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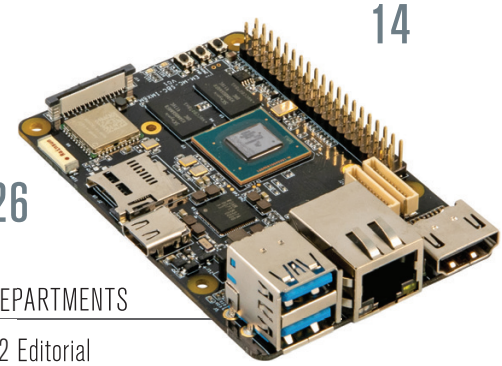

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EDITOR'S NOTE

Machine learning boosts electrolyte search

The search for the optimum molecules for use as electrolytes in lithium-ion batteries involves an examination of billions of potential candidates. The challenge, according to scientists at the U.S. Department of Energy's Argonne National Laboratory, lies in the tradeoff between molecular modeling accuracy and computational cost. Fortunately, artificial intelligence and machine learning may be able to help.

One of the scientists' tools is a computationally intensive model called G4MP2. Using this tool, the scientists accurately modeled tens of thousands of small organic molecules, as described in a recent paper. "Energies for the ~133,000 molecules in the GDB-9 database, containing organic molecules having nine or less atoms of carbon, nitrogen, oxygen, and fluorine as well as hydrogen atoms, have been calculated at the G4MP2 level of theory," the authors write.[1] (GDB-9 refers to a database available at the Wolfram Data Repository of molecular quantum calculations describing geometric, energetic, electronic, and thermodynamic properties.)

However, those 133,000 molecules represented only a small subset of 166 billion total molecules, including large ones, the scientists wanted to evaluate as potentially suitable for use as electrolytes. Applying the G4MP2 model to that huge number of molecules would be a computationally impossible task, even for the BEBOP supercomputing cluster at Argonne's Laboratory Computing Resource Center, which the scientists used in their research.

That's where machine learning comes in. The authors explain that the G4MP2 energies of the GDB-9 molecules will be useful in future investigations of the application of machine learning to quantum chemical data.

A second paper describes the details. The researchers applied a less computationally intensive quantum-mechanical modeling framework based on density functional theory, which is less accurate than G4MP2. But by using the G4MP2 results, they could train the density-functional-theory model to improve its accuracy while keeping compute costs down.

"Our resulting models learn the difference between low-fidelity, B3LYP, and high-accuracy, G4MP2, atomization energies and predict the G4MP2 atomization energy to 0.005 eV (mean absolute error) for molecules with less than nine heavy atoms (training set of 117,232 entries, test set 13,026) and 0.012 eV for a small set of 66 molecules with between 10 and 14 heavy atoms," the authors of the second paper write.[2]

"When it comes to determining how these molecules work, there are big tradeoffs between accuracy and the time it takes to compute a result," said Ian Foster, Argonne Data Science and Learning division director and an author of one of the papers, as quoted at Newswise.[3] "We believe that machine learning represents a way to get a molecular picture that is nearly as precise at a fraction of the computational cost."

"The machine-learning algorithm gives us a way to look at the relationship between the atoms in a large molecule and their neighbors, to see how they bond and interact, and look for similarities between those molecules and others we know quite well," added Argonne computational scientist Logan Ward, an author of one of the studies. "This will help us to make predictions about the energies of these larger molecules or the differences between the low- and high-accuracy calculations."

Machine learning has demonstrated its usefulness in application areas ranging from banking to medicine. It's applicability to the search for stable, safe electrolytes for lithium-ion batteries represents yet another. EE

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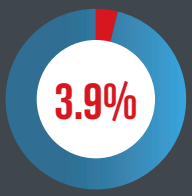
2. Ward, Logan, et al., "Machine learning prediction of accurate atomization energies of organic molecules from low-fidelity quantum chemical calculations," MRS Communications, September 2019.
3. "Building a better battery with machine learning," Newswise, Nov. 26, 2019.

BY THE NUMBERS

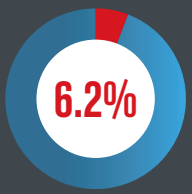
2.11 BILLION

Semiconductor equipment billings in October

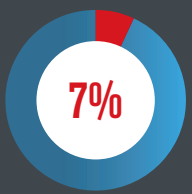


Increase in billings from October 2018

Source: SEMI

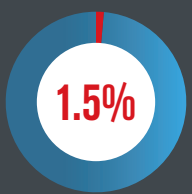


Increase in October North American PCB shipments year-to-year



Year-to-date October North American PCB order growth

Source: IPC



Predicted worldwide smartphone market growth in 2020

190 MILLION

5G smartphone shipments expected in 2020

Source: IDC

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2011 First Metrology-Grade USB VNA

2012 Handheld USB VNA that Requires No Measurement Cable (US Patent 9,291,657)

2013 Direct Receiver Access USB VNAs

2014 Compact USB VNAs

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2015
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Advanced Performance Compact VNA - SC Series

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The EMC Shop acquires Arris facility, launches testing & design division

The EMC Shop has acquired the facility, test chambers, and talent of the former ARRIS facility in Nevada City, CA, thereby allowing The EMC Shop to offer services for testing DFS (essential for 5 GHz Wi-Fi), EMC, antenna pattern measurement, and environmental product evaluation necessary for regulatory compliance. In addition, design, development and testing services for antennas and embedded Wi-Fi products are also available. A fully anechoic 3-m chamber, antenna test chamber, and other enclosures will allow The EMC Shop to immediately provide the above test and design services.

The talent and experience that was retained from ARRIS include an EMC test engineer, a hardware design engineer, an antenna design engineer, a test engineer, and a software engineer. Each engineer will support the core business of The EMC Shop, provider of custom test solutions, as well as the Testing & Design Division.

Utilizing test systems and assets from The EMC Shop's Roseville location, testing capabilities already include RF and electromagnetic immunity and emissions testing for automotive, commercial, medical, military, and aerospace products. The devices under test can be up to 1 m^3 in size, with power handling capacity supported up to 100 A, 3 Phase. Utilizing the experience of ARRIS engineers, customers are able to make in-lab adjustments and redesign to get the most out of their lab time.

INDUSTRY REPORT

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ADLINK Teams with Intel and AWS to Offer AI at the Edge

SAN JOSE, CA. ADLINK Technology announced it has joined forces with Intel and Amazon Web Services (AWS) to simplify artificial intelligence (AI) at the edge for machine vision. The integrated solution offers an Amazon Sagemaker-built machine-learning model optimized by and deployed with the Intel Distribution of OpenVINO toolkit, the ADLINK Edge software suite, and certification on AWS Greengrass.

The ADLINK AI at the Edge solution closes the loop on the full cycle of machine-learning model building—from design to deployment to improvement—by automating edge-computing processes so that customers can focus on developing applications. The ADLINK AI at the Edge solution features:

- Intel Distribution of OpenVINO toolkit, which optimizes deep learning workloads across Intel's architecture;
- Amazon Sagemaker, a fully managed service that covers the entire machine learning workflow;
- AWS Greengrass, which extends AWS to edge devices so they can act locally on the data they generate, while still using the cloud for management, analytics, and durable storage;
- The ADLINK Data River, offering translation between devices and applications to enable a vendor-neutral ecosystem; and
- The ADLINK Edge software suite, which builds a set of deployable applications to communicate with end-points, devices, or applications.

"We've worked on multiple industrial use cases that benefit from AI at the edge, including a smart-pallet solution that makes packages and pallets themselves intelligent so they can detect where they're supposed to be, when they're supposed to be there, in real-time," said Toby McClean, VP, IoT Innovation & Technology, at ADLINK. "This enables warehouse customers to yield improved logistics and productivity, while also decreasing incorrectly shipped packages and theft. And this use case can be replicated across verticals to improve operational efficiency and productivity."

Companies join forces to advance integrated photonics

Keysight Technologies Inc., FormFactor Inc., and CompoundTek have joined forces to accelerate integrated photonics innovations. Integrated photonics, also called silicon photonics, is a revolutionary technology that multiplies data-transfer capacities while reducing power consumption and cost. While photonics integrated circuits (PICs) offer an exciting alternative to the limitations of traditional datacenter networking, they also introduce new design and test challenges for component and device manufacturers. Adoption of PICs is primarily dependent on an industrial ecosystem comprising new foundries, commercial modeling tools, and photonic test capabilities.

KEYSIGHT TECHNOLOGIES

FORMFACTOR

CompoundTek

Keysight, FormFactor, and CompoundTek have jointly developed an advanced photonics on-wafer testing solution that delivers industry-first capabilities including automated alignment as well as simultaneous optical-optical and optical-electrical device tests.

The joint solution, to be offered by CompoundTek, includes

- The FormFactor CM300xi-SiPh, with automated wafer-level photonics positioning combined with Keysight's industry-standard IL/PDL engines and N7700A Photonics

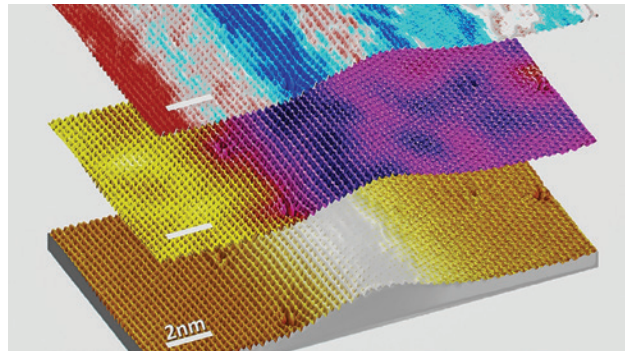
Application Suite (PAS), to support wavelength repeatability of ±1.5 pm at two-way sweeps up to 200 nm/s within 1,240nm to 1,650nm to ensure accuracy and repeatability from O-band to L-band;

- Keysight's N4373E 67-GHz lightwave component analyzer, which delivers the necessary bandwidth for both optical receiver testing and optical transmitter testing with guaranteed specifications for electro-optical S-parameter measurements for device traceability;
- Keysight's PathWave software platform, which provides a consistent user experience as well as common data formats and control interfaces; and
- FormFactor's SiPh software that enables automated calibrations and alignments and simplifies integration with Keysight's PathWave software platform, as well as optical instrumentation, to ensure ease of use.

Silicon photonics also delivers benefits for industrial segments such as intra-datacenter communication and datacenter interconnects (DCI), telecom, 5G and automotive connectivity, high-performance computing, light detection and ranging (lidar), as well as sensing and medical applications.

Scientists discover 'ripple' in flexible material that could improve electronic properties

Two-dimensional materials—those either only an atom or layer thick—display a number of interesting properties and could form the foundation for a range of new devices. One of these materials, molybdenum disulfide (MoS_2), has shown an unusual flexibility that could make it attractive as a semiconducting component of bendable electronics.



Scanning tunneling microscopy topography of a rippled MoS_2 single layer as a result of strain relaxation (bottom). The corresponding dI/dV map at the valence band edge (middle), and the strain map (top) are overlaid.
Argonne National Laboratory

In a new study from the U.S. Department of Energy's Argonne National Laboratory and Temple University, scientists have discovered an intriguing new behavior in MoS_2 at the atomic level as it is stretched and strained, like it would be in an actual flexible device.

After straining a film of the material grown on graphite, the researchers noticed that the formerly two-dimensional sheet of MoS_2 would slip, relaxing the strain. This, in turn, formed a rippled pattern at a larger scale that translated into an altered electronic structure within the individual atoms.

"You can think of it like stretching a rubber band," said Argonne nanoscientist Saw-Wai Hla, an author of the study. "After you release the tension, the rubber band snaps back together even more tightly than its initial position."

The ripple pattern remains after the strain is removed and leaves the material looking like a rug that has been bunched up as the material loses its total two-dimensionality. Introducing the ripple through strain could be either deleterious or helpful to the functioning of an actual flexible electronic device, according to Hla, who explained that while an unintentional strain relaxation would likely impair the material, a directed strain response could achieve precisely targeted electronic behavior in MoS_2.

A paper based on the study, "The effects of atomic-scale strain relaxation on the electronic properties of monolayer MoS_2," appeared in the July 3 issue of ACS Nano. Additional collaborators on the study included Argonne's Yuan Zhang and Temple's Fabrizio Bobba, Xiaoxing Xi, and Maria Iavarone.

AR enters agreement with NEXIO in North America for EMC solutions

Amplifier Research (AR) announced that it has added a significant component to its offerings for the EMC market. The company said it has been appointed an exclusive distributor of NEXIO products and services when incorporated as part of a turnkey solution. With the addition of this suite of NEXIO products, AR said, it is now a 1-stop total solutions provider for the electromagnetic compatibility testing market.

As a specialist in EMC and RF testing, NEXIO serves laboratories worldwide in the commercial, automotive, and aerospace and defense market sectors with a range of test automation software, EMC test engineering, and simulation-analysis services.

"The arrangement with AR represents the first step to global collaboration. NEXIO is excited to participate in an alliance consisting of industry-leading companies working together to deliver optimal customer solutions," explained Frederic Amoros-Routie, president of NEXIO.

Cadence, NI enter into strategic alliance agreement

National Instruments on Dec. 2 announced a "system innovation strategic alliance to create an integrated design-to-test flow, leveraging reusable data and test IP from electronics design and verification to validation and production test for electronic system and semiconductor companies." The expressed intent in a press release from National Instruments is "to provide customers with a seamless flow from pre-silicon development to post-silicon test, leveraging design, verification, and analysis data between Cadence and NI technologies." EE

◀ Rohde & Schwarz R&S ZNA vector network analyzer.

SPECIAL REPORT

FROM ON-WAFER TEST TO BREAST-CANCER DETECTION

VNAs find use cases extending from IoT to medical and materials-science applications

By Rick Nelson, Interim Chief Editor

Vector network analyzers are versatile instruments offering top operating frequencies extending from megahertz and lower ranges up to hundreds of gigahertz. They handle test-and-measurement chores ranging from power-supply design and debug to characterization of mmWave devices used in 5G systems and beyond. In addition to serving in the electronics lab, the availability of low-cost, compact, USB-connected VNAs in the gigahertz ranges is opening up the use of the instruments in materials-science, medical, and other applications areas. While IoT and 5G are key applications focuses, the applicability of the instruments extends from power-distribution-network (PDN) impedance measurements to breast-cancer detection.

A look at recently introduced VNAs and options highlights the ranges of specifications, capabilities, formfactors, features, and applications.

According to Rich Pieciak, product manager for vector network analyzers at Rohde & Schwarz, "The most recently introduced vector network analyzer platforms from Rohde & Schwarz are the R&S ZNA family, in the high-performance segment, and the R&S ZNBT40 platform, which expands our multiport solutions to 40 GHz."

"The new VectorStar ME7838G system is the latest version of the broadband line of VectorStar VNAs," said Steve Reyes, VNA product manager at Anritsu Co. "The single-sweep range is from 70 kHz to 220 GHz through a 0.6-mm DC connector. The VNA is geared toward on-wafer applications, including device characterization." He continued, "On-wafer measurements

are taking on a more significant role in new transceiver designs for emerging microwave communication applications."

"Recently Keysight introduced network analyzes in three formfactors—USB, modular PXI, and benchtop," said Matt Campbell, product marketing engineer, Keysight Technologies Inc. "We have existing models in all three form factors already, but the wide application coverage makes the new models special. Now you can fully characterize devices, no matter which formfactor you're using while using the same GUI and remote API."

Subbaiah Pemmaiah, application engineer, Copper Mountain Technologies, said the SC5065 2-port 6.5-GHz and SC5090 2-port 9-GHz VNAs are the newest additions to the company's product line. "These VNAs are compact in size and yet capable of providing excellent 140-dB dynamic range at 10-Hz IF, 16-ms/point measurement speed, and a higher output power up to +15 dBm," he said.

