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Microwaves & RF®

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March/April 2023 | *VOLUME 62, ISSUE 2*

FEATURES

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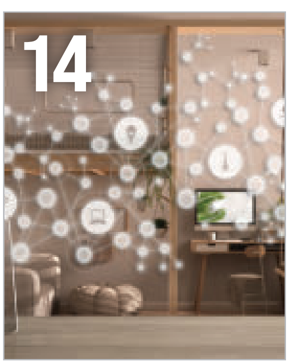
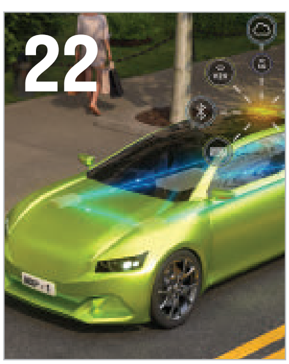
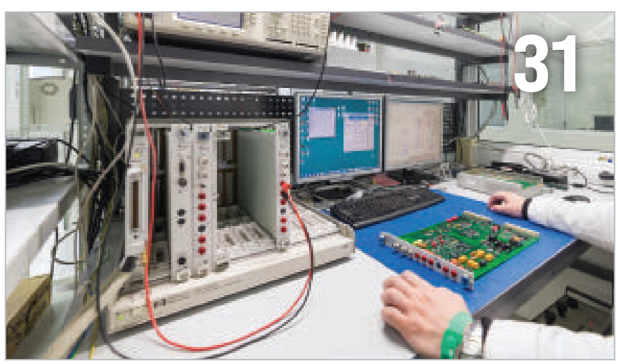
DEPARTMENTS



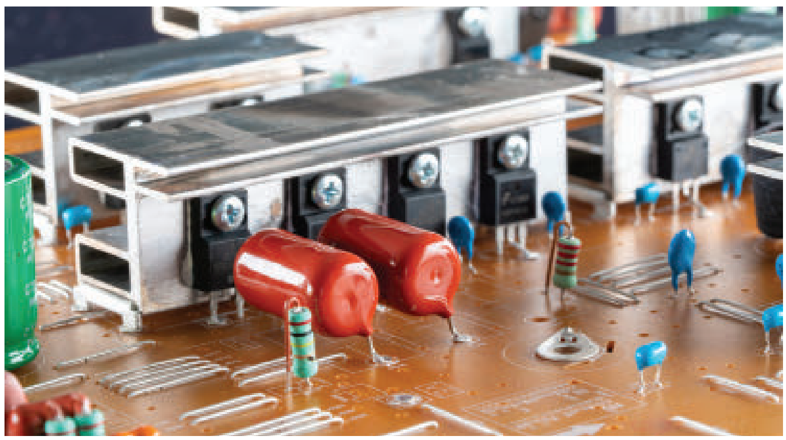




DAVID MALINIAK, Senior Editor

POWER: Overlook It at Your Own Peril

Often an afterthought in board- and system-level design, power can literally trip you up. Fortunately, there are resources for learning like at the recent APEC show in Orlando.



183244249 © Luchschen | Dreamstime.com

WHEN I WAS a much younger editor, I covered segments of the OEM electronics industry that were a lot less exotic than the wireless world. We're talking things like components and packaging, interconnects, passives, wire and cable—real nuts-and-bolts stuff. Sometimes, even, actual nuts and bolts or other fasteners.

Exotic to me, back in the day, were things like flip chips and ball-grid arrays and concepts related to 3D packaging. And, not infrequently, I'd find myself talking to purveyors of items like dc-dc converters or other board-level, power-related products. Such elements of system design were almost as ho-hum to me as toroids.

A frequent line of discussion with power-supply people was how often power was overlooked by system designers. I'd hear cautionary, and possibly apocryphal, anecdotes about designers who'd approach power-supply apps engineers with serious last-minute problems: "I needed X watts of output on this bus, but the board layout left very little space on the board for the supply. I'm really stuck. Can you possibly come up with a custom device that will do the job?"

The point of these tales was that in any context, overlooking board- or system-level power requirements is a critical mistake. All too often, though, power was one of the last things considered. A power supply that's not up to the task of responding to dynamic load changes can wreak untold havoc with digital logic, causing false switching and/or timing problems. Thus, it behooves designers to always have power in mind during the course of a project, rather than treat it as an afterthought.

Fortunately, great resources are available to help designers learn about the latest developments in power electronics. One of them is the annual Applied Power Electronics Conference (APEC), which recently took place at the Orange County Convention Center in Orlando (March 19-23, 2023). Power-electronics professionals converged on APEC for a smorgasbord of workshops, technical sessions, seminars, and social events that focused on one thing and one thing only: power.

APEC offered up professional education seminars that delved into practical aspects of complex power-electronics topics, adding in theory to further designers' education. A full slate of technical sessions brought peer-reviewed presentations covering highly innovative technical solutions. At the exhibitor seminars, industry vendors updated attendees on new products or initiatives in the power-electronics arena.

And the exposition itself featured hundreds of vendors serving the power-electronics industry, showing off their latest and greatest in technology and solutions. They were eager and waiting to help you solve all of your power-related problems, including that space on a PCB that's too small for so many watts of output.

We were at APEC, too, canvassing the show floor to catch up with what's new in the power-electronics space. If you missed the event, you can find our coverage of it in a special digital magazine on our website. ■

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STMicro and Gridspertise Expand Smart-Meter Collaboration

A NEW PHASE has begun in the long-term collaboration on smart-meter technologies between STMicroelectronics and Gridspertise, a company that supports distribution system operators worldwide in accelerating the digital transformation of electricity grids. Gridspertise integrated ST's latest power-line communication (PLC) SoC into its smart meters for the Italian market, enabling a near-real-time cybersecure communication channel for in-home devices.


STMicroelectronics

Building on a collaboration that began in the early 2000s, the two companies have moved onto what they're calling Chain 2 technology. The plan is to integrate smart-meter technology initially deployed in Spain, Eastern Europe, and Latin America into new metering products in the Gridspertise portfolio. The resulting products will make Chain 2 technology suitable for the U.S. market and other areas of the world.

According to ST and Gridspertise, Chain 2 technology improves consumers' awareness of the energy consumed and self-produced. It enables a multitude of new enhanced services that simplify their energy usage through home automation and encourages a more active role for all players in the energy market, as well as the penetration of distributed renewable sources.

For example, the technology can provide recommendations to the end customer on tailor-made behaviors based on real-time data production from its own generation system, like photovoltaic panels. It also enables the smart meter to collect real-time data on home appliances' consumption. Such data can be used, for instance, to modulate the charging power of an electric-vehicle charger according to the available capacity and other demands for power in the house.

Beyond working on approving the ANSI C communication standard for the U.S. market, the companies are cooperating on adoption of the latest Device Language Message Specification (DLMS)-certified standards into Gridspertise smart meters, further enhancing interoperability and interchangeability between devices and systems. Both companies' U.S. branches will directly engage with tech companies, power-grid operators, policy makers, and regulators, accelerating the region's electric future. ■

Sub-GHz SoC Ready to Take On Smart-City and Long-Range Deployments

Wi-SUN IS OFTEN touted as the low-power, mesh-network protocol that will underlie smart-city IoT implementations. Wi-SUN field-area networks (FANs) are highly robust solutions that support a range of data-rate options with scalability, security, and interoperability. They're also self-forming, self-healing networks that can handle thousands of nodes in the face of disrupting events such as storms, cyberattacks, and/or power-usage constraints.

In efforts to bolster its Wi-SUN portfolio, Silicon Labs last year announced its EFR32FG25 sub-GHz wireless systems-on-chips (SoCs), which the company claims as a superior solution for long-range, low-power transmissions. Now widely available, the FG25 SoCs are able to broadcast up to 3 km with minimal data loss in dense, urban canyon environments when coupled with SiLabs' forthcoming EFF01 front-end module.

In addition, the FG25 is the first of SiLabs' SoCs to support the orthogonal frequency-division multiplexing (OFDM) modulation schemes introduced in Wi-SUN FAN 1.1. OFDM supports highly efficient modulation with data bandwidths of up to 3.6 Mb/s. Thanks to the higher data rates, the FG25 SoC enables the large networks needed by smart cities where the nodes can number in the thousands. The device also is now certified by the Wi-SUN Alliance for the PHY layer of the FAN 1.1 profile, which lessens the burden placed on designers as they design Wi-SUN FAN 1.1-compliant devices.

As an example of the FG25's utility in large-scale smart-city rollouts, Landis+Gyr adopted the device for use in smart meters. With the FG25, Landis+Gyr has a device that offers more random-access memory (RAM) than SiLabs' FG12, which it had been designing into its meters. The company also needed a means of implementing OFDM schemes, which the FG25 offers as well. Integrating both the MCU and transceiver on the same SoC, the FG25 uses the same form factor as Landis+Gyr's existing module, making it easier to integrate the new device. ■

Air Force Teams with Howard University on Research Center

HOWARD UNIVERSITY HAS been selected by the U.S. Air Force to lead a University Affiliated Research Center. As the first Historically Black College and University (HBCU) to lead such an Air Force research center, Howard will receive $12 million per year to support studies on tactical autonomy technology for military systems.

U.S. Secretary of Defense Lloyd Austin *(see image below; at center)* explained the importance of the research to the troops, "Autonomous systems make our military faster, smarter, and more combat-credible. They equip commanders with the best possible information to support life-and-death decisions."

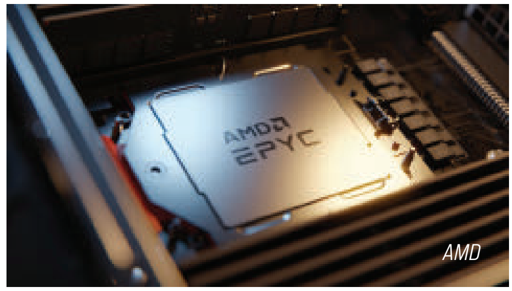
With the addition of Howard University, the U.S. Department of Defense (DoD) now has 14 university affiliated research centers. They share space with DoD officials and work with industrial partners as needed.

The university's primary mission will be to maintain engineering, research, and development of tactical autonomy in support of Air Force and DoD applications. In the engineering efforts, Howard will lead a consortium of schools that includes Alabama, Delaware State, Jackson State, the University of Maryland, and Norfolk State. ■

U.S. Air Force | Eric Dietrich

AMD Touts New RFSoCs, Test Lab, and Adaptive Computing Products

AMD BROUGHT A spate of news to its presence at Mobile World Congress 2023—more support for its 5G partner ecosystem from core to radio-access-network (RAN) applications, new test capabilities, and new 5G products.



AMD

Telco Solutions Testing Lab

With the formation of its Telco Solutions testing lab, AMD provides critical resources for operators and telco solution providers to test, validate, and scale computing resources to deliver on the ever-increasing demands from RAN and edge-to-core. The testing lab supports validation of end-to-end solutions, including both hardware and software to leverage the performance and power efficiencies of the latest AMD processors, adaptive SoCs, SmartNICs, FPGAs, and DPUs.

AMD chose the Viavi end-to-end testing suite to analyze, develop, and validate the impact of real-life conditions across an entire telco network. The Telco Solutions testing lab will enable traffic simulation and generation across core, CU/DU, edge, and RAN using both current and future AMD technologies. It will allow for full functional and performance testing that meets current and future generation ecosystem requirements. Based in Santa Clara, Calif., the Telco Solutions testing lab will bring in its first 5G ecosystem partners beginning Q2 of 2023.

RFSoC Devices for Emerging 4G/5G Growth Markets

AMD is expanding its Zynq UltraScale+ RFSoC digital-front-end (DFE) portfolio with two additions to the family: the Zynq UltraScale+ RFSoC ZU63DR and Zynq UltraScale+ RFSoC ZU64DR devices. These new RFSoCs will enable the expansion and deployment of 4G/5G radios into markets around the globe where lower cost/power and spectrum-efficient radios are required to address increased wireless connectivity.

The Zynq UltraScale+ RFSoC ZU63DR specifically targets four transmit and four receive (4T4R) and dual-band, entry-level O-RAN radio-unit (O-RU) applications. The Zynq UltraScale+ RFSoC ZU64DR is aimed at eight transmit and eight receive (8T8R) O-RU applications using the 3rd Generation Partner Project (3GPP) split-8 option, which supports alternative and legacy radio-unit architectures. Both RFSoC devices leverage the deep DFE integration available in the flagship Zynq UltraScale+ RFSoC ZU67DR device and are expected to be in full production in Q2 of 2023.

