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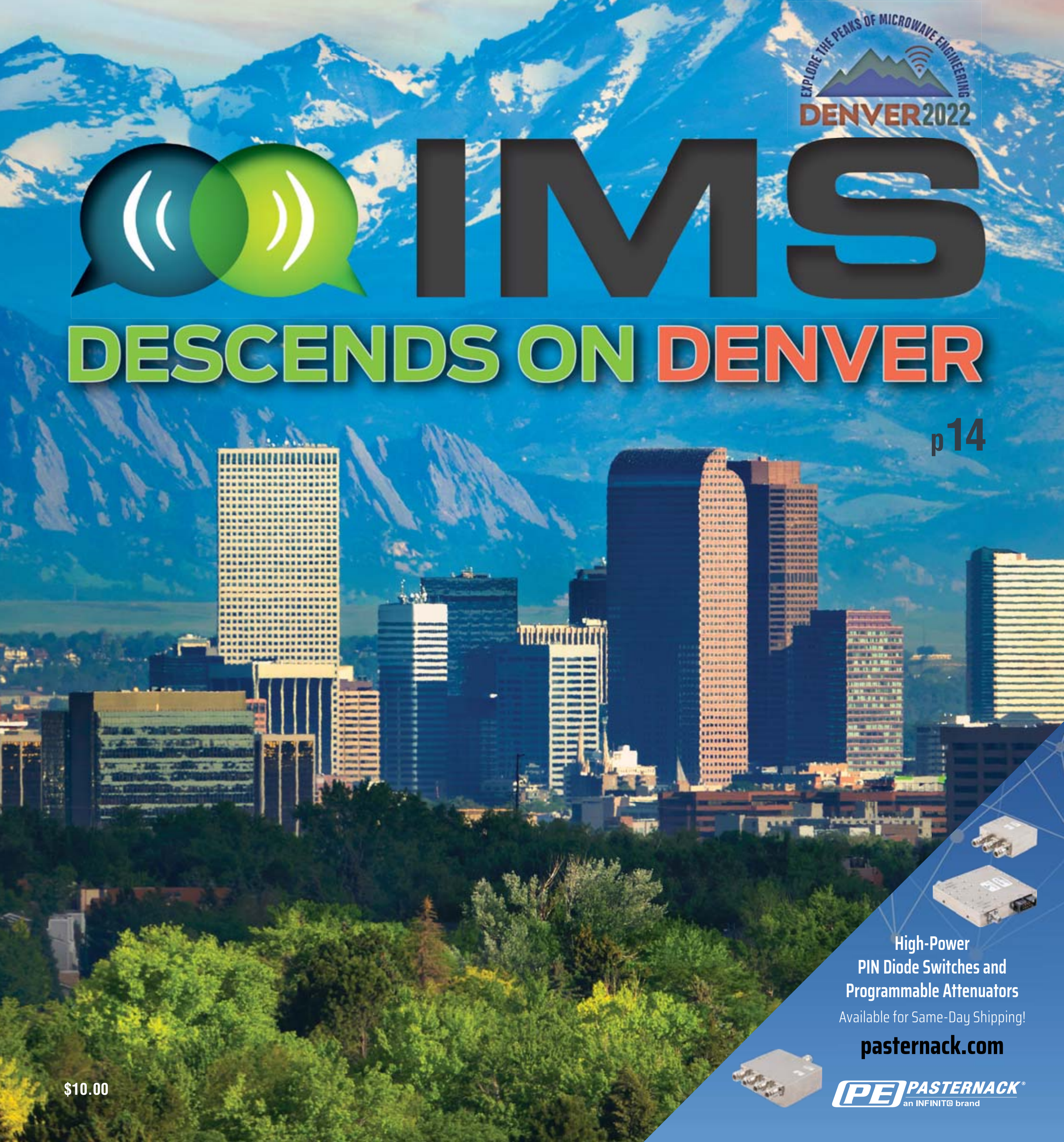

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Taking the Pulse of the RF/Microwave Industry

IN MY MARCH COLUMN, I unveiled a shift in *Microwaves & RF's* editorial approach and some of the recent improvements we've made to our technology coverage and our website. I'm excited about these improvements, but we're not stopping there.

The most important part of my job is to gain insight into what's coming and why, so that we can better inform your decision-making process. To that end, I'm announcing the formation of *Microwaves & RF's* Editorial Advisory Board, a group that's been drawn from industry to help us stay on top of coming trends so that our editorial content is relevant not just today, but for some time to come.

I'd like to introduce the inaugural members of *Microwaves & RF's* Editorial Advisory Board:

Tony Testa is director of marketing for Qorvo's Wireless Connectivity Business Unit. With more than 20 years of experience supporting industry alliance activities and customers, Tony helps engineers create state-of-the-art RF solutions that have a profound impact on our daily lives.

Dan Monopoli, chief technology officer of Wireless Telecom Group since June 2017, joined the organization in September 2015 as general manager of its Test and Measurement segment. Before that, Dan worked for 13 years in applications engineering, product management, and marketing at Teledyne LeCroy.

Tony Messina is a director of design engineering in Analog Devices' Integrated Solutions group, part of the company's Aerospace & Defense division. Tony brings 15 years of experience designing RF/microwave/mmWave components, modules, and subsystems for aerospace applications, and has held roles in design, management, and business development.

Sherry Hess, product marketing group director at Cadence Design Systems, has over 20 years of EDA experience in sales, marketing, support, and business management at NI, AWR, CebaTech, Ansoft (now Ansys), and Intel. She's also currently chairing the IEEE MTT-S Women in Microwaves (WIM) and Women in Engineering (WIE) organizations.

Donna Moore is CEO and chairwoman of the LoRa Alliance, overseeing the organization's strategy and direction to drive global adoption of the LoRaWAN standard. Prior to that, she served as the executive director of the Digital Living Network Alliance (DLNA), where she successfully led DLNA to become the de facto IoT standard for streaming video, audio, and picture files over a LAN.

Nizar Messaoudi is product manager for Performance Network Analyzers at Keysight Technologies. He has over 15 years of RF test equipment experience and began his career as an RF application engineer at Keysight in 2016. Before joining Keysight, Nizar taught at the University of Waterloo, training well over 3,000 engineers in the art of making RF measurements.

I'll be meeting with these industry experts to get their insights on the latest trends. I'm hoping that at least some of our discussions can be shared with you in the form of TechXchange Talks videos. I'm grateful to all of them for coming aboard to help me in the ongoing task of providing the information you need to be more effective in your role as a design engineer or engineering manager. mw

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DTA-100M50G-30-CD-1


DTA-200M18G-100-CD-EXT


DTA-18G40G-50-CD-1


PVVAN-0R4G6G-40-MP-1

PMI Model No.	Frequency Range (GHz)	Attenuation Range (dB)	Attenuation Flatness (dB)	Switching Time (Max)	Insertion Loss (dB)	Control / Size (Inches) / Connectors
DTA-30M6G-60-CD-1	30 MHz - 6	60	10 dB: ±1.0 20 dB: ±1.5 40 dB: ±3.0 60 dB: ±5.0	50 µs	4 dB Max	8-BIT TTL 2.0” x 1.8” x 0.5” SMA (F)
DTA-100M50G-30-CD-1	0.1 - 50	30	10 dB: ±0.95 20 dB: ±1.47 30 dB: ±2.13	On: 1 µs Off: 0.5 µs	5 dB Typ to 20 GHz, 8 dB Typ to 40 GHz 10 dB Typ to 50 GHz	5-BIT TTL 2.0” x 1.8” x 0.5” 2.4mm (F)
DTA-200M18G-100-CD-EXT	0.2 - 18	100	20 dB: ±1.0 40 dB: ±1.25 60 dB: ±1.5 80 dB: ±2.0 100 dB: ±3.0	On: 1 µs Off: 0.5 µs	12 dB Max	8-BIT TTL 4.0” x 1.8” x 0.5” SMA (F)
PVVAN-0R4G6G-40-MP-1	0.4 - 6	40	12 dB: ±0.23 24 dB: ±0.15 36 dB: ±0.54 40 dB: ±0.68	5 µs Typ, 10 µs	4.0 dB Max, 2.8 dB Typ	0 to +10 VDC (Linearized) 2.0” x 1.81” x 0.88” SMA (F)
PVA-500M18G-60-SFF	0.5 - 18	60	0-10 dB: ±1.0 10-20 dB: ±1.5 20-40 dB: ±2.0 40-60 dB: ±2.5	3 µs	4.5 dB Max, 0.5-12 GHz 5.8 dB Max, 12-18 GHz	10 dB / Volt 2.0” x 1.8” x 0.5” SMA (F)
DTA-1G18G-60-7-CD-1-HERM	1 - 18	60	20 dB: ±1.0 40 dB: ±1.25 60 dB: ±3.0	On: 1 µs Off: 0.5 µs	5 dB Max, 4.8 dB Typ	7-BIT TTL 2.0” x 2.79” x 0.66” SMA (F)
PVVAN-2040-60-MP	2 - 4	60	10 dB: ±0.45 20 dB: ±0.80 40 dB: ±1.50 60 dB: ±1.60	500 ns	2 dB Max	10 dB / Volt 2.0” x 1.8” x 0.5” SMA (F)
DTA-2G18G-60-12-CD-1-20DBM-TS	2 - 18	60	20 dB: ±1.0 40 dB: ±1.25 60 dB: ±3.0	On: 1 µs Off: 0.5 µs	4.8 dB Max	12-BIT TTL 2.0” x 1.8” x 0.5” SMA (F)
PVVAN-8018-60-MP	8 - 18	60	10 dB: ±0.80 20 dB: ±1.10 40 dB: ±1.50 60 dB: ±1.60	500 ns	3.7 dB Max	10 dB / Volt 2.0” x 1.8” x 0.5” SMA (F)
DTA-18G40G-50-CD-1	18 - 40	50	±1.5	On: 1 µs Off: 0.5 µs	8.5 dB Typ	10-BIT TTL 2.0” x 1.8” x 0.5” 2.92mm (F)


DTA-1G18G-60-7-CD-1-HERM


DTA-2G18G-60-12-CD-1-20DBM-TS


PVA-500M18G-60-SFF


PVVAN-2040-60-MP


PVVAN-8018-60-MP

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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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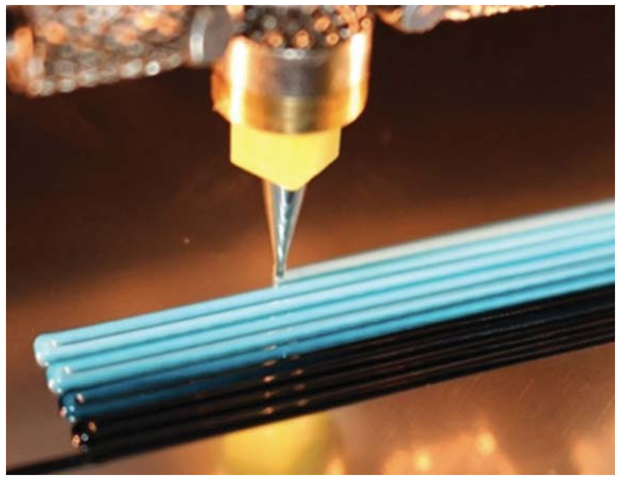
News

3D PRINTING Shields Satellite Components

A custom print nozzle developed by MIT Lincoln Laboratory enables 3D printing of shielding materials directly on electronic components.


