supply arrangements with their customers, and in many cases, these are NCNR (non-cancellable, non-returnable) agreements which provide a certain measure of protection.

We also expect that the pricing for strategic components that support the move towards electrification as well as associated trends of ADAS/autonomy, connectivity, domain/zonal and centralized architectures will not see a return to the same demands for year-on-year price declines as traditionally observed for mainstream automotive components. This should further help insulate suppliers from the risks of excess inventory, avoiding a false slowdown in 2023 and 2024.

In conclusion, the much-vaunted recovery in vehicle production failed to materialize in 2021, and the recovery in 2022 will also be more muted than originally forecast. Ongoing waves of COVID-19, coupled with risks to the supply chain due to material shortages and a decline in consumer confidence represent challenges and risks. Nonetheless, the industry move towards electrified platforms will underpin growing semiconductor content per vehicle and maintain growth for the automotive semiconductor industry.

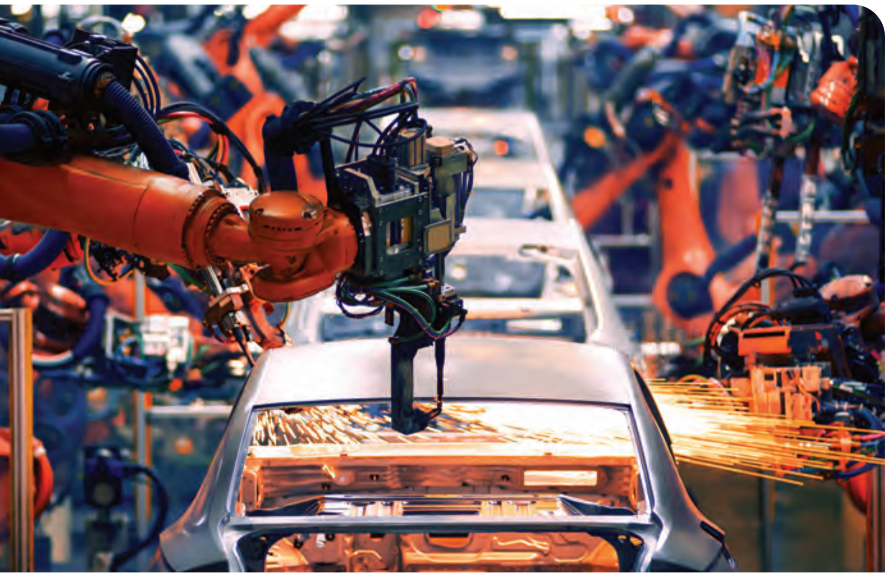
Automotive sector trends and opportunities

Power Electronics World Technical Editor Mark Andrews asked Strategy Analytics Director Asif

Anwar to examine the most recent developments affecting the on-going light vehicle semiconductor shortage, exploring where consumer demand and OEM production intersects with a finite supply of vital components including power ICs.

MA: *How are semiconductor manufacturers supporting their automotive customers in early 2022 compared to 2021 and 2020?*

AA: I wouldn't say that there is a measurable difference with the way that semiconductor manufacturers are supporting their automotive customers in 2022 compared to 2020 and 2021. Obviously, in 2020 and 2021, the automotive semiconductor suppliers were playing catch-up, and as highlighted, dealing with multiple issues that were beyond their control. What we are seeing is the direct relationship between OEMs and semiconductor suppliers becoming more pronounced, as OEMs recognise the strategic importance of maintaining sourcing arrangements for key components. This is helping semiconductor manufacturers to better plan their output to meet the needs of the automotive industry as they have greater insight into the demand outlook.



MA: *Has automotive IC production continued to increase?*

AA: The automotive semiconductor makers ramped up extra capacity in 2021 to meet demand. In many cases this was coupled with longer term actions, some of which were already in place and resulted in the opening of new facilities, e.g., Infineon, Bosch, Wolfspeed, etc., as well as ongoing investments in new capacity, e.g., TI (Texas Instruments). The foundational actions have already been taken and 2022 will start to see the results from these actions rather than being a year away.

MA: *What are current production levels and revenues (2022) compared to 2021, 2020 or even 2019?*

AA: Depends on the metrics being used. What we have observed is that semiconductor companies have continued to increase their revenues in the first quarter of 2022 by an average of 8% (quarter-on-quarter), suggesting that demand remains strong overall.

MA: *Are some power device shortfalls worse than others, and if yes, which areas seem to be the most problematic?*

AA: In the area of power devices, there is a growing demand for wide bandgap semiconductors with SiC penetration growing strongly, followed by GaN. This is the area that is being focused on by the automotive semiconductor suppliers and we see this reflected in the investment strategies of the major manufacturers. This includes signing sourcing deals for materials as well as making investments that will translate to vertically integrated capabilities so that they can offer material production through to packaged modules.

MA: *Is automotive production being affected by other issues besides a lack of some ICs / SoCs, such as supply chain gaps, higher component prices, materials shortages, or the move away from conventional power plants to EV drivetrains?*

AA: Yes, as highlighted above, there are several factors that are impacting automotive production besides the supply of semiconductors.

MA: *What is the latest picture on when power electronics component production could match demand?*

AA: The automotive semiconductor suppliers are making the requisite investments to keep pace with demand, but it is fair to say that we are only at the beginning of the cycle of investment needed as the market moves towards electrified platforms with an emphasis on fully electric vehicles. By 2029, we see electrified vehicles (mild hybrid, full hybrids, plug-in hybrids and battery electric vehicles) accounting for around 50% of global vehicle production. The market will accelerate towards battery electric vehicles as the government mandates, charging infrastructure and consumer knowledge and preference converge around this platform, and this will dictate the demand for power semiconductors and associated investment strategies.

MA: *Are there other power electronic devices besides automotive ICs that are in short supply, such as devices intended for household appliances, photovoltaic systems, consumer electronics or other applications?*

AA: This is not an area that I cover, but I'm not aware of any major issues related to supply. Household and consumer electronic applications are making use of GaN-on-Si technologies. The underlying Si-based production can meet ongoing demand and we see this reflected in the financials and milestone announcements of companies such as EPC, Navitas, GaN Systems, etc. For higher voltage/higher power applications including renewables, transportation etc., this demand is being met by both Si IGBT and SiC MOSFET technologies and I would suggest that supply is probably sufficient to meet demand given the comparatively lower volumes in these markets.

MA: *Are there indications that auto makers (and other manufacturers suffering from a lack of power ICs,) are changing designs or making other accommodations to keep operating?*

AA: Automotive OEMs adopted a number of strategies to address the challenges associated with semiconductor and other material shortages. This included:

- Allocation of semiconductor and other resources to production lines focused on the most profitable and/or high-volume brands and nameplates.
- Ongoing reduction in shift hours.
- Vehicles produced but with final finishing delayed until certain components are secured.
- Vehicles produced with certain non-critical components missing that allow a vehicle to be finished with the final production vehicle noting a minor reduction in aesthetics, performance, or fuel economy.
- Temporary shutdown of production lines

We've also seen OEMs now selling and delivering vehicles to the end customer with certain non-critical features missing. In these cases, the customer will then be contacted and asked to return to a dealer to activate the functionality once the components are available. We also see a move away from designing application specific standard parts, which will allow a MCU, for example, to be used across several applications in the vehicle rather than being consigned for a particular use. This provides greater flexibility and the practice is being adopted by both semiconductor suppliers and their customers.

We also see the adoption of more centralized software driven architectures being accelerated. This moves away from the distributed E/E architectures that have been employed by the industry for decades, and potentially allows for the number of ECUs to be reduced, as non-critical functionality can be virtualized in software and processing requirements uplifted into more power SoCs. This move towards use of domain controllers and zonal architectures is not expected to have a significant impact in reducing component demand in the short-term. But we see its use accelerating as the new platforms, which will by default be electrified, adopt these new E/E architectures almost exclusively.

Engineering simulation can accelerate Power IC production

Increasing the supply of microcontroller units (MCUs), switches and related devices is a continuing challenge as the world seeks a reset after two years battling the COVID-19 pandemic. But as viral variants continue emerging and manufacturers battle supply chain headaches, Power Electronics World asked engineering simulation leader Ansys whether multiphysics simulation can speed IC development including the power devices needed by automotive manufacturers and many other sectors. Ansys Director of Business Strategy Christophe Bianchi shares his insights.

BY MARK ANDREWS, TECHNICAL EDITOR, POWER ELECTRONICS WORLD

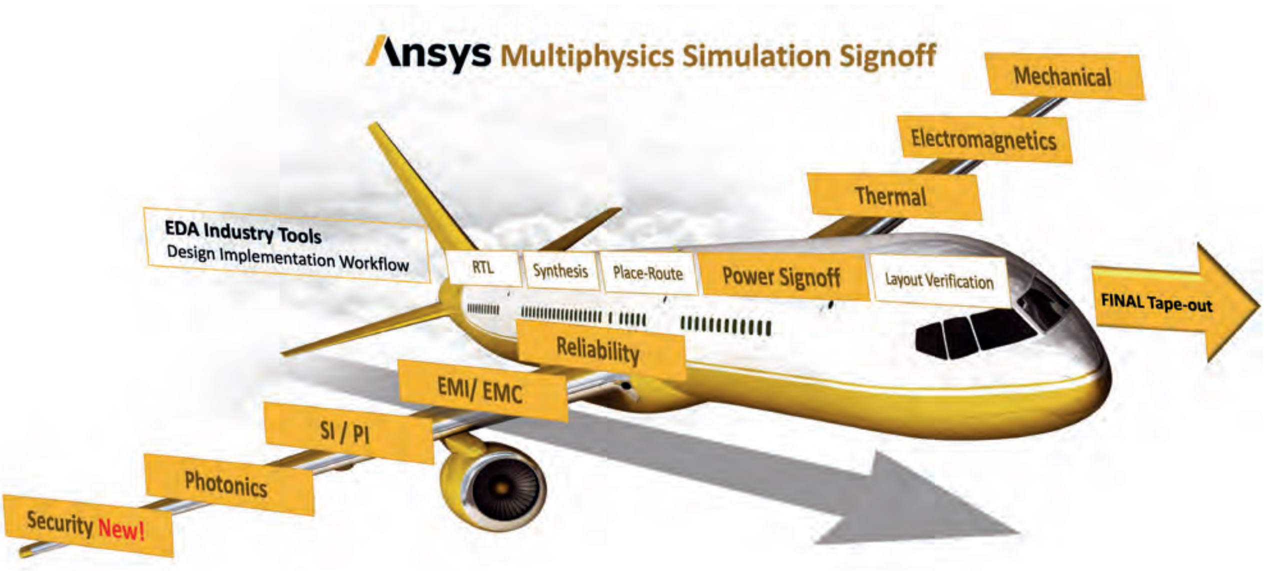
THE CHIPS for America Act. The European Chips Act. Initiatives by GlobalFoundries, Intel, Samsung, TSMC, and more – All are efforts by governments and manufacturers to grow semiconductor supplies when IC shortages of every type have dogged a global recovery following the calamitous years spent fighting COVID-19.