Ecosystem Collaboration with Nokia

As part of AMD's growing telco ecosystem, AMD and Nokia are jointly announcing an expanded collaboration using 4th Gen AMD EPYC6 processor-based servers to deliver Nokia Cloud RAN solutions to help communications service providers achieve their most stringent energy-efficiency goals. AMD and Nokia recognize the challenges faced by operators dealing with spiraling energy costs and the growing importance of meeting carbon-reduction targets at the core as well as the network edge. ■

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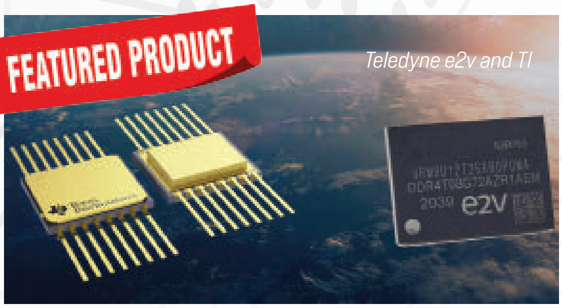
Teledyne e2v and TI Team on Rad-Tolerant DDR4 Memory



Teledyne e2v and TI

The Overview

Teledyne e2v and Texas Instruments have collaborated on a radiation-tolerant DDR4 modular platform. The platform consists of e2v's DDR4T0xG72 DDR4 memory with 4- or 8-GB capacity paired with TI's TPS7H3301-SP DDR termination low-dropout (LDO) voltage regulator that provides a stable supply for the DDR4 module.

Who Needs It & Why?

Satellite OEMs looking to streamline their system development work while reducing the time and associated engineering effort will find the new platform beneficial. The components that comprise the platform have already been through comprehensive space characterization and qualification testing, enabling the platform to deliver long-term operation without single-event latchup (SEL) and single-event upset (SEU) issues causing problems.

Under the Hood

The DDR4/TPS7H3301-SP platform, which is optimized for deployment under tight size, weight, and power (SWaP) constraints, is very compact and convenient to use. It carries high levels of data-storage capacity within a very small form factor. According to e2v, the platform requires 3X less PCB area when compared to competitive platforms, with a volume that's smaller by a factor of 10.

With its 4- and 8-GB densities, the DDR4 devices provide a 72-bit bus width, which is typically used as 64 bits of data with 8 bits of error correction. This offers both single- and dual-bit error-correction capabilities. Transfer speeds are 2.1 and 2.4 GT/s (up to 150 Gb/s).

Versatility is another advantage—the DDR4T0xG72/TPS7H3301-SP modular platform is applicable across a wide range of space-grade processors (including Teledyne e2v and others), FPGAs/ACAPs (such as AMD/Xilinx, Microchip, and NanoXplore), as well as custom-built ASICs.

The radiation-validated TI and Teledyne e2v devices that make up this DDR4 platform are featured in Alpha Data's ADK-VA600 Versal Core development kit.

Mercury Drops First Signal-Processing Board with Intel's Latest Direct RF Technology

The Overview

Mercury Systems launched its DRF3182 Direct RF Processing Module, the first standard product purpose-built for the aerospace and defense industry that leverages Intel's new Stratix 10 AX SoC field-programmable gate array (FPGA).

Who Needs It & Why?

Designed for radar and electronic-warfare (EW) applications, the DRF3182 with Direct RF technology can enhance a wide range of applications including software-defined radio and communications. Considering today's rapidly evolving threat environment, advanced processing capabilities need to be deployed at the tactical edge. Mercury's collaboration with Intel ensures that modern EW and radar systems can provide a decision advantage to U.S. and allied forces and make the world a safer, more secure place.

Unlike traditional systems that use costly analog frequency-conversion hardware, direct RF technology allows for the direct processing of broadband signals. This streamlined architecture reduces the total system size and cost while increasing flexibility.

Mercury Systems

Under the Hood

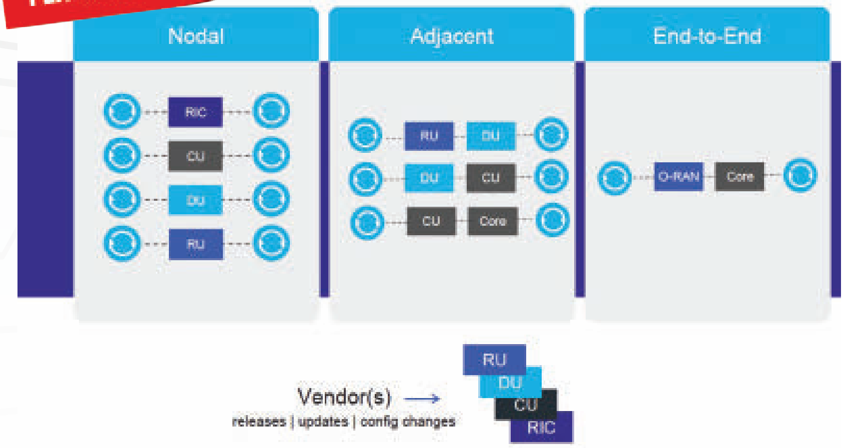
Mercury's DRF3182 Direct RF Processing Module features:

- Four 10-bit ADC channels and four 10-bit DAC channels at 51.2 Gsamples/s
- Intel Stratix 10 AX-Series SoC FPGA
- Ku-band range from 2 to 18 GHz
- Six 100GigE data-plane interfaces for an aggregate throughput rate of 75 Gb/s
- 3U OpenVPX form factor

The DRF3182 Direct RF Processing Module is now available for commercial order.

Integrated Emulation Suite Takes on End-to-End O-RAN Test and Validation

FEATURED PRODUCT



The Overview

Spirent Communications is now offering end-to-end, open distributed-unit (O-DU), and RAN intelligence controller (RIC) testing, completing its Open RAN (O-RAN) test solution portfolio. By building on its previously available open central-unit (O-CU) and open radio-unit (O-RU) test solutions, the company offers robust and realistic O-RAN testing, which will both accelerate widespread O-RAN adoption and ensure O-RAN functionality, interoperability, and field-ready performance.

Who Needs It & Why?

O-RAN cellular network architectures enable service providers to run key network functions as virtualized software on vendor-neutral hardware. This gives O-RAN architectures lots of potential in terms of innovation and cost. At the same time, however, there's a level of complexity added to test, especially for operators saddled with the integration of network elements coming from multiple vendors.

Spirent has identified four key customer groups that can benefit from its end-to-end O-RAN testing:

- **Chipset makers** who have DU/RU components in development can gain from test capabilities that go beyond incremental testing and show how the devices will perform in the full network context.
- **Network equipment and software makers** who must evaluate products at a level that transcends standard 3GPP test requirements.
- **Network operators** who must shoulder more of the test responsibility as they adopt O-RAN architectures.
- **System integrators** who work with network operators to deploy O-RAN architectures.

Under the Hood

With the growing proliferation of O-RAN architectures, emulation comes to the forefront as a critical technology of any O-RAN testbed. To enable the above sets of customers to realize the potential of O-RAN, ultimately spurring innovation and lower costs, real-time emulation must run the gamut from the 5G core to individual O-RAN components to the RF environment. Functional and performance tests of any of these components must have real emulation in real-time, at performance and at scale.

"This comprehensive O-RAN portfolio reduces test time while increasing test coverage and enabling CI/CD processes," said James Kimery, VP of product management for Spirent's Lifecycle Service Assurance business. "Nodal testing is new, isolating a RAN functional block and testing at scale has never been done before. These solutions will go a long way toward maturing O-RAN technology."

The suite provides what's said to be a simplified and automated approach to real-time emulation. It offers fully integrated solutions, pre-built test cases, and centralized control through a unified user interface.

Spirent's unique O-RAN portfolio provides the following:

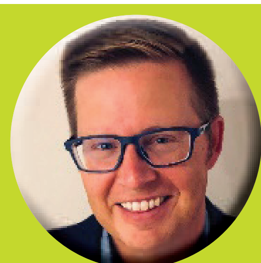
- **Comprehensive multi-vendor interoperability and advanced performance testing using real-time emulation:** The company offers thorough, reliable, and realistic testing using comprehensive test portfolios and real-time (bidirectional) emulation, which most accurately reflects a live, real-world O-RAN environment.
- **Automation:** Spirent's O-RAN solutions provide pre-built test libraries across performance, resiliency, security, compliance, and more via a fully integrated system with open APIs. In addition, the solution is designed to plug-and-play seamlessly into any automation pipeline.
- **Single-user experience:** O-RAN testing requires a variety of testing and emulation approaches, which the company integrated into a system managed through a single-user experience, regardless of the testing type being executed.

Week At-A-Glance & Plenary Speakers

	Sunday 11-Jun-23	Monday 12-Jun-23	Tuesday 13-Jun-23	Wednesday 14-Jun-23	Thursday 15-Jun-23	Friday 16-Jun-23
Workshops	■	■				■
Technical Lectures	■		■	■	■	
RFIC Plenary Session, Reception, Industry Showcase	■					
Quantum Bootcamp	■					
AI/ML Bootcamp	■					
RF Bootcamp		■				
RFIC Technical Sessions and Interactive Forum		■	■			
Three Minute Thesis		■				
IMS Industry Showcase, Plenary and Welcome Reception		■				
IMS Technical Sessions and Interactive Forum			■	■	■	
Panel Sessions		■	■	■	■	
Connected Future Summit			■			
Exhibition			■	■	■	
MicroApps and Industry Workshops			■	■	■	
Amateur Radio Reception			■			
Young Professionals Reception			■			
Industry Hosted Reception				■		
Women In Microwaves Reception			■			
IMS Closing Ceremony					■	
101st ARFTG						■

Workshops Technical Lectures RFIC Bootcamp Three Minute Thesis IMS Panel Sessions
Connected Future Summit Exhibitor Activities Focus Groups ARFTG

RFIC SPEAKER
Prof. Mau-Chung Frank Chang
Wintek Chair in Electrical Engineering and Distinguished Professor, *University of California, Los Angeles (UCLA)*



RFIC SPEAKER
Dr. Todd Younkin
President & CEO, *Semiconductor Research Corporation (SRC)*

IMS SPEAKER
Ed Godshalk, PhD
Consultant and Engineer in Residence, *George Fox University*

For the latest on IMS and Microwave Week visit ims-ieee.org

Video ▶ APEC 2023 Insights with Lee Goldberg

2023 marks the conference's second year as a live event after spending a couple of years in COVID-induced cyber-lockdown. We've tried to capture some of the excitement and innovation we saw at APEC in a series of video vignettes shot live on the APEC exhibit floor, which highlight a different aspect of the power sector. **www.mwrf.com/21263351**

Video ▶ Uhnder's 4D Digital Automotive Radar-on-Chip Floods the Data Zone

At its CES 2023 suite, Uhnder's CEO and co-founder, Manju Hegde, discusses the company's flagship S80, a 77-GHz, 4D digital imaging radar-on-chip. With the device's launch in 2022, Uhnder became the first company to mass-produce a fully automotive-qualified, 4D digital imaging radar-on-chip, making possible next-generation advanced driver-assistance systems (ADAS), autonomous vehicles (AVs), and automated mobility applications. **www.mwrf.com/21260669**

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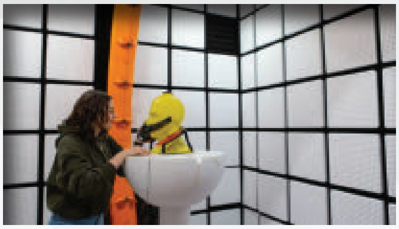

Advanced 6G Research Focus of Joint Effort

The research program will develop novel techniques for channel sounding and communication channel sensing in new 6G frequency bands. **www.mwrf.com/21262841**

Ka-band Satellites: The Key to Implementing Reliable Vehicle Connectivity

Cellular comms simply can't reliably provide vehicle connectivity for mapping, infotainment, and emergencies. This article looks at how satellite comms can be implemented cost-effectively as a failsafe and discusses the technology's lingering challenges. **www.mwrf.com/21261452**

How Smaller-Sized OEMs Can Speed Product Time-to-Market with a Development Distributor

This article highlights how OEMs that may not be the biggest can capitalize on partnering with a development distributor, including accelerating the design process and implementing eCommerce. **www.mwrf.com/21261194**