MIT Lincoln Laboratory

MIT LINCOLN LABORATORY'S Advanced Materials and Microsystems Group has developed an approach for a three-dimensional (3D) printing process to shield satellite components from the ills of radiation exposure. The conceptual process prints conformal shielding on discrete components and ICs, transforming commercial-off-the-shelf (COTS) parts to radiation-hardened (rad-hard) devices suitable for satellite use. The approach fabricates conformal shielding on the components, rather than adding traditional shields with much larger size and weight.

Bradley Duncan, a technical staff member with the Advanced Materials and Microsystems Group and lead investigator for the research, said, "This program, if successful, will allow the U.S. Department of Defense to use virtually all integrated-circuit technologies in extreme radiation environments, such as space, by shielding commercially available electronics from destructive radiation."

The novel shielding approach employs a custom, active mixing nozzle *(see figure)* developed by MIT Lincoln Laboratory. The tool deposits shielding materials directly on components, such as ICs, to protect them from the effects of radiation in space. A robotically controlled print head substitutes a paste-like shielding material for ink, spreading it conformally around a component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to achieve a required level of shielding without undue changes in component size and weight. Self-supporting filaments built from the 3D-printing nozzle form the shielding.

Devon Beck, an associate staff member in the same group working on the 3D-printing project, said, "By printing custom shield architectures directly onto electronics, we can potentially enable the most advanced commercial off-the-shelf electronics to exist in space environments."

The MIT research is driven by the need to miniaturize components as part of efforts to reduce component size, weight, and power (SWaP) for various satellite systems, such as communications and surveillance satellites. Pascale Gouker, a senior staff member in the MIT group, added, "3D-printed shielding will be a disruptive innovative approach to producing high-performance radiation-hardened microsystems." ■

VERUS RESEARCH

Receives SBIR to Assist DoD's JIFCO

NEW MEXICO SCIENTISTS and researchers at Verus Research have been incentivized by a small business innovative research (SBIR) contract to support the U.S. Department of Defense (DoD) and the Joint Intermediate Force Capabilities Office (JIFCO) efforts for ongoing defensive strategies. The contract funds work on a broadband counter-electronics weapon (BCEW) for the purpose of stopping long-range vehicles and vessels using nonlethal means.

Dr. J. Mark DelGrande, chief technology officer at Verus Research, said, "We are honored to receive a new contract to support the JIFCO and continue our relationship with the Department of Defense. Our work will bring cutting-edge directed energy solutions to the Defense Department and we are thrilled to be a part of this special project."

The contract seeks a long-range, nonlethal alternative to the large jammers and other electromagnetic (EM) weapon systems that rely on directing a high-power beam of EM energy at a target. The new weapon would stop an adversary's vehicles and vessels without destroying them and not causing fatalities among the crew.

As with the current trends in DoD R&D, the contract seeks solutions that are significantly smaller in size, weight, and power (SWaP) as well as in power consumption, amount of heat generated, and cost compared to current approaches. It's hoped that Verus Research's work will benefit numerous branches of the armed forces, including the U.S. Army, Navy, Coast Guard, and Marine Corps. ■

ACCELLERAN BRINGS OPEN RAN 5G to the U.S. CBRS Market

The Overview

Accelleran has introduced additional functionality to its dRAX Open RAN 5G private network software with a new Citizens Broadband Radio Service (CBRS) feature. This will allow users to install high-performance 5G infrastructure with spectrum automatically allocated through a CBRS spectrum access system.

Who Needs It and Why?

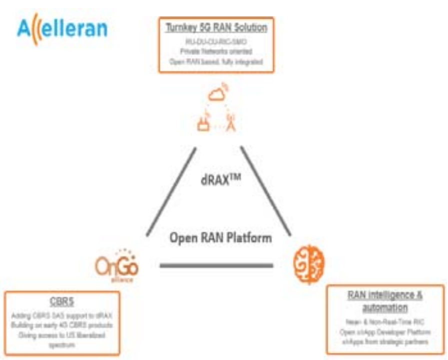
The CBRS band is a 150-MHz-wide segment of the 3.5-GHz band (3,550 to 3,700 MHz) in the U.S. Since the FCC authorized use of the CRBS band for wireless service providers, it's been possible to deploy 5G private networks in that spectrum with no licensing requirements. By incorporating CRBS functionality into its dRAX platform, Accelleran hopes to make 5G private network implementations happen much faster and at lower engineering costs.

Under the Hood

Through its turnkey solution, the company is already providing a way for customers looking to implement 5G private networks to avoid all of the specifying and integration work involved. Consisting of the near real-time RAN intelligent controller (RIC), centralized unit (CU), distributed unit (DU), and radio unit (RU), plus the service management and orchestration (SMO) software, all of the key elements have been pre-selected, pre-integrated, and optimized.

Users gain access to the RAN intelligence and automation functionality provided by the dRAX RIC platform to address the specific challenges of their particular use-case requirements. The additional CBRS feature now incorporated will enable automated micro-licensing of spectrum issued by the CBRS SAS server for the U.S. 5G private networks market. ■

The CBRS band is a 150-MHz-wide segment of the 3.5-GHz band (3,550 to 3,700 MHz) in the U.S.



MWC 2022 Brought Over 61,000 Attendees to Barcelona

THE CURRENT EXPANSION and evolution of wireless technologies, devices, services, and infrastructures has placed a renewed emphasis on RF systems development. The GSMA recently held MWC 2022 in Barcelona, and the event was well attended considering the current social environment. Presented as the world's largest and most influential connectivity event, over four days more than 1,900 companies met over 61,000 attendees from almost 200 countries.

"Nothing beats MWC in person, and it was exciting to bring our community, which is so passionate about connectivity, back together to discuss the opportunities that lie ahead" said John Hoffman, CEO GSMA Ltd. "On behalf of the GSMA, I would like to thank all of our attendees, exhibitors, sponsors, and partners who came together to make MWC22 so productive, safe, and successful.

Hoffman added, "I also want to thank Barcelona City Council, Generalitat de Catalunya, the Ministry of Economy and Digital Transformation, Fira de Barcelona, Tourism de Barcelona (the Host City Parties), the L'Hospitalet de Llobregat, Mobile World Capital, and the people of Catalonia and Spain. Your support is unwavering, and your creativity, hospitality, and perseverance continually inspire us."

Reflecting the cloud-enabled, IoT-driven ecosystem being developed, upgraded, and deployed in a variety of next-generation configurations, the event emphasized mobile technology and connectivity. However, there were also policy-oriented activities like the Ministerial Program and global digital policy debate.

More than 160 delegations from countries and international institutions were on hand, along with the international development community, exchanging points of view on how to build policies for a digital world that maximizes the potential of 5G, closes the digital gap, and addresses global climate targets. Leaders like Jessica Rosenworcel, Chairwoman of the U.S. FCC, and Minister Paula Ingabire of Rwanda, were among the participants of the Ministerial Program as well as being MWC keynote speakers.

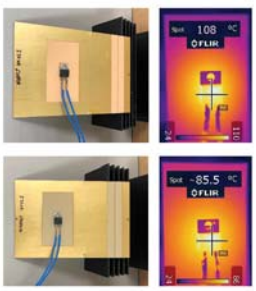
MWC22 by the Numbers

- Over 61,000 unique people attended in person
- Around 500,000 unique virtual and daily viewers on MWC22 and partner platforms
- Representation from almost 200 countries and territories
- Over 1,900 exhibitors, sponsors, and partners
- Over 1,000 speakers, 97% in person and 36% women

Following MWC22 in Barcelona, the GSMA's next event, MWC Shanghai, will take place from June 29 to July 1, followed by the inaugural MWC in Las Vegas from September 28-30, and then MWC Africa from October 25-27, returning to Kigali for the first time since 2019. ■

GRAPHITE EMBEDDING CAPABILITY Furthers PCB Thermal Management

TELEDYNE LABTECH HAS developed the capability to embed layers of synthetic graphite within RF and microwave printed circuit boards (PCBs). Heat management is a significant concern in many aerospace defense and space applications where size, weight, and power (SWaP) are key attributes. Gallium-nitride (GaN) solid-state power amplifiers (SSPAs) are examples of increasingly common devices that benefit from careful heat management. This new technique allows for efficient conduction of heat away from such devices, saving system weight and increasing their lifetime.



Test Structures with 6.7W Dissipation Devices

Managing waste heat is a significant problem in today's electronic systems, impacting reliability and requiring added expense and weight to control effectively. In the latest consumer mobile phones, it's common to employ sheets of self-adhesive synthetic graphite on top of critical semiconductor devices to conduct away waste heat from small areas. Aerospace, defense, and space applications require more precision, repeatability, and area of coverage.

To address this, Teledyne Labtech devised a method of embedding thin layers of synthetic graphite inside the structure of the host PCB reliably, saving size and weight, while increasing the lifetime of active devices (MTBF) by permitting operation at cooler steady state.

"Synthetic graphite is 4X lighter than copper, and transfers heat 4X better in the X-Y plane," said John Priday, CTO of Teledyne Labtech. "Replacing PCB ground plane layers with it in critical applications such as T/R modules can cause devices to run up to 20°C cooler in our testing."

Labtech has demonstrated that thermal copper layers can be replaced with the new graphite technique while remaining reliable and experiencing minimal impact on the passage of microwave signals on grounding layers. ■

> "Synthetic graphite is 4X lighter than copper, and transfers heat 4X better in the X-Y plane."

DAVID MALINIAK | Editor

Featured New Product

6-GHz VNA Forges Versatility from USB and Software

By pushing complex data processing and calculation into software, Mini-Circuits' eVNA-63+ delivers an affordable and powerful vector-network measurement package to RF engineers' benches.

The Overview

Mini-Circuits' eVNA-63+ is a high-performance, software-controlled, yet affordable vector network analyzer (VNA) with a powerful user interface and full API with SCPI support. Banner specs include a dynamic range of >132 dB typical, trace noise of <0.005 dB_{RMS} typical, and output power of −50 to 10 dBm.

Who Needs It and Why?

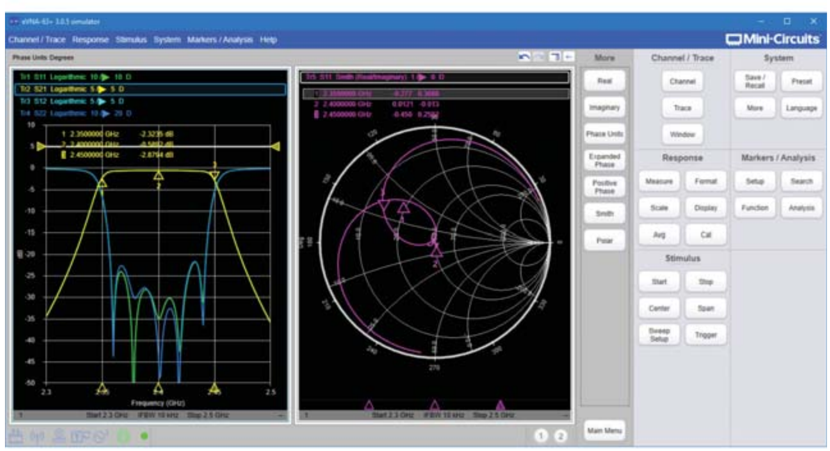
Just about all RF/microwave engineers can benefit from having a versatile and portable VNA on the test bench. By moving the complex data processing and calculation required of vector network measurements out of the instrument and into an advanced software package, the eVNA-63+ comprises a fully featured instrument. The VNA's eVNA software will feel familiar to any engineer with VNA experience, and the software's full API allows for automation of VNA calibrations, measurements, trace displays, and data exports from a custom control program.

