

# HIGH FREQUENCY

E L E C T R O N I C S

## PONDERING ON POWER MEASUREMENTS

### IN THIS ISSUE:

Eliminate High-Speed ADC  
Flicker Noise with Chopper  
Upgrade

MMIC Broadband Feedback  
Amplifiers

In the News

Market Reports

Featured Products

Product Highlights

IMS 2015 Show Issue



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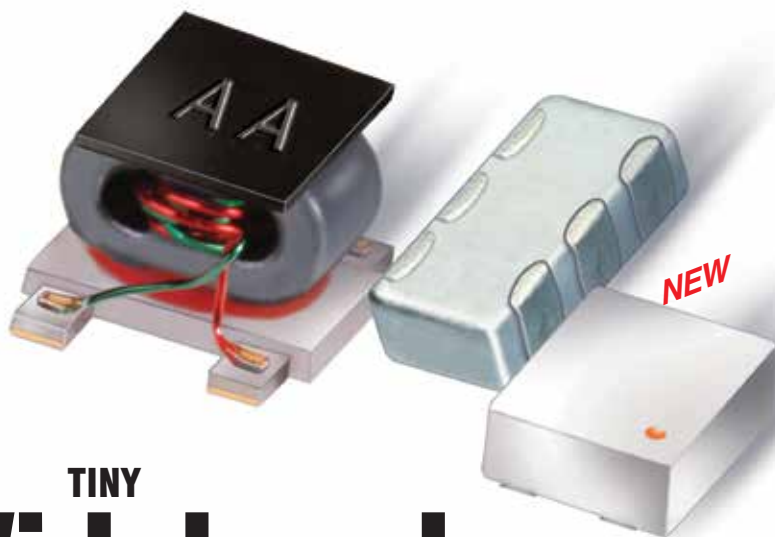
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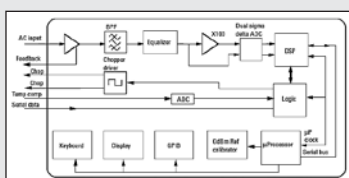
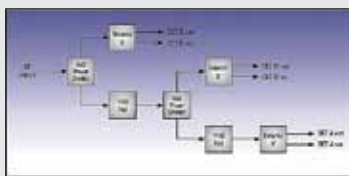


# HIGH FREQUENCY

## E L E C T R O N I C S

**22**

### Feature Article



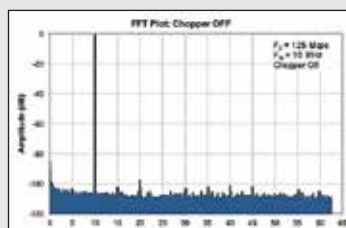
#### Pondering on Power Measurements

By Joseph Cahak

Reviewing the various methods of measuring RF power.

**36**

### Feature Article



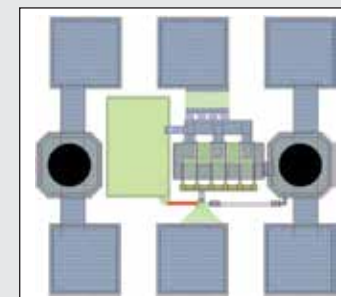
#### Eliminate High-Speed ADC Flicker Noise with Chopper Upgrade

By Tommy Neu

ADCs are moving into more advanced CMOS process nodes.

**44**

### Feature Article



#### MMIC Broadband Feedback Amplifiers

By John E. Penn

A simple design approach for broadband gain stages where noise figure and power efficiency are not a primary driver.

**52**

### Product Highlights



Featuring Boonton, OML, Master Bond, AmpliTech, Copper Mountain Technologies, Anritsu, and more.

**12**

### In The News



Highlighting Tern, Versatile Power, NI AWR Design Environment, the ASW Continuous Trail Unmanned Vessel, and more.

**79**

### In Memoriam



Remembering Vincent McHenry.