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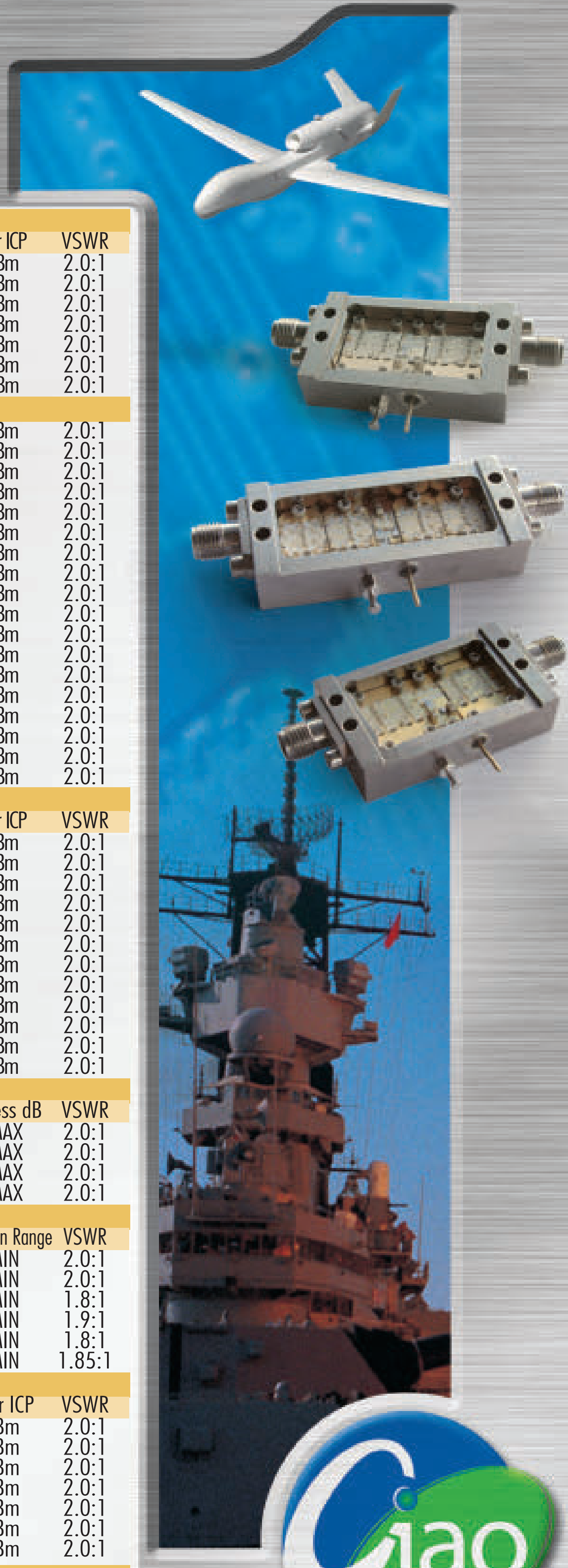

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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Interoperability Will Drive IoT Innovation Across Industries in 2023

Wi-Fi 6, Matter, and Wi-SUN will help fulfill capacity, efficiency, and performance needs for enhanced IoT connectivity. These advances will benefit industrial, commercial, and utility industries, triggering more innovations in product development.

By Ross Sabolcik, *Silicon Labs*

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As the IoT industry rapidly evolves with each year, we can expect a new array of possible applications in every sector. However, with technology innovation on the rise, the industry has quickly grown oversaturated with devices and networks, leading to challenges in meeting connectivity, capacity, efficiency, and performance needs.

On that front, Silicon Labs recently developed Wi-Fi 6 solutions, Matter over Wi-Fi 4 and 6 solutions, the FG25 SoC, and a Wi-SUN standards-based stack. These technologies provide ultra-low-power capability, integrate robust security to protect devices and customers against cyberattacks, and help users with faster IoT-device integration.

In the upcoming era of IoT, these connectivity achievements can address the fractured market, advance industrial and commercial industries, grow economies, and improve home and life applications.

Wi-Fi 6: Addressing Capacity Needs

Although Wi-Fi has been around for many years and is the most prevalent protocol available to consumers, the technology has yet to reach its full potential. Users are eager for connected devices with advanced visual, audio, and data-processing functions that they can easily control from their phones—and all of these features require more bandwidth and energy.

Because many Wi-Fi devices use the 2.4-GHz spectrum, the network is significantly crowded with these devices. Such oversaturation can cause poor performance, particularly in high-density areas.

As the next generation of Wi-Fi, Wi-Fi 6 has unique features such as OFDMA enabling a host of 2.4-GHz devices to coexist, alleviating the need to move to 5-GHz spectrum and support more applications. Still, designers need optimized SoCs for Wi-Fi 6 to create higher-performing, more energy-efficient products.

Addressing density challenges, the SiWx917 ultra-low-power Wi-Fi SoC is a fully integrated, single SoC with an accelerator for machine learning. It runs all wireless stacks, networking stacks, and user applications on the same chip, and offers interoperability with Matter. Other features include a high memory capacity and higher data rates as well as robust security. These types of SoCs will help speed time-to-market, reduce cost, and deploy new devices in residential, commercial, and industrial environments more rapidly.

Matter-Over-Wi-Fi and Matter-Over-Thread: Simplifying IoT Connection

Last year, the new Matter 1.0 standard was released by the Connectivity Standards Alliance, promising the convergence of the major IoT ecosystems and offering one wireless protocol to connect all IoT networks and devices.

Before Matter, building smart-home products was challenging due to the fractured market, and likewise, home setup could be difficult for consumers to manage. In the coming year, we'll see the Matter standard improve interoperability across devices, ecosystems, and brands, simplifying the lives of device manufacturers and

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We expect advances in sensor and wireless IoT technologies to continue paving the way for smart city innovation.

consumers, and significantly reducing time and costs for deploying devices.

Matter development solutions developed by Silicon Labs provide support for Matter-over-Wi-Fi, Matter-over-Thread, Bluetooth LE commissioning, as well as Matter bridges to 802.15.4, Zigbee, and Z-Wave. The 2.4-GHz wireless MG24 SoC with support for Bluetooth and Thread, and the Wi-Fi 6 SoC, SiWx917, feature ultra-low power capabilities and are central to the company's Matter platform.

As designers and developers begin to have more leverage with building Matter-ready products, we'll see many more Matter-certified products on the market and at work in our homes in the near future.

Wi-SUN: Enabling Smart Cities

Increasingly, industrial and commercial industries are looking to IoT to build more scalable, safer, efficient, and sustainable infrastructure. Utility companies are beginning to consider how data from IoT devices can inform how to streamline and manage energy efficiency. City planners and municipal engineers want to connect streetlights, cameras, weather stations, utility transmission systems, parking systems, and more to extract the most benefits from municipal services.

Due to the steadily expanding number of city and smart utility applications, we'll need flexible and versatile solutions for large-scale IoT wireless communication networks to support these applications.

Silicon Labs' FG25 SoC for Wi-SUN, the world's first open protocol for smart-city and smart-utility applications, will help simplify wireless connectivity for major community infrastructure. It's designed to support long-range, low-power transmission that can broadcast data up to three kilometers in dense urban environments. It also maintains higher data rates, enabling the large networks needed by smart cities and increasing their solution's performance.

The FG25 is built with sustainability in mind and optimized for low power and performance for network and connected devices. It's also one of the first devices to be certified for FAN 1.1 PHY.

Wi-SUN SoCs will enable cities to monitor municipal assets in real-time, control when and where they need power, and allow residents to track their energy consumption.

We expect advances in sensor and wireless IoT technologies to continue paving the way for smart city innovation.

Looking Ahead to 2023

Last year was an exciting time to accelerate IoT achievements while the world reopened from the pandemic and sought new solutions. This year, we expect widespread interoperability, simplified device management, robust security, and seamless connectivity, as advances like Wi-Fi 6, Matter, and Wi-SUN represent only the beginning of new innovations in our homes, communities, and businesses. ■

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The Evolution of **Modern Calibration**

The science of measurement has evolved from the cubit to the latest calibration tools. What's on the horizon?

***By Michael Johnston,** Software Portfolio Product Manager, Fluke Calibration*

A timeline showing the evolution of calibration from the beginning would have to start hundreds of years ago *(Fig. 1)*. The science of measurement has progressed from the earliest uses of the human body as reference measurements, like the cubit in early Egypt, to a sun dial to measure the passage of time, to our modern calibration tools. As trading developed, so did the need for accurate measurements. And as international trade and industry became the global standard, so did a critical need for precise measurements.

Precise Moments in Calibration History

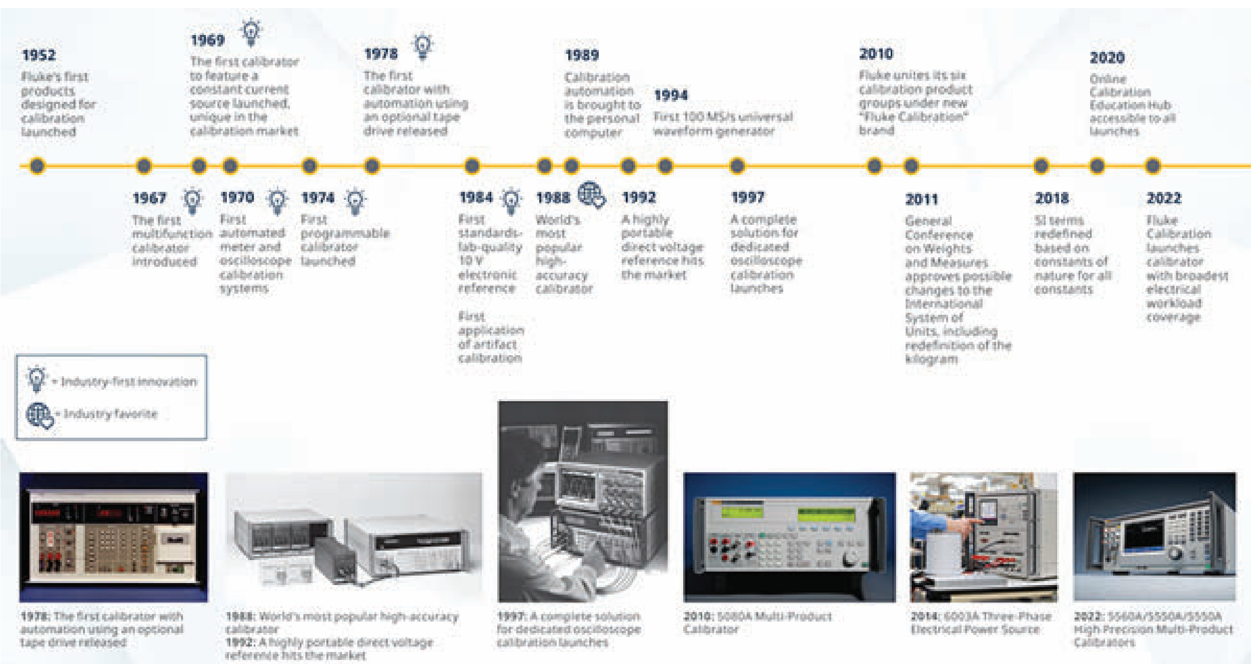
Since the signing of the Metre Convention on May 20, 1875, creating the Bureau international des poids et mesures (BIPM), the world recognized a need for standard measurements.

In the 1950s, products designed for digital calibration began hitting the market. Fluke launched into the calibration space with the 301 Series Universal Waveform Generator in 1952. This waveform generator allowed technicians to calibrate the digital meters that had recently become popular.

In 1960, the global need for standardized measurements led to the creation of the International System of Units (SI), further strengthening the standards for measuring everything in our lives.

For the next couple decades after the SI establishment, the calibration industry would see quite a few firsts hit the market *(Fig. 2)*. Each new first offered advancement toward further consistency and reliability of measurement. No matter what lab was using these instruments, they allowed users to realize better and better measurements over the years.

A huge component of the calibration workflow is consistency. With so many different methods of calibrating and checking measurements against the SI, every lab, and every technician within that lab, may have a slightly different way of doing things.



1. Fluke Calibration has played a role in many of the industry firsts. Photos courtesy of Fluke Calibration

However, that began to change in the late 1980s, as calibration automation started to rise *(Fig. 3)*. MET/CAL Software allowed even further levels of consistency along with improved speeds. Knowing that the measurements and calibrations are performed in exactly the same way every time, no matter who's doing the work, is of paramount importance to reducing measurement uncertainty.