Under the Hood

Here are some of the many capabilities that the eVNA-63+ analyzer brings to the test bench:

- It provides full support for the S_{11}, S_{12}, S_{21}, and S_{22} measurements of two-port devices. Phase and magnitude data extracted from such devices can be visualized in rectangular, Smith chart, or polar pilots formats, or exported as a Touchstone .s2p data file.
- Users can add time-domain-reflectometry (TDR) capabilities to their arsenal by determining the distance or time-to-impedance changes in a transmission line. These changes may include shorts, opens, connectors, or other ways in which impedance could be altered.
- Measurement results can be corrected to exclude test-fixture effects by mathematically moving the reference planes up to the DUT input and output.
- Powerful marker functions enable automation of common measurements, including filter bandwidth, ripple calculations, and display of pass/fail test results.
- A pair of internal bias-tee inputs allow for provision of up to +24 V dc/200 mA maximum on either measurement port (or both), useful for powering amplifiers in-line for .s2p/P1dB characterization.
- Users can configure an automated power-sweep sequence at a fixed frequency, which is suitable for measuring linearity or compressing amplifiers or other two-port devices.

The eVNA-63+ has a host of available accessories, including calibration kits, cables, adapters, terminations, and torque wrenches. U.S. list price for the instrument is $7,995.



With Mini-Circuits' eVNA software interface, data can be visualized in Smith chart, rectangular, or polar pilots formats. *Mini-Circuits*

- Focus in the space, cryogenic, 5G, mil/aero, test & measurement industries
- Champion of proprietary thin-film resistive chips and state of the art thermalization methods
- In-house design and fabrication of several dynamic passive product portfolios
- Superior technical support and customization consultation

IMS
Connecting Minds. Exchanging Ideas.
EXPLORE THE PEAKS OF MICROWAVE ENGINEERING
DENVER2022

ALIX PAULTRE | Editor-at-Large

IMS 2022 Welcomes the Wireless World

IMS 2022, the flagship event dedicated to all things microwaves and RF, also includes the IEEE MTT-S Radio Frequency Integrated Circuits Symposium and the Automatic Radio Frequency Techniques Group.

WHAT YOU'LL LEARN:

- When and where is IMS 2022?
- What will be covered at the event.
- Some of the companies and products you'll see.

Wireless systems have become a significant part of our civil, commercial, and personal infrastructure, to the point where society itself would collapse if it ceased to function. One of the interesting aspects of the microwaves and RF ecosystem is that it's still a work in progress, as the core technologies and products and services based on them are still maturing. In June, the wireless community will be coming together again in Denver for the 2022 International Microwave Symposium to discuss developments in the industry, exhibit their solutions, and exchange ideas.

The first International Microwave Symposium, or IMS, was held by the Professional Group of Microwave Theory and Techniques (PGMTT), a group founded in 1952 as a part of the Institute of Radio Engineers (IRE). IMS 2022 will have an exhibition with over 350 exhibitors from around the world, as well as a MicroApps Theater, Systems Pavilion, and Systems Demo Zone, along with networking and social events on the show floor *(Fig. 1)*.

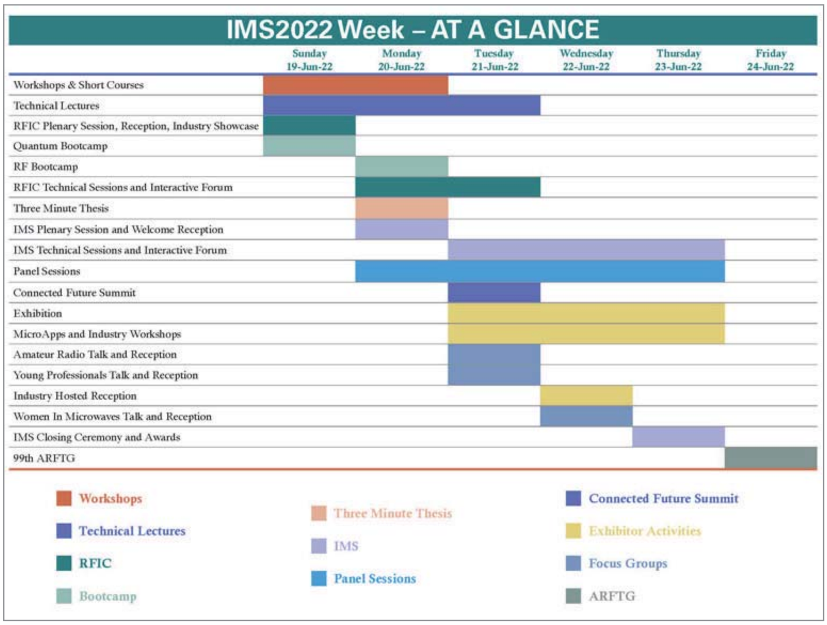
IMS 2022 also will include the IEEE MTT-S Radio Frequency Integrated Circuits Symposium (RFIC) with the Automatic Radio Frequency Techniques Group (ARFTG). In addition, the MTT-S and the IMS Steering Committee has on tap a program that encourages the professional growth of its future leaders. There will be technical sessions on various RF technologies and solutions and panel sessions discussing industry trends.

A variety of events at the show are designed for young professionals beginning their microwave career, from the industry sessions and technical presentations to the Editors-in-Chief Reception and Networking Reception for Young Professionals. An RF Interference Fox Hunt will take place, too, in which participants can team up to find RF signals hidden throughout the event area. A "Young Professionals Lounge" is planned as well, offering a space to relax between sessions.

The Systems Forum is New for 2022

A new initiative at IMS 2022, the "Systems Forum," highlights MTT activities of interest to system engineers, providing an additional outlet for system-level research for the industry. The forum will tap into areas of interest such as mil/aero and defense, 5G/6G, quantum systems, edge computing, phased arrays, AI in the cloud, and others. There also will be a reception related to the Forum.

The Systems Forum will supplement the regular technical program, arranging technical content in themed "Days." Tuesday is Quantum Systems Day and Connected Future Summit, Wednesday is Radar & Aerospace Day, and Thursday homes in on Phased Arrays & OTA Applications. Event activities will be related to



1. IMS 2022 is packed with workshops, lectures, technical sessions, receptions, and much more.

the thematic topic areas, with panel sessions, focus and special sessions, overview papers, and an Interactive Forum Plenary Poster session.

Technical Competitions Overview

Another interesting part of IMS 2022 will be the technical competitions at the event, intended to foment technology development and recognize new ideas. These include an Industry Paper Competition that will recognize outstanding technical contributions from industry sources.

Eligible papers can have several authors, but the work described must come from a corporate or otherwise private source, not a government or academic institution. Another is the Advanced Practice Paper Competition (APPC) to recognize outstanding technical contributions that apply to practical applications. An eligible paper could have authors in any sector, from industry, government, or academia.

Furthermore, a Three Minute Thesis (3MT) Competition has been created for eligible students and young professionals. They can submit a paper to enter the competition that will be accepted for either oral or interactive forum presentation. A Student Paper Competition (SPC) will recognize outstanding technical contributions from individual students, and their presentations will be judged by a specially formed SPC committee of experts.

All eligible students, alone or in teams, are invited to participate in the International Microwave Symposium 2022 Student Design Competitions (SDCs). The SDCs encourage students to employ creative problem-solving while gaining practical design experience. They must develop a solution to address the problem stated in the competition rules while following specified constraints.

Technology Boot Camps

Boot Camps are scheduled for those who want to get a better handle on some of these technologies. For example, the RF Boot Camp is a one-day course ideal for newcomers to the microwave world, such as college students and engineers changing their career path, as well as marketing and sales professionals looking to get a grasp of RF and microwave circuit and system concepts and terminology.

The format of the RF Boot Camp is like that of a workshop or short course. Multiple presentations cover a variety of topics such as the RF/microwave signal chain, network characteristics, analysis and measurement, the fundamentals of RF simulation, spectral analysis, signal generation, modulation and vector signal analysis, and microwave antenna basics, among others. Those completing the course will earn two CEUs.

There also will be a Quantum Boot Camp, which will introduce the basics of quantum engineering for those who want to understand how they can make an impact in this emerging field. It's intended for engineers interested in this space and those who may be changing their career path, as well as marketing and sales professionals seeking a better understanding of quantum technology. It's also useful for university students looking to learn more about the practical aspects of quantum technology.

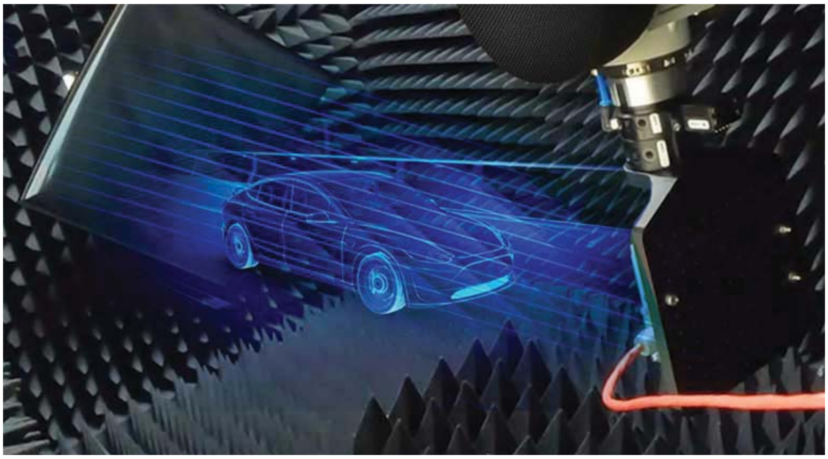
The Quantum Boot Camp will have a series of speakers covering quantum-engineering basics, with a focus on the control and measurement of quantum systems. It will conclude with a hands-on introduction to the design of superconducting qubits using modern microwave CAD tools. The boot camp is geared toward making the remainder of quantum week more accessible to attendees.

The Connected Future Summit

The Connected Future Summit (formerly known as the 5G Summit) has been a fixture of the IMS since its inception at IMS 2017, in collaboration with IEEE Communications Society (Comsoc). Drawing together academic, government, and industrial communities, the event enables them to interact and exchange technology ideas related to technologies of 5G and beyond.

The Summit committee is part of the IMS Technical Program Committee, and will address several timely topics with speakers and a creative agenda. This event has attendance every year ranging from about 300 to 400 people.

2. Wolfspeed's GaN HEMT-based MMIC power amplifier delivers 18 dB of gain from dc to 6 GHz.



3. dSPACE's radar test benches and automotive radar test systems provide easy-to-use, yet realistic, over-the-air tests.

Beyond the latest advances with 5G and moving toward 6G, the wireless connectivity landscape is changing rapidly, and designers are being challenged by the latest technologies. These include the evolution of Wi-Fi and the addition of broadband wireless satellite networks based on low-Earth orbit satellite constellations. 5G standardization and deployment, along with the research & development needed for the next generations that are making a significant impact on the future directions of connectivity.

The Connected Future Summit will be held on Tuesday (June 21) during IMS 2022. The one-day program will feature experts from industry, government, and academia sharing their technical knowledge and strategies on a range of topics. These include the future trends of 6G and beyond, the standardization of cellular (3GPP) and Wi-Fi, satellite constellations and other high-altitude platforms, and automotive V2X technology. It also will address semiconductor technologies, reconfigurable front ends and system architectures, and the test and measurement challenges impacting next-generation connectivity.