Roger Denker, general manager, MegiQ, said recent products include the USB-driven VNA-0460 6-GHz, 2-port VNA with PC software and the MegiQ VNA-0460e 6-GHz, 3-port VNA with built-in bias-T and bias voltage/current generator. "We are developing a new generation VNA with a wider frequency range and more baseband processing applications," he said. As for application areas, "We see a growing business in RF tools for IoT development," he said. "We also see innovative applications in detection using VNAs to map reflection patterns." Denker said MegiQ offers calibration kits for UFL connector-based measurements and balanced measurements, affordable 6-GHz SMA calibration kits, and an application programing interface for production testing and other automated tasks.

Jason Chonko, applications marketing manager at SIGLENT Technologies North America, said SIGLENT's newest VNA, the SVA1032X analyzer, "...extends our vector measurements from 100 kHz up to 3.2 GHz. The SVA Series features an easy-to-use interface and solid performance in a lightweight benchtop design."

Picotest sells the OMICRON Lab Bode 100, the Keysight E5061B, and the R&S ZNL, according to Steve Sandler, CEO of Picotest. "The Bode 100 is our low-cost, low-frequency VNA and the most popular," he said. "It is a true VNA (not just a frequency response analyzer) that goes to 50 MHz and supports S-parameter measurement (s_{11} *and* s_{21}) and touchstone output." He said Picotest supports a range of applications with a selection of signal-injector accessories and probes that can be used to measure components as well as circuits.

"It should be noted that Picotest makes accessories for *all* VNAs," Sandler continued. "We are the largest developer of support hardware. Many of our products are essential; you can't make the measurement with the VNA without an accessory we make. We have the largest offering of signal injectors, probes, and PDN cables." He added that the company also offers training, specialized demo boards, and tutorials.

▼ MegiQ USB-driven VNA-0460 6-GHz, 2-port VNA and VNA-0460e 6-GHz 3-port VNA.

VNA differentiators

When asked what is unique about his company's vector network analyzers, Reyes said, "The Anritsu Non-Linear Transmission Line (NLTL) harmonic sampler provides optimum performance of high-frequency measurements with excellent noise-floor performance and dynamic range. The compact Anritsu NLTL modules offer industry-best calibration and measurement stability at millimeter-wave (mmWave) frequencies."

"With exceptional measurement performance becoming standard, it's hard to buy a bad network analyzer these days," said Campbell. "Looking beyond measurement performance, Keysight considers the many methods required to characterize modern RF devices—spectrum analysis, fixtured measurements, noise-figure/parameters, as well as new methods to accurately characterize your device using active-parameters and EVM/ACPR. On our network analyzers, we simplify RF characterization by offering the broadest software and measurement application portfolio in the industry."

"The R&S ZNA family has exceptional RF characteristics, highlighted by sensitivity, power sweep range, and linearity," said Pieciak. "It also has a modern user interface and a unique hardware architecture with four internal phase-coherent sources that provide new measurement versatility for testing mixers or other frequency-translating devices such as satellite up/downconverters or TR modules.

A second internal local oscillator source speeds up mixer measurements or can be used as an additional source—for example, as the LO (up to 26.5 GHz) for the mixer under test. High power accuracy with extremely short control times is achieved with the R&S ZNA digital automatic level control (ALC), even in combination with external test setups."

He continued, "The R&S ZNBT40 is a turn-key solution for measurements up to 40 GHz that provides unparalleled measurement accuracy up to 24 ports and under high power requirements."

"All our VNAs are USB-based," commented Pemmaiah at Copper Mountain Technologies. "This form factor separates the measurement module (which is the VNA) from the processing module (a PC), thereby providing advantages such as compact size, flexibility, and security as well as automation support and speed. The compact size of the analyzers makes for a much smaller and lighter instrument, which increases options for testing."

The company supports both Windows and Linux. "The VNA application can be run from larger desktop computers to smaller board computers," Pemmaiah said. "The ability from the USB formfactor to use newer computers offers engineers larger storage space and eliminates the need for data purging or hard-drive removal in secure environments." A test-automation program and the VNA application can run on the same computer, which can improve the overall measurement speed, he said, adding, "Our engineering team is available to support users with automation scripts at all times. In addition, the superior internal wideband coupler design and the advanced DSP+FPGA processors have helped achieve wide dynamic range and fast measurement speed."

Denker said MegiQ offers small formfactor, low-priced lab-grade VNAs with color-guided calibration on the front panel, a built-in matching-circuit calculator and simulator, and built-in bias-T and bias voltage/current generator (to allow for parametric measurements). He added that the VNAs are optimized for IoT development workflow and provide for easy to store/recall full measurements and setup as well as readable (noncryptic) graphic reports.

Mark Ashcroft, RF business development manager, Pico Technology, said that despite several recent new entrants in the USB-controlled VNA space, "The PicoVNAs continue to hold the leading low price, high-performance position. The PicoVNAs are full-function professional metrology instruments that will typically match or exceed the measurement accuracy of all other 6-GHz VNAs on the market. It is not lost upon educationalists and lab or test managers that this powerful combination of low cost and high capability presents the opportunity for every student or engineer to now have a VNA each. How long have we all waited for that? In industry, let alone education!"

According to Chonko at SIGLENT, "The SVA Series incorporates a novel design that enables a number of operation modes that can be used to troubleshoot a number of common RF/broadcast issues." The instrument includes a spectrum-analyzer mode for monitoring transmitters and interference investigations, a VNA mode for RF device and cable characterization, an optional distance-to-fault mode for cable-integrity tests, and optional digital demodulation with I/Q demod. "The instrument also features a 10-in. touchscreen with up to four-trace overlay, USB mouse/keyboard support, and onboard web control for remote operations and monitoring without programming," he said.

"The Bode 100 is unique in its combination of capability, ease of use, and price point," said Sandler at Picotest. "Priced at $5,400, it is almost one-third the cost of its nearest major competitor with significantly more features. It is the only VNA that natively includes our unique NISM noninvasive stability software."

VNA trends

"Continuation into the mmWave frequencies for fundamental communication bands is a major trend, as is the continued requirement for device characterization beyond 110 GHz for accurate device modeling and simulation," said Reyes at Anritsu. "Another trend is the integration of subsystems into wafers with advancements in wafer composition, thus requiring *in situ* on-wafer calibration and measurement."

"As devices for RF applications become more highly integrated, complete characterization requires more than passive S-parameters," said Campbell at Keysight. Customers may have to perform active parameter measurements to accurately characterize gain vs. traditional S-parameters, as well as spectrum analysis, pulsed measurements, and noise-figure measurements, he said, adding, "We expect to see more customers streamlining their workflows by performing multiple types of measurements with their network analyzers."

"As devices get more compact and complex, the higher number of ports and operating frequencies are driving more test-time reductions," commented Pieciak at Rohde & Schwarz. "Having the ability to perform a suite of tests that fully characterizes a device with minimal setup increases test yields and drives down recurring test costs."

Copper Mountain Technologies has seen an increase in demand for portable handheld VNAs that support material measurement applications, said Pemmaiah. "5G has pivoted the need for analyzers capable of characterizing components in the mmWave frequencies," he said. "This has also increased the necessity of characterizing the material dielectric properties. The compactness and the portability of some of Copper Mountain Technologies' VNAs have paved way to use the analyzers on a robotic arm, to mount it on a drone for remote measurements, and even send it in space."

"The IoT market is booming," said Denker at MegiQ. Consequently, many engineers are faced with implementing RF circuits and antennas—tasks they are not necessarily trained to do. "Engineers need no-nonsense, easy-to-use VNAs to start developing wireless applications," Denker emphasized.

Chonko also cited the IoT and a trend on the low end of the spectrum toward increasing capabilities at lower price points. "Ten years ago, there were almost no options for low-cost VNAs," he said. "You had to settle for a used unit or pay $20k or more for a basic instrument. That has changed dramatically in

the past few years, due to the increased demand for RF testing in IoT research and development."

Chonko added, "On the high end, 5G is driving technology advancement and capabilities to higher frequencies than ever before, with systems over 100 GHz commonly available."

Sandler at Picotest said more manufacturers are addressing power-integrity applications, with most manufacturers now supporting the 2-port shunt-through impedance measurement and offering Picotest's NISM noninvasive stability software.

Challenges from IoT to 5G

VNA users face new challenges as they confront 5G and the IoT. "5G and IoT bring new frequencies to customers who haven't worked in the millimeter-wave frequency range before," said Campbell at Keysight. "At higher frequencies you have smaller margins for error, and you need to pay careful attention to your hardware setup—a small cable shift after calibration can cause large phase errors, for example." He said that in addition to providing test equipment for 5G and IoT, "We help our customers enhance their expertise in new test challenges by sharing our experience through webinars, papers, and presentations. Using new measurement methods along with VNA correction techniques applied to EVM measurements offers more repeatably and accurate measurements."

"Technology advancements in areas such as beamforming, utilized by 5G architecture, are necessitating system and component performance validation at many operational states, each of which require accurate characterization," said Pieciak at Rohde & Schwarz. "This higher port count, with associated calibration, raises the likelihood of measurement errors, so all advances focused on providing a single-point connection to a device under test, preceded by guided calibration steps, would greatly increase measurement accuracy and heighten overall test confidence."

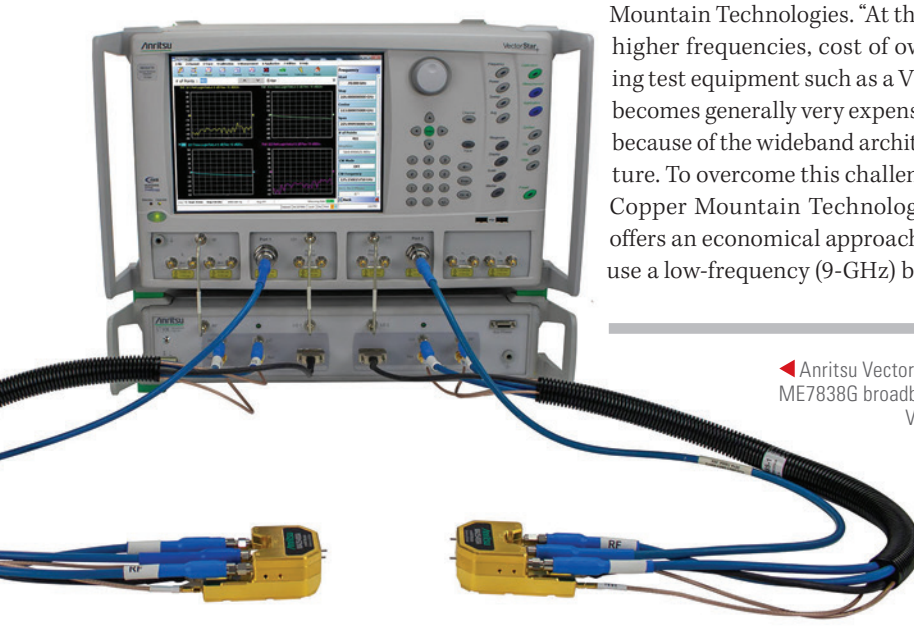
When asked what challenges his customers are facing, Reyes at Anritsu said they want to conduct accurate, cost-efficient on-wafer measurements via multiple measurement capability per probe-station setup. "The key for improved probe-station efficiency and productivity to achieve this goal is to have broad frequency coverage using small compact modules," he said. "The VectorStar ME7838G system provides the widest broadband frequency coverage with the smallest, lightest mmWave modules, for excellent measurement capabilities and easy installation on smaller probe stations."

"With new technologies, frequencies of operation climb to the mmWave regions to accommodate wider data bandwidths," said Pemmaiah at Copper Mountain Technologies. "At these higher frequencies, cost of owning test equipment such as a VNA becomes generally very expensive because of the wideband architecture. To overcome this challenge, Copper Mountain Technologies offers an economical approach to use a low-frequency (9-GHz) base VNA with frequency-extender modules like the FET1854 (18 to 54 GHz), FEV-15 (50 to 75 GHz), FEV-12 (60 to 90 GHz), and FEV-10 (75 to 110 GHz), which operate only in the mmWave band region." This approach offers two advantages. "First, the cost will be a fraction of the cost of a wide-band VNA which might cover the entire range," he said. "Second, the frequency extender 'head' can be placed physically close to the DUT. This minimizes signal loss and improves the dynamic range of the measurement."

When asked about trends, Ashcroft at Pico Technology said, "I want to focus here upon IoT and materials-measurement proliferation, because both of these introduce microwave design and the need to use a VNA to, for instance, digital engineers, small companies, and scientists that have never used these technologies before. It is these demands that have driven Pico's simplified GUI design, with which, we are proud to say, first-time users are typically able to perform a calibration, check their calibration against the optional PicoVNA verification standard, and perform accurate measurements right from opening the box."

He also cited a partnership between Pico and the computer-aided-design company NI/AWR. "The PicoVNA now has an 'AWR Connected' wizard that can control and import measurement data from the VNA right into the AWR Design Environment," he said, adding that AWR's Microwave Office or VSS (Visual System Simulator) can either use the measurements within a simulation or for direct comparison of simulation with the real-world. "Students and newbie microwave engineers alike can enter and quickly transition between all of the 'Design-Simulate-Implement-Validate-Iterate' phases of the development cycle," he added.

"The biggest challenges are the lack of experience and knowledge," said Chonko at SIGLENT. As with most engineering disciplines, RF design has its own language and common rules that differ from analog and digital design, presenting challenges to traditional analog and digital companies that now want to integrate RF so that they can capture pieces



◀ Anritsu VectorStar ME7838G broadband VNA.

of the IoT market. "But it isn't nearly as simple as 'adding a radio' to the block diagram," Chonko said. "Along with this are the proper test techniques and processes to ensure success and the additional knowledge and testing required when adding an intentional radiator for FCC/compliance testing—when to use a certain test for a certain problem, etc. SIGLENT is constantly building up our applications library to assist customers in getting started. We consider ourselves partners to our customers. If they are successful, we will be too."

IoT, 5G, and beyond

A variety of applications areas are emerging, including IoT and 5G but extending to materials science and medicine. Chonko at SIGLENT commented that while IoT and broadcast testing have the largest growth possibilities from his perspective, "Basic science and material characterization are an important part of the VNA market and represent a stable and consistent customer group."