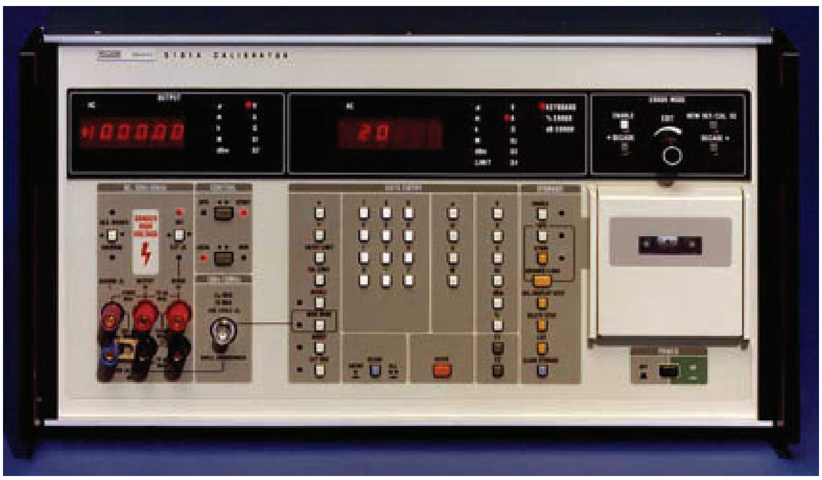
Knowing that the measurements and calibrations are performed in exactly the same way every time, no matter who's doing the work, is of paramount importance to reducing measurement uncertainty.

As you continue through the decades, our ability to measure precisely continued to improve. New products hit the market, allowing technicians to repeat the same steps and measurements in any lab to get closer and closer to the standards set forth in the SI.

Which brings us to the other reason behind both the BIPM and SI existence: to have a system of measurement that was available to everyone. Originally, this proved to be difficult as the standards created were physical items often kept under lock and key to preserve them.

However, in 2018, those standards saw the biggest change of all: adjusting their definitions to refer to constants of nature instead of physical standards. With this change, the level of uncertainty we just had to live with due to the physical artifacts is eliminated. Laboratories and manufacturing facilities around the world can have access to the highest levels of measurement capabilities with these new constants, which further enables more technological evolution.

Taking these standards into account, and our constant trek toward greater precision, Fluke Calibration launched the newest multi-product calibrators in 2022. The 5560A/5550A/5540A High Performance Multi-Product Calibrators *(Fig. 4)* offer broad electrical workload coverage and the highest accuracy available thus far in this class of instruments, according to the company. The new calibrator features a handful of industry firsts:



2. Two firsts for the calibration industry occurred in 1978: the first calibrator with automation using an optional tape drive in the 5100A Multifunction Calibrator, and the first range of digital multimeters with full "Autocal" range hit the market.

3. The year 1988 saw the arrival of the high-accuracy 5700A Multifunction High-Accuracy Calibrator.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4. The 5560A/5550A/5540A High-Performance Multi-Product Calibrators define a new era in multi-product calibration.

- Fuse-free design
- Reverse power protection, preventing costly operator errors
- 4:1 test TUR for calibrating 6.5-digit multimeters
- 30-A continuous current output, extending ac-dc measurement ranges

The Future of Measurement Sciences

We're not done evolving how we measure the world. With the recent changes to the SI, its original goal has been realized: a standardized measurement system that's accessible for anyone. However, each metrology discipline will continue to evolve in their own way given the technology available at the time.

Also on the horizon are digital calibration certificates that would enable customers to export data into other organizational systems for convenient trending and analysis. There's much more being done in the digital arena, and Fluke Calibration along with other global partners will play vital roles in setting and executing on the coming standards.

Over the years, we've already seen this evolution in our everyday lives; for example, having smaller electronics that allow for more power in the palm of your hand than ever before. Without the evolution of calibration and the constant push toward better measurement accuracy, those advances, and future advances, would not be possible. ■

With the recent changes to the SI, its original goal has been realized: a standardized measurement system that's accessible for anyone.

The Future of **Automotive Connectivity**

Today's cars are bursting with wireless connectivity solutions, but they're distributed throughout the vehicle, creating implementation challenges and cybersecurity nightmares. Connectivity-domain controllers may provide an answer.

NXP

***By Jim Bridgwater,** Director, Global Product Marketing, Automotive Edge Processing, NXP Semiconductors*

As the number of automotive electronic subsystems balloons, the underlying architectures used to support internal and external connectivity are evolving to accommodate the ever-changing requirements of manufacturers and end-users.

Until relatively recently, the electronic subsystems in automobiles were predominantly based on flat distributed architectures. In this case, specific electronic control units (ECUs) are dedicated to certain functions, with each ECU having its own sensors and actuators.

Problems begin to arise with these architectures when software in so many ECUs needed to be updated. With such a high number of interconnected ECUs (sometimes more than 80), testing and verifying every possible software combination becomes very challenging.

To address these problems, the automotive industry is moving to concentrate electronic functions into fewer, larger ECUs by adopting domain-controller architectures that group similar functions together in a single "domain." A related approach is zonal architectures—a vehicle's functions (including their associated sensors and actuators) are grouped into zones based on their physical location, with each zone having its own zonal controller.

In parallel, the traditional automotive wiring harness is being replaced by a high-speed network in the form of automotive Ethernet. Such a network provides the time-sensitive-networking (TSN) capabilities required to enable engineers to design automotive networks with predictable latency and guaranteed bandwidth.

Uncontrolled Connectivity

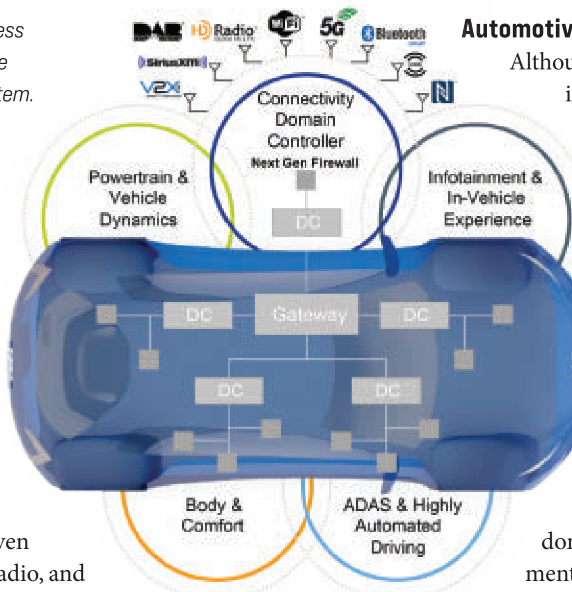
We live in an increasingly connected world and automobiles are no exception, with both internal and external wireless interfaces growing dramatically. Prior to the year 2000, the only wireless interface in a car was typically an AM/FM radio tuner. The first Bluetooth hands-free car kit appeared on the market circa 2001. This was soon followed by a wide variety of increasingly sophisticated wireless connectivity solutions.

Today's automotive wireless connectivity solutions are typically distributed across various ECUs. In the case of infotainment and the e-cockpit, for example, there may be Wi-Fi (for hotspots), Bluetooth, digital audio broadcasting (DAB), HD Radio, and SiriusXM, to name but a few.

With respect to body and comfort, which includes seats, doors, and windows, we find Bluetooth and ultra-wideband (UWB), with near-field communication (NFC) as a backup technology if all else fails. These can be used for applications like smart car access—detecting when a phone is in range and then determining where the phone is to know when to unlock the doors.

More recently, some automotive manufacturers and OEMs started adding cellular modems (currently 5G) to provide cloud connectivity as well as support telematics use cases. They've also started to add Wi-Fi as an external interface (in addition to having Wi-Fi as an internal interface).

The current trend toward software-defined vehicles—that is, vehicles whose features and functions are primarily enabled through software—requires the ability to upgrade the vehicle's software from the cloud, which demands high-speed connectivity. If the vehicle is close to a Wi-Fi network, that's going to be faster than a cellular connection. Manufacturers are even starting to use this approach in a production-line setting rather than plugging in an Ethernet cable.



1. In the future, all of the vehicle's wireless connectivity will be managed by a single connectivity-domain controller subsystem.

NXP

Having been added ad hoc over time, these wireless interfaces to the outside world are typically spread all around the car. This leads to a variety of problems, including RF coexistence challenges and security.

Cybersecurity is now seen as a critical requirement. All of the wireless connectivity interfaces provide a means for data to get into the car from the outside world. Even broadcast systems like DAB, HD Radio, and Satellite Radio let the user download images and other files, any of which may be infected by malware (malicious software).

The ideal solution is to have a single point of entry into the car, allowing the data to be controlled and filtered using advanced firewall technology. Using such technology is almost impossible to do with existing distributed connectivity architectures.

Yet one more consideration is that different vehicles are created by different teams, each doing things in different ways. As a result, each new vehicle provides a new adventure when it comes to things like addressing RF coexistence challenges and ensuring data and system security.

Controlling Connectivity

One way to address the above concerns is to have all of the vehicle's wireless connectivity managed by a single subsystem called a connectivity-domain controller *(Fig. 1)*.

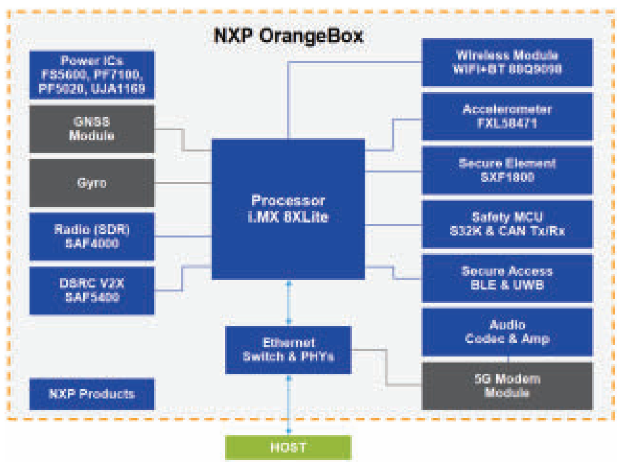
Having a single high-performance processor controlling every wireless interface means the system requires only a single instance of next-generation firewall (NGFW) technology. This enables consistent, state-of-the-art security protection to be applied to all traffic entering the vehicle.

In addition to facilitating cybersecurity, a connectivity-domain controller offers many other advantages, including managing any RF coexistence challenges and ensuring the desired quality-of-service (QoS) associated with each wireless interface. By means of its connection to the cloud via cellular or Wi-Fi, this approach also makes it easier to download, verify, and install the latest versions of any applications, drivers, and security software.

The connectivity-domain controller concept fits nicely into the modern vehicle architecture by providing a single connection into the automotive Ethernet network. Furthermore, it offers a scalable solution that can be deployed by multiple development teams working on different automotive platforms.

Automotive Connectivity Future

Although several OEMs are already working on their own proprietary solutions for automotive wireless connectivity, so too are semiconductor vendors like NXP. An example is its OrangeBox reference design and development platform to help other manufacturers, OEMs, and Tier 1 suppliers get started. OrangeBox is a comprehensive development platform providing extensive secure wireless connectivity to develop automotive solutions that meet both domain and zonal controller requirements *(Fig. 2)*.



2. The OrangeBox connectivity-domain controller provides a comprehensive platform for prototyping and use-case development, enabled by NXP hardware and pre-integrated software.

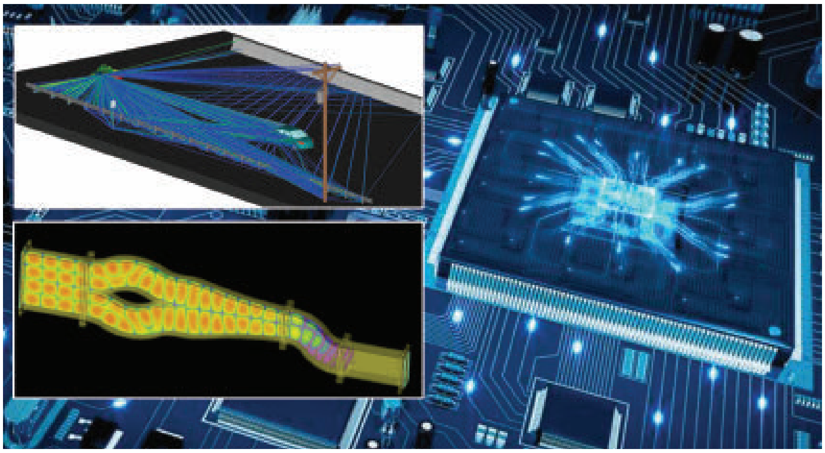
The OrangeBox incorporates the scalable i.MX 8XLite applications processor (AP), an S32K safety co-processor, and the wireless connectivity required to implement V2X, Wi-Fi, Bluetooth Low Energy (BLE), UWB, and cellular connectivity between the vehicle and the outside world in a secure and safe manner.