On the Exhibition Floor

The exhibition at IMS 2022 will include over 380 exhibitors from around the world, showcasing their products and services. The show hours are from 9:30 am to 5 pm on Tuesday, 9:30 am to 6 pm on Wednesday (June 22), and 9:30 am to 3 pm on Thursday (June 23).

The Connected Future Summit will be held on Tuesday (June 21) during IMS 2022.

Conference pass holders have free access to the exhibition, but "EXPO Only" passes also are available for the exhibition only. You can sign up for a complimentary EXPO Only pass for Wednesday or have access to all three days of the exhibition, as well as the show-floor presentations in the MicroApps Theater, for $30.

Show-floor networking highlights include a continental breakfast each morning of the event, an afternoon treat on Tuesday (Sweet Treat Tuesday), and coffee breaks throughout each day. In addition, there's an industry-hosted reception on Wednesday from 5 to 6 pm, as well as a Societies Pavilion and Systems Pavilion, and three networking lounges with charging stations for your devices.

Companies exhibiting their wares at IMS 2022 include hardware, software, and service vendors, all offering their ideas and solutions to the international audience. For example, at Booth 2060, Wolfspeed will show its CMPA0060025 GaN HEMT-based MMIC power amplifier *(Fig. 2)*. Operating up to 50 V, this MMIC enables very wide bandwidths to be achieved in a small footprint, featuring an 18-dB small-signal gain from dc to 6.0 GHz.

AmpliTech (Booth 3036) will debut its full 5G system, which uses the company's proprietary low-noise-amplifier (LNA) technology to create a cost-effective solution that achieves true 5G data transmission at speeds of up to 1 Gb/s. It can retrofit existing cell towers as well. The company's LNA MMICs offer low-noise performance that challenges legacy solutions across a range of high and low frequencies, with a substantially smaller chipset form factor and lower power requirements.

dSPACE (Booth 2014) will exhibit its radar test benches and automotive radar test systems for both validating and specifying next-generation radar sensors and realistic testing of radar-based vehicle functions *(Fig. 3)*. Providing precise testing of radar sensors and applications, dSPACE Automotive Radar Test Systems (DARTS) enable easy-to-use but very realistic over-the-air tests, by simulating radar echoes of objects in road traffic with programmable distance, speed, and size. mw

EVERY BLOCK...
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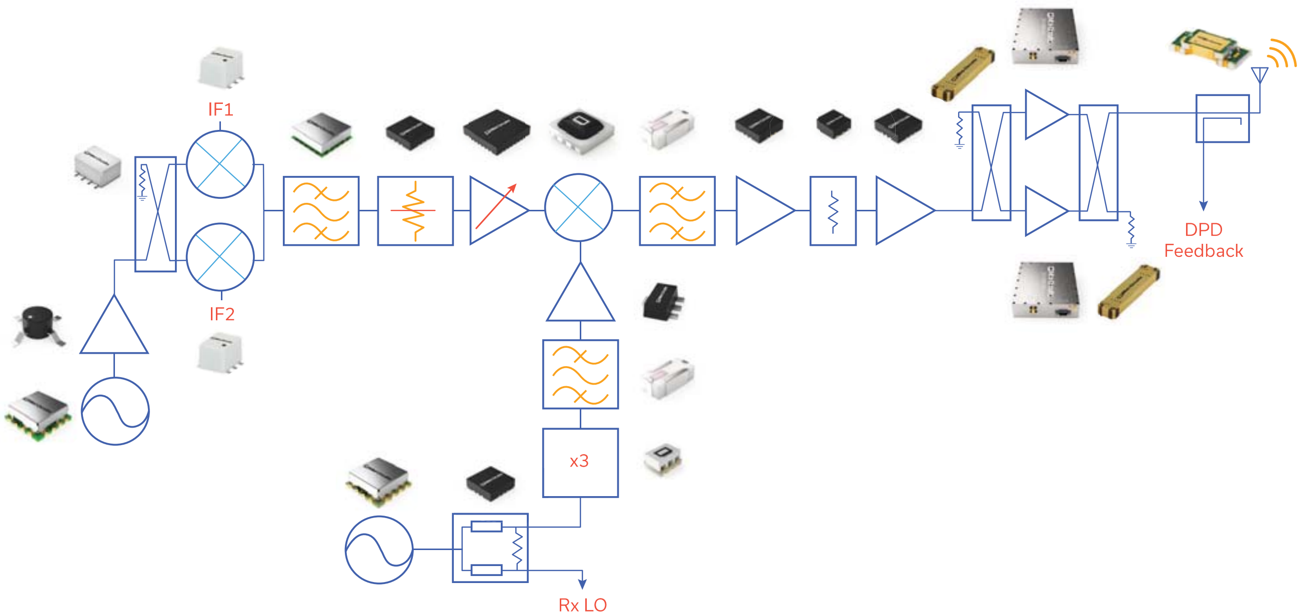

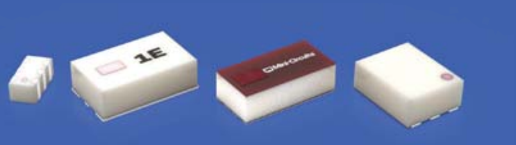

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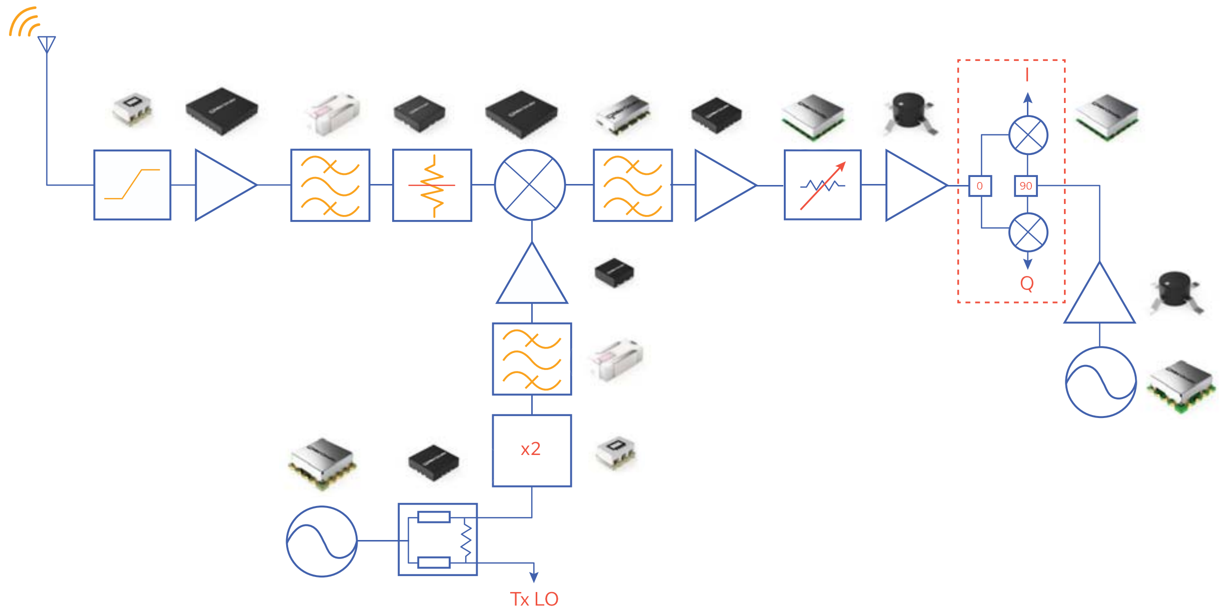

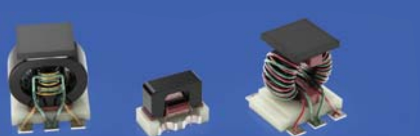

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- **Directional Couplers**: 1 MHz to 6 GHz
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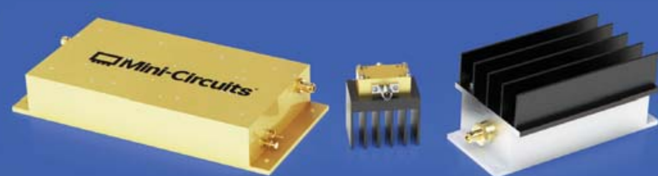

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- **Low Noise**: Up to 85 GHz
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Mini-Circuits®

DR. PATRICK CONNALLY | Product Marketing Manager, Teledyne LeCroy

Fundamentals of Power-Integrity Measurements

Measurements are key to understanding power quality across your power distribution network and within the integrated circuits that populate your embedded system.

Power integrity is of critical concern for embedded-system designs, extending from a power-distribution network's (PDN) power rails on a printed circuit board to its integrated circuits. Taking steps to maintain power integrity will ensure that voltage noise levels remain within the tolerances required for the various devices that make up your design.

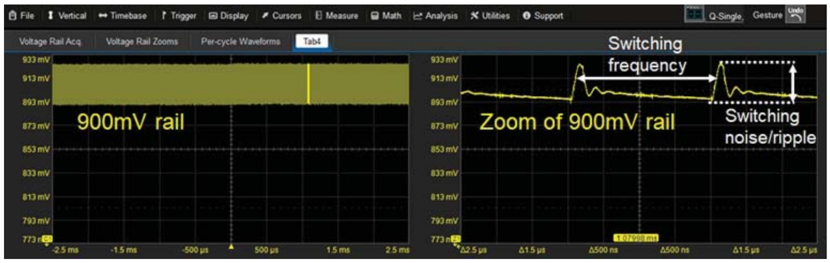
As a rule of thumb, logic components can tolerate disturbances of 5% of the rail voltage. For higher-speed digital components such as transceivers, tolerance drops below 5%, while for mixed-signal, analog, and RF components, tolerance drops below 1% of the rail voltage.

A typical embedded system incorporates a microcontroller and peripheral components including memory and I/O, with each component powered by a voltage-regulation module (VRM) that gets its power from a bulk supply. In addition, an embedded system includes interconnects, traces, planes, and decoupling capacitors, all of which can affect power integrity.

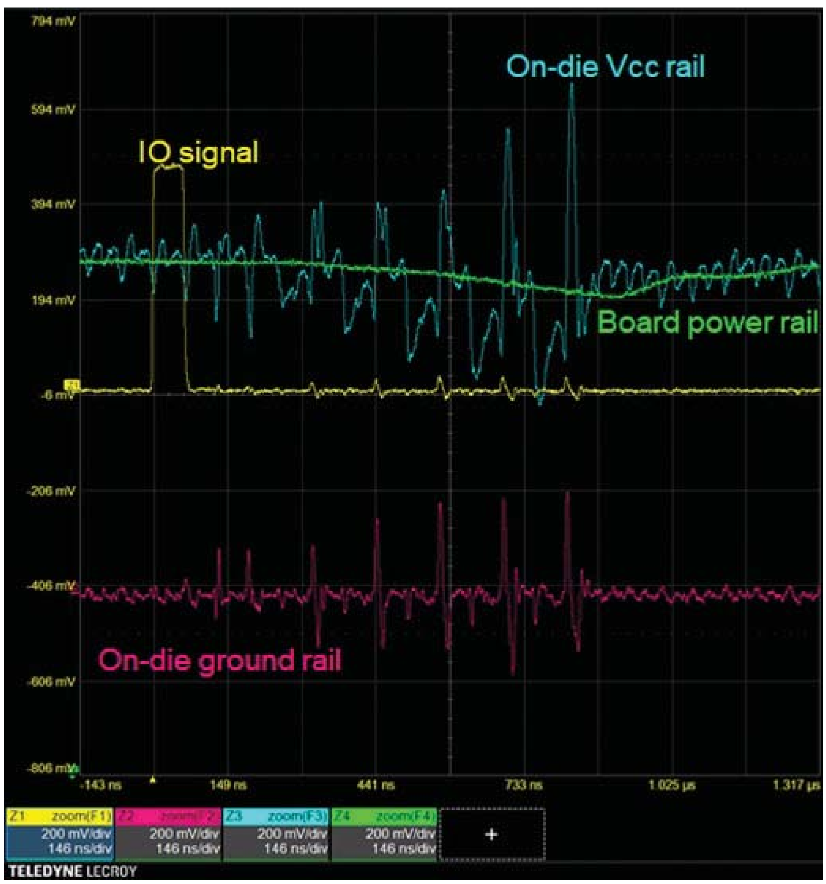
Noise Categories

There are three categories of PDN noise: self-aggression noise, board interconnect pollution, and mutual-aggressor noise.