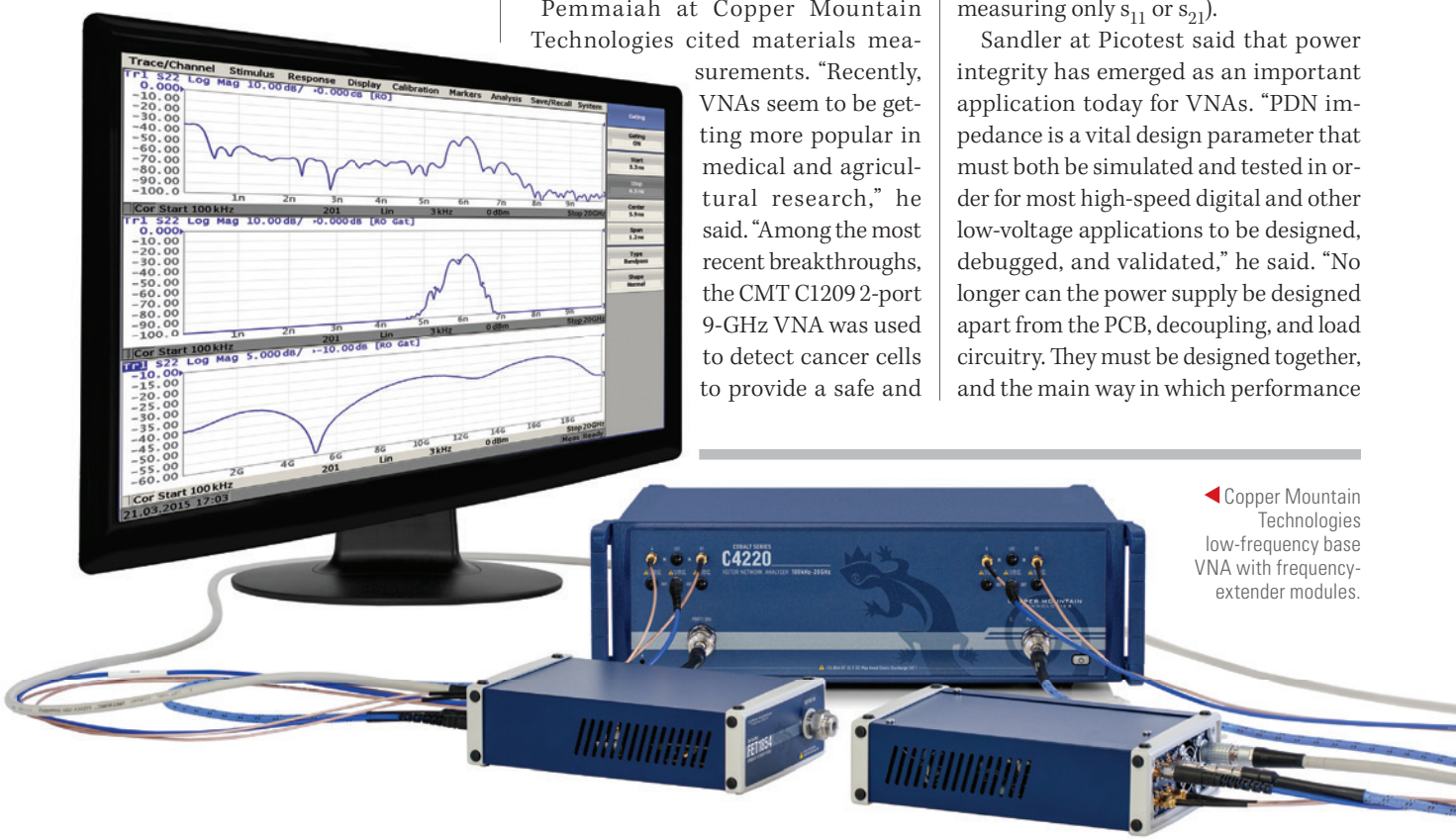
Campbell at Keysight drilled down on 5G. "Multiport phased-array antennas address 5G's need for faster wireless data transmission, but they come with unique test challenges," he said. "Modern transmitters and receivers operate at low power levels over wide bandwidths and require extreme measurement precision to characterize. Low-power measurements have little room for error, but switch-based multiport measurement setups degrade the network analyzer's accuracy. Keysight's response to the growing need for multiport test is modular multiport network analyzers like the M980xA Series, which reduce uncertainty with exceptional performance—no matter how many ports you use."

"Continued advances in high-speed digital design are clearly taking on more importance with regard to signal integrity," said Pieciak at Rohde & Schwarz. "The proliferation of differing standards and corresponding board layouts are necessitating new ways of probing and analyzing signals in both frequency and time domains. The need for high-performing multiport testing arises from steered antenna arrays for radar systems or 5G antenna arrays."

Pemmaiah at Copper Mountain Technologies cited materials measurements. "Recently, VNAs seem to be getting more popular in medical and agricultural research," he said. "Among the most recent breakthroughs, the CMT C1209 2-port 9-GHz VNA was used to detect cancer cells to provide a safe and cost-effective solution for breast-cancer screening. MammoWave from Umbria Bioengineering Technologies (UBT) utilizes two antennas, and each is connected to a port of the VNA.[1] Screening is performed with the patient laying in a face-down position. The antennas rotate around the cup, without any compression, performing measurements approximately every four degrees. The measurements from the VNA are then processed through UBT's software to detect the presence of suspected tumors in the breast tissue."

Ashcroft at Pico Technology cited antenna matching, gigabit data-cable test, material dielectric properties, and penetrative imaging as applications that have grown strongly in recent years and continue to do so. "All of these proliferate to industries that typically haven't previously owned a VNA, heard of S-parameters, or made these measurements before," he said. "Uncluttered ease of use and fast, high-quality measurements are everything here. Imaging in particular is demanding of speed," such as PicoVNAs' to 5,500 full and corrected 2-port measurements per second (10,000 per second if measuring only s_{11} or s_{21}).

Sandler at Picotest said that power integrity has emerged as an important application today for VNAs. "PDN impedance is a vital design parameter that must both be simulated and tested in order for most high-speed digital and other low-voltage applications to be designed, debugged, and validated," he said. "No longer can the power supply be designed apart from the PCB, decoupling, and load circuitry. They must be designed together, and the main way in which performance



Copper Mountain Technologies low-frequency base VNA with frequency-extender modules.

is measured is via the VNA impedance measurement."

VNA options

Vendors offer a variety of options for their VNA products. For example, "Anritsu offers the ability to upgrade lower frequency 2-port VectorStar VNAs to higher frequencies, up to 220 GHz, as well as up to 4-port configurations without extensive modification to the existing 2-port systems," said Reyes. "That is one customer benefit of the modular approach Anritsu has taken with its mmWave and 4-port systems."

"One problem customers run into when testing high-performance 5G components is that the residual error vector magnitude (EVM) of their test setup is close to the EVM of the component under test," said Campbell at Keysight. "Therefore, it is hard to differentiate the component's EVM from the test setup's EVM. Our new modulation distortion application for the PNA-X provides space to clearly see the device's performance with the lowest residual EVM in the industry. The PNA-X's exceptional error correction helps remove noise and uncertainty from EVM, adjacent channel power (ACP), noise power ratio (NPR), and band power measurements."

According to Pieciak at Rohde & Schwarz, the R&S ZNA offers a multichannel architecture of eight coherent receivers in the 4-port model, all accessible from the front panel of the instrument, and two internal LOs. "With the vector-corrected mixer option and coherent sources, phase measurements on frequency-converting devices can be performed with ease, without the need for reconverting or reference mixers," he said. "Corresponding group-delay measurements can also be made with ease, utilizing a 2-tone measurement technique that can be used on frequency-translation devices with or without the embedded LO access."

Copper Mountain Technologies VNAs come with time-domain analysis and gating as standard features in the software, according to Pemmaiah. The software can be used in demo mode and downloaded for free from the website. "Having time-domain and gating included has led to additional measurement capabilities using just a VNA," he said. "Frequency offset and vector-mixer-measurement capabilities are another standard feature in the VNA software and is an important feature for 5G development."

Pemmaiah added, "The new Epsilometer solution offers dielectric material measurements for specimens with thickness 0.3 to 3 mm. This solution utilizes an advanced computational electromagnetic modeling to compute the dielectric permittivity with our R60 1-port VNA. This makes the overall solution very cost effective compared to the existing solution available in the market. The 4-port VNAs also come with balanced measurement capability, which is very useful for signal-integrity measurements."

"Pico has been busy supplementing the PicoVNA product line with a low-cost network metrology training kit aimed at trainers, universities, and training centers," said Ashcroft. "Paired with only a VNA, the PCB-based kit facilitates calibration and measurement of both passive and active devices, lines, and lumped-element networks." Training supports the use of, display of, and embedding and de-embedding of S-parameters; reference plane shift; time-domain reflectometry; and nonlinear effects such as P1dB and PM due to AM compressions. "Additionally, the Network Metrology Training Kits are supplied with their full AWR Microwave Office design project file," he said. "This allows students and trainers to leverage the 'AWR Connected' partnership discussed above. They are able to open the design project, simulate and perhaps modify each element, and then compare with real-world measurements that they can make with the kit. Full engagement with an entire microwave design cycle right there in the classroom!"

According to Chonko, the SIGLENT SVA1X Series offers several options that can quickly provide clear answers to tricky troubleshooting issues. "For broadcast and interference monitoring, the Advanced Measurement toolkit includes an onscreen waterfall plot as well as ACP, OBW, and a number of other common measurement types," he said. "Engineers working on wireless data transfer may be interested in viewing transmission performance. Here, demodulation analysis is available for common analog and digital modulation schemes including I/Q demodulation up to 256 QAM."

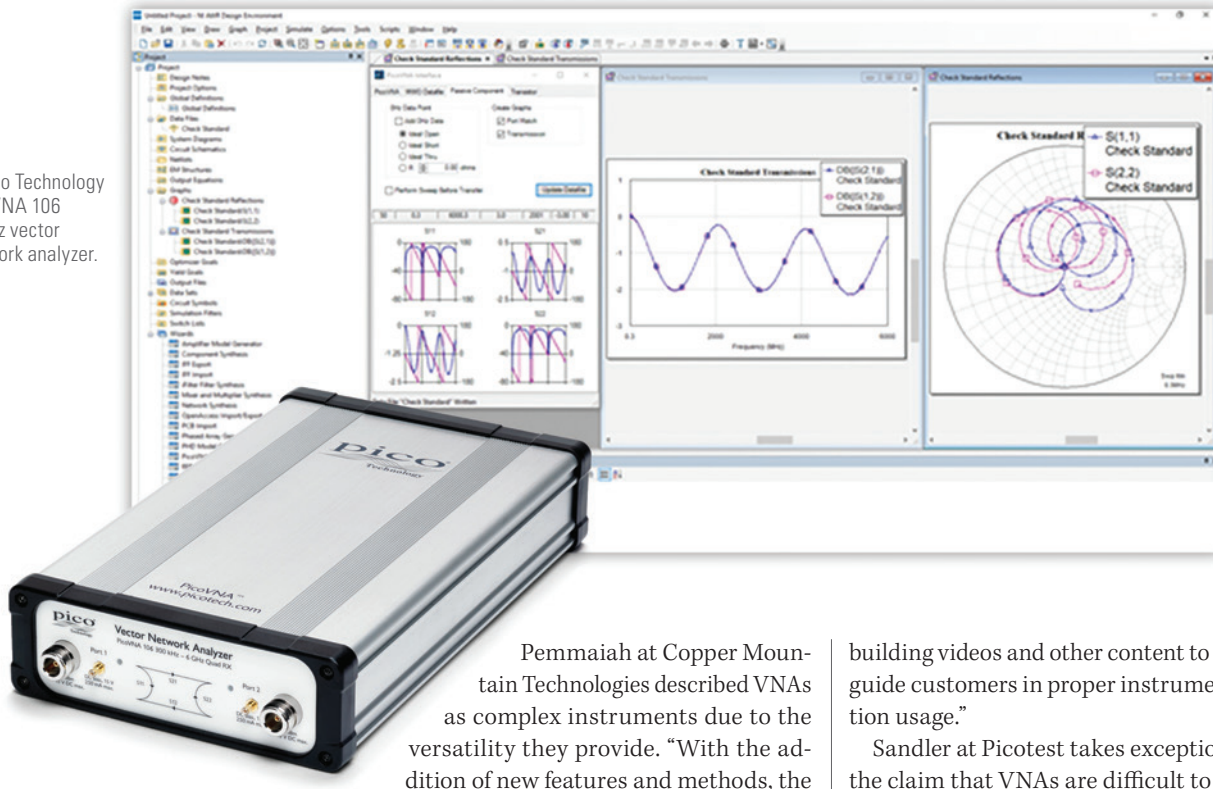
In addition, Chonko said, "For technicians performing antenna tower work finding breaks and impedance differences throughout cable runs and adapter troubleshooting, the distance-to-fault (DTF) option is available. There is also an EMI option that provides instrument settings specifically designed to help shed light on electromagnetic compatibility and interference issues."

Sandler cited Picotest's NISM. "This is a critically important technology for today's power-supply designers," he said. "There are many situations where a Bode plot cannot be made or is not accurate. For many switchers, POLs, linear regulators, references, and op-amps, output impedance is the way to accurately test stability. This software accessory converts output impedance to stability/phase margin. It is available for or included with several VNAs including Keysight's E5061B/E5071C, Rohde & Schwarz's ZNL/ZNLE, and OMICRON Lab Bode 100. Several other analyzers from Anritsu and Copper Mountain are in the process of incorporating it with the free Picotest NISM API toolkit. Picotest also offers many accessories for power-integrity measurements and even specialized coaxial cables, specifically designed for the 2-port shunt through impedance measurement."

Ease of use

Vector network analyzers are typically considered difficult to use by novices, yet experts might be reluctant to see any changes in operation. Vendors offer several strategies to cope.

"Anritsu offers a choice of menu-guided setup or advanced controls," said Reyes. "For example, our Mixer Setup menu helps users configure the system for mixer measurements. If more advanced control is needed, the VectorStar Multiple Source



▶ Pico Technology PicoVNA 106 6-GHz vector network analyzer.

Control provides extensive access into the configuration of the sources and receivers.

"The vast application coverage of network analyzers can intimidate new users, but we organize our user interface to give experts the functionality they expect while keeping the fundamentals accessible to beginners," said Campbell at Keysight. "For basic measurements, users can press the 'New Trace' button and easily adjust all of the relevant parameters in one pop-up. For advanced measurements on the PNA family, beginners can follow the Device Measurement eXpert (DMX) assistant tool to configure and optimize complex measurements. These enhancements for beginners do not interrupt traditional workflows that experts may prefer."

"Ease of use was of key importance in the design of the R&S ZNA platform," said Pieciak. "A DUT-centric test approach was incorporated to allow for straightforward parameter entry depending on the measurement task at hand, with two independent touchscreens providing convenient access to the pertinent setup and measurements menus."

Pemmaiah at Copper Mountain Technologies described VNAs as complex instruments due to the versatility they provide. "With the addition of new features and methods, the complexity only increases," he said. "In addition to providing webinars and tutorials, Copper Mountain Technologies also offers plugins to help users with a quick and easy way to perform specific types of measurements."

According to Denker, "MegiQ products focus on the measurements and the results, not merely on the equipment. Our goal is to provide an out-of-the-box measuring solution for wireless developers. Our VNA-Sandbox with tutorial makes it easy to get started with VNA measurements, and it provides a starting point for wireless product development. MegiQ offers a UFL and balanced toolkit for small applications."

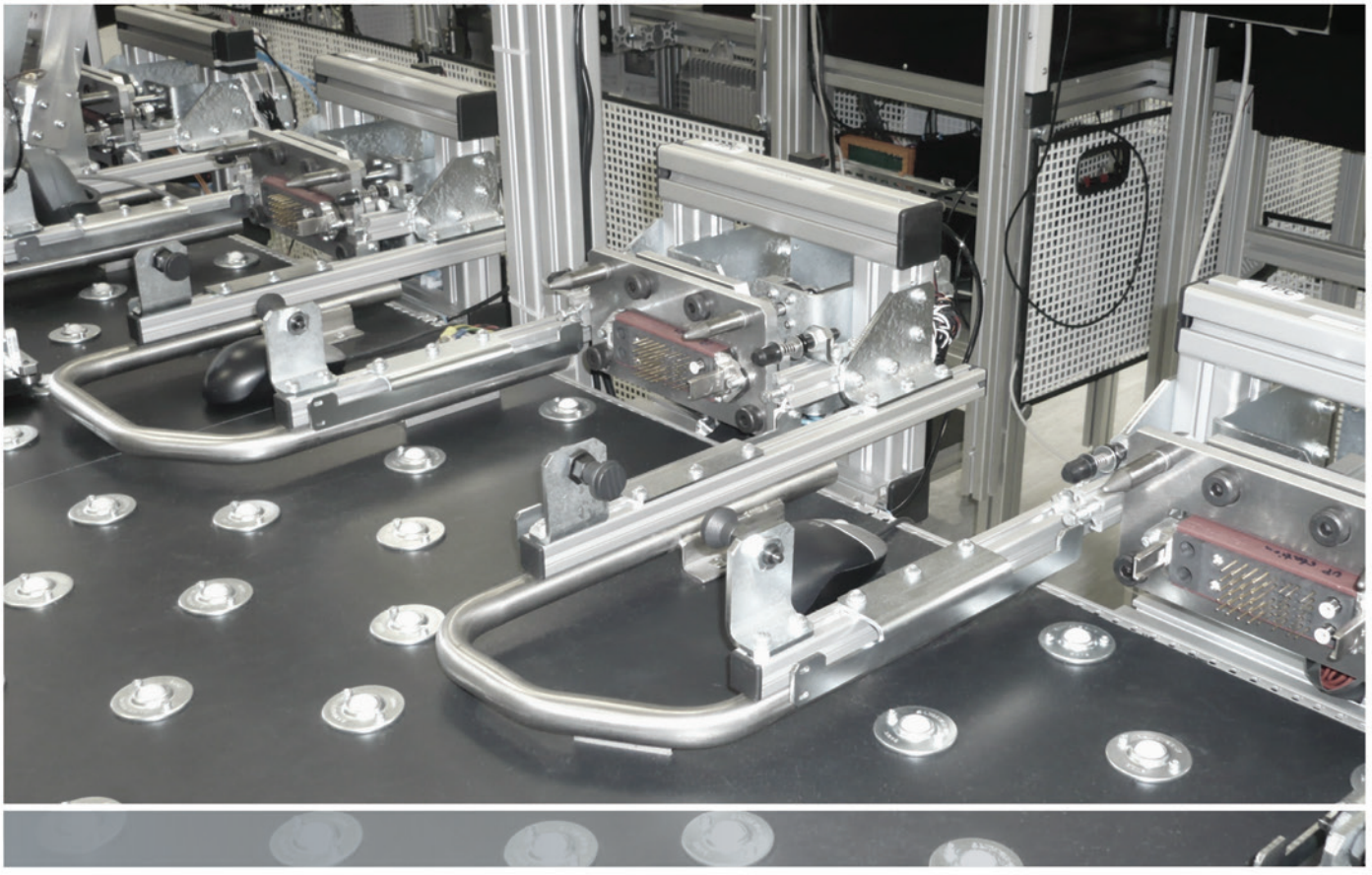
"There is a balance when it comes to creating a user interface (UI) that pleases both new and experienced users," said Chonko. "SIGLENTs approach has been to put standard measurement functions where they traditionally have been but to add shortcut buttons or menu items that make it easier to perform tasks that are often repeated. Touchscreen, mouse/keyboard support, and a web control interface that exactly copies the front panel UI also aid in minimizing the learning curve." He added, "We are also constantly building videos and other content to help guide customers in proper instrumentation usage."