**6** Editorial

**12** In the News

**16** Featured Products

**8** Meetings & Events

**52** Product Highlights

**80** Advertiser Index



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## ► Editorial

# Modern Phoenix: Rich in History

**Scott L. Spencer  
Publisher**



The City of Phoenix provides a modern yet historic setting for IMS 2015. Long before Governor John C. Fremont signed legislation that made Phoenix an incorporated city in 1861, there was a civilized community that inhabited this land. Today the Pueblo Grande ruins, which were occupied between 700 AD and 1400 AD, provide confirmation of the city's early origins.

The Salt River runs through the city and as early as 300 BC, the Hohokam were farming in what is commonly called "The Valley of the Sun." They built a system of canals to provide irrigation to the otherwise dry land. Many of these ancient canals still exist today buried beneath the streets of metropolitan Phoenix. The ultimate fate of this ancient society is a mystery. The accepted belief is that it was destroyed by a prolonged drought. Native Americans, observing the Pueblo Grande ruins and the vast canal system these people left behind, gave them the name "Ho Ho Kam"—the people who have gone.

### Jack Swilling and Water Diversion

Phoenix's modern history began in the second half of the 19th century. In 1867, Jack Swilling stopped to rest his horse at the base of the White Tank Mountains. He saw the expansive Salt River Valley surrounded by rich, but dry, soil. He saw farm land. All it needed was water. Soon he began cleaning out ancient Hohokam canals and diverting water from the Salt and Gila Rivers. By the summer of 1868 the era of modern agriculture had begun.

That same year a small settlement was established approximately four miles east of present day downtown Phoenix. By 1874, downtown lots were selling for \$7 to \$11 each and the first telegraph line had arrived. The first operator of this station was a man named Morris Goldwater whose nephew, Senator Barry M. Goldwater, would become one of the region's early ham radio operators, with call letters K7UGA.

Phoenix saw rapid growth between 1950 and 1970 fueled by the "Five C's": Copper, Cattle, Cotton, Citrus and Climate. Today Phoenix and its surrounding communities are home to a thriving high-tech economy. Companies like Raytheon, Honeywell, General Dynamics C4 Systems, Boeing, United Technologies, and Northrup Grumman all have operations in the area. There are over 15 industry and trade associations within the state. Arizona State University alone boasts an enrollment of nearly 85,000 students and its Fulton School of Engineering graduate school is ranked in the top 20 in the US.



With a rich history, modern infrastructure, and beautiful mountainous desert landscape Phoenix will be a superb gathering place for Microwave Week 2015.

### Microwaves Soaring Towards the Future

The theme of this year's conference is "Microwaves Soaring Towards the Future." In his welcome message IMS 2015 General Chair Vijay Nair said there will be an emphasis on new and emerging fields like wearable electronics, internet of things, 3D printing, 5G, and RF/MW technology in life science. The theme will resonate throughout the keynote talks, panel sessions and technical presentations.

Microwave Week kicks off on Sunday with the co-located RFIC Plenary Session featuring two intriguing topics: "*THz Imaging to Millimeter-Wave Stimulation of Neurons: Is there a Killer Application for High Frequency RF in the Medical Community?*" presented by Dr. Peter H. Siegel of Jet Propulsion Laboratories; and "*RF as the Differentiator*" presented by Dr. Hermann Eul of Intel.

The traditional IMS Plenary session will be held Monday evening and will feature a keynote address, "*Soft Assemblies of Radios, Sensors and Circuits for the Skin*," by Dr. John Rogers from the University of Illinois.

The week concludes with another co-located event, the 85th meeting of ARFTG (Automatic RF Techniques Group). The first meeting held at the Hughes Aircraft Fullerton facility in 1972 brought together individuals who were users of Hewlett-Packard automatic network analyzers. Today, according to the group, "ARFTG is a technical organization interested in all aspects of RF and Microwave test and measurement." This viewpoint is reinforced by the variety and

depth of this year's oral and interactive forum papers.

### IMS and HFE

Once a year, IMS offers the single best opportunity to see what's new, expand your technical knowledge, network with colleagues and meet one-on-one with a wide range of vendors. I hope to see you there!