How are we doing? According to most measures, the semiconductor shortages faced by automotive, consumer electronics and commercial manufacturers are likely to continue through 2022 and into the first quarters of 2023. Shortages persist despite the fact that SEMI, the SIA and other global trade groups report that there are 60 semiconductor fabs under construction and that manufacturers have already increased production.

The what's and why's behind a persistent shortage of semiconductors have already been explored in this business magazine and many others.

Essentially, getting more devices into the hands of global OEMs and contract manufacturers is going to take time. Even though the extra capacity coming online later in 2022 through 2024 will no doubt ease the crunch, can anything be done now that has not already been tried?

One place *Power Electronics World* sought answers was with the engineering simulation experts at Ansys, a leader in the field that is constantly expanding its portfolio of simulation services that embraces not just the ICs that fabs manufacture, but also the in-plant processes of multiple industries.



➤ Ansys multiphysics simulation can speed the design process across device types while enabling faster review and approval cycles between team members

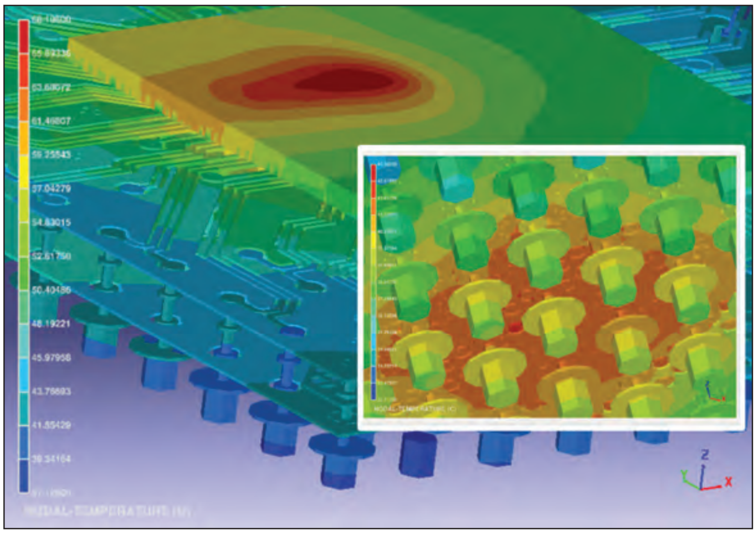
Engineering simulation has come a long ways since Ansys helped create the field 50 years ago. Today, engineering simulation offers the chance to test components in a virtual environment across thousands of scenarios that will materially affect device functionality, lifetime and adherence to specifications, amongst many parameters. Ansys reports that H3C Semiconductor, for example, uses the company's multiphysics platform to engineer an advanced processor chip for cybersecurity, AI and 5G backhaul applications, effectively improving product sign-off efficiency and accelerating product development. Through simulation, it is possible to ensure that, once in service, the chips meet the reliability, performance, and longevity requirements of their respective applications, Ansys stated. According to Ansys Director of Business Strategy, Christophe Bianchi, engineering simulation is already at work to improve quality and speed production by guiding designers away from likely-to-fail scenarios while speeding design by automatically applying years' worth of computational experience to test and verify myriad design options, materials parameters and other key metrics.

MA: *Is highly accurate engineering simulation best suited for the design phase of a new product, or can it benefit other key aspects of IC manufacturing to help close the gap between supply and demand?*

CB: Engineering simulation is pervasive across the entire engineering practice. Of course, the design phase is where trade-offs are made based on complex simulation, for example, thermal, mechanical, electromagnetic or Infrared. But simulation is also used to develop and optimise manufacturing processes, such as the Chemical-Mechanical Polishing (CMP) process, or tuning the performance of wafer handling in the fab. What we see becoming a critical use of simulation, combined with AI/ML technology, is the advent of digital twins of various manufacturing equipment (such as UV lithography tools). Here, the twin, running in the cloud or on the edge, provides invaluable information to pilot predictive maintenance and therefore optimise both performance and yield of these complex manufacturing processes.

MA: *How do today's most advanced engineering simulation programmes differ from previous generations?*

CB: Although performance and capacity remain two critical development threads in engineering simulation, for which the advent of distributed computing has provided a boost in productivity, there are two major paradigm shifts that new generations of engineering simulation impact design methodologies and product developments: Firstly, the multiphysics aspect of simulation becomes even more critical at advanced semiconductor nodes. With design margins shrinking even further, and complexity of products reaching new heights, it is now impossible to treat each phenomenon independently. The combined and interdependent effects of thermal, electromagnetic, radiation, mechanical stress, and power distribution variability must be assessed jointly in a true multiphysics way.

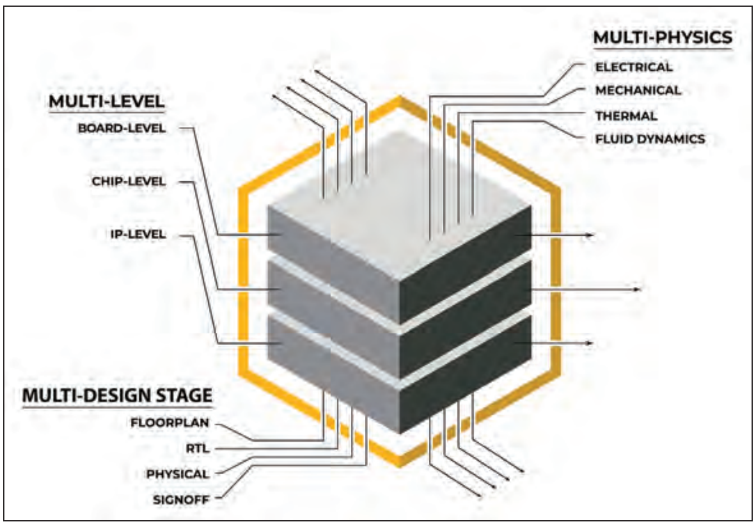


➤ Ansys multiphysics simulation can speed the design process across device types while enabling faster review and approval cycles between team members

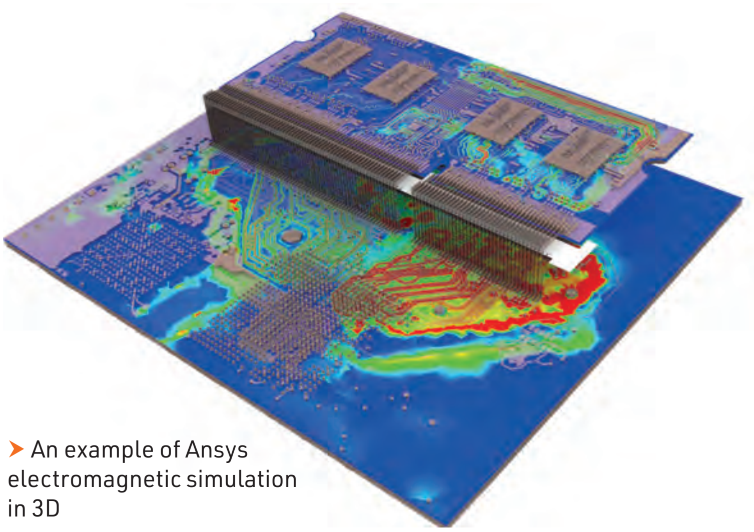
Another major shift is the advent of AI/ML methods assisting the designers and developers throughout their engineering tasks. With the increased complexity of today's most advanced engineering simulations, designers must explore much more complex solution spaces, and the help provided by AI/ML facilitates those efforts by assessing parameter sensibility, and design space optimisation using automatically trained reduced-order models for faster convergence.

MA: *Is it possible to estimate, if looking at a hypothetical product, how much time engineering simulation could save compared to developing said product without it or with outmoded tools?*

CB: I don't think it is a question of saving time when the alternative to simulation is prototyping. It is not



➤ Ansys simulation programmes can handle a wide variety of engineering requirements including IP validation and sign-off protocols



An example of Ansys electromagnetic simulation in 3D

just the exorbitant cost of prototyping (reaching above $1 million in advanced semiconductor nodes), but the sheer fact that the chances of silicon success without simulation is close to zero, and that is what makes engineering simulation an essential part of the design cycle. I cannot think of a situation where a design team would risk developing a product without simulation for the sake of development time.