Sandler at Picotest takes exception to the claim that VNAs are difficult to use. "This sentiment is at least 10 years behind the times," he said. "Take a look at the latest Bode 100 VNA software. It is incredibly easy to use. Fully wizard-driven, it eases the test setup and the data analysis by both describing the test setup and walking the user through the measurement setup. Everything is software-driven on one screen. This is not the HP3577. Gone are the days when Bode, Nyquist, Nichols, or impedance plots were challenging to obtain, interpret, and publish. Now look at today's oscilloscopes. They are far more complicated."

Sandler continued, "Having said that, I think much of the hard-to-use issue was wrapped up in the 'hard to interpret' box. Engineers are still not taught S-parameter theory or network-analyzer usage in schools. Introductions to the VNA at the college level is sorely lacking. It is not clear why, given there are many low-cost solutions, and the importance of impedance measurement is critical to designing all types of circuits." EE

REFERENCE

1. "9 GHz VNA Used in MammoWave Breast Cancer Detection System," Case Study, Copper Mountain Technologies.



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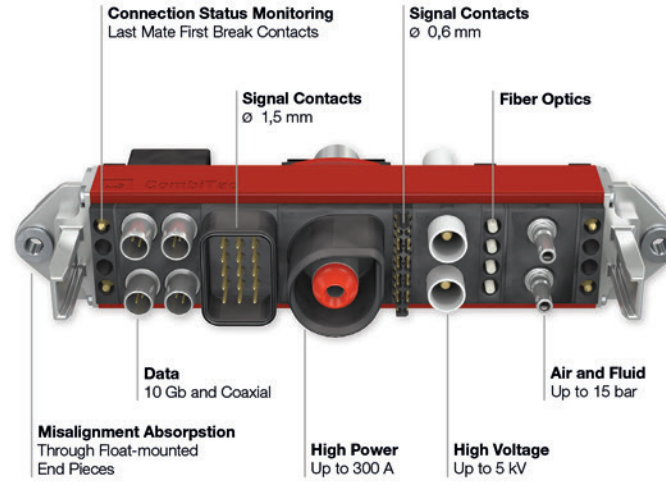

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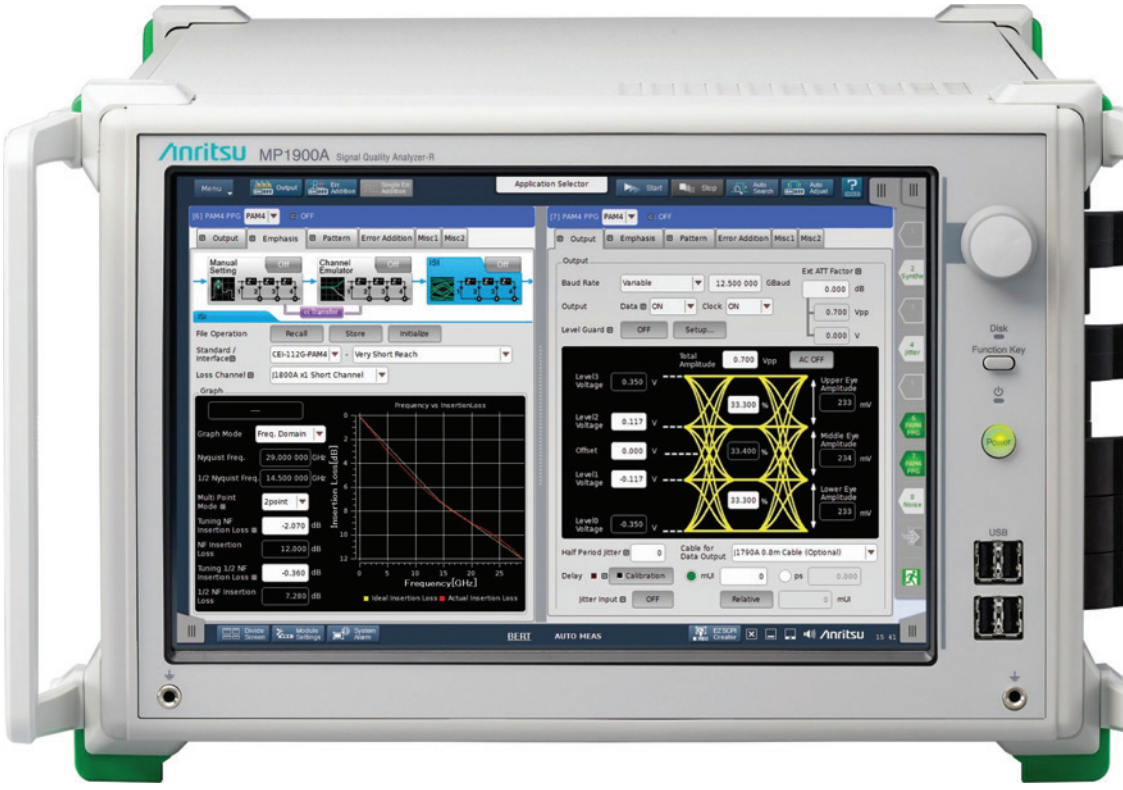


Anritsu Signal Quality Analyzer-R MP1900A Series with PAM4 error detector.

SPECIAL REPORT

TARGETING NEXT-GENERATION SIGNALS

Instrument makers address PAM4, PCIe 5, DDR5, USB 4, 800 GbE signals and more

By Rick Nelson, Interim Chief Editor

High-speed digital test presents a variety of challenges that can be addressed by instruments ranging from oscilloscopes to bit-error-rate testers. Challenges relate to PAM4 signal measurement, DDR5 probing, USB 4.0 transmitter test, PCIe Gen5 transmitter and receiver tests, forward error correction, phase-noise analysis, and time-domain reflectometry (TDR).

For example, Anritsu Co. recently introduced a PAM4 error detector (ED) supporting 116-Gb/s bit error rate tests for its Signal Quality Analyzer-R MP1900A Series. "With the new module installed, the MP1900A is the only instrument to achieve error-free measurement of PAM4 signals at 116 Gb/s with industry-best-operation bit rates and high Rx sensitivity performance," said Hiroshi Goto, business development manager at Anritsu. "Combined with the previously released MP1900A Series PAM4 pattern generator that supports high-accuracy BER measurements of PAM4 signals, the BERT allows engineers to accurately evaluate bit error rates of 400 GbE/800 GbE communications equipment and devices."

The MP1900A will be on exhibit at DesignCon 2020 in January in Santa Clara. "It is a bit-error-rate tester for communications speeds of 400G and faster, supporting high-speed signal generation and signal performance analysis," Goto said. "We will highlight the built-in high-bandwidth and high-input-sensitivity Rx circuit and the new PAM4 ED MU196040B module that supports error-free measurement of 100-Gb/s PAM4 input signals even at a low input amplitude of just 36 mV (typical)."

For its part, Rohde & Schwarz has recently introduced the R&S RTP 16-GHz real-time oscilloscope, which the company will highlight at DesignCon, according to Randy White, strategic oscilloscope planner at Rohde & Schwarz. He also cited other recently launched products for high-speed digital test, including the R&S RTP-B7 differential pulse source (for TDR) as well as the R&S RTP-K121 real-time de-embedding option and R&S RTP-K130 TDR/TDT analysis option.

Keysight Technologies recently introduced a DDR5 solution that integrates software and hardware across the entire customer workflow from design through validation, according to Brig Asay, director, strategic planning, high-speed digital solutions, at Keysight. "We also introduced our new USB 4.0 Tx solution," he added. "Keysight also has a new probing system to make probing a DDR5 signal possible." At DesignCon, "We will highlight several products designed to test next-generation high-speed digital devices" Asay said. "This includes a full suite of testing solutions for DDR5, PCIe Gen5 Tx/Rx testing, USB 4.0 Tx, integrated forward error correction (FEC) debug and analysis, a fast error detector, and a phase-noise analysis tool."

According to Trevor Smith, T&M business development manager at Pico Technology Ltd., "Our most recent product introduction for engineers doing high-speed digital communications design is the PicoScope 9404-16, which is a 4-channel, 16-GHz Sampler Extended Real-Time ("SXRTO") PC-based oscilloscope." That product will be featured at DesignCon "… along with other high-performance test and verification tools such as the AS108 8-GHz agile synthesizer/generator and the popular PicoVNA 106 vector network analyzer that is being widely used for characterization of high-speed serial-data channels," Smith said.

Matt Burns, product marketing manager, high-speed, at Samtec, commented that at DesignCon 2019, eSilicon, Wild River Technology (WRT), and Samtec launched a new in-circuit testing and evaluation platform targeting 56-Gb/s PAM4 data rates. The new solution included Samtec's 50-GHz Bulls Eye high-performance test system, eSilicon's 56-Gb/s PAM4 SerDes, and WRT's test fixture.

"One design goal was to future-proof the kit for 112-Gb/s PAM4 data rates," Burns said. He added that at the Samtec booth at DesignCon 2020, eSilicon, WRT, and Samtec will demonstrate the 112-Gb/s PAM4 version of the kit with Samtec's 70-GHz Bulls Eye high-performance test system, eSilicon's 112-Gb/s PAM4 SerDes, and WRT's test fixture. In addition, he explained that WRT and Samtec will provide correlated simulation and test data at the 112-Gb/s PAM4/70-GHz ranges to drive confidence in the performance of the kit.

Teledyne LeCroy has introduced several products recently with applicability to high-speed digital test, according to Hilary Lustig, marketing communications manager. Those include the SierraNet M648 protocol analysis and traffic impairment system, which offers protocol analysis and jamming for PAM4 50G Ethernet and 64G Fibre Channel interconnections.

In addition, the company has announced support for the Gen-Z protocol on the Summit M5x protocol analyzer and jammer system and the availability of USB 3.2 analysis in the Voyager M4x analyzer. Lustig said the Voyager M4x started shipping in early 2019 as the industry's first test solution supporting USB 4 and Thunderbolt 3 protocol analysis. It now supports USB 3.2 to allow testing of systems that utilize dual 10-Gb/s links or 20-Gb/s aggregate bandwidth over USB Type-C cables.

Teledyne LeCroy has also recently announced Summit PCIe protocol analyzers for the next-generation PCIe 5.0 specification and the WavePulser 40iX high-speed interconnect analyzer for interconnect testing and validation. Lustig said that at DesignCon 2020, the company will present live demonstrations and best measurement practices for PCI Express, USB, DisplayPort, power integrity, and more.

EE-Evaluation Engineering asked several industry experts to weigh in on various aspects of high-speed digital test. Read on to see what they had to say.

Rohde & Schwarz R&S RTP 16-GHz real-time oscilloscope used in a TDR and TDT analysis application.

Unique features

What is unique about your solutions?

White, Rohde & Schwarz: The R&S RTP high-performance oscilloscope combines superior front-end signal integrity with fast acquisition and analysis. This fast performance comes from hardware-accelerated signal processing that enables a combined digital trigger, 16-Gb/s clock-data

▲ Pico Technologies 5-GHz PicoScope 9404-05 and 16-GHz 9404-16 Sampler Extended Real-Time (SXRTO) PC-based oscilloscopes.

recovery, de-embedding, and many other signal-integrity analysis features.

Goto, Anritsu: With the 116-Gb/s PAM4 ED, the MP1900A has industry-best high input sensitivity of 36 mV (typical at 53.125 Gbaud) that supports more accurate evaluations up to 116-Gb/s PAM4. The MP1900A also has built-in clock-recovery and equalizer functions that eliminate the need for external equipment and components for faster testing and debugging. By doing so, it simplifies the previously difficult PAM4 error troubleshooting measurements.

Asay, Keysight: In today's high-speed digital market, designers must get to market as fast as possible. Keysight was first to market to enable our customers in developing solutions for PCI Express Gen5, DDR5, USB 4.0, error detection, and forward error correction. As part of our PCI Express Gen5 Rx calibration software, we offer the UXR with industry-leading noise performance, which allows for more stressing of a device than any other solution. For our DDR5 solutions, we are the only company to offer full integration from design through validation, increasing the ease of use of our solutions. Finally, with our PathWave 2.0 solution, we provide deep analytics and visualization for any design.

Smith, Pico Technology: All Pico test-and-measurement products are PC-based, meaning that they take advantage of the latest advances in PC processing performance and display capabilities, such as 4K UHD monitors.

Burns, Samtec: OEMs want a complete solution for their technical challenges. The collaboration between eSilicon, WRT, and Samtec offers a comprehensive solution of ICs, interconnect, and SI expertise at bleeding-edge data rates answering the needs of next-gen system design.

Specifically to Samtec, the Bulls Eye high-performance test system has many key features and benefits crucial to system design. Bulls Eye offers a compression interface to the board to provide easy on/off and eliminate soldering costs, a small footprint design, microstrip or stripline PCB transmission, support for 1.85/2.40/2.92-mm jack/plug options on End 2, and phase-match pairs for differential signals

Key challenges

What key challenges do your customers face in the design and test of high-speed serial interfaces and communications links, and how do your solutions help them solve their problems?

White, Rohde & Schwarz: One challenge that we have observed with the customers we work with is the increasing complexity of high-speed interfaces as they are adopted into mainstream or nontraditional applications. For example, 4K video is becoming standard for new automotive designs. The bandwidth requirements to support this resolution force some automotive companies to implement higher speed technologies such as PCI Express or Ethernet. Another example is increasing bandwidth for radar digital backend processing systems. Wider bandwidth antenna arrays need higher throughput to allow for real-time processing. This might necessitate the move to an even higher speed serial interface.

Mainstream designers who are moving to higher speed links still need to address system-level issues like power-supply noise, EMI or common-mode voltage, high bit-error rates, or even battery life (if applicable). The R&S RTP real-time oscilloscope provides enough bandwidth to accurately measure many of today's high-speed technologies but also includes a flexible suite of signal-integrity debug tools.

Goto, Anritsu: Next-generation data centers are developing 100-Gb/s per single-lane transmission technology for commercial deployment of 400 GbE services, resulting in increased demand for 53.125-Gbaud 4- and 8-lane PAM4 BER tests to evaluate 400-Gb/s and future 800-Gb/s PAM4 transceivers and devices.

Since the PAM4 method representing data with four amplitude levels has gaps between signal levels one-third that of the 2-level NRZ approach, measuring instruments for evaluating signal quality must have much higher input sensitivity performance. The MP1900A has industry-best high sensitivity input of 36 mV (typical at 53.125 Gbaud). In addition to fast speeds, the impact of transmission-path losses in printed circuit boards, cables, components, and similar devices on measurement results cannot be ignored.