An example of *self-aggression noise* is that which a VRM induces on its own output. To measure self-aggression noise, you must eliminate other sources of noise—ideally, the rest of the system will be in a known quiet state. *Figure 1* shows a 900-mV rail with no load on the



1. Zoom lets you examine noise and ripple on a 900-mV power rail.



2. Low noise on a board's power rail doesn't guarantee low noise on a processor's on-die V_{CC} rail.

Micro Lambda Single Channel

Programmable Attenuators 10 MHz to 21 GHz

Micro Lambda Wireless, Inc offers the MLAT-Series single channel programmable attenuators, ideal for a wide range of test equipment applications. They provide 0 to 30 dB or 0 to 60 dB attenuation in 0.5 dB steps over the 10 MHz to 21 GHz frequency range. All Attenuators are housed in a compact package with SMA Female RF connectors.

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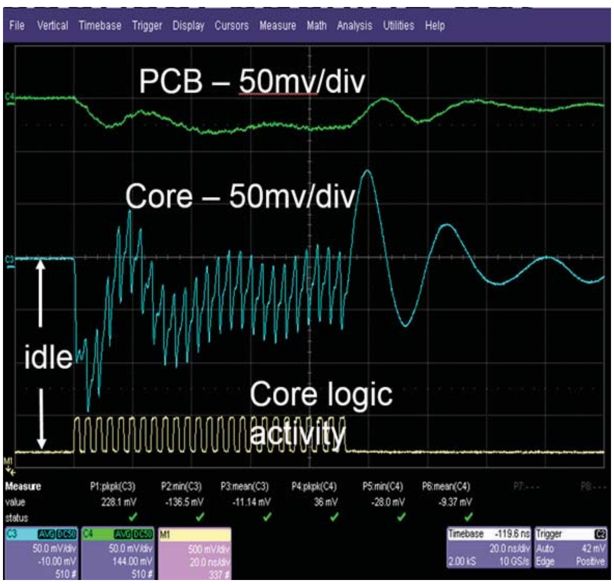
VRM, and you can see the switching noise and ripple—a relevant figure of merit.

You also can observe the self-aggression noise of V_{CC}, as shown in *Figure 2*, where the blue trace represents the on-die V_{CC} rail. The green trace represents the board power rail; you can see that the board power rail and V_{CC} noise is correlated but not identical. One noise source is I/O-driver switching, with one I/O signal represented by the yellow trace. A key takeaway here is that observing a small amount of noise on the board power rail doesn't guarantee that there isn't a lot of noise inside the integrated circuit.

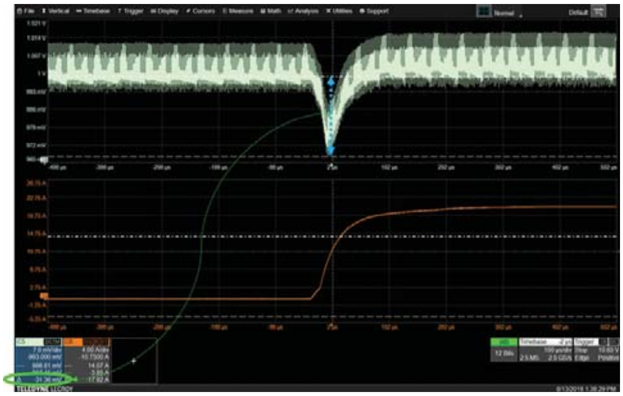
The next category is *board interconnect pollution*. An example is the appearance throughout the PDN of VRM switching noise. I/O switching can cause noise pollution, too. In addition to showing V_{CC} noise, *Figure 2* shows the on-die ground rail. When I/O signals switch, they create current flow in the return path, which will in turn induce voltage changes on the ground rail.



3. Noise from core activity can "leak" out onto the board's PDN.

Figure 3 illustrates the impact of logic-switching activity on both the board power rail and core power rail, indicated by the green and blue traces, respectively. Clearly, the noise on both traces is correlated to the core logic activity. Note that the core noise is a much larger amplitude than the board noise. This is caused by a non-ideal PDN impedance profile.

The PDN connects to potentially every system component, and problematic noise coming from one place can spread everywhere. The measurement challenge is to determine which component or phenomenon is causing the observed noise; then, you can take on its mitigation. The most effective way to do that usually involves using a spectral approach to identify problematic aggressors. In an oscilloscope, one would typically use a fast



4. A current step (orange trace on bottom) results in an output voltage dip (light green trace).

Fourier transform (FFT) math function or a spectrum-analyzer software package.

The last noise category, that of *mutual aggressors*, includes coupling from the PDN back into the components. If a component turns on and applies a load step to the VRM driving that component, the VRM will require time to react, and during that time there will be some noise. *Figure 4* shows a current step and the resulting VRM output voltage dip before recovery.

You can also get crosstalk coupling from the PDN onto I/O signals. For example, say you have voltage noise on the PDN that's shifting the threshold of a high-speed transmitter, and the signal being clocked out has a non-zero transition time. In such a circumstance, any shift up or down to the threshold becomes a corresponding shift in the timing determined by the slew rate of the signal.

That threshold shift will cause the signal edge to clock slightly earlier or later than expected. The impact to the circuit could be a rather large increase in clock jitter, leading to problematic system operation.

Accessing Signals

When choosing a probe to access power-rail signals, keep five considerations in mind:

- The signal of interest is usually a small disturbance riding on a larger voltage, so you will need to ensure the measurement system noise doesn't swamp out the signal of interest.
- If you're measuring high-frequency content, then any impedance discontinuities in your measurement path can cause reflections, distorting the content of interest.
- Ensure that your measurement system provides sufficient offset to match the rail voltage without compromising the signal-to-noise ratio (SNR).
- Many power-supply noise signals (including ground bounce and crosstalk from serial-data signals) have high-

frequency content, so make sure your measurement system has adequate bandwidth to capture and characterize them.

- Note that low-impedance probing options can cause unacceptable loading on the PDN.

You can choose from five common probing options for power-rail measurements. First is the 10-MΩ passive probe—the type that comes with most oscilloscopes. This probe has 10X attenuation, resulting in a 10X reduction in SNR compared to some other probing options, but it is low cost, its loading is low, and it is unlikely to cause reflections.

Another option is to include a coaxial connector on your board and connect that directly to a 1-MΩ oscilloscope input. This one-to-one probing option keeps noise and loading low, although reflections may occur if you're observing a signal with high-frequency components because of the transition from the 50-Ω coaxial environment to the 1-MΩ oscilloscope input.

A third option is to connect the coaxial connector on your board to a 50-Ω oscilloscope input. This approach offers high bandwidth with little reflection. However, presenting a 50-Ω load to the PDN could be problematic.

A fourth option is to build or buy a 10:1 coaxial probe. This approach similarly offers high bandwidth with little reflection, although the 10X attenuation will reduce your SNR. This option offers moderate loading at 450 Ω, which should be suitable for many PDNs.

The fifth option is the gold standard—a voltage-rail probe, such as the Teledyne LeCroy RP4030. That probe offers bandwidths up to 4 GHz, and it's specifically designed to present a 50-kΩ load at dc, so the PDN doesn't see a significant low-impedance load. At higher frequencies, it transitions to a 50-Ω load, minimizing reflections and distortion. It also contains a built-in offset digital-to-analog converter (DAC) to permit the maximum offset adjustment to view small voltage changes on dc power rails.

Figure 5 shows a summary table comparing the five different probing options.

	10MΩ passive probe	Coaxial connection to 1MΩ scope input	Coaxial connection to 50Ω scope input	Coaxial 10:1 probe	Voltage rail probe
Noise	High 10x attenuation applies only to signal – SNR is reduced 10x	Low	Low	High 10x attenuation applies only to signal – SNR is reduced 10x	Low
Reflections	No	Possible	No	No	No
Offset range	Depends on scope Usually relatively large for 10MΩ passive probe	Depends on scope	Depends on scope	Depends on scope	Very large Up to 30V
Bandwidth	Low ~500 MHz	Low 1 GHz nominal, 20 MHz practical with cable reflections	High	High	High Up to 4 GHz
Loading	Low 10 MΩ	Low 1 MΩ	High 50 Ω - Can be significant if rail impedance is low (<1Ω)	Moderate 450Ω	Low 50 kΩ at DC, 50 Ω at high frequency
Cost	Low Usually included with oscilloscope	Low Only requires a coaxial cable	Low Only requires a coaxial cable	Low/Moderate Can be "homemade" or purchased for moderate cost	~$2,500

5. This summary table compares five different power-rail probing options.

Measurement Examples

Several examples illustrate some specific power-integrity measurements. First is rail transient response, measured using an active voltage-rail probe and a current probe. (Alternatively, you can measure current by measuring the voltage across a shunt resistor.) The goal is to measure steady-state rail behavior prior to a load being applied (mean voltage and ripple amplitude), step response (droop, recovery time, and settling time), and steady-state rail behavior after the load is applied.

You can make these measurements using cursors. To measure droop, for example, you can place the cursors at the observed mean rail voltage level and the observed negative peak, as shown in *Figure 4*. This approach isn't very precise, though. Zoom traces can provide better visibility into high-frequency behavior while limiting parameter measurements to subsets of the acquired waveform.

An alternative is to use power-integrity and digital power-management application software designed to simplify this type of analysis. Teledyne LeCroy provides such software that will use a synchronizing signal—such as a VRM's clock signal—to enable per-cycle measurements and analysis. The software provides easy access to commonly measured parameters, including RMS values, standard deviation, mean, peak-to-peak, positive peak, negative peak, and frequency, and it can present them in tabular form *(Fig. 6)*.

Another example is multi-rail analysis. In *Figure 7*, the power rail represented in light green on the left middle grid experiences a load release, signified by the current waveform transition (orange trace on the left). Clearly, the rail experiencing the load release exhibits a transient response, but the question arises: Do other power rails represented by the four traces at the top left experience any effects?

With the synchronizing signal used to derive the mean per-cycle voltage values of the four other rails, the digital power-management software generates the plot on the top right. It shows that the other rails do change, but by less than a millivolt.