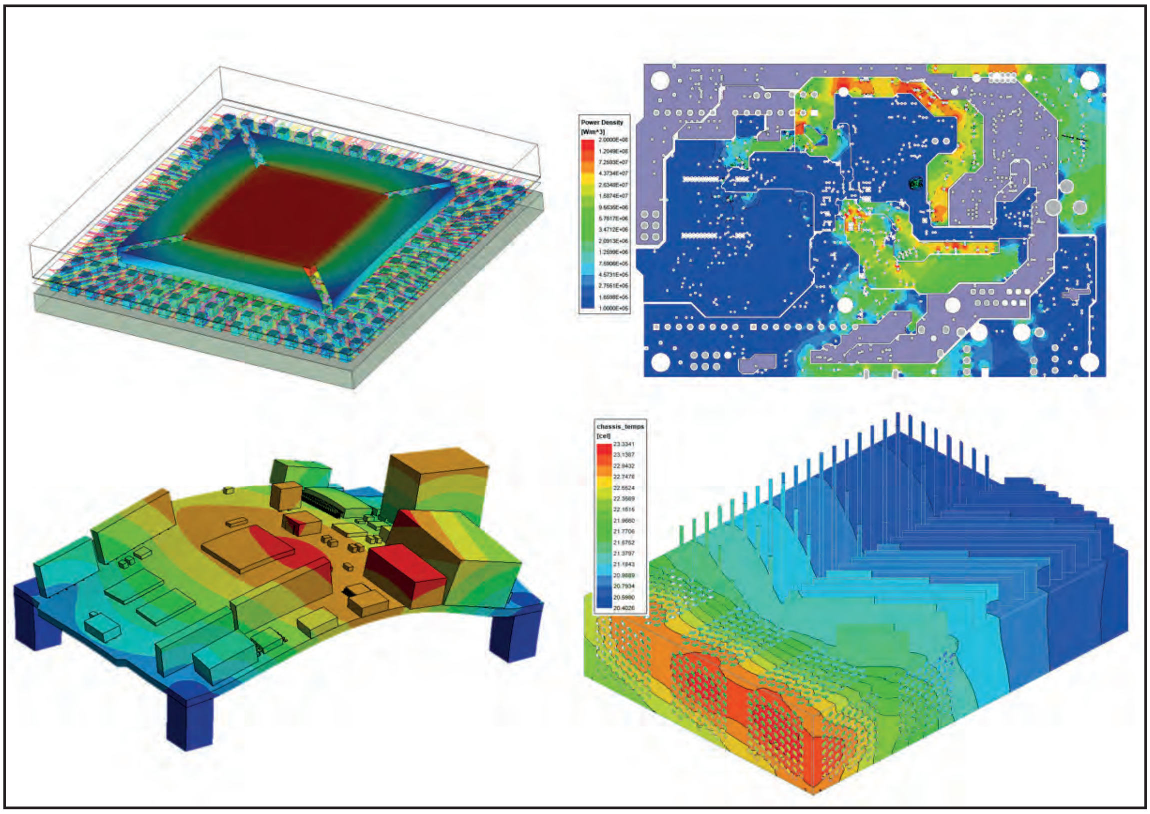
MA: *One challenge semiconductor manufacturers faced during 2020-21 that persists is addressing demand in a more agile fashion, such as rapidly changing what is being manufactured. Can engineering simulation help manufacturers rapidly retool?*

CB: The IC supply crisis the semiconductor industry is currently facing is more a capacity than an agility problem. As the most affected industry by this problem, the automotive sector did not foresee the impact of "just in time" inventory practices when facing fierce competition from computing and communication for the same manufacturing capacity. These industries rebounded faster during the pandemic and secured the wafer supplies, leaving no room for peak demand from auto Tier 1s and OEMs. Running at (or slightly above) full capacity, further agility would not really solve the IC shortage crisis.

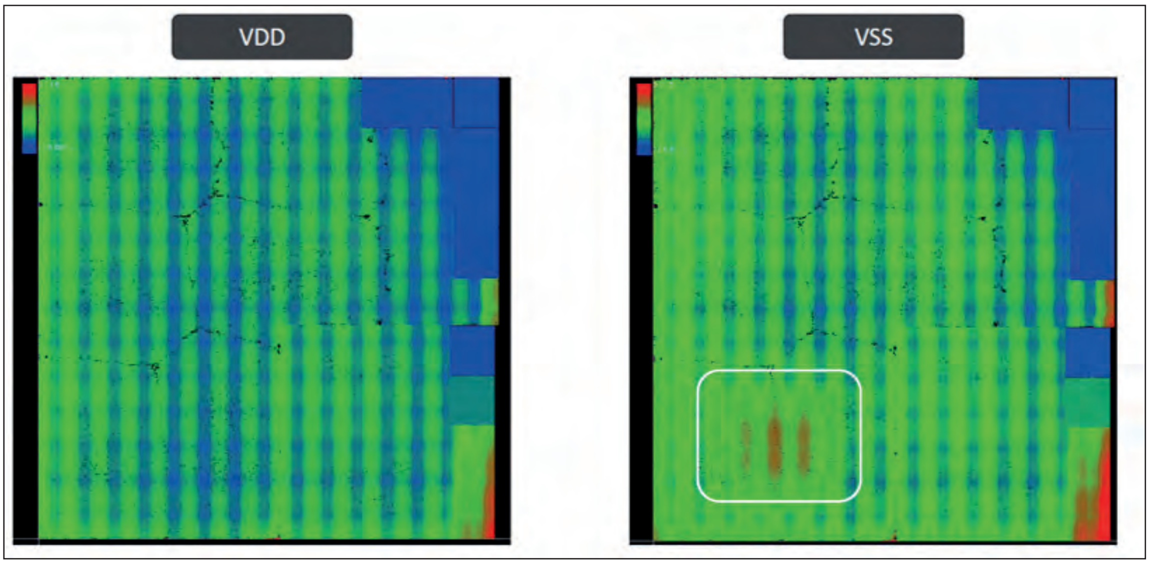
On the other hand, leveraging engineering simulation to tune and improve manufacturing yield has the potential to increase production throughout, without the delay and investment required for additional capacity. This is an area where several initiatives have been launched since the beginning of the crisis, ranging from modelling and simulation of process variability to digital twins of complete manufacturing toolchains.

MA: *If better engineering simulation can indeed shorten lead times in some circumstances, are there other factors manufacturers ought to consider to address rapidly changing customer needs?*

CB: In the automotive sector, the shortage of devices resulting from a combination of ultrafast demand change and a "just in time" inventory



A sampling of various multiphysics simulations at differing scales



➤ The Ansys Redhawk SC Security application assesses build quality metrics (BQM) and in this example detects a weakness in the VSS grid

strategy have been exaggerated by the extremely large number of different components required to equip today's cars. Calls for more standardisation and a move towards software-defined systems (using less and more standardised programmable devices) are two of the ways we are seeing improvements. But developing such multi-purpose devices brings an order of magnitude in the design complexity and requires significantly more simulation in the development and design phase.

MA: *Engineering simulation has grown more sophisticated and capable. Can you please describe key breakthroughs or developmental milestones that enabled this progress?*

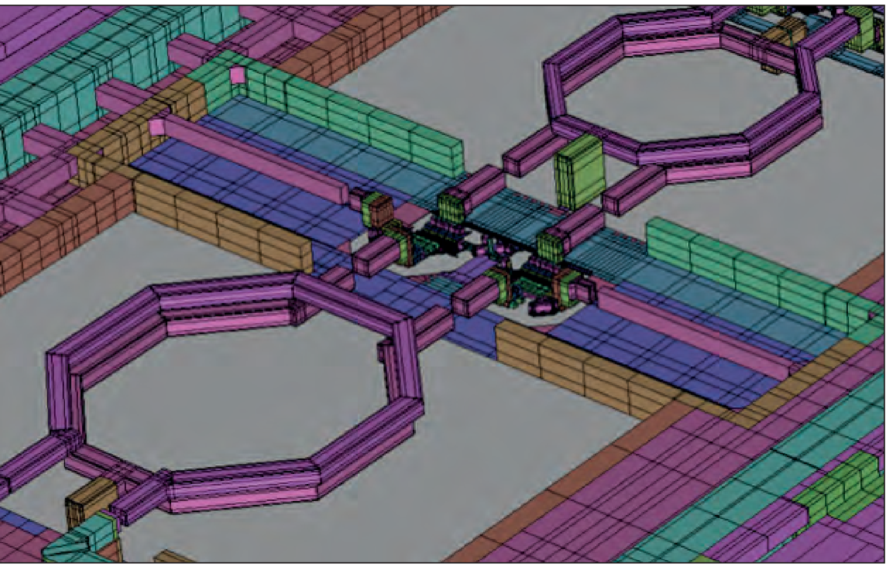
CB: Ansys has been refining the art of engineering simulation for the past 50 years and is not planning on stopping. Our history of acquisitions demonstrates the will to combine more and more laws of nature in our multi-physics solutions: for instance, we recently added photonics and optical simulation.

The main research and development axes that have increased the capabilities and sophistication of our solutions range from continuous research in numerical methods (For example, iterative solver methods, explicit/implicit/hybrid/bayesian computational model) to AI/ML improvement of the parametrisation of our solvers, high performance computing (task-based, shared memory, message passing, fine grain (GPU) and the future use of exascale and quantum computing) as well as platforms, workflows and data management - all targeting a more pervasive use of the cloud.

MA: *Can better engineering simulation enable a reduction in the number of prototypes a manufacturer needs en route to rolling out a new product?*

CB: Physical prototyping, in the development of semiconductor devices, is an extremely costly and time-consuming effort. A 7nm mask set costs about $15 million (3x the cost of 16/14nm node) and prices almost double when moving down to 5nm. But this cost remains small in comparison with the total development cost of the chip. (An advanced-node large SoC development is estimated to cost around $200-$300 million). Due to the large number of parameters (and physics) that can impact a chip's behaviour, performance and quality, simulation can provide a guarantee of convergence of the design effort, whilst solely prototyping would lead to an uncontrolled number of iterations.

Physical prototyping, in the development of semiconductor devices, is an extremely costly and time-consuming effort. A 7nm mask set costs about $15 million (3x the cost of 16/14nm node) and prices almost double when moving down to 5nm. But this cost remains small in comparison with the total development cost of the chip. (An advanced-node large SoC development is estimated to cost around $200-$300 million)



➤ A depiction of an RF coil simulation designed to detect potential flaws in the device makeup

MA: *Could you please describe some key ways developing a new device today is assisted by Ansys software compared to development with little to no engineering simulation?*

CB: Using engineering simulation enables the integration of physics constraints early in the design cycle. By taking into account the electromagnetic and Infrared effects at the planning level, designers can optimise PDNs (Power Distribution Networks) for higher performance (less DvD impact on timing), higher reliability (less fatigue and electromigration) and lower cost (optimised power grid).