Evaluating the genuine performance of the measured DUT not only requires

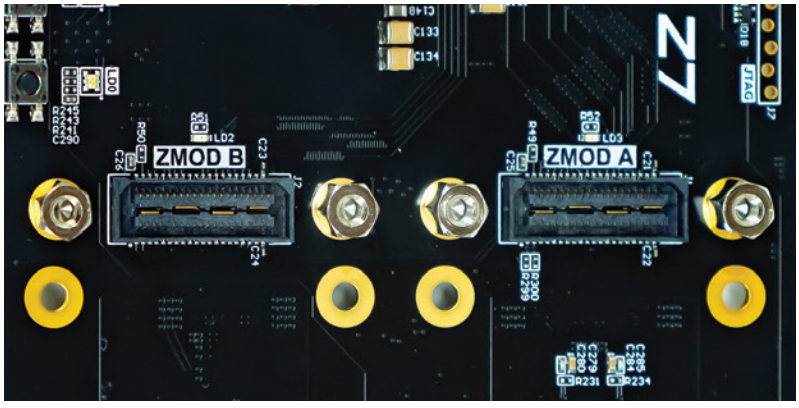
excellent fundamental performance, such as sensitivity and bandwidth, but also a highly integrated solution with functions such as clock recovery and an equalizer for correcting loss effects. To meet these needs, Anritsu has developed the new ED with built-in clock recovery and equalizer to implement a PAM4 BER measuring instrument with market-leading high performance.

Asay, Keysight: This isn't different than what you will see from a lot of the T&M vendors, but today's HSD designers and integrators are under severe pressure to get products to market fast and to move to faster and faster speeds. Faster speeds mean shrinking design margins, putting further pressure on engineers. With Keysight solutions, we focus our products to help companies get their products to market as fast as possible. Our solutions offer superior signal integrity, so validation engineers are truly seeing their device performance as opposed to the noise of the instruments. We strive to be first to market with full automation of solutions, so designers and validation engineers can focus on their designs and automating their test systems.

Smith, Pico Technology: Above 1 Gb/s, "the channel is the problem," so engineers need to understand, model, and verify the characteristics of channel design on high-speed systems. Signal-integrity issues become increasingly severe at high speeds, so we're trying to address that with affordable tools to verify signal-path

Testing high-speed analog I/O

While the accompanying article addresses high-speed digital test, Digilent Inc. has been helping its customers meet challenges related to the design and test of high-speed analog interfaces and data-acquisition applications.



▲ Digilent Eclypse Z7 top view showing Zmod connectors

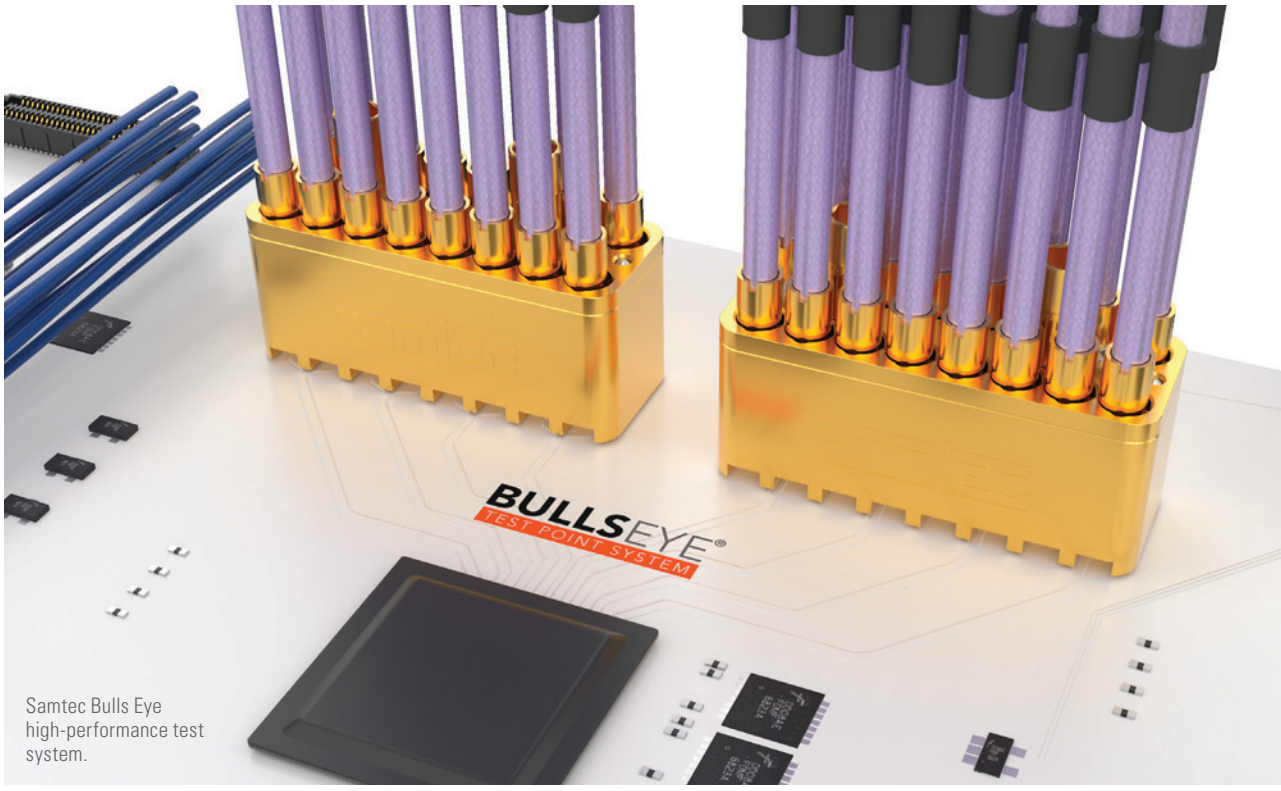
"Many modern electronic systems, including RF, instrumentation, imaging, and test devices require high-speed and/or high-precision analog inputs," said Steve Johnson, Digilent president. "These subsystems require a complex mix of analog, digital, and power-supply circuitry"—design specialties that he said are often difficult to find and therefore often slow down the design process and raise the cost to develop and prototype cutting-edge systems.

Continued Johnson, "Digilent's new Eclypse platform with SYZYGY-compatible Zmod expansion modules and software infrastructure drastically simplifies the challenge of adding instrumentation-grade analog I/O to FPGA-based systems, speeding the development and prototyping process."

Johnson said there's a lot that makes the company's new Eclypse Z7, to begin shipping in January 2020, unique. "At first, it looks to be an FPGA board, but it harnesses the new SYZYGY I/O standard, as well as a unique software environment to help connect software languages (C++, Python, etc.) to hardware," he said. "That means that you don't need to be a hardware engineer to program it. The 500-MHz data rates of the SYZYGY connectors allow for a concept versatile enough to cover a range of high-speed instrumentation and test applications. Since it's not a turn-key product, it will require development effort," but it is suitable for specialized applications and especially for OEMs or integrators that have challenging applications with budget and space constraints.

"Semiconductor companies are constantly pushing the speed and bit-depth or precision of their ADC and DAC devices, and also the bandwidths needed to communicate with those devices," Johnson continued. "FPGAs are a good match to interface with these devices, providing both parallel and high-speed transceiver interfaces and the specialized compute resources often required for in-line signal processing and/or control. Digilent's Eclypse platform allows semiconductor companies to create Zmod modules with new silicon, allowing customers to easily evaluate the latest devices without designing the low-level interfaces and specialized power supplies, but still giving them direct access to the converters for ultimate flexibility."

When asked about current and expected trends in high-speed analog test, Johnson said, "We expect to see higher precision and higher speed converters along with lower power as demand for more portable and mobile devices increases. We also expect the trend for more RF communications, test, and software-defined radio (SDR) to drive the integration of more high-speed analog into new devices and to generate additional test challenges."



Samtec Bulls Eye high-performance test system.

simulations and real-world communications—all of that within a realistic equipment budget.

Burns, Samtec: Most IC/connector evaluation boards feature a number of discrete SMAs that high-performance signals route to for connectivity to test equipment. The Bulls Eye high-performance test system improves density 4:1 over discrete SMAs and enables smaller evaluation boards with shorter trace lengths.

Digital communications standards

Are any emerging digital communications standards presenting significant test-and-measurement challenges that you can help your customers address?

Asay, Keysight: There are a couple of unique problems that we help to solve. First, for DDR5, the eyes are fully closed, which has never happened in a memory before—meaning that for the first time, equalization must be utilized to open the eye. Once equalization is used, then it must be "tuned" to find the optimal equalization setting for the receiver. We provide a fully automated Rx calibration system for DDR5. While PCI Express Gen6 is just beginning, it will represent the first time many of today's high-speed digital engineers use PAM4 signaling. We offer a full suite of tools aimed at PAM4 for both the receiver and the transmitter. Finally, as the world moves to 800-Gb/s signaling, the baud rates are moving above 100 Gbaud. This is fast. Designers need a way to see how good their device is doing under these circumstances. Keysight is the only vendor to provide error detection above 100 Gbaud.

Smith, Pico Technology: Emerging standards are always more challenging to implement that the previous ones! Digital designers are increasingly using tools that were previously the preserve of RF and microwave engineers to get the job done. The best example is the use of a vector network analyzer for channel characterization with S-parameter measurements. Previously they were using exclusively time-domain tools such as a TDR. VNAs have higher dynamic range of 118 dB or more, which is important for low-voltage transmission standards that have very tight noise margins.

Key trends

What key trends in high-speed digital test have you seen over the past year, and what trends do you expect to see in 2020?

Asay, Keysight: The biggest trend was move to Gen5 for PCI Express and DDR. As we move into 2020, USB will become the focus again as USB 4.0 begins to take over. As you look beyond 2020, PAM4 begins to enter the HSD test area. From the testing side, we are seeing a trend to speed up the test automation. This is critical given the need for companies to get to market faster.

Smith, Pico Technology: The past year has thrown up a few new challenges with applications that demand deep understanding of timing and phase-noise characteristics. The 9404 SXRTO's address that with a full suite of automated measurements with statistics. EE

MENTOR TARGETS HIERARCHICAL DFT AND AUTOMOTIVE SAFETY

By Rick Nelson, Interim Chief Editor

Hierarchical DFT methodology and automotive functional safety have been two recent areas of focus for Mentor, a Siemens business. Legacy design-for-test flows impose inefficiencies when transitioning to a hierarchical methodology, according to Geir Eide, product marketing director, Tessent Design-for-Test, at Mentor. What's required for fast time to market, he said in a recent phone interview, is optimal end-to-end automation for hierarchical implementation. And with respect to automotive functional safety, the required tools and technologies extend beyond DFT to embrace a safety ecosystem that included third-party tools, added Eide's colleague Lee Harrison, automotive IC test solutions manager at Mentor.

To address both automation for hierarchical implementation and automotive functional safety, Mentor in November introduced two new solutions. First, the Tessent Connect DFT automation methodology delivers intent-driven hierarchical test implementation that helps IC design teams achieve manufacturing test quality goals faster and with fewer resources compared with traditional DFT methods. Second, Mentor also introduced the Tessent Safety ecosystem, which leverages the automotive IP portfolio of Arm as part of a Functional Safety Partnership Program.

Hierarchical DFT

Eide explained that advanced IC designs can achieve high defect coverage for manufacturing and in-system test by making use of dedicated on-chip infrastructure such as embedded compression, built-in self-test, and IEEE 1687 Tessent Connect IJTAG networks. But as IC designs grow in size and integrate more on-chip IP, engineers are increasingly adopting hierarchical DFT approaches that break down the traditional DFT process into smaller, more manageable elements.

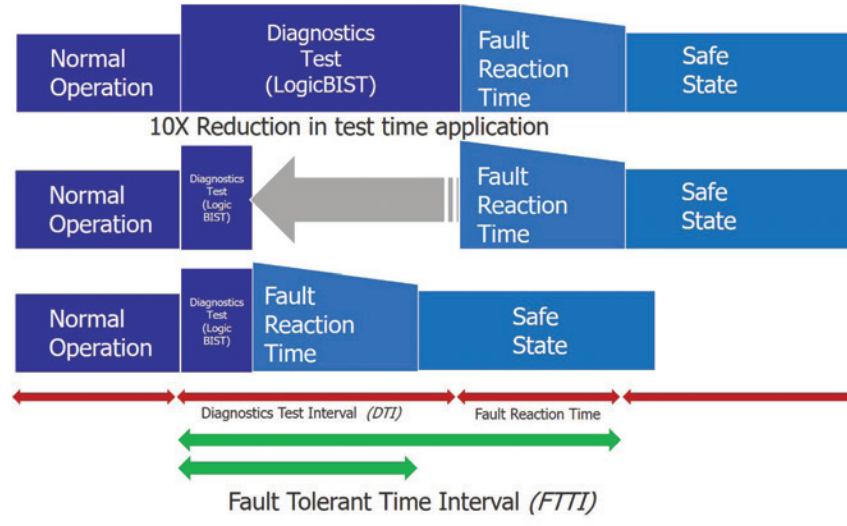
DFT is becoming a critical path to tape-out, said Eide, adding, "The transition to hierarchical DFT methodologies is inevitable." Without automation, he explained, engineers need to describe what they want the tools to do each step of the way, information from one step must be carried over to the next, and errors discovered late in the process can result in time-consuming iterations. With intent-driven automation, engineers can use fewer, shorter scripts, with the tool handling integration, setup, and pattern generation, resulting in shorter turnaround time and reliable, sustainable flows.

"Tessent Connect is the optimal way of implementing the Tessent Shell Flow for Hierarchical Designs," Eide noted.

Eide said an early adopter of Tessent Connect is eSilicon, a provider of FinFET ASICs, market-specific IP platforms, and advanced 2.5D packaging solutions. By employing Tessent Connect, he said, eSilicon improved IC DFT implementation cost while enabling system-level DFT testing and debug capabilities for a sophisticated next-generation ASIC.

"eSilicon uses Tessent Connect to help us meet our aggressive production schedules and deliver industry-leading ICs like those based on eSilicon's neuASIC 7-nm platform for machine learning," said Joseph Reynick, director of DFT services at eSilicon, in a press release. "As design complexity continues to grow, our system/OEM customers' needs expand from just focusing on high-quality IC manufacturing test to also providing effective in-system test and functional debug capabilities. With today's complex 2.5D/3D devices, we are not shipping in volume until our chips are fully operational in our customers' systems, including DFT and IP test. It would be very difficult to meet these challenges without the Tessent DFT portfolio and the efficiencies gained from Tessent Connect automation."

As part of the Tessent Connect rollout, Mentor also announced the Tessent Connect Quickstart program,



▲ **Figure 1:** FTTI reduction enabled by Tessent LogicBIST with Observation Scan technology.

offering detailed flow assessments and customized insights from Mentor's applications and consulting services engineers to help IC design teams optimize and automate their DFT processes when using Tessent Connect.

"The Tessent Connect Quickstart program is the fastest way to elevate your DFT flow to Tessent Connect," concluded Eide.

Automotive functional safety

Mentor describes its new Tessent Safety Ecosystem as a portfolio of its automotive IC test solutions with links to its partners, providing an alternative to competing programs based on closed, monolithic, single-source models.

"New requirements require new test techniques or safety mechanisms, outside of the scope of traditional DFT," explained Harrison. "Monitoring and managing all of the different in-system test functions is now critical to the safe operation of an automotive IC. This often requires a dedicated safety island or manager." He added that in-system logic test time, with a defined fault-tolerant time interval (FTTI), is now a critical component of meeting safety requirements (**Figure 1**).

"To address the challenge of in-system logic test time," Harrison said, "Tessent LogicBIST with Observation Scan technology (LBIST-OST) can reduce the in-system runtime by 10x, enabling a much reduced FTTI when used in an automotive application."