Figure 7 also illustrates the bulk 12-V supply (purple trace, lower left), which appears to experience reduced noise after the load release, based on the change in thicknesses of the trace before and after the load release. The digital power-management software can help quantify it. *Figure 8* shows that the 12-V supply's standard deviation (pink trace, top right), which is related to RMS noise, drops significantly from about 80 mV to about 25 mV after the load release.

A final example focuses on rail-noise-induced jitter with a wireless router as the device under test (DUT). The blue trace (upper right) in *Figure 9* is a 500-µs acquisition of a 10-MHz clock on the DUT. The red trace (lower left) is a time-correlated plot of time-interval-error (TIE) jitter measurements of the 10-MHz clock vs. time. The software compares the actual clock signal with an ideal one, performing a TIE measurement for each transition to determine how early or late each edge arrives.

The orange histogram (upper right) is a display of the statistical distribution of all TIE jitter measurements shown in the red trace. Software derives the jitter spectrum of the TIE values (not the vertical noise values) in picoseconds (lower right trace), with the largest value of 9.9 ps appearing at 2.956 MHz, as shown in the table in the lower right portion of *Figure 9*.

The conclusion is that the biggest contributor to power-rail noise is clock jitter occurring at 2.956 MHz. Eliminating the source of this clock jitter could significantly reduce power-rail noise.

The conclusion is that the biggest contributor to power-rail noise is clock jitter occurring at 2.956 MHz. Eliminating the source of this clock jitter could significantly reduce power-rail noise.

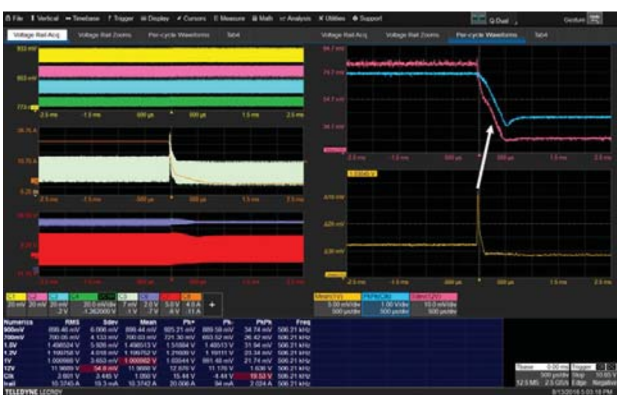
In summary, understanding the potential sources of embedded-system noise and knowing how to choose the optimal probe for measuring it can help you maintain power integrity throughout your design. A recent webinar provides more details and is the first webinar in an 8-part Power Integrity Masters Series *(go to https://teledynelecroy.com/events/)*. mw

REFERENCE

Connally, Patrick, *Fundamentals of Power Integrity*, June 2, 2021. https://teledynelecroy.com/events/

6. Digital power-management software can display parameters in tabular form.

7. A load release on one power rail has minimal effect on other power rails.

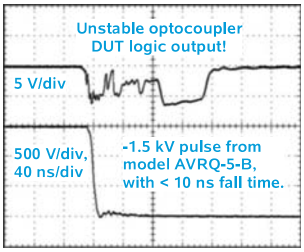


8. A bulk 12-V supply's standard deviation drops significantly after load release.

9. A dc-dc converter's noise peak at 2.956 MHz corresponds to a jitter spectrum peak at the same frequency.

Transient Immunity Testers

The Avtech AVRQ series of high-voltage, high-speed pulsers is ideal for testing the common-mode transient immunity (CMTI) of next-gen optocouplers, isolated gate drivers, and other semiconductors. GPIB, RS-232, Ethernet ports are standard.



- Kilovolt amplitudes (±1 kV, ±1.5 kV, ±2 kV)
- Transition times down to < 10 ns, dV/dt rates up to 120 kV/us
- Daughterboards to handle a variety of DUT package styles

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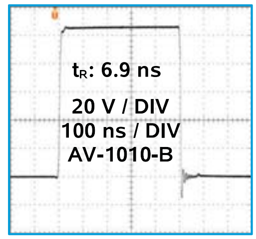
Avtech offers an extensive series of user-friendly ±30V, ±50, and ±100 Volt general-purpose lab pulsers. In many applications, these can replace the discontinued Agilent 8114A or HP214. Higher-voltage models are also available.



AV-1015-B:	±50V, 10 MHz, 20 ns - 10 ms, 10 ns rise
AV-1010-B:	±100V, 1 MHz, 20 ns - 10 ms, 10 ns rise
AV-1011B1-B:	±100V, 100 kHz, 100 ns - 1 ms, 2 ns rise
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Includes switchable output impedance and double-pulse modes. Flexible triggering. GPIB / RS-232 / Ethernet.

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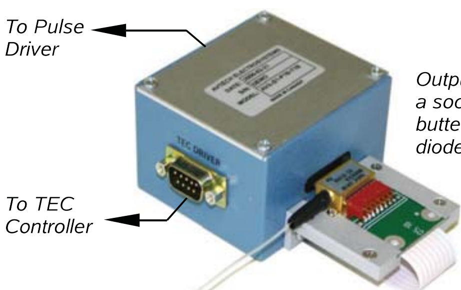
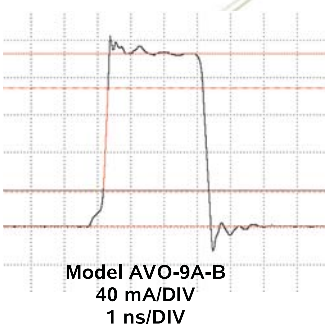
Nanosecond Laser Diode Drivers With Butterfly Diode Sockets



Output module with a socket-mounted butterfly-packaged diode installed.



Each of the 18 models in the Avtech **AVO-9 Series** of pulsed laser diode drivers includes a replaceable output module with an ultra-high-speed socket, suitable for use with sub-nanosecond pulses.

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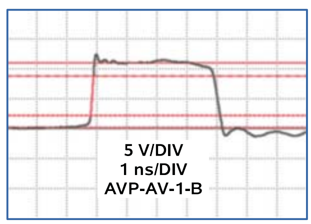

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Ampl	tRISE	Max. PRF	Model
5 V	80 ps	1 MHz	AVP-AV-1S-C
10 V	120 ps	1 MHz	AVP-AV-1-B
20 V	120 ps	1 MHz	AVP-AV-HV2-B
20 V	200 ps	10 MHz	AVMR-2D-B
40 V	150 ps	1 MHz	AVP-AV-HV3-B
50 V	500 ps	1 MHz	AVR-E5-B
100 V	500 ps	100 kHz	AVR-E3-B
100 V	300 ps	20 kHz	AVI-V-HV2A-B
200 V	1 ns	50 kHz	AVIR-1-B
200 V	2 ns	20 kHz	AVIR-4D-B
400 V	2.5 ns	2 kHz	AVL-5-B-TR

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EZER BENNOUR | Product Manager, Signal and Spectrum Analyzers, Rohde & Schwarz

Oscilloscope or Analyzer? Choosing the Right Instrument for Your App

Can an oscilloscope replace an analyzer in microwave/mmWave applications? What are the limitations of an oscilloscope, and where does the signal and spectrum analyzer remain the instrument of choice?

Modern high-end oscilloscopes contain high-speed analog-to-digital converters (ADCs), which allow them to cover frequency ranges that historically could only be investigated using a spectrum analyzer. By also integrating a high-bandwidth analog front end, modern oscilloscope architectures enable direct sampling of high-frequency signals without analog downconversion, leading to unprecedented analysis bandwidth ranges.

Some oscilloscopes in the market today have a bandwidth of up to 16 GHz and are capable of directly acquiring a nominal 8-GHz RF signal with 16-GHz bandwidth. As of now, this can't be done with a signal and spectrum analyzer.

Spectrum analyzers, on the other hand, can cover frequency ranges up to 85 GHz and beyond, enabling them to address most applications of wireless, cellular or satellite communications, radar equipment, and IoT devices. For such apps, qualities exclusive to spectrum analyzers come to the fore. These include high dynamic range, which allows them to display very small signals in the vicinity of a strong carrier signal. Moreover, spectrum analyzers also can be used for measurements in the time domain, such as measuring the transmitter output power of time-multiplex systems as a function of time.

In this article, we will examine the differences between both instruments and the use cases, where each of them represents a best fit for the typical requirements of the corresponding measurements.

1. ACLR analysis involves assessing the integrated power over frequency of the neighboring channels of a communications signal.

Signal and Spectrum Analyzers

A spectrum analyzer shows the signal level versus frequency at a selected

resolution bandwidth. This can be employed to measure basic signal parameters, while other parameters such as the filter settings or a frequency response could be estimated from the signal shape visible on the screen. Other measurements include signal-to-noise ratio (SNR) and the detection of spurious emissions, which may need to be measured over a large frequency range.

In swept-spectrum mode, the analyzer only regards a small part of the spectrum at a time. This frequency selectivity is the key to the analyzer's high dynamic range and lets the instrument measure and display the entire spectrum from 2 Hz to 85 GHz in a single measurement. With external mixers, the displayable frequency range can be expanded by hundreds of gigahertz.

A spectrum analyzer is usually chosen when spectrum measurements are required to ensure conformity with standards and regulations. In mobile radio, for example, these include spurious emissions, adjacent-channel leakage ratio (ACLR), and spectrum emission masks (SEM).

While SEM measurements are concerned with single spurs, ACLR analysis *(Fig. 1)* involves assessing the integrated power over frequency of the neighboring channels of a communications signal. Both require measuring very small levels in the immediate vicinity of a strong signal, hence benefiting from the spectrum analyzer's dynamic range and frequency selectivity.

Spectrum analyzers also are typically preferred for measuring electromagnetic interference (EMI) during pre-compliance testing. The respective EMI standards require a minimum of spurs to be measured with the appropriate EMI detectors (quasi-peak, CISPR-Average and RMS-Average (CISPR-RMS)).

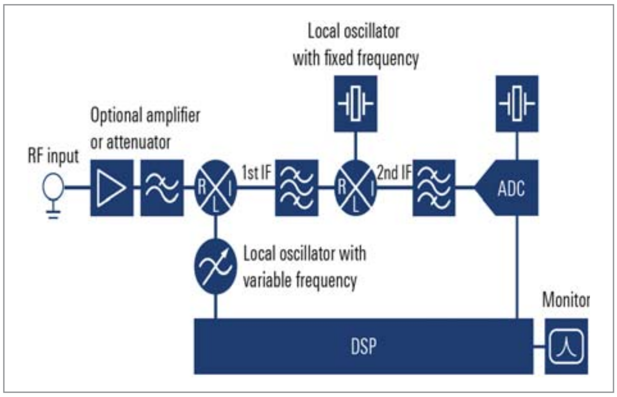
Digital Signal Analysis

Many of today's spectrum analyzers can handle digital signals, too. An input signal bandwidth up to 1 GHz is common, while some instruments have bandwidth up to 8.3 GHz. The analyzer's front end *(Fig. 2)* mixes the signal to a low intermediate frequency (IF) before sampling with a wide-bandwidth ADC and then digitally downconverting into the baseband to be equalized. The resulting digital I/Q values contain all signal information within the bandwidth and dynamic range.

The signal can then be further processed using appropriate application-specific measurements. These may be available on the device or via PC software like Rohde & Schwarz's Vector Signal Explorer (VSE).

Thus, the analyzer is used when working with communication systems to measure, for example, important signal parameters such as error vector magnitude (EVM), I/Q offset or imbalance, and the level ratio of pilot to data channels. In radar applications, it's able to help with measurements of interest, including the phase, frequency, modulation, and level of pulsed signals over the pulse duration.