What was a signoff, late-stage process in former design methods becomes a mandatory component of design planning and convergence for more complex advanced 3D ICs where multiple elements must be co-simulated in a true Chip-Package-System (CPS) view of the IR/EM/Mechanical and Thermal phenomenon impacting performance and reliability.

MA: *Many of today's advanced devices are developed by multiple engineering teams working on different aspects of the same project. How can engineering simulation aid dispersed design teams?*

CB: The physics impacting a chip's behaviour are not limited to the sub-system or component being developed by an individual contributor. These effects cross the system's hierarchy; creating physics-true bloc and chip models (power, electrothermal, etc.,) is essential to manage parallel engineering efforts. Let's consider, as an example, a 3D IC project that consists of 2 silicon dies in a complex package. These projects are usually split between 3 different teams (Die 1, Die 2 and Package). The computing and exchange of CPMs (Chip Power Models) of the two dies between the separate design teams is critical to avoid specific integration and EM/IR problems on each chip. This also reduces drastically the amount of data required to run the validation of each die (CPMs are compact models and replaced hundreds of Test Vectors). This issue is even more relevant when thermal analysis is to be performed as it is impossible, without using CPMs, to decouple heat emitters (dies) from the heat dissipater (package).

MA: *Developing future ASIC generations often begins with what worked in a previous generation. How can engineering simulation support faster, more accurate generational evolution?*

CB: The use of AI/ML to increase productivity and performance of design teams requires large amounts of data. When transitioning from Generation A to Generation B of a line of ASIC products, all the simulation and design data created in the previous generation is an extremely valuable dataset to train ML algorithms that will guide the designers in their new development. This data-driven method is becoming an essential component of the new design methodologies and must be combined with intelligent Simulation Data Management solutions to enable breakthrough productivity gains.

MA: *How can engineering simulation programmes benefit the development of entirely new devices?*

CB: Engineering simulation is as important in the case of a totally new product. And if historical data is lacking, our learning algorithms can automatically create the various configurations and parameter sets required to launch the simulations that will produce the data needed to build physics-informed optimisation solutions for the new design. Whether totally new or incrementally constructed, an ASIC is governed by the laws of physics and therefore must be modelled and entirely simulated, taking into account a large set of parameters (thermal, Infrared, electromagnetic, mechanical, etc.,) in order to guarantee first-silicon success.

MA: *Does engineering simulation aid in IP management and sourcing?*

CB: This is a very relevant question: what we are witnessing and supporting is the move towards stronger demand from IP users to IP suppliers for accurate, "true to physics" models for the IPs. These models are critical to the validation of the full system and the absence of such models can force an IP user to switch supplier. When moving from one technology node to another, even if the IP functionality remains the same, all these models have to be recreated as the physics (EM, IR, Thermal, etc.,) are highly process-node dependent.

MA: *Cybersecurity is a well-established concept, but device level security design adaptations are relatively new. Can engineering simulation help designers create ICs less susceptible to corruption?*

CB: In the emerging Internet-of-Things (IoT) market, data security and privacy are essential concerns for communication between a large number of ubiquitous edge devices and the internet backbone. While modern cryptography is heavily used in IoT devices to assure information security, it can be compromised by exploiting vulnerabilities in the physical implementation of underlying integrated circuits. Side-channel leakage analysis (SCLA) is a technique to extract sensitive information from sub-optimally protected hardware by probing a variety of physical phenomena, such as power consumption, electromagnetic radiation, and thermal emissions. As ICs cannot be altered in the field, it is essential to verify side-channel countermeasures in the pre-silicon design stage.

At the end of 2021, Ansys released a breakthrough technology (Ansys Redhawk SC Security) leveraging its multiphysics simulation platform that enables system-on-chip (SoC) design teams without hardware security background to predict and quantify design vulnerabilities to side-channel analysis and assess the effectiveness of their design.

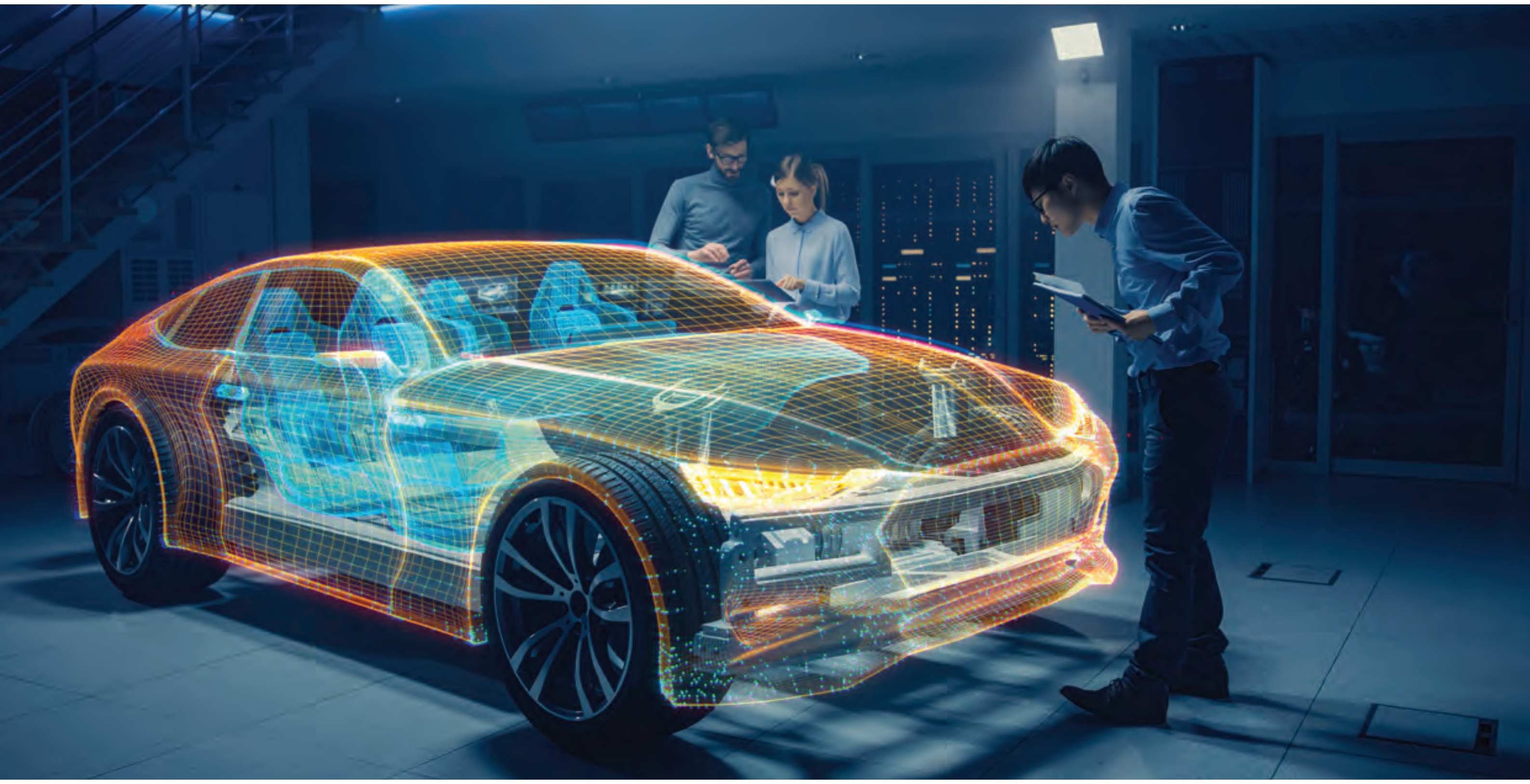
But security is also a system-level concern and, across the entire electronics architecture, we are using additional technologies (named Ansys medini analyse for Cybersecurity) that carry out system-oriented cybersecurity analysis strategy to quickly identify vulnerabilities and design weaknesses, and address them to mitigate any real-world threats by implementing key security analysis methods (TOE modelling, Attack Trees, Threat Analysis and Risk Assessment (TARA), Vulnerability Analysis, etc.) in one integrated tool.

MA: *Engineering simulation is rapidly evolving. Could you please consider what the future of this technology may hold for the semiconductor industry?*

CB: Engineering simulation will continue to broaden its scope to all industries as we are already seeing in fields such as Healthcare (with simulation assisted surgery and, on digital twins of human organs) and agriculture (with simulation-driven crop planning and autonomous farming machines)

From an underlying technology standpoint, we will continue to leverage the innovations in high-performance computing for on-the-cloud and on-the-edge deployment of simulation, along with continuous development of data-driven physics-informed machine learning methods.
The pervasiveness of simulation is also opening new avenues for Ansys with the structuration of a developers ecosystems around the pyAnsys Framework: a community for python developers wanting to embed our true-physics solvers into their project/market specific applications for further adoption of engineering simulation.

More physics will continue to challenge our engineering minds and engineering simulation will continue to bring the necessary proof points and validation to enable more innovative products.
As such, we are already deploying, with our most advanced users, simulation solutions for quantum physics, enabling what is believed to be the next revolution with quantum computing.



The billion dollar fab that could change industries

In an iconic moment for silicon carbide and electric vehicles, Wolfspeed opens 'the first, largest and only 200 mm SiC fab in the world'. What comes next, asks REBECCA POOL

On the day that Wolfspeed opened its 200 mm automotive-qualified SiC fab in Mohawk Valley, Upstate New York, the SiC tech supplier also announced a multi-year agreement with Lucid Motors, to supply SiC power semiconductors. Right now, these can be found in the luxury, all-electric Lucid Air.

The two industry developments go hand-in-hand because, as Lucid's senior vice president of product and chief engineer, Eric Bach, exclaimed at the company's ribbon-cutting event: "We need every single SiC chip that we can get." Indeed, a few weeks earlier, Rohm Semiconductor revealed that Lucid was using its SiC MOSFETs in the Air's on-board charger. However, the latest events also signal to the SiC industry that great things are coming.