A key feature of the OrangeBox is the inclusion of modular upgradable components that use standard interfaces, thereby allowing it to address changing standards and requirements. For example, it supports Wi-Fi 6 + BT wireless connectivity and 5G cellular connectivity today, and it will be able to support Wi-Fi 7 + BT wireless connectivity and 6G cellular connectivity in the future.

RF/mmWave Design Tools Cut Prototyping Costs

By Jack Browne, Technical Contributor

Software design tools can shave the time and expense of multiple development iterations when striving for a first-round success or when making modifications to improve performance.



High-frequency design tools are evolving much like the computers that run them, growing in performance and versatility over time. As electronic applications continue to consume frequency spectrum, use of millimeter-wave (mmWave) frequencies is becoming more common, as in advanced driver-assistance system (ADAS) radars and 5G wireless communications systems. Thus, more components and devices are needed to support mmWave applications.

Computer-aided-design (CAD) software tools help create innovative designs at higher frequencies, modeling the behavior of components, devices, printed circuit boards (PCBs), and systems before expensive mistakes can be made. The latest high-frequency CAD tools support models well into the mmWave range (30 to 300 GHz), enabling simulation of a design's performance whether at component, device, circuit, or even system level.

Selecting a CAD software program from the many available choices requires some work to narrow the field. Many CAD software programs are based on analysis of the electromagnetic (EM) fields around a conducting structure, such as a solder joint or transmission line, by solving Maxwell's equations. They can be used at component, circuit, or system level for simulations.

Some simulators are geared for only one type of component, such as antennas or filters. While they're easy to operate and can speed the design of a specific component, they fall short for many simulation chores such as modeling PCBs and systems.

Anticipation of future needs also should be part of this sorting process. A 3D EM simulator may enable precise visualization of the EM fields around different antenna structures within the RF/microwave frequency range. However, it may lack the accuracy and resolution to simulate the EM fields generated by an antenna design meant for the smaller wavelengths at mmWave frequencies.

In addition, connectivity is an important capability between and among modern CAD software tools. The usefulness of an EM simulator that can accelerate the design of a compact antenna is extended even further when the files or models representing the antenna are compatible with a system-level CAD simulator. It helps define the requirements for other components within the system, such as power amplifiers (PAs) and low-noise amplifiers (LNAs).

Component Considerations

Models created by CAD design tools often consist of device parameters, such as scattering (S) parameters, or Spice parameters, so that they can be interchanged from one software design tool to the next. When sorting through the large number of RF design tools on the market, model compatibility is essential if component models, such as filters and oscillators, will be part of a system-level simulation of a receiver using those filters and oscillators (along with many other component models).

Even at the component level, a voltage-controlled oscillator (VCO) may consist of several transistors and a varactor diode to change the component's frequency as a function of tuning voltage. Each of the VCO's component parts is a separate model. The multiple models must work together so that the simulated performance of the combination tracks an amplitude-vs.-frequency plot of the measured performance of a VCO constructed from those same building blocks.

While suppliers of CAD design tools attempt to back their simulators with comprehensive model libraries, new RF/micro-

wave components are introduced almost daily. Building accurate models takes time to match simulated performance to measurements of the new component—CAD software suppliers can't be expected to keep track of every new IC and component on the market.

Fortunately, CAD tools from many major suppliers are backed by companies specializing in software models compatible with individual circuit simulators and full CAD software suites. This helps facilitate the pursuit for the best models for a simulation.

Start the Search

Ansys

Selecting software simulation tools takes some time at Ansys, perhaps best known by RF/microwave designers for its High-Frequency Structure Simulator (HFSS) full-wave 3D EM simulation software. The software simulates the behavior of high-frequency components, PCBs, and multifunction subsystems. However, it's only one of 80 software tools available from the company to handle tasks such as mechanical and structural analysis, fluid dynamics, lightning analysis, material analysis, and thermal-management analysis and optimization.

Starting several decades ago as Ansoft, with Ansoft Designer schematic-capture software and HFSS EM simulation software, Ansys has grown into a global force for EM simulation with a wide range of design tools for different markets, including high-frequency electronics. Among its software tools are Ansys Maxwell for 2D and 3D EM and electromechanical analysis, and Ansys Multiphysics for thermal management and analysis.

To help those starting out with CAD software tools, Ansys has enjoyed a 40-year partnership with SimuTech Group. The latter provides engineering support and guidance starting from software installation on a PC.

One software tool of interest to RF/microwave designers is Ansys Discovery, a simulation-driven 3D EM software simulator available on a free trial basis *(see "Free Software Tools: Try Before You Buy" at the end of the article)*. Another is Ansys SIWave, which simplifies the analysis and simulation of the signal-integrity (SI) and electromagnetic-interference (EMI) behaviors of electronic packages and PCBs.

For filter designers, Ansys Nuhertz FilterSolutions software provides automated RF/microwave and digital filter design, synthesis, and optimization. The filter design software interacts with Ansys HFSS to automatically provide on-screen controls for EM analysis and optimization of a design created in Nuhertz FilterSolutions.

For those hoping to expand high-frequency simulations from component to circuit to system levels, the Ansys Electronics Desktop integrates EM, circuit, and system simulation into a single user interface. Free downloads are available for students to help new users apply EM simulations during different design phases.

Cadence Design Systems

Cadence Design Systems, a long-time supplier of digital circuit design tools, supports high-frequency circuit and system designers with a wide range of EM-analysis-based software tools. The company's AWR Design Environment platform provides the multiple function integration of its many software tools needed to synthesize, simulate, and optimize complete communications and radar systems at microwave and mmWave frequencies, from component through system stages.

The platform links the versatile AWR Microwave Office component and circuit simulator with programs such as the AWR Visual System Simulator (VSS), which models interconnected analog and digital components and subsystems. The VSS software provides time-domain, frequency-domain, and circuit-envelope analyses, and is an effective tool for performing baseband-through-RF/microwave system analysis of receivers, transmitters, and antenna arrays. It also adheres to mechanical design constraints that may impact a manufacturing process.

Additional Cadence EM-based design tools include the AWR AXIEM 3D planar method-of-moments (MoM) analysis and simulation software and the AWR Analyst 3D finite-element-method (FEM) software. These programs analyze the physical side of an electronic design, e.g., packaging and placement on a PCB, and how physical characteristics impact electrical behavior, e.g., EMI and electromagnetic compatibility (EMC). AWR AXIEM performs 3D planar EM analysis and simulation of passive antennas and transmission lines, while AWR Analyst analyzes and optimizes 3D structures and interconnections in high-frequency analog and high-speed digital designs.

For high-frequency circuit and component designers, Cadence offers the Spectre RF Option to both its Spectre X simulator and its Spectre Accelerated Parallel Simulator (APS) tools. The Option features several simulation engines, including shooting Newton, harmonic balance, and frequency-domain (FD) solvers, enabling a user to choose the best approach for a simulation, such as when optimizing oscillator phase noise. It works with the Cadence Virtuoso RF Solution to handle simulations of RF/microwave circuits and subsystem modules.

COMSOL

COMSOL Multiphysics from COMSOL Inc. is a far-reaching software design tool that attempts to include as many variables as possible when analyzing a circuit or component. The company recently released its latest version, 6.1. The software includes the RF Module program with multiple solvers for EM simulations.

Among the solvers, finite-element-method (FEM) techniques are typically used for higher-frequency simulations, but the tool also uses frequency-domain (FD) and time-domain (TD) solvers. Simulations couple physics effects, device surface deformations, material properties, thermal effects, and other variables.

A process known as adaptive meshing is used, in which mesh elements of many shapes (such as pyramids) and sizes subdivide

a component under study into small sections to analyze how they will react to an EM field. The RF Module relies on accurate models to simulate and optimize RF, microwave, mmWave, and photonic designs.

Keysight Technologies

Keysight Technologies brings an abundance of RF/microwave measurement capabilities to its family of RF/microwave CAD tools. If a single word could best describe the strength of its software tools, it would be "connectivity" for the almost unlimited capabilities of enhancing and verifying simulations with measurements to aid in speeding design and optimization processes.

The collection of PathWave software tools enable circuit- and system-level simulations at RF through mmWave frequencies with PathWave System Design (formerly SystemVue software). They also provide access to programming for automatic testing aligned with CAD simulations via PathWave Vector Signal Analysis (VSA) software. The simulators are backed by large libraries of reference designs based on measurement data from the company's highly accurate test instruments.

Other PathWave software tools include:

- PathWave Advanced Design System (ADS) for higher-level system simulations, such as combining modules developed in PathWave System Design.
- PathWave RFIC Design for frequency- and time-domain analyses of semiconductor devices and integrated circuits (ICs).
- PathWave EM Design for EM simulations.
- PathWave RF Synthesis (the former Genesys software).

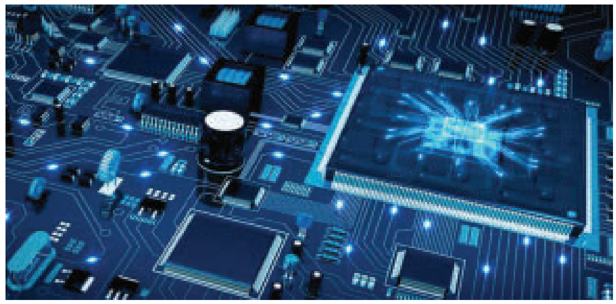
Designs developed in PathWave RFIC also are compatible with the Cadence Virtuoso design environment from Cadence Design Systems and the Custom Compiler design environment from Synopsys.

MathWorks

Mathematics is the formula for building accurate RF models from available data, such as transistor S-parameters or transmission-line dimensions. On that front, MATLAB system-level software from MathWorks is probably the most well-known and widely used math-based simulation and design tool available. It provides the analysis and visualization capabilities to explore design models, including PCBs, prior to prototyping to save manufacturing time and expenses *(Fig. 1)*.

The system-level software includes RF Toolbox with applications for designing, modeling, analyzing, and visualizing networks formed of RF/microwave components. It's well-suited for modeling wireless communications and radar systems and can perform signal-integrity analysis of simulated received and transmitted signals.

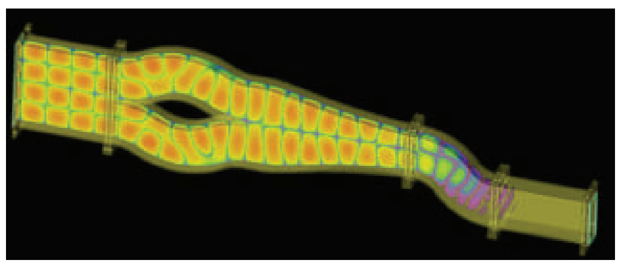
One application in RF Toolbox, the RF Budget Analyzer, makes it possible to analyze transceiver signal chains for noise, power, and nonlinearity and generate RF Blockset models that simulate signal envelope behavior. The RF Toolbox also provides the capability to transform model formats, such as S-parameter models to Spice netlists, for compatibility when using MATLAB models in other simulators.



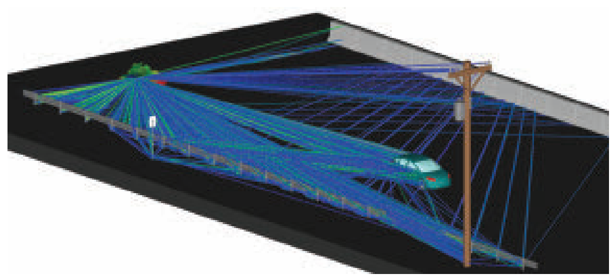
1. MATLAB simulation software applies mathematics-based models to analyze everything from transmission lines to systems. MathWorks

Remcom

XFdtd 3D EM simulation software from Remcom visualizes EM fields around a structure *(Fig. 2)* by solving Maxwell's equations in the time domain rather than the frequency domain. It uses a unique finite-difference-time-domain (FDTD) solver approach with space divided into box-shaped cells minute enough to resolve dimensions at mmWave frequency wavelengths. The EM field around a structure is analyzed in these small sections and calculated in discrete steps.



2. XFdtd 3D EM simulation software performs time-domain analysis of PCBs and components through the mmWave frequency range. Remcom



3. WaveFarer radar simulation software continues to be a useful tool for developers of ADAS radar systems. Remcom

The software has been used to simulate everything from antennas and oscillators to complete receivers, modeling operation at frequencies well into the mmWave range. The company also offers WaveFarer radar simulation software for analysis of radar pulses through different media and material, a useful tool for developers of ADAS radars *(Fig. 3)*.