Analyzers can perform various other measurements at component, module, and device level, particularly when used with an appropriate measurement application. These include the noise figure and gain of amplifiers and the phase noise of oscillators. With these instruments, one may make very precise measurements, almost down to the thermal noise floor.



2. Many of today's spectrum analyzers also can handle digital signals. An input signal bandwidth up to 1 GHz is common, while some instruments feature bandwidth up to 8.3 GHz.

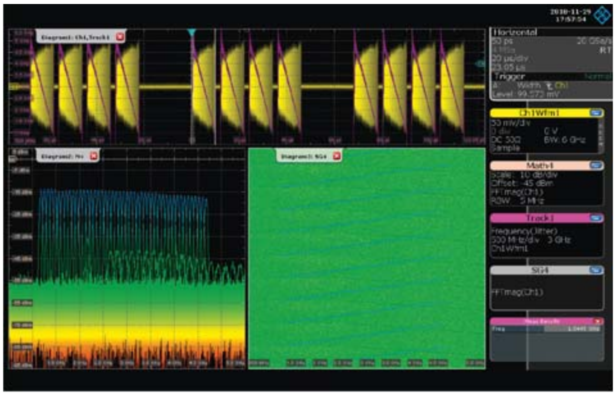
Some high-end instruments also can perform measurements such as uninterrupted real-time spectrum analysis and uninterrupted streaming of digital I/Q data.

RF Testing with Oscilloscopes

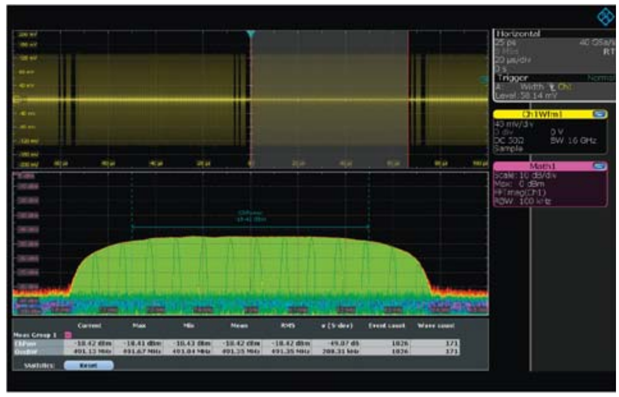
With their large analysis bandwidth, today's leading oscilloscopes can address a wide variety of applications such as radar. Radar range resolution is a key parameter and is directly proportional to the available bandwidth. In other applications, although the signal of interest may have a relatively narrow bandwidth, the oscilloscope can measure out-of-band signals such as harmonics, neighboring channels, and interfering signals.

On the other hand, a high analysis bandwidth can call for extra care when acquiring narrowband signals. Consider a 2-MHz-wide Bluetooth Low Energy (BLE) signal at a center frequency of 2.4 GHz. Acquiring the signal of interest may be relatively easy. However, unless filters are applied, all possible interference signals from dc up to the oscilloscope's maximum frequency also will be acquired. With some high-end oscilloscopes, users can constrain the analysis window to the signal of interest by designing digital filters with software tools and importing the filter coefficients.

Although applying an appropriate digital filter improves the SNR, the question arises whether the achievable capture time can still be improved for such a narrowband signal. Even if the sample rate is reduced to the minimum stated by the Nyquist theorem, the capture time for the BLE signal in the previous example is less than one second. Digital downconversion, available on some high-end oscilloscopes, allows the time to extend to about 500 seconds.



3. Oftentimes, tools for basic analysis in the time and frequency domain are built into oscilloscopes, such as in this example of automotive radar signal analysis.



4. An oscilloscope's FFT capability enables simultaneous examination of the UWB signal in both the time and frequency domains.

Advanced Trigger Systems

Oscilloscopes are typically equipped with a much more advanced trigger system than signal and spectrum analyzers. This enables a very accurate detection of short, intermittent, burst, or pulse signals. It's a significant advantage in radar applications, in which a precise detection of a pulse/chirp start is essential.

Whereas oscilloscopes with a conventional analog trigger will split the signal into two paths, instruments from Rohde & Schwarz provide a fully digital trigger system that operates directly on the samples of the ADC. This results in a lower trigger jitter and a flexible trigger sensitivity. Moreover, all trigger types support the full bandwidth of the oscilloscope.

Phase-Coherent Multichannel Analysis

For various reasons, multi-antenna designs have become essential in a range of wireless applications. In radar, for example, multi-antenna systems are state-of-the-art for estimating the angle of arrival (AoA) —the direction from which the surrounding objects are coming—based on the phase difference between multiple receive paths.

Test equipment needs multichannel capabilities to characterize these types of systems and ensure that all channels are constantly phase coherent. Oscilloscopes typically provide multiple tightly aligned channels. Unlike spectrum analyzers, they require no additional enhancements such as time-base and local-oscillator (LO) sharing to perform phase-coherent measurements. Hence, they're a cost-effective and easy-to-use solution for testing multi-antenna systems.

When testing equipment using frequency ranges beyond the oscilloscope's maximum bandwidth—e.g., automotive radar in the 77-to 81-GHz range, or the new 60-GHz radar for gesture sensing—signal acquisition is accomplished using external mixers. An oscilloscope that supports real-time de-embedding can compensate for the losses induced by the additional components in the signal path. While tools for basic analysis in the time and frequency domains are often built-in *(Fig. 3)*, a dedicated tool such as R&S's VSE software may be needed for a more in-depth pulse and transient analysis.

Similarly, 5G NR communications rely on multiple antennas with beamforming to transmit the signal in a desired direction. This is accomplished by generating a defined phase shift of each adjacent input signal stream, which must be kept constant to ensure the generated beam stably points in the wanted direction.

An oscilloscope like the R&S RTP, with its multichannel input, allows a phase-coherent measurement of up to four input streams. Therefore, it can handle multiple 5G NR input channels. With the R&S VSE, it's able to perform a wide range of measurements, including MIMO-specific measurements like the phase difference between the input signals to characterize the beams when testing the transmitters of 5G NR base stations or small cells.

System-Level Debugging

Whereas signal and spectrum analyzers are dedicated instruments for RF signal analysis, oscilloscopes are general-purpose instruments that allow for multiple measurements besides the acquisition of RF signals. Various options are available for bus triggering and decoding, as well as power and time- and frequency-domain measurement.

The consistent time alignment between all of those measurements can help users correlate acquired RF signals with other signals, such as the supply voltage or digital bus signals. An example may be simultaneously acquiring CAN or Ethernet signals together with radar signals when developing and debugging automotive radar modules.

FFT and Zone Trigger

Most state-of-the-art oscilloscopes provide fast-Fourier-transform (FFT) capabilities, which enable correlation to the time domain. With the UWB 802.15.4z standard gaining traction in automotive applications, for example, the FFT capability makes it possible to simultaneously examine the ultra-wideband (UWB) signal in both the time and frequency domains.

Using the gated FFT feature provided by R&S oscilloscopes, engineers can define a signal portion in the time domain and plot the spectrum of this specific portion. One may also make spectral measurements such as the channel power and the occupied bandwidth *(Fig. 4)*.

In addition, when combined with a dedicated near-field probe, the FFT and trigger capabilities are useful for investigating EMI in electronic designs.

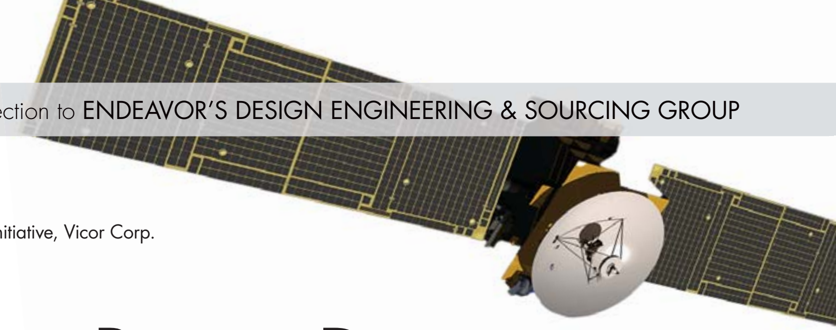
Some high-end oscilloscopes also provide a zone trigger, which is useful for EMI debugging purposes as well. Often, multiple zones can be graphically defined in the time and frequency domain and combined through logical operators to help investigate conditions such as fading effects on a WLAN signal caused by short or intermittent interference, which are otherwise hard to track down.

Summary

The main advantages of signal and spectrum analyzers result from the frequency selectivity. These include the high dynamic range, which allows low-level signals to be analyzed in the vicinity of a strong signal. Standard-compliant ACLR and SEM measurements are usually only possible with a spectrum analyzer.

With signal demodulation, an analyzer can deliver significantly better results, such as EVM values, particularly for signals with a large bandwidth and a high crest factor. Other advantages include the high maximum input frequency and continuous sweep from minimum to maximum frequency, as well as very long, seamless recording times, depending on the bandwidth. Moreover, analyzers are usually preferred when measuring phase noise and noise figure/gain, and for real-time spectrum analysis.

The main advantages of an oscilloscope result from the superior analysis bandwidth and full signal capture, including dc components, as well as the availability of several (typically two or four) phase-coherent inputs. Typically, an oscilloscope is preferred for wideband measurement of signals in the analog baseband, phase-coherent measurements of several sources, and time-correlated multi-domain measurements. mw



KEN COFFMAN | Field Applications Engineer, New Space Initiative, Vicor Corp.
SALAH BEN DOUA | Principal Applications Engineer

Delivering Higher Power Density and Low Noise for New Space Apps

Today's satellite power-system designers face several tough challenges, especially when it comes to delivering high current and low voltage efficiently. The factorized power architecture offers a path toward achieving those goals.

TO REDUCE EXPENSIVE COMMUNICATION TRAFFIC between satellites and the Earth, satellite platforms are hosting a greater amount of processing power. Thus, meeting the demands of more onboard computation and signal- and data-processing hardware means an increase in system power and point-of-load (PoL) requirements. Because hard-switched converters have drawbacks in size, efficiency, and electromagnetic interference, system engineers and power-supply designers are driven to consider more advanced power-supply topologies.

Due to the physical size of modern ASICs, FPGAs, CPUs, and GPUs—and their necessary cooling solutions—circuit-board real estate around these big chips is precious. These chips require progressively lower voltages with increasing currents; hence, the need for an optimized power-delivery network (PDN).

Therefore, it's helpful to divide the PDN task into two sections: a regulation section that can be placed in a convenient location, and a power-delivery section that benefits from being placed as close to the load as possible. This is a fundamental principle of the factorized power architecture (FPA).

Soft-switching topologies hold distinct advantages over hard-switched converters by enabling high fundamental conversion frequencies with low harmonic noise. Compared to a hard-switched, multi-phase topology:

- A zero-voltage switching (ZVS) and zero-current switching (ZCS) topology, running at the highest practical frequency, is more space-efficient and wastes less power.
- A ZVS and ZCS topology doesn't have the high-frequency, harmonic-series noise profile character.
- Converters with a >1-MHz operating frequency don't have troublesome 100- to 500-kHz frequency content.
- Low harmonic content and a high fundamental conversion frequency means a compact noise-filter implementation.

Power modules operating at >1 MHz help engineers create low common- and differential-mode (CM and DM) noise designs, particularly when component arrangements and device interconnects are properly considered.