Officially opened on April 25th and dubbed 'the first, largest and only 200 mm SiC fab in the world', the Mohawk Valley facility is churning out SiC MOSFETs and packaging these up into its XM3 half-bridge power module. Six of these SiC packages will be used in each Lucid Air power-train inverter, providing the low switching losses and high power density necessary for the sedan's modest-sized, 74 kg, 500 kW electric motor.

➤ Wolfspeed is making wafers for Lucid Air electric cars – an Air vehicle cuts the ribbon at the new 200 mm SiC facility.

The Air itself is Lucid's first production model, and has already won the *2022 MotorTrend Car of the Year*, beating the all-electric Porsche Taycan and Mercedes-EQ EQS. The vehicle boasts up to 1100 horsepower and an impressive range of 520 miles.

As Wolfspeed chief executive, Gregg Lowe – who perhaps not surprisingly drives a Lucid Air – highlighted at his facility opening: "This all-electric car has every whistle and bell you can imagine; it's breaking all kinds of electric vehicle records including driving range and recharge time."

Accolades aside, the new facility opens at a time when the buoyant SiC industry is bucking general, worldwide trends. Driven by electric vehicles, analysts predict billion dollar growth for the SiC market with France-based Yole Développement forecasting figures beyond $6 billion by 2027, up from $1 billion in 2021.

In preparation, SiC players far and wide, including Sanan IC, Rohm, II-VI and Infineon, have been building up production capacities. But what sets the new Wolfspeed facility apart is its 200 mm wafers.

Competitors are working on this larger wafer size – for example, STMicroelectronics announced its first 200 mm SiC wafers for prototype devices in July last year while Sanan IC has aired hopes of manufacturing many thousands of 200 mm wafers come 2024. Still, the Mohawk facility is the world's first 200 mm fab, which could accelerate the industry transition to the larger wafer size, given many companies work with legacy 200 mm silicon wafer equipment. Current yield figures are not available, but the larger-sized wafer is set to raise chip yields by nearly 85 percent compared with 150 mm wafers, helping to ensure the future wafer supply many manufacturers are still striving to truly secure.

Further expansion

Following Wolfspeed's billion dollar investment, the Mohawk Valley SiC fabrication facility comes in at 674,000 ft^2 and is home to a 150,000 ft^2 clean room. Coupled with expanding operations in Durham, North Carolina, Wolfspeed intends to establish what it calls a national SiC corridor along the US East Coast, and also raise SiC wafer and device production capacity by 30-fold, by 2024, from 2020 levels.

Looking beyond 2024, this figure is only set to swell. In its latest earnings call, on 4 May, for the third fiscal quarter of 2022, Wolfspeed revealed a revenue of $188.0 million, a 37 percent revenue increase compared to the same time in 2021, and up 9 percent from the previous quarter in 2022.

In the same call, Lowe also pointed to future capacity expansion saying: "A top priority going forward is increasing capacity for both materials and devices… Wolfspeed will very likely need to add more materials production as well as consider the construction of another wafer fab."

"At this point in time, I can't tell you precisely when and where, but it will certainly be sooner than we anticipated back at our Investor Day [November 2021]," he added.

This spells good news for manufacturers of SiC devices worldwide, the future SiC industry, but also the US East Coast, a region that many at Wolfspeed's ribbon-cutting event referred to as 'Silicon Carbide Valley'. While the Mohawk facility has already generated more than 200 jobs, come 2029 numbers are expected to rise to 600. And along the way, Wolfspeed has been investing millions of dollars in neighbouring SUNY Polytechnic Institute, creating an internship programme, scholarship scheme as well as two endowed faculty chairs, to secure its future workforce.

As SUNY Poly acting president, Tod Laursen, highlighted at the event: "We now have the opportunity to build a curriculum specific to the SiC industry, collaboratively with our industry partner [Wolfspeed]."

And his words were backed by New York governor, Kathy Hochul, who also said: "Tell us the skills that you need and we will make sure that our world class institutions in the Mohawk Valley are teaching those skills… [This] is where it's happening, I can feel the energy."

➤ Chief executive of Wolfspeed, Gregg Lowe, shows New York governor, Kathy Hochul, the manufacturing processes at the new SiC fabrication facility in Marcy, New York, US.

The Air itself is Lucid's first production model, and has already won the 2022 MotorTrend Car of the Year, beating the all-electric Porsche Taycan and Mercedes-EQ EQS. The vehicle boasts up to 1100 horsepower and an impressive range of 520 miles

Innoscience aims high at global GaN

With new operations in the US and Europe, China's Innoscience is increasing investment and ramping 8-inch GaN-on-silicon production for worldwide markets, reports REBECCA POOL

IF YOU WANTED yet more confirmation that GaN players anticipate significant market growth soon, China-based Innoscience recently launched design and sales operations in the US and Europe. Founded in December 2015 to develop high and low voltage HEMTs using its 8 inch GaN-on-silicon technology, the integrated device manufacturer has already shipped more than 30 million devices globally and is currently ramping production at its two China-based fabs.

As Denis Marcon, general manager of Innoscience Europe, tells *Compound Semiconductor*: "We have a very nice market share in China, which is getting bigger and bigger, so saw the opportunity to expand our market to Europe and the US. We believe that today's customers are now ready to move full speed into GaN, which is different to how things were several years ago," he adds.

While many GaN players are currently manufacturing GaN-on-silicon devices on 6-inch wafers, Innoscience has been focused on 8-inch production from day one. Marcon highlights how company founders always believed the market would 'explode', and wanted to make affordable chips within a large-scale manufacturing capacity and high-throughput silicon manufacturing processing that guaranteed security of supply. With this in mind, Innoscience opened its first fab in Zhuhai in 2017 with its second, Suzhou fab, following in 2020. Combined manufacturing capacity right now is some 10,000 8-inch wafers per month – with 4,000 wafers coming from Zhuhai and 6,000 from Suzhou – but this figure is expected to rise to around 70,000 come 2025, as expansion at Suzhou continues.

Critically, the fabs are kitted out with the latest 8-inch manufacturing tools, including Aixtron G5+C MOCVD reactors – Marcon reckons the company can produce nearly twice as many devices on an 8-inch wafer compared with a 6-inch wafer. And the already automotive-qualified Zhuhai fab is expected to churn out devices for automotive applications

➤ On-board charging is a market that Innoscience in targeting.

come 2024. “We really invested in production and people used to ask are you going to need that much capacity?” he says. “But now we have a lot of capacity – and huge market requests.”

Delivering HEMTS

Innoscience is currently manufacturing low-voltage, 30 to 150 V, and high-voltage, 650 V, enhanced-mode HEMTs. As Marcon points out, the company has worked hard to reduce specific on-resistance and shrink device size by depositing a stress-enhancement layer after gate formation, during epitaxy. He also claims both $R_{DS(ON)}$ and off-state leakage show excellent wafer-to-wafer reproducibility, with both wafer and device yields being high.

“Many companies focus on either low or high voltage devices – as far as I know, we are the only one that competitively offers both in several applications,” says Marcon. “And as well as performance, we offer the largest volume capabilities with strong security of supply.”

So far, power delivery and fast charging has been a key market for Innoscience, with the company also making in-roads to DC-to-DC conversion in data centres and LED drivers. But, of course, electric vehicle markets are key, with Marcon describing lidar laser drivers and DC-to-DC conversion within electric vehicles markets as ‘low hanging fruit’. “I think we will also reach 650 volt on-board chargers in the near future and then of course there is the main power inverter which is where we all want to go to,” he says. Marcon isn’t overly fazed by market competition from technology-rival, SiC, here. “We already have a nice history and I think the main battle, especially at 400 and 800 volt, is going to be on price, and our intrinsic cost will be more competitive than silicon carbide,” he says. “But what is missing right now is 1200 V GaN - this is something that we are thinking alongside multi-level conversion as a possible alternative [solution].”

But what about GaN’s age-old reliability concerns? Like many in the industry, Macon believes these are no longer a real issue. As he puts it: “There is tonnes of reliability data and we’ve been carrying out a lot of advanced reliability tests.”

Marcon also points to Texas Instrument’s links to the JEDEC JC-70 Committee for Wide Bandgap Power Electronic Conversion Semiconductors, which recently devised test methods and circuits for continuous switching of GaN power transistors. “We really need to keep working with JEDEC on qualification, which will provide good consumer confidence,” he says. So what now for Innoscience? Besides new US and Europe operations, recent news reports from Asia indicate the company recently won nearly CN¥ 3 billion, some £360 million, in investment funds and now intends to get GaN into as many applications as possible.

For his part, Marcon reckons it will take years for industry players, currently working with 6-inch wafers, to make the transition to 8-inch substrates and deliver wafer capacities that match Innoscience’s present volumes. “We are not yet so well-known in the Western world but this is changing very quickly,” he says. “We are the largest IDM fully-focused on GaN technology, have more R&D engineers than many companies have employees, and want to see GaN in widespread use.”

“So we will now put ourselves in partnership mode and want to form collaborations to see how we can make this happen faster,” he adds.

Bosch steps up SiC chip production

With SiC chips flowing from its Germany fab, Bosch has its sights firmly set on leading the electromobility market, reports **REBECCA POOL**

➤ Ralf Bornefeld, Bosch Senior Vice President of Automotive Electronics. [Bosch]

IN RESPONSE to the ever-buoyant SiC device market, Germany-based Bosch has laid out plans to start volume production of its SiC power semiconductors. As part of its December 2021 announcement, Bosch board member, Harald Kroger stated: "The future for silicon carbide semiconductors is bright. We want to become a global leader in the production of SiC chips for electromobility."

And as Ralf Bornefeld, senior vice president of the engineering and technology heavyweight's Automotive Electronics division tells *Compound Semiconductor*: "It's pretty simple. We've been developing this technology for a long time and are now market-ready – customers trust our automotive history and want to use our chips."

More than a decade ago, Bosch started research on how to fabricate SiC semiconductors, homing in on SiC trench MOSFETs with a vertical architecture following its successes with silicon-based MEMS sensors. Here, a high-aspect ratio plasma etching process, known as the Bosch Process, had been developed to create deep, steep-sided holes and trenches in wafers.