Siemens EDA

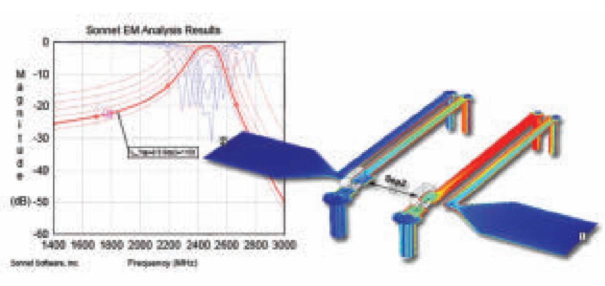
When thermal management of a design is a concern, Siemens EDA offers FloTHERM thermal analysis and simulation software as part of its Simcenter integrated CAD environment. The company added the software, which aids in developing thermal-management solutions for PCBs, in its acquisition of Mentor Graphics.

The software is backed by large libraries of thermal models for a variety of materials employed in electronic designs. It incorporates efficient thermal-modeling techniques for thermal analysis and optimization, ensuring the highest temperature-related reliability possible for a design.

Sonnet Software

Sonnet Software is a company name that's perhaps most synonymous with EM simulation. The firm's Sonnet Suites performs 3D full-wave EM analyses of planar structures, such as PCBs, using Maxwell's equations and MoM analysis routines to include all coupling and material effects within a simulation. The Sonnet Suites focuses on planar analysis to create accurate models of a structure or PCB at frequencies well into the terahertz range. The models are available in a variety of formats, including those based on S-, Y-, and Z-parameters and even Spice simulation models.

A free version of the firm's EM simulation software, Sonnet Lite, is downloadable from the website with easy-to-follow online tutorial lessons on using the software. Although scaled down compared to the comprehensive Sonnet Suites, Sonnet Lite *(Fig. 4)* and its newest version, Sonnet Lite Plus, can perform full-wave EM analysis of 3D planar circuits, such as microstrip or stripline filters and microstrip couplers, well into the mmWave frequency range.



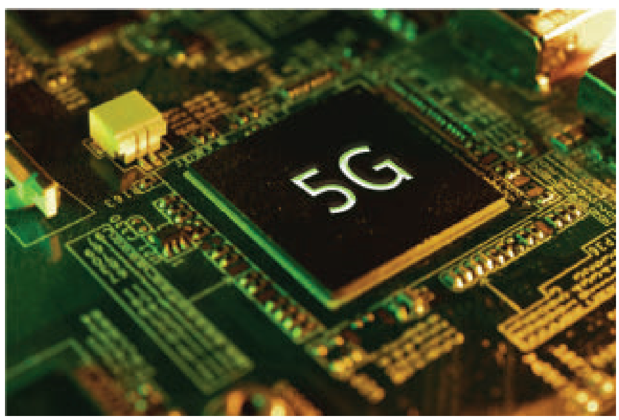
4. Sonnet Lite, a free version of EM simulation software, is capable of analyzing 3D planar circuits operating through the mmWave frequency range. Sonnet Software

Making Models

Many CAD tools feature generous libraries of component models that can be used as circuit building blocks, but the introduction of new electronic components occurs daily. Thus, it becomes difficult for every CAD tool provider to be up-to-date with models for all of the newest components. Fortunately, CAD software users often can obtain models supporting their design tools of choice from engineering firms specializing in simulation model development and validation.

For example, Coventor develops 3D device models based on different semiconductor processes, such as field-effect transistors (FETs), from a variety of suppliers. The active-device models are compatible with many EM simulators on the market. This is a result of Coventor working closely with each semiconductor supplier on acquiring S-parameters and other parameters to build a model that will provide simulation results closely matched to measurements of the physical device.

One of the best-known CAD simulation model suppliers is Modelithics, with models for most of the major RF/microwave design and simulation tools. The Modelithics Library for Cadence Spectre RF Option is available with a mmWave and 5G library, where component models have been validated to 30 GHz, some to as high as 125 GHz *(Fig. 5)*. The sub libraries can be specified for components from a single vendor or from multiple vendors to enhance design flexibility.



5. Accurate component models are available from third-party developers such as Modelithics for most major RF/microwave simulation tools. Modelithics

The Modelithics COMPLETE Library for Sonnet Suites also provides a diversity of sub libraries, including for die, surface-mount components, and devices validated at mmWave frequencies. The company supports most of the major RF software tools with extensive component model libraries, including RF/microwave inductor-resistor-capacitor (LCR) model libraries.

Some software design tools focus on the design and simulation of a single component or type of component, such as filters or antennas. Take PCAAD 7.0 from Antenna Design Associates, which is the latest version of an antenna design and simulation program for the Microsoft Windows OS, in particular Windows 7 and 10. The easy-to-follow, menu-driven software models microstrip antennas, arrays, wire antennas, and other forms of antennas with more than 50 built-in design routines.

Another "single-purpose" software design tool, HFWorks from EMWorks Inc., is a 3D EM simulator that's nominally for antenna design but also can be used to analyze high-frequency thermal effect, resonators, and high-speed digital interconnections. It features an integrated electro-thermal analysis tool that predicts the effects of input power on the resulting temperature of a design.

ICAP/4Rx RF Deluxe from Intusoft is a design and simulation suite of modeling tools for designs within the RF range to about 200 MHz. It's well-endowed with thousands of dedicated models and is available in a Windows version with added design verification capability.

Finally, SoftWright LLC's TAP 7.6 Terrain Analysis Package (TAP), which is not quite modeling a communications system but related to how it works, provides RF signal-path analysis for point-to-multipoint wireless networks over a wide range of terrain models. It can be modified as needed to simulate how a communications system is expected to perform across different areas. ■

Free Software Tools: Try Before You Buy

No-cost trial versions of RF/microwave design tools offer painless ways to explore a software simulator's capabilities.

LEARNING WHETHER AN RF design tool is suitable for an application can be quite painless when taking advantage of free scaled-down versions or no-charge introductory trial periods of full-fledged software tools offered by many CAD software suppliers.

For example, Cadence has free trial versions of its AWR Design Environment, an assortment of design and simulation tools for RF/microwave projects at device, circuit, and system levels. When choosing a trial option, users can download trial versions optimized for RF/microwave component design, EM analysis for antenna design, and radar and communications design simulation at the system level.

PathWave System Design from Keysight Technologies, with a large library of measurement-proven reference designs, is available on a free trial basis, as is the company's PathWave RFIC Design software for designing high-frequency ICs. MathWorks has a free trial version of its popular RF Toolbox software for the design and simulation of RF/microwave components for use in radar and communications systems.

In addition, Sonnet Lite and Sonnet Lite Plus are free, feature-limited versions of the popular suite of EM simulation tools from Sonnet Software, downloadable from the company's website. For those interesting in learning more about very basic EM simulation and design, RFSim99 is a freeware RF design software tool that can be downloaded from the AD5GG website.

Beyond software developers, many high-frequency component and device suppliers provide free software tools on their websites, tailored to the use of their products.

Circuit designers using high-performance, low-loss circuit laminates for microwave transmission lines such as microstrip, stripline, and coplanar-waveguide (CPW) lines, can check out circuit material supplier Rogers Corp.'s free impedance calculator for transmission lines fabricated on its substrate materials. Analog Devices, a supplier of system-on-chip (SoC) and system-in-package (SiP) semiconductors, offers a variety of free software design tools from its online engineering design center in support of the company's active devices.

For designers in need of crystal oscillators and other timing devices where minimizing jitter (or phase noise in the frequency domain) is essential, component and IC manufacturer Kyocera AVX recently announced a circuit-matching service to identify the optimum timing device for a particular circuit design. The online tool matches a user's requirements to components from 40 different global suppliers of oscillators and timing devices, including a detailed report covering key performance parameters like startup time, drive level, and initial frequency deviations.

In addition, Kyocera AVX offers many RF component design tools and provides free libraries of S-parameters and other simulation model parameters for its components, compatible with Ansys HFSS and many other RF design tools.

The 5 Benefits of Fully Software-Defined Instrumentation

Now more than a decade old, software-defined instruments are starting to provide a tangible impact for scientists and engineers. With several recent advances, the next generation of these instruments offer many advantages over standalone hardware.

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By Daniel Shaddock, Co-Founder and CEO, Liquid Instruments

Software-defined instrumentation—a more versatile alternative to traditional, fixed-function lab and engineering equipment—has existed for more than a decade. But recent advances in underlying capabilities have propelled the technology from a hobbyist niche into high-end tools gaining wide adoption among mainstream test and measurement applications. Software is enabling exciting new ways for scientists and engineers to enhance research and accelerate technology development.

Significant performance improvements in field-programmable gate arrays (FPGAs), expanded cloud services, and intuitive user-experience design have launched next-generation devices with a broad range of distinct advantages over traditional standalone hardware. Thanks to powerful software enhancements, these new devices are easier to use, remotely accessible, and instantly upgraded when new features are released. They also provide valuable hardware-accelerated processing and enable greater flexibility than ever before.

Why Software-Defined Instruments?

The appeal of software-defined instruments is founded in pairing the flexible configuration and control enabled by easy-to-use software with the high-performance execution delivered by robust hardware. These innovative tools provide a range of advantages over traditional equipment, as well as massive potential to support new applications across the commercial, research, and education sectors.

While software-defined instruments provide a range of benefits, here are the five most important ways they can help users:

1. They integrate many instruments into one reconfigurable and customizable hardware device.

With software-defined instrumentation, users can reconfigure hardware on the fly to perform different functions, such as an oscilloscope, a network analyzer, or a real-time control loop. This means that a single device replaces multiple instruments—often at a fraction of the cost.

Initially, different instruments had to be switched in and out one at a time. Thanks to the rapid advances in FPGAs, different instruments can now be run simultaneously, allowing for an entire system of conventional equipment to be replaced by one software-defined device.

2. They offer the ultimate in flexibility.

The reconfigurability of the hardware enables users to customize their instruments. Users can define custom protocols, add custom pre-compensation to a waveform generator, or pre-process data before viewing and recording with an oscilloscope. Software-defined instrumentation also helps users quickly build entirely new instruments or capabilities, tasks that were previously the domain of development boards and not for the faint of heart.

In the next five years, expect to see significant advances that will make instrument customization even more accessible using high-level, industry-standard tools like MathWorks' Simulink and MATLAB.

3. They're easier to maintain and increase asset longevity.

With most of their functionality enabled by software, these new devices can be remotely upgraded through over-the-air software updates that add new instruments and significant new capabilities. This eliminates the need to frequently replace expensive, outdated equipment, because instant upgrades enable the technology to keep up with the latest standards and evolving requirements. The result is simplified logistics, fewer end-of-life headaches, and better reuse of hardware.

4. They're easier to use, despite offering more sophisticated features.

Software-defined instrumentation leads the pack when it comes to best practices for user-interface (UI) design. This means tighter integration with Python, cloud storage, data-analysis tools, and more. Ease of use is more important than you might think.

What's the most expensive part of most test systems? The engineers who run them. Thanks to the intuitive UI, engineers can get up and running without opening a manual and with significantly less training. Better UI helps ensure a more efficient workflow, improved productivity, and shorter time-to-impact.

5. They make business sense for many organizations.

Rather than the large, up-front purchases familiar to many hardware buyers, software is easily and widely accessible on a subscription basis. Subscription can be a win-win for users and vendors alike. For users, new capabilities can be turned on (and off) as a project's funding wedge grows or declines, optimizing costs. For vendors, subscriptions motivate sustained investment to enhance instrument features, and they can help ensure software upgrades and customer support are continuously improved.

A World of Untapped Potential

The increased capabilities of software-defined instrumentation represent the next major paradigm shift in the test and measurement space. These enhancements will allow for new applications and implementations across many scientific fields, from astrophysics to cancer research. A couple of recent notable examples include:

- Researchers at the University of Alberta are developing ultra-sensitive devices that can improve dark-matter detector technologies, a project that requires high-precision measurements and remote monitoring. Detectors are deployed more than a mile underground, where the faintest signals can be detected with limited interference, making remote, online monitoring essential for operation. The small form factor and flexibility of software-defined instrumentation enables researchers to perform complex experiments in various environments far away from traditional lab settings.
- At the University of Washington, researchers are using chemical imaging tools to help detect cancer earlier and increase understanding of neurodegenerative disease progression. They use two-color stimulated Raman scattering, a process where two instruments conduct simultaneous scans. Equipped with newly developed, software-defined tools, the researchers can perform a variety of experiments and extract the low-intensity SRS signals with one compact, multichannel device.