The Tessent Safety Ecosystem includes the following technologies in addition to the new Tessent LBIST-OST:

- Tessent MemoryBIST, which features an automation flow that provides design rule checking, test planning, integration, and verification at either the RTL or gate level. Because Tessent MemoryBIST features a hierarchical architecture, BIST and self-repair capabilities can be added to individual cores as well as at the top level.
- The Tessent MissionMode product, which provides a combination of automation and on-chip IP for enabling semiconductor chips throughout an automotive electronics system to be tested and diagnosed at any point during a vehicle's functional operation.
- The Tessent DefectSim transistor-level defect simulator for analog, mixed-signal (AMS) and non-scan digital circuits. Suitable for both high-volume and high-reliability ICs, Tessent DefectSim measures defect coverage and tolerance.
- Mentor's participation in the Arm Functional Safety Partnership Program (AFSPP). The Mentor Tessent Safety ecosystem leverages Arm Safety Ready IP functionalities like the Cortex-R52 processor, which combines real-time execution with the integrated functional safety capabilities of any Arm processor, hypervisor technology to simplify software integration, and separation functionality to protect safety-critical code.
- Mentor's automotive-grade automatic test pattern generation (ATPG) technology, which detects defects at the transistor and interconnect levels often missed by traditional test patterns and fault models.
- Close links to Mentor's Austemper SafetyScope and KaleidoScope products, which add safety analysis, autocorrection, and fault-simulation technology to address random hardware faults. Austemper technology analyzes a designer's RTL for faults and vulnerabilities and is capable of smart fault injection to help safety mechanisms react in a planned manner for covered faults. Through parallelized and distributed operation methods, proprietary acceleration algorithms achieve speed-ups of many orders of magnitude over standard gate-level fault injection techniques.

Among the early adopters of key technologies in Mentor's Tessent Safety ecosystem is Renesas, which evaluated Mentor's new Tessent LBIST-OST solution in designing one of its newest automotive processors.

"Leveraging the Observation Scan technology featured in the new Tessent LBIST-OST solution, we were able to reduce the test time for in-system Logic BIST by 5x, thereby enabling a much faster coverage ramp up," said Hideyuki Okabe, director, Digital Design Technology Department, Shared R&D EDA Division, IoT and Infrastructure Business Unit at Renesas Electronics Corp., in a press release. "This enabled us to reduce our Fault Tolerant Time Interval…when using Logic BIST as a safety mechanism and improve the safety response when detecting new defects in our automotive products. We hope to continue to adopt this technology going forward for our automotive products." EE

CONFORMANCE AND COOPERATION MOVE 5G FORWARD

By Rick Nelson, Interim Chief Editor

Conformance and regulatory issues must be addressed in the rollout of any technology such as 5G. And effective development and deployment strategies require cooperative efforts among component manufacturers, test providers, industry organizations, standards and certification bodies, and universities and research institutions.

Several industry experts who provided input for our recent report on 5G technology[1] commented on efforts in conjunction with other companies, universities, government agencies, and standards bodies.

"Our first priority when we started our 5G program over five years ago was to build collaborations with the market leaders from commercial, government, and academic institutions," said Roger Nichols, 5G program manager, Keysight Technologies Inc. "As of today, we have over 35 of these collaborations around the globe, across different technologies, and across the ecosystem." That ecosystem, he said, includes operators like Docomo, modem companies like Qualcomm and base-station companies like Nokia; universities including the University of California at both Berkeley and San Diego, the University of Bristol, Southeast University in Nanjing, and NYU Wireless; and standards bodies like 3GPP, CTIA, and GCF. "These have been rich engagements with mutual benefit plus helping drive the overall 5G commercialization across the ecosystem" he said.

Rohde & Schwarz has partnered with several 5G development groups, including the 5G Lab Germany, hosted and managed by the Technical University of Dresden, according to Andreas Roessler, technology manager, Rohde & Schwarz USA. In addition, "Since the early days of 5G, Rohde & Schwarz has been partnering with the Fraunhofer Heinrich-Hertz Institute (HHI) of Berlin on channel-sounding measurement campaigns for frequencies up to 300 GHz, including the measurements of the angle-of-arrival (AoA)."

Roessler also said Rohde & Schwarz recognizes the importance of industry cooperation in meeting the demand for end-to-end system optimization in new and emerging vertical markets, noting that the company was early to join the 5G Alliance for Connected Industries and Automation (5G ACIA) and the 5G Automotive Association (5GAA). "In both organizations, Rohde & Schwarz provides its expertise from a test and measurement perspective and actively contributes to the related working groups," he said.

According to Alejandro Buritica, senior marketing manager, Semiconductor Solutions, National Instruments, "Collaboration with industry, standards bodies, and research institutions is key to realizing successful 5G deployment and adoption. We continue to invest and work together with top researchers on core measurement challenges."

Added Buritica, "With regards to standards bodies, we actively participate in key RAN 1 and RAN 4 3GPP meetings to make sure we stay abreast of upcoming test needs. We have a good relationship with NIST on test and calibration methodologies for new 5G device types."

He continued, "In terms of academic research, NI is involved with many non-public collaborations, but one public example of a 5G collaboration is with the University of Warwick. They have been using NI's mmWave Transceiver System as well as NI's 5G NR test UE to research various topics related to vehicular communications. Also, the University of Bristol and Lund University partnered with NI to demonstrate world records in 5G wireless spectral efficiency using massive MIMO."

NI has also collaborated with several companies. "For example, we have worked very closely with semiconductor industry leaders Qorvo and Analog Devices to help them create extensive test solutions for new 5G parts," said Buritica. "We also cooperated with Tokyo Electron, FormFactor, and Reid-Ashman to demonstrate a 5G mmWave semiconductor wafer-probe test solution that helps reduce risk and cost for validation and production test of 5G mmWave ICs."

In addition, he said, NI introduced its 5G New Radio Test UE earlier this year. It is a fully Release 15 NSA-compliant UE that can attach to commercial gNB hardware. He added that NI has also partnered with Spirent on a 5G NR gNB solution that, combined with other Spirent products, can create a full end-to-end 5G network. "Complete with logging capabilities, this end-to-end network offers valuable validation capabilities for 5G equipment," he said.

Additional collaborative efforts include Spirent's work the UK Government-sponsored 5GIC (5G Innovation Center) at Surrey University. "This multivendor environment fosters innovation around 5G industry verticals," said Stephen Douglas, head of 5G practice, Spirent. "Spirent 5G traffic emulation is used to make the facility the largest capacity representative 5G test network for research, innovation, and development in the world."

Spirent is also working with the Warwick Manufacturing Group, which Douglas described as an academic department providing research, education, and knowledge transfer in engineering, manufacturing, and technology. "WMG is leading the UK research around 5G for the future of autonomous vehicles and Industry 4.0," he said. "Spirent 5G digital-twin emulation solutions are helping turn the test beds into representative and

flexible 5G network testing environments, allowing automotive and industry partners to research and innovate."

Recent efforts of Marvin Test Solutions with respect to 5G test have centered on a mmWave/5G semiconductor production test system capable of delivering 50-GHz signals to a DUT, according to Jon Semancik, director of marketing, Marvin Test Solutions. He said that for production test applications requiring integration with an automated handler, the TS-960e-5G is available with an inTEST manipulator, which provides precise positioning of the test head and the flexibility to interface to automated probers and device handlers, adding that the device interface board (DIB)/receiver interface is designed to be compatible with virtually any device handler. He noted that available digital vector conversion tools support standard ASCII, WGL, STIL, VCD, eVCD, and ATP vector formats. In addition, he said, "MTS is collaborating with leading VNA instrumentation suppliers, including Keysight and Rhode & Schwarz, to develop open-platform solutions that best fit customer's requirements and price-points."

Compliance and regulatory news

Several companies have recently announced news with respect to compliance and regulatory issue. For example, Anritsu in October announced it has upgraded its MT8000A radio communication test station with 5G protocol-test functions. The upgrade uses NR (New Radio) fading software that, when implemented with built-in baseband fading tests, allows the MT8000A to support 3GPP TS 38.521-4 B.1/B.2 V15.0.0-compliant 5G NR channel (TDL) model tests.

The MT8000A covers the key frequency bands used by the first 5G services, such as the sub-6-GHz band (FR1) frequencies of 2.5 GHz, 3.5 GHz, and 4.5 GHz as well as the mmWave band (FR2) frequencies of 28 GHz and 39 GHz.

Also in October, Keysight announced that PCTEST had selected Keysight's 5G network emulation solutions to address testing of critical regulatory requirements mandated by the FCC for 5G mobile devices. Keysight said its end-to-end 5G test solutions enable PCTEST to characterize the performance of a 5G mmWave device in an over-the-air (OTA) test environment and certify the device according to the FCC EMC and SAR requirements for measurement of power levels, signal strength, and emissions produced by a 5G mobile device. Keysight said it combines the company's 5G network emulation solutions with its compact antenna test range (CATR) chambers to support regulatory radio-frequency (RF) testing of 5G mobile devices in both conducted and radiated test environments across the sub-6-GHz (FR1) and mmWave (FR2) spectrums.

And in November, Rohde & Schwarz announced that The Global Certification Forum (GCF) and the PTCRB certification organization have accepted first test case validations in various FR1 and LTE band combinations using its new R&S TS8980FTA-3A 5G RF conformance test system. The company said the R&S TS8980FTA-3A is the latest version of a family of RF conformance test systems supporting mobile technologies all the way from 2G to 5G on one platform.

▲ Rohde & Schwarz R&S TS8980FTA-3A 5G RF conformance test system.

▼ Anritsu MT8000A radio communication test station with 5G protocol-test functions.

Myriad applications

Vendors' efforts have been opening up a range of applications. Buritica at NI said customers have been using NI's PXI platform to set up highly automated test benches for characterization of RF front-ends in both FR1 and FR2.

"They are taking advantage of our mmWave heads with built-in, calibrated switching to test new device types like multichannel beamformers with dual polarization without having to maintain complicated switching schemes," he said. "Also, we've helped significantly reduce the time it takes to run full 3D-spatial OTA tests of new mmWave antenna-in-package (AiP) devices using our novel approach to OTA test."

Buritica elaborated on OTA, saying, "To help engineers in charge of mmWave OTA characterization and validation test of AiP beamforming devices reduce test times without compromising accuracy, NI developed the mmWave OTA Validation Test reference architecture, which takes a platform-level approach that integrates NI's real-time motion control, data-acquisition, and PXI triggering and synchronization to take fast, high-bandwidth RF measurements synchronized with the instantaneous (ϕ, θ) coordinates of the positioner's motors," he said. "Unlike traditional OTA test solutions, NI's approach moves the DUT in a smooth and continuous motion across the 3D space while the RF engine takes rapid measurements.

This eliminates the time waste of moving discretely from point to point."

Nichols at Keysight also commented on OTA test, noting that 100% of mmWave test cases are OTA. "OTA testing is not unique to 5G, but there are parts that are particularly novel," he said, citing the directional nature of the radio transmission. "The concept of managing a beam that points from the transmitter to the receiver and focusing the receiver on that beam is new to 5G," he said. "What makes this extraordinary is that one of the radio transceivers involved is mobile and can be moved to any location and any orientation with the radio system making every possible effort to maintain the link. Testing this involves a complex set of measurements that validate the flexibility of the spherical coverage of the UE for both Tx and Rx—and all of these are calibrated over-the-air measurements. The standards for managing mobility for mmWave are not yet complete, so it is easy to assume that this will continue to present challenges."

Nichols also commented on the company's FieldFox portable analyzer for 5G, satellite-communications, signal-monitoring, and electronic-warfare applications. "Complex beam sweeping technologies used with radar and EW systems, as well as with 5G control channels, will require wider bandwidths and real-time spectrum-analysis tools to capture these intermittent and elusive signals," he said. "FieldFox can connect to 89600 VSA software to demodulate 5G NR and LTE-A signals up to 100 MHz or easily switch to over-the-air (OTA) measurements for 5G and 4G LTE to verify gNB performance."

Roessler at Rohde & Schwarz noted that 5G requires an increasing amount of OTA testing. Rohde & Schwarz launched three new OTA solutions based on CATR technology: the R&S ATS800B benchtop solution, the R&S ATS800R rack solution, and the R&S ATS1800C 5G NR mmWave test chamber. "All these OTA solutions feature a high-precision CATR reflector to generate a big useable measurement area (the so-called quiet zone, QZ) in a very compact setup," he said. "The R&S ATS800B and R&S ATS800R provide a 20-cm QZ whereas the R&S ATS1800C offers a 30-cm QZ, which complies with 3GPP RF conformance test requirements. The portable compact chamber solution provides very high shielding efficiency and features a 3D positioner that can even move more heavy devices up to 8 kg."

Douglas at Spirent emphasized digital-twin applications. "The 5G digital twin is an emulated software replica of the physical network, allowing continuous prototyping, modeling, and research," he said. "As 5G moves us from being a physical network to a living system, the digital twin is an ideal solution. The digital twin consists of multiple emulation, traffic, and signal-generation functions working in harmony to provide a virtual software version of the 5G network."

Investment protection

The move to 5G has implications for investment protection. Adnan Khan, senior business development manager for wireless products at Anritsu, noted that the company's existing customers can repurpose their 4G assets towards 5G, using, for example, Anritsu's MT8821C radio communication analyzer as an LTE anchor. "This also gives customers the option of using a GUI they are familiar with for testing," he said. "Also, for conformance systems, Anritsu is able to use many 4G solutions in 5G applications."

Nichols at Keysight noted that in some cases equipment used to test 4G can test 5G, possibly with software updates. In other cases, test equipment must be completely rebuilt to address mmWave frequencies and OTA requirements. Keysight, he said, works on line extensions as well as commercial technology refresh programs. "Of course, we have to ensure that new platforms can manage the demands of not just the new technology, but also that of the legacy and of the interaction between the generations," he said. "In the case of 5G NSA Core testing, we have evolved our test solution such that our customers can seamlessly use all 4G functionality they have been using without change. In this case, our customers' investments are protected with 100% reusability. 5G SA core testing brings a new architecture and a new test paradigm, but even in this case we expect to be able to provide our customers with 'fallback' capabilities such that their validation of standalone 5G services is not conducted at the expense of 4G validation."

Roessler at Rohde & Schwarz cited the company's widely used R&S CMW500 platform. "The initial roll-out of 5G is based on non-standalone (NSA) mode where an LTE anchor is required for the exchange of control and signaling information," he said. "Therefore, it was evident to Rohde & Schwarz to save our customers' investment into the R&S CMW500 for 4G LTE testing and reuse the platform to provide this anchor functionality. The R&S CMX500 uses an advanced hardware design concept and intelligence unified web-based graphical user interface to make it the platform to test 5G for decades to come and beyond."

Douglas at Spirent said he doesn't see the need for 4G test and measurement diminishing in the short to medium term due to four industry trends. "First, many CSPs are aggressively building out underlay LTE-A Pro networks alongside 5G for 'coverage and fallback' to guarantee customers a premium experience and look to quickly close and refarm 3G," he said. "Second, many Tier 2 CSPs will stay with 5G evolution (NSA) utilizing the 4G Core (vEPC) for a protracted period. Third, the growth of private networks will initially be via LTE evolving towards 5G from 2022 on. And fourth, in automotive, C-V2X will first harness LTE before evolving to 5G from 2022 on." Consequently, "4G test systems will still be critical," he said. "Customers are asking Spirent to help create a future-proof pathway for test tools to evolve to 5G as needed. To provide this pathway, Spirent has been developing many of its systems to support software-defined architectures, virtualization, and cloud-native micro-services. In addition, our recent partnership with National Instruments to use their industry leading SDR to underpin our radio test systems benefits customers from future-proofed investment." EE

REFERENCE

1. Nelson, Rick, "Innovations from semiconductors to digital twins drive 5G," *EE-Evaluation Engineering,* December 2019, p. 6.

EMA DESIGN AUTOMATION'S MARCANO LOOKS TO THE FUTURE OF PCB EDA

By Rick Nelson, Interim Chief Editor

EMA Design Automation, a full-service provider of electronic design automation (EDA) solutions, celebrated its 30th anniversary in 2019, having begun selling EDA tools in 1989. *EE-Evaluation Engineering* interviewed Manny Marcano, president and CEO, on the past and present of printed-circuit-board EDA.