Fast forward to today, and Bosch has applied the technology to SiC, with Bornefeld firmly believing his company's vertical MOSFETs will have the edge on competitor's planar devices. "The trend is to shrink the cell design and save SiC area, and thus cost – so we have used this technology right from the beginning," he says.

Bosch's target market is electric vehicles, with the company intending to fabricate devices for traction inverter, onboard-charging and DC-DC conversion applications. According to Bornefeld, thanks to the high power and high voltage operation, and high semiconductor-count demanded by traction inversion, this application holds huge appeal for SiC semiconductors.

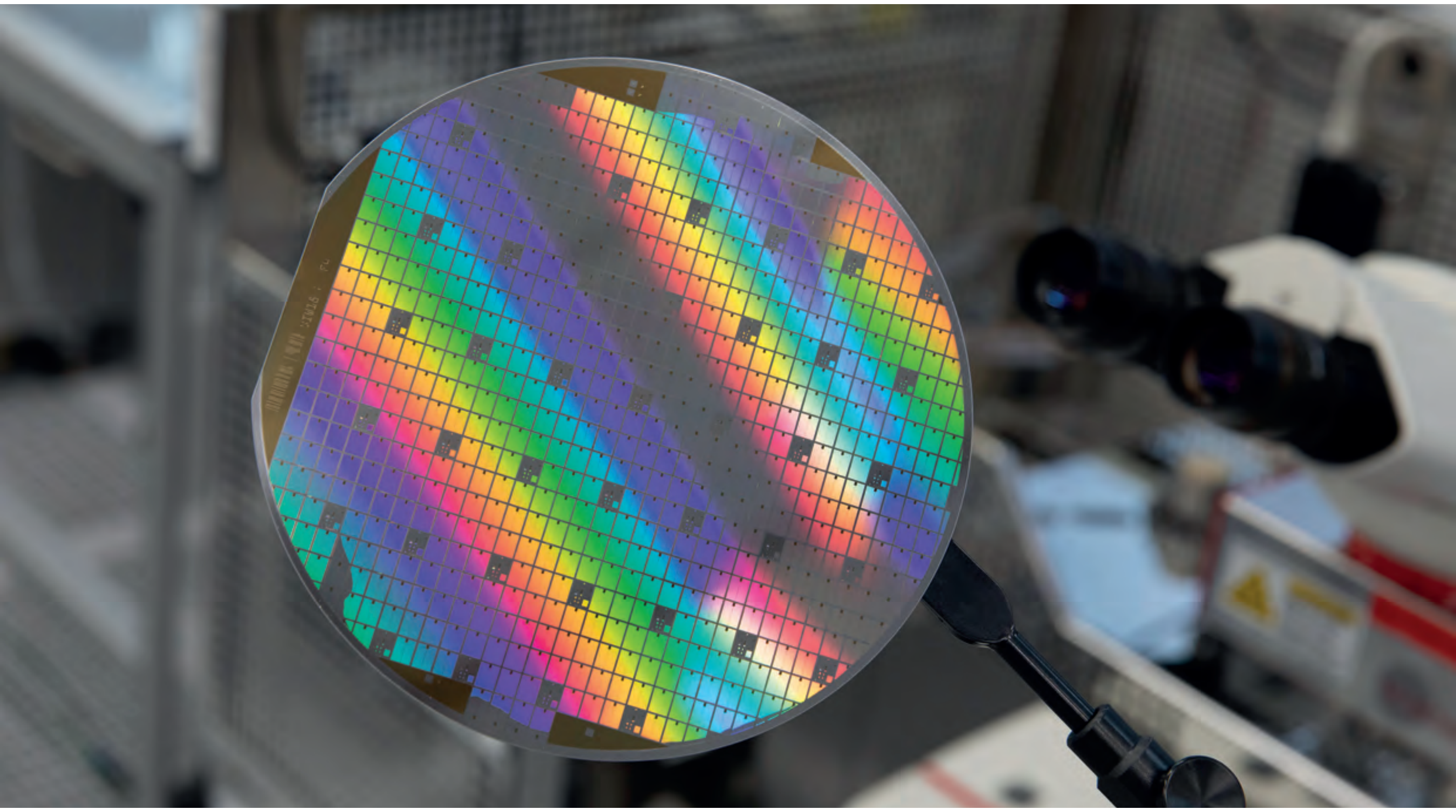
But the Bosch executive is equally confident that the technology will make strong in-roads into onboard charging and DC-DC conversion, despite competition from GaN-based devices. Pointing to onboard charging, he highlights how the market is veering towards fast charging, which could require high voltage battery packs – in the 800 V range – operating alongside 1200 V SiC devices. "If this trend holds, I do not see gallium nitride being a competitive technology here in the foreseeable future," he says.

Still, Bornefeld confirms Bosch is also active in GaN and has some ideas that are in their very early stages. In the meantime, all eyes are on the latest activities at the company's Reutlingen wafer fab, which has been producing SiC chips for customer validation since early 2021 and is now expanding clean room space at the facility.

Alongside expansion, silicon chip production is being shifted from Reutlingen to Bosch's recently opened 300 mm silicon wafer facility in Dresden, which as Bornefeld highlights, frees up space for SiC manufacture and a transition from 150 mm to 200 mm wafers. "We've already started running 200 millimetre silicon carbide wafers on our line," he says. "I cannot say exactly when the wafer transition will happen but it could be somewhere between 2024 and 2026."

So what now for Bosch? The company is currently heading up the €89 million European Union-funded Transform – *Trusted European SiC Value Chain for a greener Economy* – project. The 34 organisations aim to build a competitive European supply chain for SiC-based power electronics devices in myriad applications, including industrial drives, power conversion, renewable energy and, of course, electric mobility.

"Silicon carbide is a core technology that will be seen as important by every region in the world,"



says Bornefeld. “I am a friend of open markets in general... but given the geopolitical tensions we sometimes see, Europe could act as what I would call a ‘neutral zone’. Also, having a complete value chain should make Europe stronger,” he adds.

And of course, manufacture of 750 V and 1200 V SiC MOSFETs continues apace, with the company developing its next generations of SiC chips along the way. Bornefeld confirms future MOSFETs will be based on its tried-and-tested vertical chip architecture, the trench MOSFET, but these smaller devices will be ‘constructed differently’.

“We’re developing the technology for the next generation, and the generation after that,” he says. “We have a lot of ideas on how to make our silicon carbide technology last for a long, successful future.”

➤ Bosch is ramping its SiC production capability [Bosch]

Audiophile amplification gains from GaN

Exceptional switching characteristics of GaN FETs underpin a new era in high-fidelity amplification

BY LEO AYZENSHTAT FROM ORCHARD AUDIO

FOR MORE THAN half a century lovers of hi-fidelity have argued over the best technology for making audio amplifiers. Sitting on one side of the divide are the valve aficionados, who claim that tubes are the key to providing an engaging, unfatiguing and rewarding listening experience. In the other camp are the fans of the transistor, who view this as by far the better option – one that delivers a realistic, powerful and faithful delivery of the recorded medium.

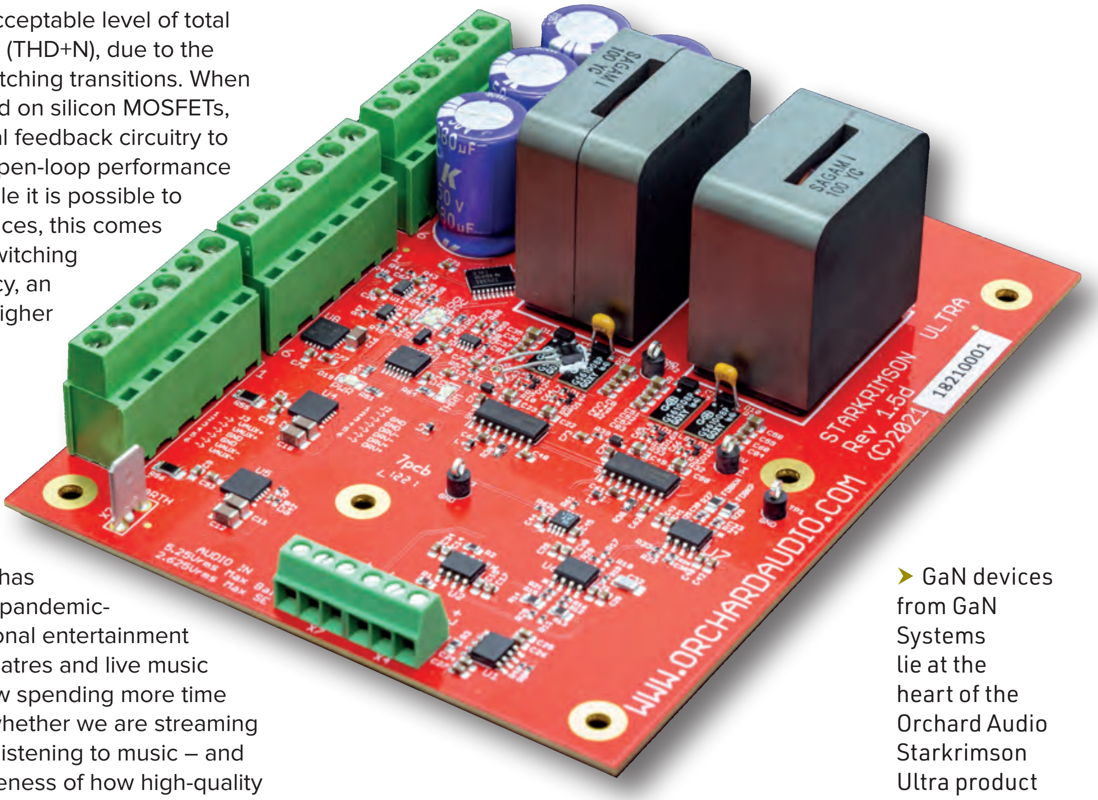
For those that prefer solid-state technology to valves, a decision now awaits. Do they hold on to their cherished amplifier that sports silicon transistors, or do they trade it in for a new breed, built around wide bandgap devices? It is not a difficult decision, because if they do invest in the future, they will reap many rewards.