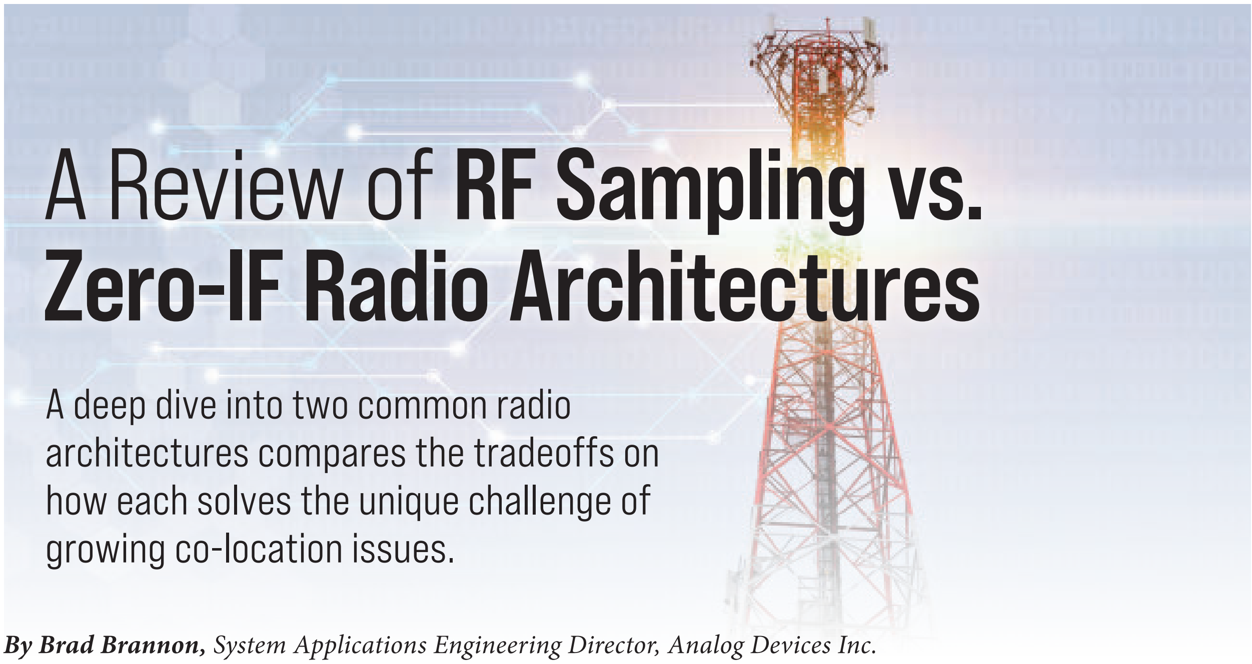
The Future of Test and Measurement

Most conventional test and measurement equipment today still looks remarkably like products available 30 years ago, apart from color screens. But with the emergence of software-defined instrumentation, the industry is experiencing a profound digital transformation.

Scientists and engineers now have better, more flexible ways to design with maximum efficiency—a critical need as the world heads into uncertain economic times. While the rising costs of raw materials are driving down profitability across industries, advances in software technology will meet this concern head-on. For engineers, being able to preview designs and extrapolate data with unprecedented accuracy before building considerably reduces overall costs and ensures that efforts are optimized.

As the world becomes increasingly connected by technology, the test and measurement industry must innovate to meet the demands of industry consumers who want tools that are easy to use and adaptable to rapid change. This is where software-defined instrumentation shines brightest, and why adopting it is the most effective way for companies to future-proof their operations.

Software-defined instrumentation is not only disrupting the test and measurement space, but due to its adaptable nature, it's helping to deliver new results and findings, and increasing our knowledge and capabilities. The innovations that will shape the future in 10 years are anybody's guess. What's certain, though, is that software-defined instrumentation will play a major role in the evolutionary path of technology. We've only just begun to tap the potential of such tools. ■



A Review of **RF Sampling vs. Zero-IF Radio Architectures**

A deep dive into two common radio architectures compares the tradeoffs on how each solves the unique challenge of growing co-location issues.

By Brad Brannon, *System Applications Engineering Director, Analog Devices Inc.*

Photos courtesy Analog Devices

THE GROWING DEMAND for wireless services not only challenges our limited spectral resources, but it also challenges the radio designer to select the correct radio architecture. A proper radio architecture provides solid performance, and it simplifies the circuit around the radio to minimize cost, power, and size.

In the era of increasing radio deployments, the "right" radio is tolerant of current and future wireless neighbors that might otherwise cause interference down the road. This article will examine two common radio architectures and compare the tradeoffs on how each solves the unique problem of escalating co-location issues.

Table 1: Engineering Tradeoffs Between Architectures

	Zero-IF		RF Sampling	
Overall architecture	Pro: Easily implemented in a frequency agile radio in a low-power monolithic single-chip design.	Con: Channel bandwidth will be limited by baseband bandwidth.	Pro: Very wideband radios can be implemented.	Con: Relatively high power solutions and requires discrete external filtering for all selectivity.
Frequency translation	Quadrature demodulator		Sample cap and digitizer	
	Pros: inherent alias protection, low power	Cons: LO leakage, baseband images	Pro: simple digitizer implementation	Cons: high power, prone to aliasing, jitter/phase noise[4]
Gain	RF: ~32 dB Baseband: ~18 dB		RF: ~50 dB Baseband: N/A	
	Pros: lower total dissipation, baseband gain easily integrated along with active filtering, input impedance easily managed	Con: bandwidth limited by amp	Pro: very wideband radios attainable	Cons: high OIP3 drive amplifier required (high power); input impedance typically capacitive unless high power buffer used
Images	LO leakage, I/Q imbalance, baseband harmonics		Direct aliases, interleave artifacts, RF converter harmonics	
	Pro: RF harmonics and converter aliases fall out of band	Con: subject to LO leakage, I/Q imbalance (can be fixed with algorithms)	Pro: no LO leakage or I/Q imbalance terms	Cons: interleaved spurs (fixed with algorithms), subject to aliases, subject to RF harmonics and clock-related phase noise
Filtering	Distributed between RF and baseband		Single frequency	
	Pros: integrated alias protection, limited external filtering required due to filter integration	Cons: none known	Pro: requirements are easy to derive	Con: high complexity filter required

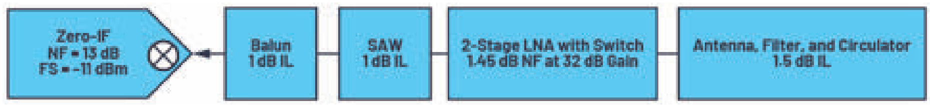
A Growing Challenge—New Wireless Neighbors

When the wireless revolution began some 30 years ago, only a handful of bands existed—confined mostly below 900 MHz—and typically there was one band per country. As demand for wireless services ramped up, new bands were steadily added. Currently, 49 bands[1] are globally assigned to 5G NR alone, not counting mmWave allocations. Most of the newer spectrum is above 2.1 GHz, with bands covering 500 MHz (n78), 775 MHz (n46), 900 MHz (n77), and as high as 1200 MHz (n96).

As these new bands come online, one of the biggest challenges is how to ensure adequate receiver performance in the presence of blockers in these legacy bands. This comes mainly from the co-location requirements where they're deployed, with bands 2, 4, and 7 in the U.S., and their counterparts, bands 1 and 3 in other regions. This is particularly critical for wideband radios servicing applications in n48 (CBRS) and any portion of n77 or n78.

Wireless demands will continue to grow in the future, and the issues with co-location and interference are always present.

1. This diagram depicts a typical RF sampling signal chain. RF sampling has all of the gain in the RF domain, given that all frequencies in the radio remain constant as the signal is processed.



2. Represented here is a typical zero-IF signal chain. For this architecture, part of the gain is at the RF frequency, but the balance is at baseband after the frequency translation.

Radio Designs and RF Protection and Selectivity

One of the key challenges for a receiver design is protection from signals that aren't of interest. From the beginning, radio engineers have sought different ways to accomplish this, initially with brute-force filtering and later employing various heterodyning techniques with distributed filtering.

Over the years, three key architectures have been developed to solve these challenges: direct conversion (zero-IF), super-heterodyne (IF), and direct RF sampling. While IF sampling is popular, it will not be the focus of this article. Instead, we'll center on comparing RF sampling and zero-IF, since these are currently the most progressive implementations in the wireless domain.

Each technique introduces different engineering tradeoffs and varying impact on the surrounding circuits and their requirements. This includes the method of frequency translation, the amount of RF and baseband gain, how RF images are dealt with, and how and where filtering is implemented. Details of these tradeoffs are shown in *Table 1*.

Gain Distribution and Power Dissipation

Key differences in gain distribution are prevalent between RF sampling and zero-IF. As shown in *Figure 1*, RF sampling has all of the gain in the RF domain given that all frequencies in the radio remain constant as the signal is processed. For comparison, *Figure 2* shows a zero-IF architecture. In this architecture, part of the gain is at the RF frequency, but the balance is at baseband after the frequency translation.

There are tradeoffs to both architectures. From a gain perspective, gain at higher frequencies requires more dc than lower frequencies due to the higher slew rates that are required, especially as the signals get progressively larger within the signal chain. This means that an RF sampling architecture dissipates more power in the linear RF section than does a zero-IF architecture, where a significant portion of the gain is at dc. At lower frequencies, the slew rates are lower and thus standing currents can be correspondingly less.

The challenge with RF sampling is the requirement to drive a largely capacitive input (sampling capacitor) at both high frequency and at relatively high voltage (~1 V). By contrast, a zero-IF input presents a well-behaved 50-Ω (or 100-Ω) impedance to the summing node of a baseband amplifier, which provides gain, eliminates and isolates the sample node from the RF signal, and reduces the RF drive required by the amount of gain it delivers.

That has a profound impact on power consumed in the linear RF section: It reduces the total RF dissipation by 25% to 50% in favor of zero-IF architectures by eliminating a third RF gain stage and the lower standing currents needed for baseband vs. RF amplification.

In addition to linear power is the power associated with the digitizer. With zero-IF converters, only the bandwidth required is digitized. With RF sampling, not only is a wide RF bandwidth digitized, but the sample rate far exceeds the Nyquist requirements.

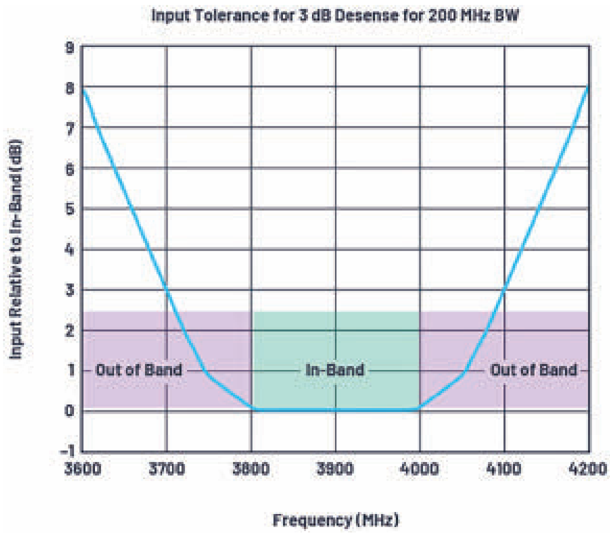
Both bandwidth and sample rate are expensive in terms of power. Exact power depends on the process, but when implemented on the same process, RF converters consume about 125% more power than baseband converters for a typical single-band application. Even when two bands might be digitized by an RF converter, the power penalty is still more than 40%.

Images and Spurious Signals

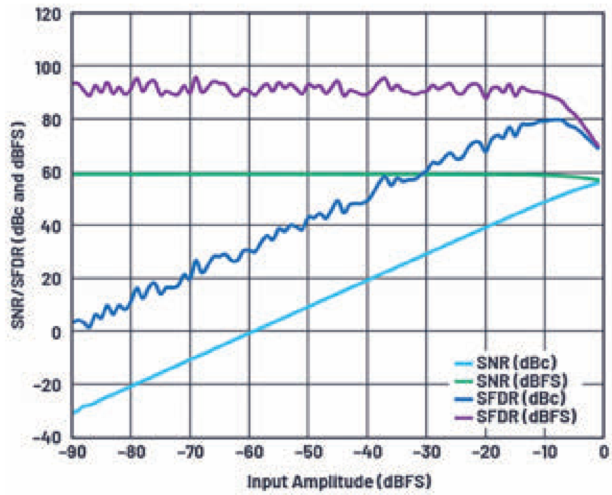
Secondary tradeoffs exist in these options as well. For example, a zero-IF architecture introduces local-oscillator (LO) leakage and I/Q mismatch image terms.[2] On the other hand, RF sampling introduces interleave spurs[3] due to mismatches within the converter architecture, as well as RF harmonics in the converter and sample-related jitter terms.[4] The good news is that most images and spurious signals are mitigated with various background algorithms regardless of architecture.