Rick Nelson: **What prompted you to found EMA Design Automation?**

Manny Marcano: I wanted my freedom and to gain direct rewards for my efforts. CAD on PC was really just getting off the ground, and there looked to be a great opportunity for someone who could help companies make this transition.

RN: **You are a reseller for Cadence tools. What value-add do you provide?**

MM: It began with just plain excellent customer service: pre-sales, installation, training, and post-sales. It evolved to creating IP to solve specific customer problems, which grew into turning those unique apps into products that we sell now. We also acquired IP, which really added to our "value add" proposition.

RN: **You offer several EMA products, including TimingDesigner, Circuitspace, and Ultra Librarian. Could you describe those and explain what's unique about them?**

MM: TimingDesigner was the first IP acquisition. The owner, Forte, decided the product was not strategic, and we were the biggest reseller, so it was a natural addition to our offering.

CircuitSpace was another perfect adjacency that fit into our top-tier Allegro customer base. It is still a great productivity tool and an integral part of some customers' design methodology.

Ultra Librarian has been the best acquisition to date. Our market is starving for content, and Frank Frank's library was the answer we needed to create a competitive edge. We now offer it at no charge to all EDA end users and a small subscription charge to interested OrCAD customers if they want a direct symbol graphic connection to OrCAD Capture.

RN: **What would you consider a key milestone in the history of EMA Design Automation?**

MM: The biggest was earning the North American exclusive contract for OrCAD in 2003. Our growth was incredible, and Cadence supported us completely throughout the process.

RN: **What are your thoughts regarding simulation and virtual prototyping in PCB design?**

MM: This is compelling technology on the horizon! The convergence of mechatronics and virtual prototyping will constitute the best practices going forward.

Consider the creation of a digital twin—older, poorly documented technology converted to a virtual digital twin that can be tested and simulated before a real prototype is made. This leads to vastly improved time to market and dramatically increases the probability of success.

RN: **How does EMA address ECAD/MCAD integration?**

MM: We have wrestled with this the hard way for several years: file out, file in, errors, very clunky—it bordered on being a dysfunctional process.

We will soon be formally announcing a next-generation solution to this problem called CADSync. We designed our approach from the ground up to consider the needs of both the electrical and mechanical users while solving the problems that plague the variety of loose ECAD-MCAD connections that exist today. The initial feedback from our early customers and partners has been extremely positive. It is clear this is a critical issue in the industry, and we are excited to help our customers take full advantage of what a modern, native, and collaborative environment can do for them.

RN: **Looking at the electronics industry in general, we see the emergence of the IoT and IIoT, with billions of sensor nodes. How does the EDA industry need to adapt to support the design of widely dispersed, compact, low-power IoT devices?**

MM: Regardless of the technology, all IoT devices and ideas must be brought into the real world with a PCB. The PCB brings them to life!

RN: **5G is moving consumer electronics out of the realm of sub-6-GHz frequencies and into the millimeter-wave ranges. What changes will the EDA industry need to make to adapt?**

MM: The industry needs to embrace cross-platform collaboration at the RF module, PCB, and IC design level. These technologies are merging into one cross-platform (IC/PKG/PCB) solution to incorporate multiple technologies (CMOS, GaAs, SiC, etc.) into a single module via an interposer for testing and then into a package for mounting onto a PCB or substrate. For this to work you need to understand the parasitics at

every level of the process, and you must have an integrated 3D field solver that works at the IC and system level. This is a tough problem that needs attention to constraints and parasitics across the domains.

You also need to support RF routing, shielding, and structures (parameterized elements) at the PCB level and stitch the models across the platforms. You need an integrated cross-platform solution to accomplish this. 5G is just one driver for this type of technology and methodology, but certainly a very strong one. So, in a way, technologies like this help to bring the design disciplines together, as operating independently is no longer feasible at this level.

RN: **Do you see other industry trends that will have an impact on the EDA industry in the coming years?**

MM: 3D printed-circuit boards constitute the next wave of prototype capability. I envision an engineer completing a design and pushing the print button in their CAD tool.

RN: **What challenges to the EDA industry will techniques like in-mold electronics present?**

MM: I think this is another example of how intertwined electrical and mechanical are becoming. In this instance, the case is the "board." Finding the best way to design, verify, and build these introduces whole new processes to be addressed. From a challenges standpoint it will mean new design methodologies and new manufacturing ones as well.

RN: **What are your thoughts on the 3D printing of PCBs in regards to the EDA industry?**

MM: Having conductive traces on a 3D device is becoming common. "Printing" passive devices is feasible, but the placement and soldering of active components is way over the horizon.

RN: **How will the industry adapt to the increasingly interdependent aspects of electrical, mechanical, EMC, and thermal design?**

MM: Through virtual prototyping that will bring all the data and models together that can be simulated on a platform. Dassault 3D Experience is a good example of this.

RN: **Testability has always been an issue, and EMA has partners in the design-for-test space. What can the EDA industry do to help support design-for-test and design-for-manufacturing in the future?**

MM: A lot of this can be helped with education and in-tool support. We need to make design for test and design for manufacturing part of the design flow, not a side process. The more we can push upstream into design, the more predicable the design process will be and the higher chance for ultimate success. Part of this is educating the engineering community on the value and need to understand these flows up front. Just as ECAD and MCAD are converging into mechatronics, design and manufacturing are converging as well. These processes are becoming very interdependent as we continue to push the boundaries of technology forward.

RN: **The semiconductor industry has been following Moore's law for decades, with densities doubling every 18 to 24 months. But as one industry expert put it, "We are running out of atoms," putting a fundamental limit on planar transistor density. Is the PCB industry facing similar limitations, and what can the PCB EDA industry do to support PCB manufacturers?**

MM: There will always be those that are pushing the limits of what is possible. From a PCB perspective, the tools are very capable and can (in theory) let you design in CAD what may not be effectively manufactured using existing processes. I think we will see more focus on manufacturing process-driven design—something like a PDK (process design kit) for PCB.

The manufacturing process really influences so much of what is possible from a design perspective and because of this, it needs to be an inherent part of the design process. The manufacturing technology will come along just as it has with the IC. It may not be linear scaling in terms of feature size, but the industry will find a way to meet the technology needs. Our objective is to help make sure the tools and flows are there to support the user in a way that is in connection with all the other downstream processes (procurement, manufacturing, PLM, etc.).

RN: **Given the potential slowdown or end to Moore's law, the electronics industry is pursuing heterogeneous integration (sometimes referred to as "more than Moore"), which involves the integration of perhaps CMOS devices and devices fabricated in other processes. What problem does this present for semiconductor EDA tools or for PCB EDA tools? Do you foresee a blurring of what once were clear lines between semiconductor EDA and PCB EDA?**

MM: I don't see this as a problem as much as an opportunity. We are clearly hitting some limitations in scaling combined with the fact that the primary drivers are not just speed anymore. Power consumption and cost are also key factors in the equation. This leads to a new way of thinking about what leading-edge is and what problems it solves.

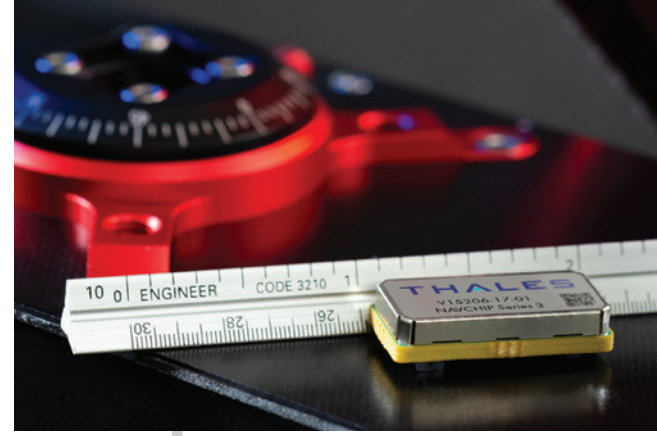
As you stated the package is becoming more PCB-like as these kinds of hybrid technologies evolve. I think there is a lot for the IC community to take from the PCB community now that these types of heterogenous devices are gaining momentum. In general, this will mean more integration and communication is needed across the chip, package, and board to drive optimal system operation.

RN: **When I got my first job as an electrical engineer (admittedly a little more than 30 years ago), PCB design was accomplished using mylar, tape, and an X-acto knife. Obviously, the industry has come a long way since then. Where will we be 30 or more years from now?**

MM: We will be printing PCBs on demand, and it will happen long before 2050. EE

TECH FOCUS

USB CONNECTIVITY



Instruments are available in a variety of form factors, as described on p. 18 of our December issue. USB continues to be a popular choice, finding use on everything from IMU evaluation boards to vector network analyzers. (For more on the latter category, see the article beginning on p. 6 of this issue.) Below is a sampling of recently introduced products offering USB connectivity—with some also offering alternatives extending from IEEE 488 to Wi-Fi.

Wi-Fi oscilloscope

TiePie engineering has introduced its WiFiScope oscilloscopes, which can be used via an Ethernet connection (LAN, Wi-Fi, or WAN) but also with a USB 2.0 or USB 3.0 connection. The built-in battery enables the WiFiScope to perform fully wireless measurements, galvanically isolated, over long distances. USB measurements for standalone applications and high-speed data acquisition can take place at 200 MS/s. Combined with the Multi Channel oscilloscope software, the 250-MHz WiFiScope WS6 (four channels) and WiFiScope WS5 (two channels) turn your PC into an oscilloscope, spectrum analyzer, multimeter, data logger, and protocol analyzer.

TiePie engineering

Range-to-fault calibration

Kaelus, a supplier of PIM test-and measurement-instruments and RF conditioning solutions, has released new functionality for its Analyzer Calibration Extender (ACE), which now supports the range-to-fault (RTF) module used for locating PIM and return-loss faults in RF infrastructure. The ACE allows customers to self-calibrate their Kaelus PIM instruments in the field. Reducing downtime of calibration to less than one hour, ACE extends the calibration due date by 12 months. ACE offers USB Connectivity for the company's iPA and iTA instruments.

Kaelus

6-axis IMU

Thales Visionix has introduced enhancements to its NavChip Series 3, the latest in the company's family of inertial measurement units (IMUs). The new NavChip Series 3 allows users to choose the optimum performance at their selected price point from both NavChip and NavChip Series 3 Class A and Class B parts. Specifications include Class A bias in-run stability to 4°/hr. (typical), 5°/hr. (max.), with an output rate of 1,000 Hz, and Class B bias in-run stability to 5°/hr. (typical), 10°/hr. (max.) with an output rate of 1,000 Hz. Evaluation kits with integration software, a USB interface, and external sync cable start at $895.

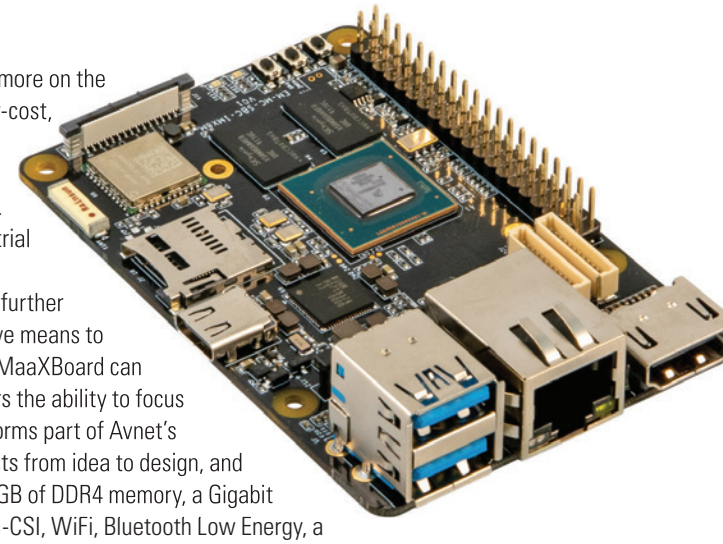
Thales Visionix

Recorder for military signal intelligence

Pentek Inc. has announced an addition to its family of Talon signal recording and playback systems, the RTR 2654 26.5-GHz RF Sentinel intelligent signal-scanning rackmount recorder. The RTR 2654 combines a Pentek Talon recording system with a 25.6-GHz RF tuner and Pentek's Sentinel intelligent signal-scanning software. The RTR 2654 automatically scans the RF spectrum from 800 MHz to 26.5 GHz for signals of interest and monitors or records bandwidths up to 500-MHz wide, making it suitable for military, security and government intelligence (SIGINT, COMINT and ELINT) applications. The Talon RTR 2654 is packaged in a 4U 19-in. rack-mountable chassis, with front-panel removable and hot-swappable solid-state drives (SSDs), front panel USB ports, and I/O connectors on the rear panel.

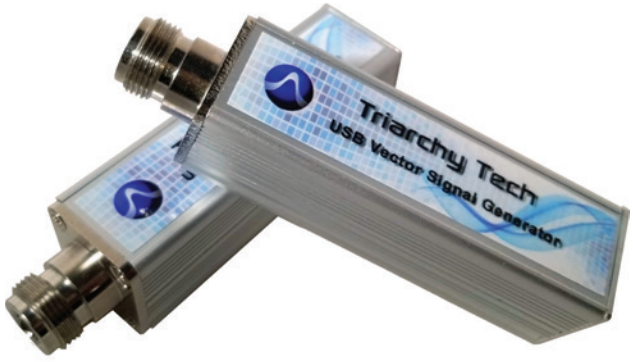
Pentek Inc.

Single-board computer



Avnet announced it is providing customers with the ability to focus more on the software side of their development by launching MaaXBoard, a low-cost, production-ready qualified single-board computer. Based on the NXP i.MX 8M applications processor, MaaXBoard is suitable for embedded computing and applications that leverage AI at the edge. It supports design engineers and end-users seeking to create industrial automation, multimedia, AI, and IoT applications with reduced cost and time-to-market. With this new single-board computer, Avnet is further enabling developers who are seeking new, flexible and cost-effective means to design and test concepts. As a production-ready qualified unit, the MaaXBoard can become part of an embedded hardware system, providing customers the ability to focus more on the software side of their development. The MaaXBoard forms part of Avnet's end-to-end product development ecosystem, helping to bring projects from idea to design, and design to production. The platform's on-board peripherals include 2GB of DDR4 memory, a Gigabit Ethernet port, dual USB 3.0 host ports, HDMI output, MIPI-DSI, MPI-CSI, WiFi, Bluetooth Low Energy, a MicroSD card slot, and eMMC storage. The complete MaaXBoard kit is $79.95.

Avnet



RF vector signal generator

Saelig Co. Inc. has announced the availability of Triarchy Technologies' VSG2G5C RF vector signal generator—a pocketable USB-connected RF signal source with capabilities that provide standalone and PC-controlled functions comparable to full-size analog RF signal generators. Offering frequencies from 100 Hz to 1 MHz (low-band) and 100 MHz to 2.5 GHz (RF band) with a frequency resolution of 1 Hz, this unit's features include frequency sweep, frequency hopping using I/Q modulation, and arbitrary signal generation. With output levels up to 15 dBm, signals can be delivered in CW, sweeping, and hopping modes. An N connector provides the signal output, while side-mounted miniature connectors provide I/Q input and output. A pulse output is available at the rear of the unit.

Saelig Co. Inc.