The benefits are not limited to a better sound for the outlay, but extend to practical gains, such as a far smaller footprint and a higher efficiency that trims household bills.

Over the last decade or so, there has been an increase in sales of all forms of Class-D audio amplifier, which operate at high switching frequencies. With this mode of operation it is challenging to realize an acceptable level of total harmonic distortion + noise (THD+N), due to the need for faster, cleaner switching transitions. When class D amplifiers are based on silicon MOSFETs, they incorporate substantial feedback circuitry to compensate for the poor open-loop performance and subsequent noise. While it is possible to reduce this with larger devices, this comes at the expense of higher switching losses, diminished efficiency, an increase system size and higher material costs.

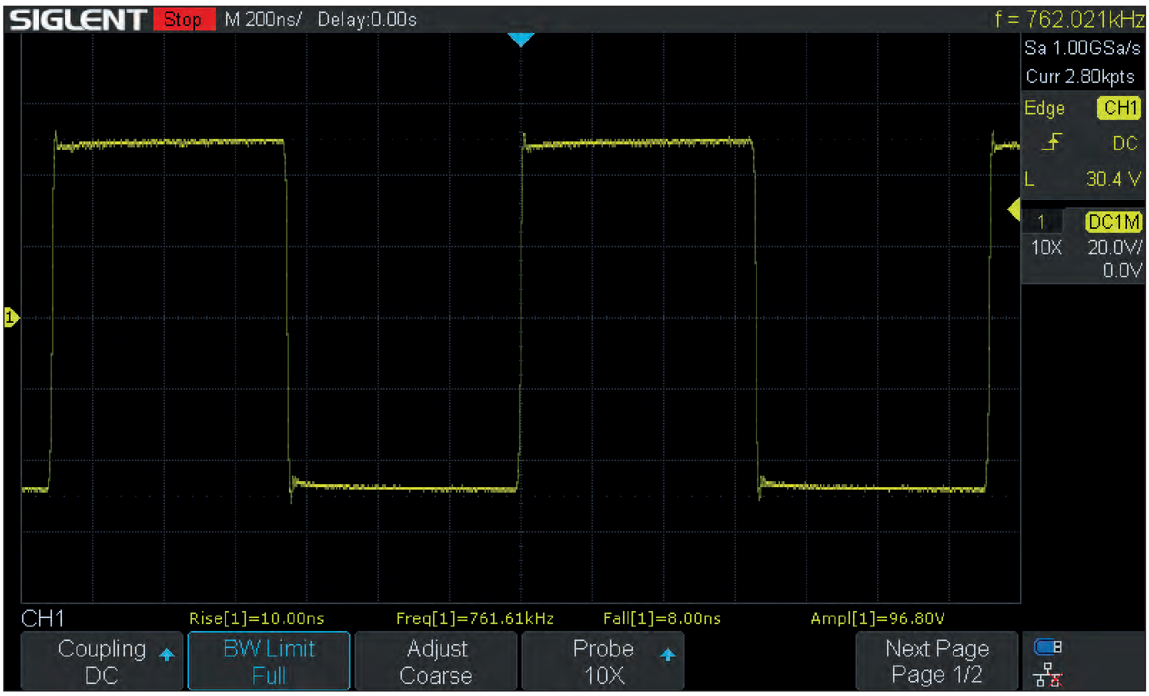
All these issues are not just of concern to high-end audiophiles, who will pay thousands and thousands of dollars for an amplifier. Over the last few years home audio has changed, partly due to the pandemic-driven shut-down of traditional entertainment sources, such as movie theatres and live music venues. Many of us are now spending more time with our audio systems – whether we are streaming movies, playing games, or listening to music – and this has heighten our awareness of how high-quality home audio systems can enhance our listening experience.

Market analysis supports this view. Those in the know are pointing out that demand for high-quality audio is fuelling the growth of the Class-D audio amplifier market, which is tipped to reach $4.92 billion by 2026. This class of amplifier is being deployed in ever more audio applications, including home theatres, high-power smart speakers, pro-touring amplifiers, portable speakers, automotive, marine, and power sports.



➤ GaN devices from GaN Systems lie at the heart of the Orchard Audio Starkrimson Ultra product range.

At Orchard Audio of Succasunna, NJ, we are playing our part in the audio revolution by launching a portfolio of products that feature amplification with GaN transistors. We have adopted these devices because they have exceptional switching speeds. Several benefits result from this attribute: very fast slew rates, which are much valued in a class D amplifier, because this narrows the gap to the ideal square wave (see Figure 1); incredibly precise timing, critical to realizing high-quality audio; and improved efficiency, with amplifier topologies being able to



➤ Figure 1. The Starkrimson Streamer Ultra operates with a very fast slew rate of around 10,000V/µS. This narrows the gap to the ideal square wave.

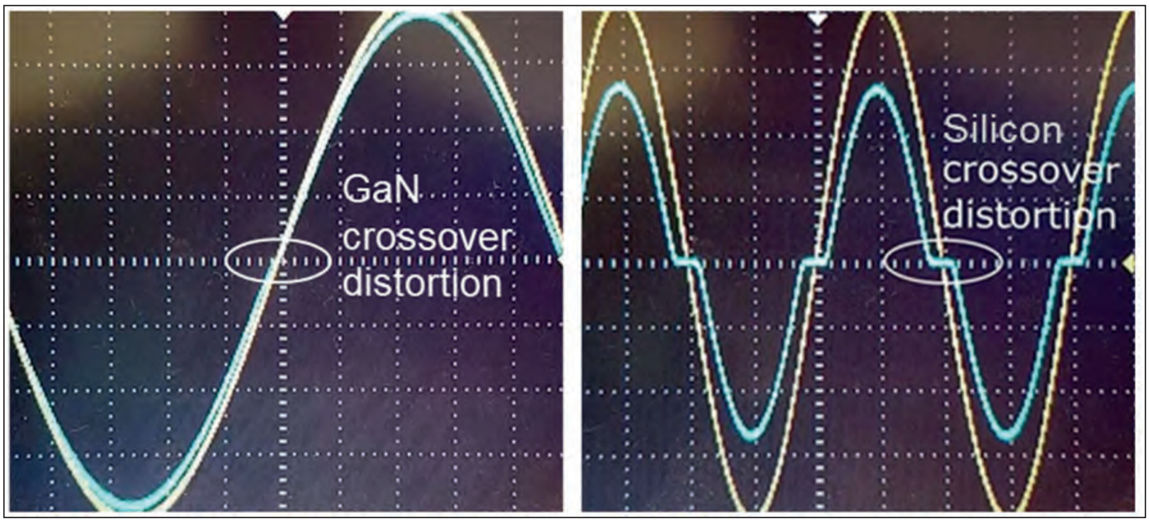


Figure 2. GaN devices result in a far lower crossover distortion than silicon incumbents.

operate with a much shorter dead time, an approach that leads to a much lower cross-over distortion (see Figure 2).

Another benefit of using GaN transistors is that it makes it much easier to design a circuit with no or very limited ringing. Minimising ringing is highly valued, because it eradicates EMI issues and prevents noise. By turning to GaN, our amplifiers combine decreased noise with less distortion, better transient response and a higher bandwidth.

But what does all this mean when it comes to sound quality, the most important metric of all? Well, quite a lot – our amps are renowned for their reduced harshness, cleaner highs, better transparency, and greater audio detail.

Like other electrical units, such as power supplies, using GaN rather than silicon also delivers benefits at the system level. There is a trimming of the cost of other system components, including capacitors, heat sinks, and inductors.

As well as a reduction in the total bill for these components, they are smaller and lighter. Thanks to this, amplifiers built with GaN can be around one-quarter the size of silicon equivalents.

Figure 3. The Starkrimson Streamer Ultra combines a digital-to-analogue converter, an amplifier and a streamer inside an easy-to-use enclosure.

That's a big selling point for potential customers with small homes, and for those that don't want a stack of large audiophile units in their living room.

Why GaN trumps SiC

You may be wondering why we are making our amplifiers with GaN rather than SiC, the other commercialised wide bandgap semiconductor. Well, there are several reasons – some are related to audio, and other due to cost and practicality.

One of the downsides of SiC is that it is not that good at switching at high frequencies. What's more, it's hard to drive this class of device at a high frequency. In comparison, that's not an issue with GaN, thanks to its much simpler, lower-voltage gate drive. Additional attributes of GaN are its low gate charge, zero reverse recovery and flat output capacitance; all of which yield a high-quality switching performance.

Where SiC has enjoyed most of its success is at high voltages, typically 1200 V. Audio amplifiers do not require such high voltages – and for the mid- and low-range voltages where they do operate, GaN has far lower switching losses. For example, at 650 V, switching losses for GaN are at least three times lower than those for SiC.

Even if SiC devices were as good on paper as those made from GaN, there are plenty of reasons to shy away from them. SiC devices are more pricey, and compared with those made from GaN there are limitations associated with both their supply and the supply chain. Amplifiers built with GaN can also enjoy a greater power density than those made from SiC, delivering savings in size and weight.