As always, input and output filters are required and must be designed and placed properly. However, the inherent nature of high-frequency, soft-switching converters makes this task easier.

Factorized Power: Delivering High Current and Low Voltage Efficiently

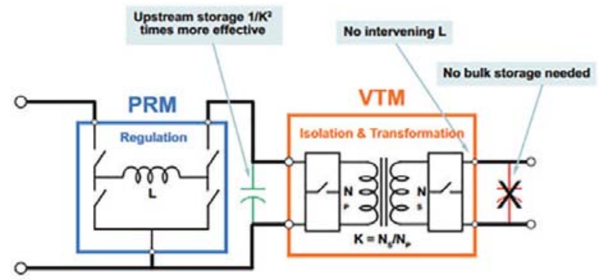
The top challenges for satellite power-system designers include:

- Higher and higher load-current requirements, from tens to hundreds of amps.
- Loads requiring faster transient response with tighter tolerance windows.
- Requirements for lower PDN losses and impedances.
- Expanding use of higher-voltage buses to reduce conductor sizes.

In addition to the advancing electrical requirements in space, radiation total ionizing dose (TID) and single-event effects (SEE) requirements enter the mix. In some cases, the "New Space" philosophy of smaller, faster, and less-costly space platforms and launches led to the adoption of rad-tolerant design methods as a cost-reduced substitute for radiation hardening.

This new approach is based on determining an acceptable level of performance and reliability based on the specific mission, then developing boards and electronics based on size, weight, and power consumption (SWaP) tradeoffs, as well as cost-effectiveness. This design strategy suits low-Earth-orbit (LEO) and medium-Earth-orbit (MEO) satellites inside the Van Allen radiation belt.

To create a high-current, high-density PDN, consider using a factorized power architecture. For example, Vicor's New Space FPA divides the PDN into three stages. The first stage is a fixed-ratio (divide by 3), isolated and unregulated module called a bus converter module (BCM). The next stage is a pre-regulator module (PRM) that provides voltage regulation as the input voltage and output load changes. The final stage is a fixed-ratio voltage transformation module (VTM) to create the low voltage required by the load.



The very low, non-inductive output impedance in the New Space FPA allows it to respond almost instantaneously to step changes in the load current.

In the current generation of Vicor New Space converters, an unregulated first-stage BCM provides isolation from the spacecraft bus, a supply voltage for the downstream converters, and voltage transformation to create an intermediate bus voltage compatible with the downstream converters. The current BCM design offers a 3:1 transformation ratio to convert 100 V_{DC} to 33 V_{DC}, but other transformation ratios are being studied and considered to support other bus voltages.

The second-stage PRM performs accurate output-voltage regulation with a trimmable output-voltage range of 13.4 V to 35 V.

The third-stage VTM involves power delivery. It transforms the higher voltage from the PRM to the voltage required by the load. Currently, there are two transformation ratios: 8:1 and 32:1. VTMs are called current multipliers because the input-to-output current transformation is the inverse of the voltage transformation ratio. As an example, 6 A injected into the 8:1 VTM results in a 48-A output current.

Designing a Low-Noise FPA for New Space

BCMs, PRMs, and VTMs are the components that make FPA possible. The current generation of radiation-tolerant New Space BCMs, using Vicor's Sine Amplitude Conversion (SAC) topology, has an impressive peak efficiency of 96.9%.

Vicor PRMs use the company's ZVS buck-boost regulator control architecture to give high-efficiency step-up and step-down voltage regulation and soft-start. Maximum efficiency is achieved when $V_{IN} \approx V_{OUT}$, with 97% peak being achieved with the latest PRMs.

High-efficiency VTM current multipliers use a proprietary ZCS/ZVS Sine Amplitude Converter, which transforms a nearly pure sinusoidal waveform with high spectral purity and common-mode symmetry. These characteristics mean it doesn't generate the harmonic content of a typical hard-switched pulse-width-modulation (PWM)-type converter and generates minimal noise.

The control architecture locks the operating frequency to the powertrain's resonant frequency, enabling up to 97% efficiency and minimizing output impedance by effectively canceling reactive components. Such very low, non-inductive output impedance allows it to respond almost instantaneously to step changes in the load current *(see figure)*.

The VTM responds to load changes regardless of magnitude in less than a microsecond. The VTM's high bandwidth obsoletes the need for large point-of-load capacitance. Even without external output capacitors, the output of a VTM exhibits a limited voltage perturbation in response to a sudden power surge. A minimal amount of external bypass capacitance (in the form of low equivalent-series-resistance/equivalent-series-inductance, or ESR/ESL, ceramic capacitors) minimizes the output transient voltage overshoot.

Because the VTMs are nearly transparent without capacitive or inductive storage, bulk capacitance can be placed on the input voltage side—taking advantage of the squared voltage term along with the linear voltage transform ratio:

$E_j = 1/2 \times CV^2$

where E_j = stored energy in joules, C = capacitance in farads, and V = voltage in volts.

As an example, for equivalent energy storage with the Vicor VTM that has an 8:1 transform ratio, 25 µF of input capacitance at 28 V acts very much like 1600 µF of output capacitance at 3.3 V *(see figure, again)*.

Because the VTMs are nearly transparent, the capacitance transfer ratio between input and output can help with pulsed loads. This transform means smaller values of capacitance (at the higher voltage) can be used to serve pulse-load requirements.

Vicor's radiation-tolerant New Space VTMs have peak efficiencies of 94.7% for 8:1 transformation (3.3 V at 50 A) and 92.9% for higher-current 32:1 transformation with capability of 0.8 V at 150 A.

Benefits of FPA

The factorized power architecture enables power-system density and high-current demands to keep pace with rapidly advancing CPU, GPU, and ASIC technologies. Some key system design advantages include:

- Reduced PDN real-estate consumption near the CPU/GPU by 50% or more.
- An order-of-magnitude reduction in PDN and associated board losses.
- Unfettered performance by placing the PRM in non-critical board edge areas.
- Simplified CPU I/O routing.
- Mitigated risk of placement near the processor's SerDes because of lower noise performance of the VTM.

Overall peak efficiency for a power system—including the combination of a BCM, PRM, and VTM—operating from an unregulated dc source and supplying a regulated, low-voltage dc output is 89% (for 100 V:3.4 V at 50-A transformation) and 87.3% (for 100 V:0.8 V at 150-A transformation). With higher efficiency comes lower total heat dissipation, an important consideration in a power system design for spacecraft where cooling mechanisms require additional mass and structure.

A Summary of Radiation-Tolerance Parameters for the Vicor New Space FPA

Lots of work is required to create power modules that will survive useful periods in low and medium Earth orbits:

- To meet TID requirements, components must be carefully selected and screened for radiation performance; parameter variations are included in worst-case analysis to assure performance.
- To meet enhanced low-dose-rate sensitivity (ELDRS) requirements, only known-ELDRS-performance-rated components are used, or the parts are tested at low-dose rates.
- To meet single-event performance requirements, one must perform extensive testing with accelerated charged particles. All selected parts are tested and analyzed to survive up to a linear energy transfer of 35MeV-cm^2/mg. To mitigate for single-event functional interrupts (SEFIs), one should implement dual-redundant internal powertrains with monitoring and power-cycling capability.

Vicor New Space radiation-tolerant power modules are survival-rated at 35MeV-cm^2/mg and TID rated at 50 krad. Worst-case circuit analysis (WCCA) was performed on all circuits, including statistical confidence limits (90% confidence with 99% probability) based on sample testing of the parts. Extreme value analysis (EVA), root-sum-squared (RSS), and Monte Carlo analysis methods were used where appropriate to evaluate the power-module designs to ensure all parts will perform as expected. mw

Ad Index

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Frequency Extender Spans 10 MHz to 30 GHz

Mini-Circuits' model FX-30G-RC is a frequency extender with buffer amplifier that provides output signals from 10 MHz to 30 GHz at levels to +20 dBm with ±1-dB output power accuracy. It forms a seamless interface with the 15-GHz model SSG-15G-RC signal generator, boosting its frequency range to 30 GHz while maintaining low harmonics of -40 dBc and spurious content of -70 dBc. It is simply controlled by an Ethernet or USB connection to an external computer running FX software.

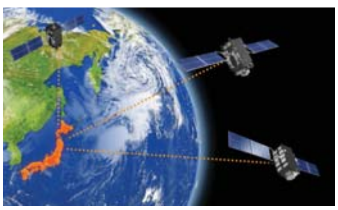
MINI-CIRCUITS, https://www.minicircuits.com/WebStore/dashboard.html?model=FX-30G-RC

Automated Test Solution Assures Conformance for High-Speed Ethernet Cables

Automation software from Rohde & Schwarz enables conformance tests of high-speed cables and backplanes according to the IEEE 802.3bj, by, cd, and ck standards. The R&S ZNrun Vector Network Analyzer Automation Suite controls a vector network analyzer and a switching solution for automated testing of high-speed Ethernet cables. IEEE 802.3bj and IEEE 802.3by provide data rates of 25 Gb/s per path and IEEE 802.3cd covers up to 50 Gb/s per path.

ROHDE & SCHWARZ, https://www.rohde-schwarz.com/us/products/test-and-measurement/vna-software/rs-znrun-vector-network-analyzer-automation-suite_63493-109824.html

GNSS Receivers Support CLAS Positioning in Japan

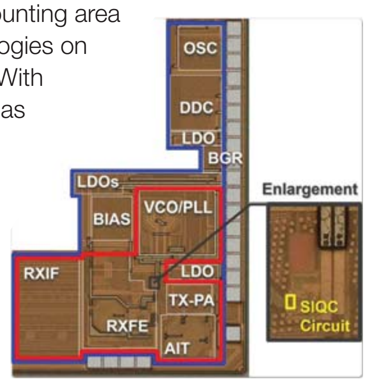


Septentrio launched its mosaic-CLASS, AsteRx-m3 CLAS and AsteRx SB3 CLAS GNSS receivers, which support Japan's high-accuracy Centimeter Level Augmentation Service (CLAS). Developed in cooperation with CORE, a leading integrator of high-accuracy positioning technology and services in Japan, the AsteRx-m3 CLAS combines PPP-RTK CLAS with dual-antenna heading functionality. The AsteRx-SB3 CLAS features a ruggedized IP68 enclosure to protect it in harsh environments. Receivers with built-in CLAS functionality offer sub-decimeter positioning accuracy right out of the box. Corrections for high-accuracy positioning are received directly from satellites, reducing the need for additional base stations or service subscriptions.

SEPTENTRIO, https://www.septentrio.com/en/products/gnss-receivers/receivers-module/mosaic-clas

Bluetooth LE RF Transceiver Saves Both Space and Power

Renesas Electronics released two 2.4-GHz RF transceiver technologies that support the Bluetooth Low Energy (LE) low-power, near-field communication standard. The technologies offer a smaller mounting area and better power efficiency. Renesas has verified the effectiveness of these technologies on a Bluetooth LE RF transceiver circuit prototype built with a 22-nm CMOS process. With a reduced the circuit area, including the power supply, of 0.84 mm^2, it is presented as the smallest available for a device of this type. This was achieved by modifying the receiver architecture to reduce the number of inductors and making enhancements such as a low-current baseband amplifier with a small mounting area and a highly efficient class-D amplifier. They offer best-in-class power efficiency, with power consumption of 3.6 mW and 4.1 mW during reception and transmission, respectively.



RENESAS ELECTRONICS, https://www.renesas.com/br/en/application/key-technology/bluetooth-low-energy