Programmable power supply

TDK Corp. has announced the TDK-Lambda 1U full-rack GENESYS 1.7-kW AC/DC programmable power-supply series. This platform provides the user with a choice of ten different models, ranging from 10 V at 170 A to 600 V at 2.8A, that suit design, test, and measurement in the laboratory/R&D environment and address

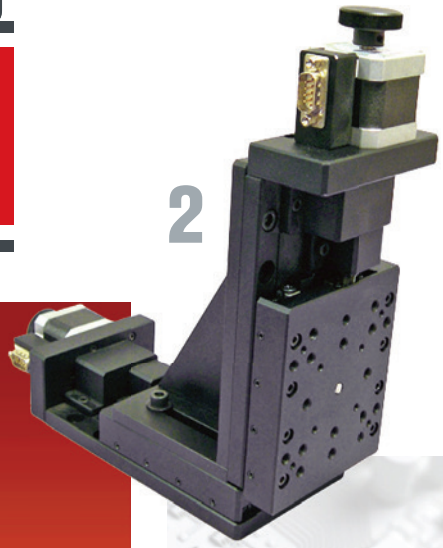
market segments including automotive, aerospace, semiconductor, industrial, and renewable/alternative energy. Built into a 1U-high, 19-in.-wide rack-mountable chassis, the 1.7-kW power supply offers five embedded front-panel setup menus that address digital communication, protective functions, operating configuration, system configuration, and system triggering. All model functions can be programmed locally via the menu-driven front panel or remotely using software instrument drivers with any one of the three built-in standard digital interfaces: LAN (LXI 1.5), USB 2.0, and RS-232/RS-485. Other programming interfaces include the built-in standard isolated analog program/monitor/control interface and an optional IEEE 488.2 interface.

TDK Corp.

EVALUATION ENGINEERING'S

FEATURED TECH

1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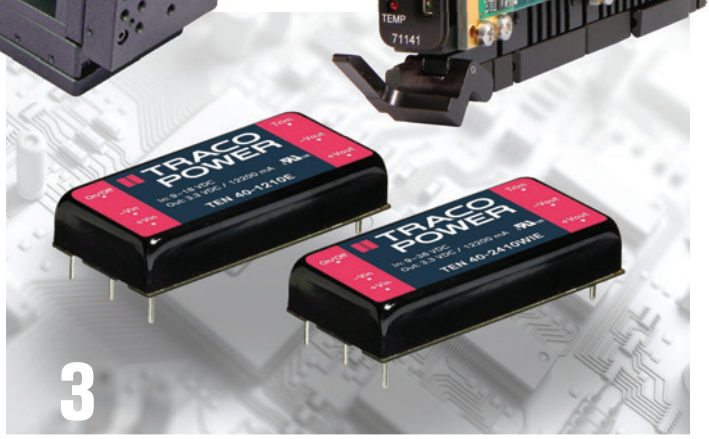


3

4

1. Frequency dividers with SMA connectorized packages

Fairview Microwave Inc. has a new line of frequency-divider modules that cover broadband frequencies from 0.1 GHz to 20 GHz. An offering of 28 different models features fixed divide-by ratios from 2 to 40. These compact prescalers are suitable for frequency-synthesizer and phase-locked-loop (PLL) circuit designs, as well as test-instrumentation systems. This line of dividers is available in compact and rugged SMA connectorized packages with input power ranging from -20 to +15 dBm and output power ranging from -6 to +5 dBm.

Fairview Microwave

2. XZ-axis motorized linear positioning stages

Optimal Engineering Systems has added a new series of 15-mm, 30-mm, 50-mm, and 75-mm linear motion positioning stages to its selection of precision motion-control components. Each of these motorized XZ-axis linear positioning stages features 1-micron repeatability and 10-micron positional accuracy. Both the X-axis (horizontal axis) and the Z-axis (vertical axis) have the travel lengths of 15 mm, 30 mm, 50 mm, and 75 mm and longer to meet your application requirements. They are suitable for sampling, assembly, sorting, testing, laser drilling and machining, and positioning in lab and manufacturing environments.

OES

3. 40-W DC/DC converters

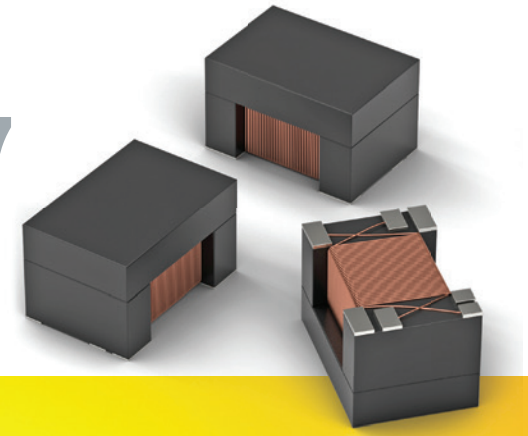
TRACO POWER's TEN 40E and TEN 40WIE families of 40-W high-density DC/DC converters are optimized to reduce cost and improve performance in the industry standard 2-in. x 1-in. footprint. The TEN 40E has wide 2:1 input ranges of 9-18 / 18-36 / 36-75 VDC versus the TEN 40WIE Series with 4:1 ultra-wide input ranges of 9-36 / 18-75 VDC. Each family offers five single outputs of 3.3 / 5 / 12 / 15 / 24 VDC and three dual outputs of ±12 / ±15 / ±24 VDC.

TRACO POWER

4. 3U VPX data-converter modules

Pentek Inc.'s newest member of the Jade family of 3U VPX data-converter modules based on the Xilinx Kintex Ultrascale FPGA is the Model 54141A—a dual-channel analog-to-digital and digital-to-analog converter with sample rates up to 6.4 GHz. Programmable DDCs and DUCs support connections to IF or RF signals. The Model 54141A complies with the VITA 65.0 3U VPX specification and also offers flexible analog and digital interface options for the VPX P2 backplane connector to meet system-specific requirements. It also supports the VITA 66.5 optical interconnect standard by providing four optical duplex lanes to a mating spring-loaded backplane connector.

Pentek Inc.



5. FPGA prototyping system

PRO DESIGN has launched the high-capacity proFPGA quad Stratix 10 GX 10M system, the next generation of its FPGA prototyping solution based on the recently released Intel Stratix 10 GX 10M FPGA. The new system handles complex ASIC and SoC designs up to 2 billion ASIC gates and gives design and verification engineers the necessary speed and flexibility for high-speed verification and bug hunting to shorten the time to market by eliminating costly re-spins and by providing early prototypes for software development and/or to end customers. The quad system offers a capacity of up to 240 million ASIC gates.

PRO DESIGN

6. Measurement software for audio interfaces

Audio Precision's APx500 Flex audio analyzer enables the use of APx audio measurement software with ASIO-capable third-party audio interfaces or sound cards. The APx500 Flex audio analyzer is Audio Precision's APx500 measurement software operating independently of an AP hardware analyzer, with licensing controlled by an APx500 Flex Key. In lieu of a purpose-built analyzer, Flex can be paired with ASIO-capable third-party audio interfaces to create a cost-effective solution for a variety of acoustic and electrical test applications. Measurement scenarios where hardware performance requirements are secondary to test system price are suitable candidates for Flex.

Audio Precision

7. LAN transformers

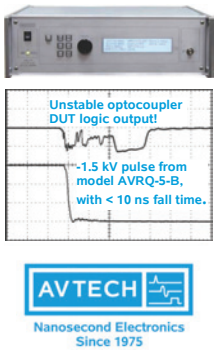
Würth Elektronik's new WE-STST Super Tiny Signal Transformers for LAN interfaces feature a maximum component height of 2.9 mm and can be used in up to 1000Base-T applications. The transformers are manufactured completely by machine, which enables the dimensions to be kept small at 4.7 × 3.22 × 2.9 mm. The 350-µH version is suitable for LAN applications with data rates to 1,000 Mb/s. The 120-µH version provides signal integrity at high frequencies suitable for 10-Gigabit Ethernet applications or for the new Single Pair Ethernet with data rates up to 1,000 Mb/s.

Würth Elektronik

8. 75-GHz BGA socket

This new BGA socket design uses a high-performance elastomer capable of 75-GHz, low-inductance, and wide temperature-range applications. The GT-BGA-2127 socket is designed for 40-mm x 40-mm package size and operates at bandwidths up to 75 GHz with less than 1dB of insertion loss. The socket is designed to dissipate 150 W using a heat sink and an axial flow fan. The contact resistance is typically 30 mΩ per pin. The socket is mounted on the target PCB with no soldering and uses very little real estate, allowing capacitors/resistors to be placed close by.

Ironwood Electronics



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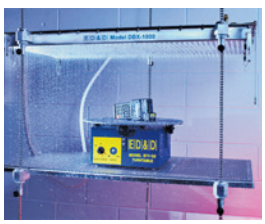

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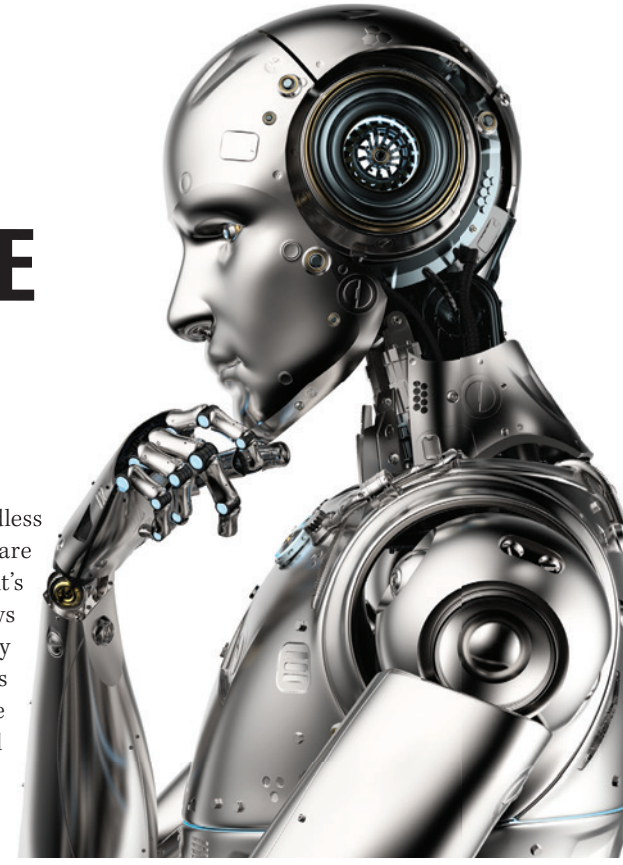
ENDEAVOR BUSINESS MEDIA

ROBOTICS FORGE THEIR WAY INTO THE 21ST CENTURY

By Ken Cormier, Managing Editor



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Robots are evolving at warp speed, advancing as quickly as human imagination and intelligence can carry them. Improvements in materials and electronic guts, coupled with the Promethean promise of AI, are giving birth to a strange new world that blurs the edges of what it means to be human. With the capabilities of learning, perception, language, problem-solving, and logical reasoning, robots are muscling their way into the human experience. Here are a few recent news snippets related to robotic development:

Robots rush in where humans fear to tread

As part of a larger effort to bring robots into every area of operations, the U.S. Army has unveiled two new bots soon to be introduced into its ranks. The Small Multipurpose Equipment Transport is a "robotic mule" to carry a squad's load on dismounted patrols. The SMET, which can be manned or unmanned, can carry 1,000 pounds and operates over a distance of 60 miles in a 72-hour period.

The other bot, the Common Robotic System (CRS-H), is a heavy robot designed to help bomb technicians. It has enhanced capabilities to detect, identify, access, render safe, exploit, and dispose of heavy explosive ordnance, according to the Army.[1]

'Cleanup on Aisle 4'

In a recent article on Robotics Business Review, Georges Mirza writes that forces of the robot industry are positioning themselves for employment in the retail world, in the very near future, for image recognition, to maximize space, efficiently move and replenish inventory, collect data, and more. "Regardless of where investments are made—brick or click—it's all connected and shows that brick is here to stay and robots are part of its future," Mirza said in the article. He further said that once robots operate to scale, they "will facilitate a truly connected supply chain and drive efficiencies and insights the industry is starved for."[2]

Enter the androids

The company Promobot has taken the anthropomorphic robot another step along with the introduction of Robo-C. This robot, which can be made to look like an individual person, is unable to walk, but it has 18 moving parts in its face. The company claims that the Robo-C has more than 600 micro facial expressions and limited movement and could be useful in homes and workplaces. As of October, four Robo-Cs were being built by Promobot: one to scan passports and other functions; one replication of Einstein for an exhibition; and two android versions of a Middle-Eastern family's patriarch to greet guests. Price for this robot is between $20k and $50k, dependent on options and customized appearance.[3]

IKEA assembly, breaking eggs, Rock Paper Scissors

The dreaded, frustrating assembly of a piece of IKEA furniture may become a thing of the past. Researchers in Singapore have fabricated a set of robotic arms that are able to assemble an IKEA chair in 20 minutes. The robot employs 3D cameras to identify parts and then assembles them.

U.K. company Moley has developed a robotic kitchen that contains dexterous arms that are able to grasp utensils, crack eggs, measure ingredients, and do dishes. Hundreds of recipes from around the globe can be downloaded from an electronic library into this robot and replicated.

Researchers at the University of Tokyo have developed Janken robot, which is unerringly unable to lose a game of Rock Paper Scissors against a human being. This is not due to the robot's ability at prediction—it cheats. It uses high-speed recognition to see what shape the human hand is about to form—inside a thousandth of a second.[4] EE

REFERENCES

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3. CNBC, "Human-like androids have entered the workplace and may take your job," Oct. 3, 2019
4. *National Post*, "Ten outrageous things robots can do right now, from cooking to building IKEA furniture," Nov. 25, 2019

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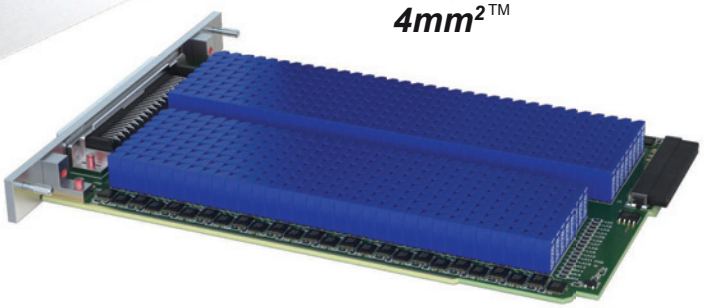

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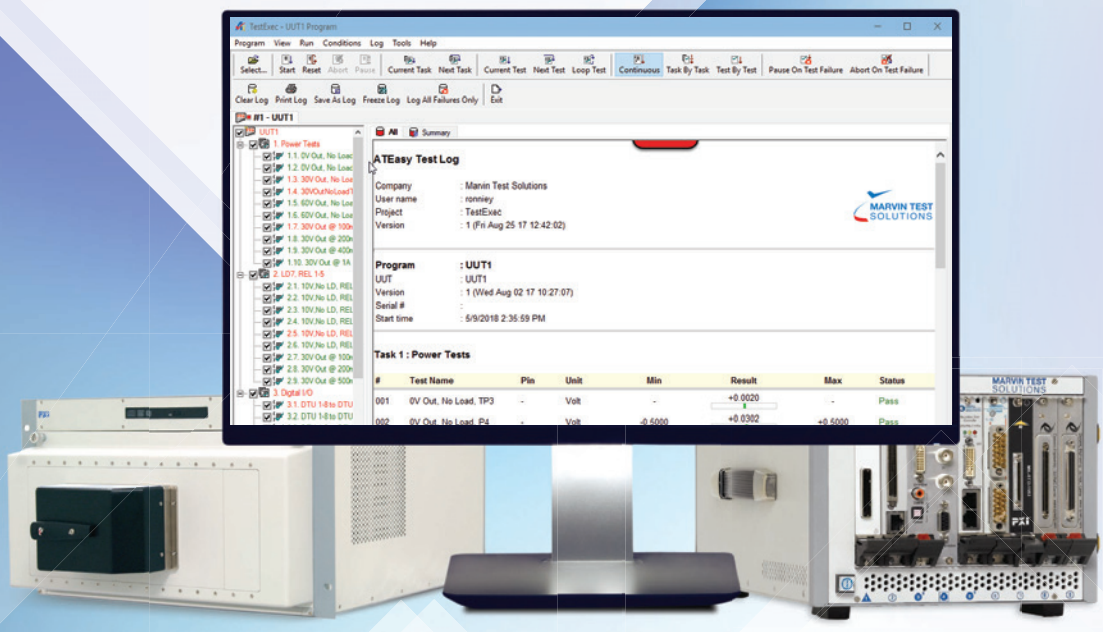

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