An expanding portfolio

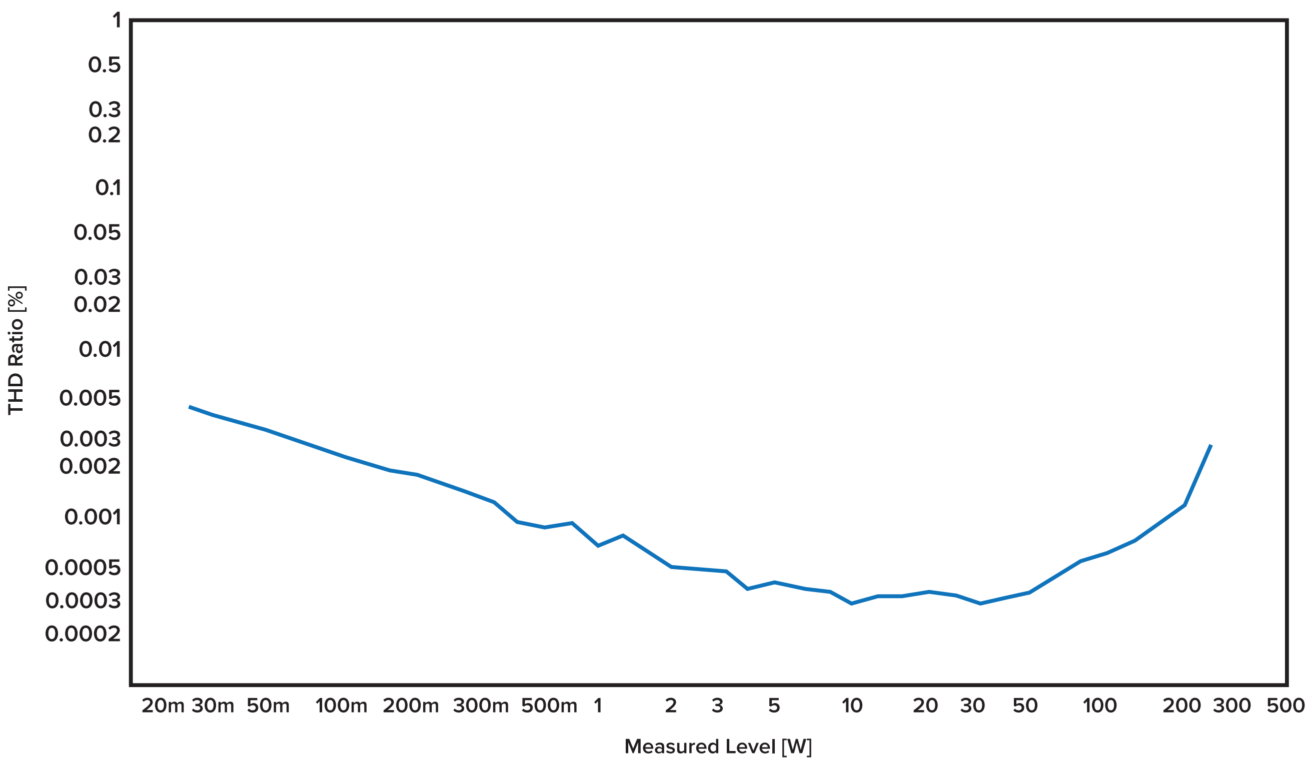
With a goal of delivering the ultimate sonic listening experience, we are continuing to expand our product portfolio. Our range currently includes expertly designed high-performance digital-to-analogue converters (DACs), streamers, and amplifiers. These products are helping consumers to elevate the sound in their home theatres, listening rooms, and recording studios.

Our belief is that every aspect of sound can be measured, a philosophy that underpins our research and development efforts. We are focussed on achieving the best possible objective measurements – and delivering the ultimate, subjective results.

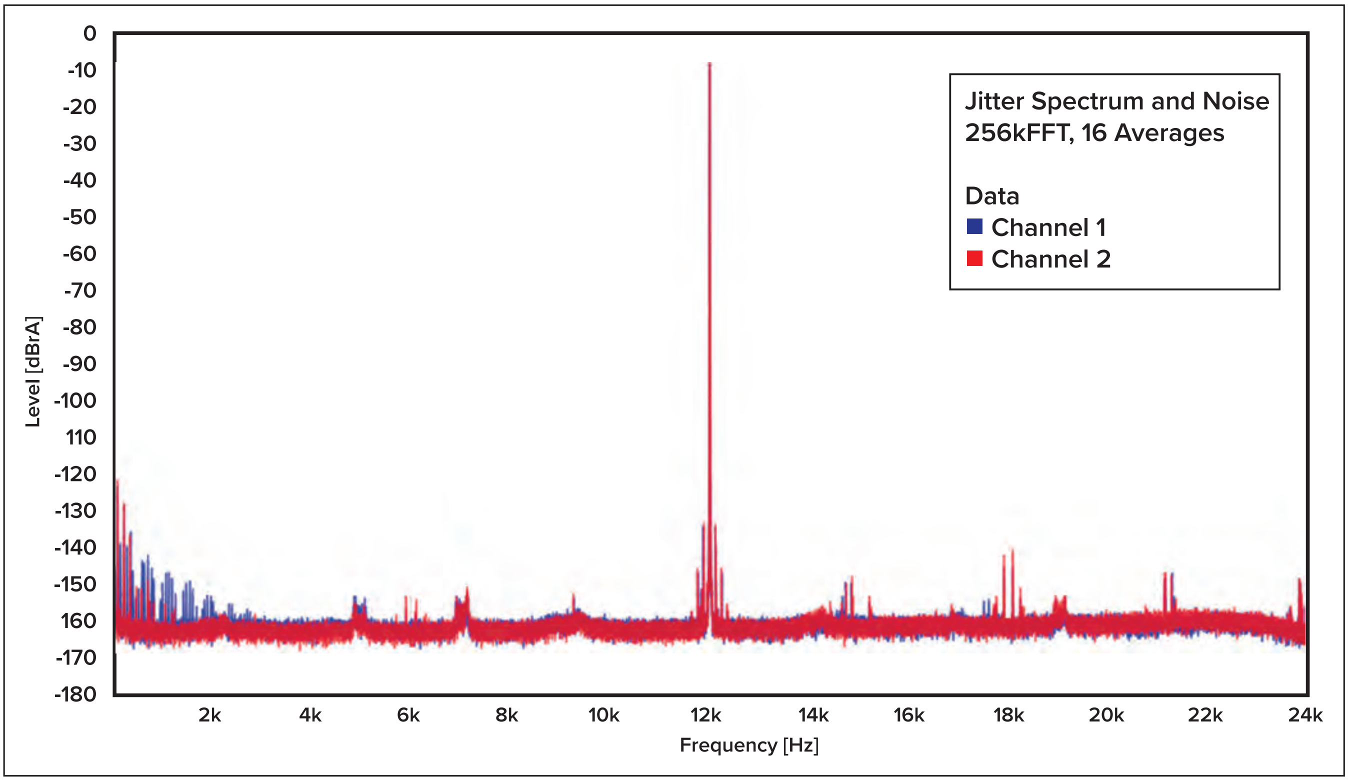
Many of our products incorporate devices made by GaN Systems. This chipmaker produces very fast, true enhancement-mode (E-mode) GaN devices with a simple unipolar gate drive, a feature that makes them close to ideal for audio applications. In comparison, devices made by many other GaN manufacturers require a more complex or slower gate drive, or are cascode, which makes it much more difficult to control the timing of the switching. Further strengths of the products by GaN Systems are a low on-resistance, and a form of packaging that makes it easy to incorporate these devices in circuit boards for audio amplifiers.

One of our most recent products is the Starkrimson Streamer Ultra. It represents a new kind of high-end audio system. Miniaturization enabled by GaN allows a digital-to-analogue converter to be united with amplifiers and a streamer, inside an easy-to-use enclosure (see Figure 3). This level of functionality is typically realised with a rack of components (see Figure 4). A comparable system, including an amplifier, preamplifier, DAC, and a streamer, would typically command a price tag two-to-three times higher than that of the Starkrimson Streamer Ultra. Measurements of our Streamer Ultra confirm the pedigree of this fully balanced unit, which can drive speakers with an impedance as low as 2 Ω. Testing confirms extremely low noise and distortion (Figure 5), ultra-low jitter (Figure 6), and native playback up to 24Bit/192k.

➤ Figure 4. To offer the same level of facilities as the Starkrimson Streamer Ultra requires an amplifier, preamplifier, DAC, and a streamer.



➤ Figure 5. Using a measurement bandwidth of 22 kHz, the total harmonic distortion of the Starkrimson Ultra Amp as a function of power at 1 kHz.



➤ Figure 6: Starkrimson Streamer Ultra Jitter Spectrum and Noise, 256kFFT 16 Averages

Like the Starkrimson Streamer Ultra, its cousin, the Starkrimson Stereo Ultra amplifier, delivers less harshness, cleaner highs, and better overall transparency and detail, alongside vanishingly low noise levels. This amplifier delivers a power of up to 500 W_{RMS} (1,000 W_{PEAK}) and up to 20 A of current, while maintaining extremely low noise and distortion. What's more, this unit has enormous reserves of energy for extended transition. Expanding linearly with load, it is capable of delivering 125 watts into 16 Ω, 250 watts into 8 Ω, and 500 watts into 4 Ω. This culminates in powerful, unrestrained music.

A significant part of every Class-D amplifiers is its filter. Thanks to the high-speed switching of GaN Systems' transistors – they ensure two-to-three times faster switching than traditional Class D amplifiers using silicon transistors – our design employs a simple LC inductor and capacitor filter. Equipped with these components, our Starkrimson Stereo Ultra amplifier produces practically no phase shift from DC (0 Hz) to 20 kHz.

In our view, high-quality audio is now a 'must-have' across all segments, from pro-audio to home-audio and portable audio. The best approach to this is a Class-D audio systems with GaN devices. Armed with this technology, audio delivers a superior sound quality from smaller, lighter units; and there is no need for active cooling – there can be either no or minimal heart sinking.

How does it sound?

Orchard Audio is winning fans within the audiophile and music lover communities. Those that have heard these audio products are saying:

My speakers are very efficient and tend to make a feature of any noise in the electronics. The Starkrimsons are super-quiet and my music now plays against a silent background. Not only that, but the sound is wonderful. Separation and clarity are improved and the bass is noticeably tighter and more forceful. They are a clear step up from the power amp…

Rich and detailed without being overly analytical, drive and grip, brilliant low end, gorgeous midrange and extra levels of transparency that lift a veil from your music.

His amp is a realization of the benefits of GaN. The Ultra has improved harmonic integrity, dynamics, and resolution over traditional silicon.

With the Starkrimson driving them, the sound became more lively and dynamic but without a trace of harshness.
The bass was on a par with the $6k amp, as was the treble smoothness, but the Starkrimson was more open. Playing reference tracks that I've heard dozens of times on the .7s, I was frequently startled — literally — by the realism of instruments and vocals. Micro-detail, textures and subtle dynamics that I hadn't noticed before became clear.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