These two architectures have vastly different frequency plans that impact the handling of aliasing and how much RF (external) filtering must be applied. Aside from architectural spurious signals, all radios will generate RF harmonics and are subject to aliasing.[5]

RF sampling radios take advantage of aliasing to down-



3. An example of the impact of on-chip zero-IF filtering, showing that zero-IF radios inherently offer good tolerance to out-of-band signals.



4. Today's converters often perform background dithering to present relatively clean spurious-free dynamic-range (SFDR) sweeps.

convert the desired signal if it's naturally beyond the first Nyquist zone. However, it's the response of unwanted signals that are generally the issue, given that they may inadvertently fall on top of desired signals after they have been aliased. These signals must be mitigated by careful frequency planning, either by aggressive RF filtering or by sample rates that are high enough to have no aliases. Each of these comes with challenging tradeoffs.

Zero-IF architectures translate the signal to baseband (near dc). While RF harmonics are certainly created, they mix well away from the baseband in all cases and are adequately filtered by the low-pass response of the typical zero-IF input structure noted in the following paragraphs. Similarly, aliasing also is mitigated by the relatively high sample rates of the baseband sampler used and the selfsame input structure.

Zero-IF Filter Requirements

One easily overlooked feature of a zero-IF architecture is that the baseband input amplifier will typically be constructed as an active low-pass filter operating as an integrated analog filter, which greatly reduces the analog filter burden. In addition to performing on-chip decimation filtering, it functions as a programmable channel filter to eliminate signals closer than those associated with Nyquist.

Furthermore, the sampling devices within zero-IF receivers often include feedback that provides additional out-of-band rejection. In effect, this means that the out-of-band regions of the radio have a larger full-scale range than the in-band regions.

As demonstrated in previous writings[6] and shown in simplified form in *Figure 3*, zero-IF radios inherently offer good tolerance to out-of-band signals. In *Figure 3*, the vertical axis represents the input power level relative to in-band signals that would cause a 3-dB desense, showing that in-band signals have a built-in tolerance to out-of-band signals not found in other architectures.

Because of this built-in filtering, the primary concern becomes protection of the RF front end—that is, the low-noise amplifier (LNA). A typical configuration will include a surface-acoustic-wave (SAW) filter between the first- and second-stage LNAs for frequency-division duplexing (FDD) and some time-division duplexing (TDD). Some TDD applications will integrate the SAW filter after the second stage, but the second stage can be bypassed under large input conditions *(Fig. 1, again)*.

Typically SAW filters will provide about 25 dB of out-of-band rejection, and that's assumed here. In addition to the SAW filter, a cavity filter is required on the antenna side of the LNA, which is shared with the transmitter.

A typical LNA might have an input 1-dB compression point of –12 dBm. If the out-of-band or co-location requirements are 16 dBm, these signals must be filtered to about 10 dB (or more) below the input 1-dB compression point of the LNA. This is a minimum of 38-dB rejection (+16 – -12 + 10). If we include the SAW filter, total out-of-band rejection is 63 dB as presented to the input of the zero-IF.

Assuming RF gain doesn't roll off and including the total filter rejection up to the core radio input, the maximum out-of-band signal level will be –20 dBm. This is well below the typical full scale and will be further attenuated by the on-chip filtering. No spurious signals or desense would be anticipated from this input level when compared to *Figure 3*.

RF Sampling Filter Requirements

Two concerns arise when working with RF converters that require direct attention for filtering. First, any signal regardless of input level can create undesired spurious signals that may occupy the same frequency as the desired signal.

Spurs related to interleaving are dealt with by algorithms, but architectural spurs are another issue as they can be unpredictable. For many older RF converters, this was a constant challenge to radio performance. Fortunately, many new converters include background dither[7] in one form or another to mitigate these issues and present relatively clean spurious-free dynamic-range (SFDR) sweeps *(Fig. 4)*.

What's notable in this SFDR vs. input level plot is that the first 15 dB show degradation due to slew-rate limitations in the converter, which will typically generate strong second and third harmonics that must be abated. Once the RF input is below this level, harmonics and architectural spurs are typically no longer an issue (consult converter performance to verify).

With a full scale of 1 dBm, it can be expected that spurious signals will reduce significantly by the time out-of-band signals are rejected below –14 dBm into the converter. With a conversion gain of 50 dB, as shown in *Table 2*, this equates to –64 dBm at the antenna. If the input is potentially 16 dBm, then the RF filtering needs to be 80 dB or more for non-aliased cases.

Assuming a SAW filter provides 25 dB, this leaves 55 dB for the cavity filter to adequately protect the RF ADC from generating nonlinearities due to out-of-band signals. It also protects the input of the first-stage LNA from being driven into nonlinearity by out-of-band signals. This example represents a well-behaved converter, but the SFDR vs. input level of the converter selected should be closely examined to determine if more filtering is required.

The other concern for RF converter architectures is based on current merchant silicon, namely alias protection. Current RF converters are based on cores that operate between 3 and 6 Gsamples/s. At these low rates, it's impossible to avoid aliased terms without the use of aggressive filtering to mitigate the impact of aliasing. This problem only abates after sample rates reach double-digit gigahertz levels.

A simplified way to consider the impact of aliasing on filter requirements is to consider the protection of a single resource element from the aliased 16-dBm co-location requirement. The goal is to suppress the aggressor to the point that should it alias to a desired rejection band, it's filtered sufficiently so that no disruption occurs.

A wide-area reference channel based on a G-FR1-A1-4 signal would account for a signal level per rejection band of –118.6 dBm at approximately 0 dB SNR. Therefore, the offender must be filtered to 10 to 15 dB lower, or about –130 dBm, to prevent disruption. Thus, a total rejection of about 150 dB is needed, or about 125 dB from the cavity filter with one SAW filter providing the balance of filtering.

Filter Summary

Figure 5 shows the cavity filter requirements for both RF sampling and zero-IF. Because the RF sampling architecture has two separate requirements, the most restricting will dominate and a realizable filter would simply have to meet the most restrictive (125 dB) rejection to cover the entire band.

While such filtering is readily available, it comes at the cost of a bulky filter. In contrast to the zero-IF architecture, where only 40-dB rejection is required, the result is a significant weight and size savings given this performance is possible with a four-cavity filter.

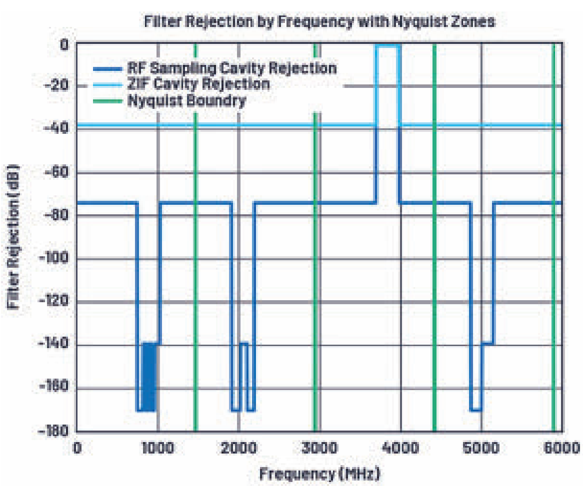
Conclusion

Both zero-IF and RF sampling architectures provide exceptional capability. However, when the goal is optimized cost, weight, and size, the zero-IF architecture wins on multiple accounts.

From the perspective of power, the zero-IF architecture with integration of significant portions of analog gain offers a compelling power savings. Similarly, when considering the impact of filtering, zero-IF offers the potential to significantly downsize the filter requirements. While the cost differential of the filters may be small, the size and weight reduction of these filters should move beyond 50% based on the required number of cavities. ■

Table 2: Gain Distribution in Different Architectures

	Zero-IF	RF Sampling
RF gain	32 dB	−50 dB
Baseband gain	−18 dB	—



5. This plot shows the cavity filter requirements for both RF sampling and zero-IF architectures.

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COAXIAL AMPLIFIER DRIVES 24 TO 43.5 GHZ

Mini-Circuits' model ZVA-24443G1+ wideband coaxial amplifier covers 24.0 to 43.5 GHz with 43 dB or more typical gain. The typical full-band noise figure is 1.75 dB or better, with output power at 1-dB compression of typically +21 dBm or better. The typical third-order intercept is +27 dBm. Available with or without a heatsink, the rugged amplifier has built-in overvoltage and reverse-voltage protection and incorporates 2.92-mm female coaxial connectors. It operates from a single supply of +9 to +15 V dc.

MINI-CIRCUITS
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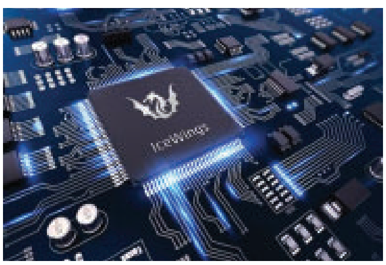


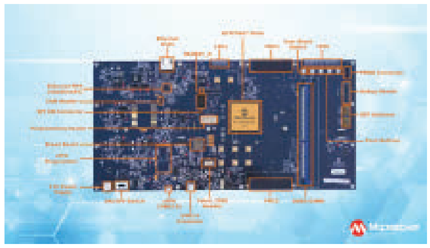
SiTuNE IS NOW ARCTIC SEMI-CONDUCTOR, SHIPS ITS FIRST 5G RF CHIPSET

Arctic Semiconductor, a creator of low-power universal RF chipsets, has rebranded from SiTune to Arctic Semiconductor to emphasize its focus on 5G RF products. The company has begun volume shipping of its first 5G silicon chipset, IceWings, its programmable, high-performance, low-power solution. The universal RF chipsets provide excellent signal quality and low power consumption in 5G wireless radios for various applications.

ARCTIC SEMICONDUCTOR
https://tinyurl.com/2al5azku

INTEGRATED DEVELOPMENT KIT SPEEDS DESIGN OF FPGA-BASED SATELLITE SYSTEMS

Developers using FPGAs for satellite system applications can speed their designs by prototyping with space-qualified devices rather than commercial off-the-shelf silicon. Microchip Technology recently combined its flight-ready RT PolarFire FPGA with the development kit and interfaces to design based on actual in-flight electrical and mechanical characteristics. Using the same package and silicon that final in-orbit or deep-space units will have, designers can evaluate high-speed transceivers and test all of their control, DSP, communications, and image-processing algorithms.



MICROCHIP TECHNOLOGY
https://tinyurl.com/2b2epxyt

FREQUENCY EXTENDER MODULES OFFER BEST-IN-CLASS PERFORMANCE TO SUB-THZ APPLICATIONS

Anritsu introduced frequency extender modules for its Rubidium line of signal generators, in partnership with Virginia Diodes (VDI). The modules complement Rubidium's performance by providing 50- to 1100-GHz frequency coverage to create a sub-THz signal generator solution. The VDI modules offer high test port power, voltage-controlled RF attenuation, and TTL-controlled ON/OFF modulation rates to a few kHz as standard.

ANRITSU
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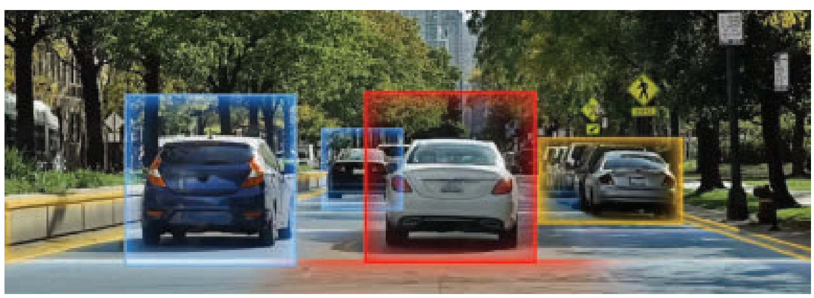

RADAR SENSOR TARGETS NEXT-GENERATION COMMERCIAL VEHICLES

NXP Semiconductor's S32R41 is part of its scalable S32R radar processor family, and can support L2+ autonomous-driving and ADAS solutions. CubTEK will leverage NXP's S32R41 processors and TEF82xx RFCMOS transceivers for its latest high-end radar sensor system. The processor also can serve in blind-spot information systems (BSIS) to assist drivers in enhancing road safety for vulnerable road users such as pedestrians and cyclists. NXP's scalable radar platform of highly integrated processors and radar one-chip, which offers a high degree of architecture compatibility and software reuse, allows CubTEK to benefit from its prior work on 4D imaging radar with NXP's S32R45.

NXP SEMICONDUCTOR
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