When you are visiting the Exhibit Hall please stop by Booth 329 and say "hello" to the staff of *High Frequency Electronics*. We always enjoy catching up with our readers and advertisers.

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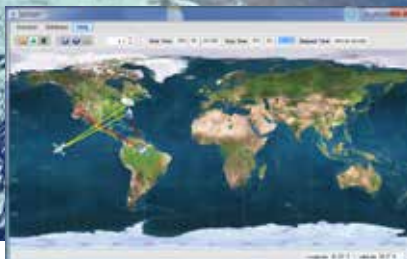
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## ► Meetings and Events

### CONFERENCES & MEETINGS

#### 2015 IEEE MTT-S International Wireless Power Transfer (WPTC 2015)

13-15 May 2015  
Boulder, Colorado, USA  
<http://www.wptc2015.org/>  
Paper Submission Deadline: 16 January 2015

#### 2015 IEEE International Microwave Symposium (IMS2015)

17-22 May 2015  
Phoenix, Arizona, USA  
<http://ims2015.org/>  
Paper Submission Deadline: 8 December 2014

#### 2015 IEEE Radio Frequency Circuits Symposium (RFIC 2015)

17-19 May 2015  
Phoenix, Arizona, USA  
<http://rfic-ieee.org/>  
Paper Submission Deadline: 12 January 2015

#### 85rd ARFTG Microwave Measurement Symposium

22 May 2015  
Phoenix, AZ, USA  
<http://www.arftg.org/>

#### 2015 IEEE MTT-S International Conference on Numerical Electromagnetic Modeling and Optimization for RF, Microwave and Terahertz Applications (NEMO 2015)

11-14 August 2015  
Ottawa, Canada  
<http://nemo-ieee.org>  
Paper Submission Deadline: 16 February 2015

#### 2015 40th International Conference on Infrared, Millimeter, and Terahertz waves (IRMMW-THz)

23 – 28 August 2015  
Hong Kong  
[www.irmmw-thz2015.org](http://www.irmmw-thz2015.org)

#### 2015 IEEE International Symposium on Radio-Frequency Integration Technology (RFIT)

26 – 28 August 2015  
Sendai, Japan  
[www.ieee-jp.org/japancouncil/chapter/MTT-17/rfit2015/](http://www.ieee-jp.org/japancouncil/chapter/MTT-17/rfit2015/)

#### 2015 IEEE MTT-S 2015 International Microwave Workshop Series on RF and Wireless Technologies for Biomedical and Healthcare Applications (IMWS-BIO)

21 – 23 September 2015  
Taiwan  
[www.ieee-jp.org/japancouncil/chapter/MTT-17/rfit2015/](http://www.ieee-jp.org/japancouncil/chapter/MTT-17/rfit2015/)

#### 2015 IEEE International Conference on Ubiquitous Wireless Broadband (ICUWB)

4 – 7 October 2015  
Montreal  
[www.icuwb2015.org](http://www.icuwb2015.org)

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## ► Market Reports

### Enterprise Femtocells Drive Market Growth

Operators, equipment vendors, and enterprise customers are all on the same page when it comes to indoor solutions; they need advanced equipment to meet the growing demands and create opportunities for new revenue streams. **As the residential femtocell market craters, enterprise femtocells will drive overall growth to almost \$800 million by 2020, according to ABI Research.**

The year 2014 witnessed vendors like Alcatel-Lucent, Nokia, and Ericsson debuting new enterprise small cells with LTE-A capabilities like carrier aggregation, VoLTE, and LAA. "Advanced LTE features accommodate enterprise's dynamic requirements while equipping operators to provide more lucrative services. Also, vendors shift efforts back into technology development after spending time on improving site services and forming partnerships within the ecosystem," comments **Ahmed Ali**, Research Analyst at ABI Research.

However, technical innovation, especially voice related, moves the femtocell market segments in different directions. "Wi-Fi calling proves disruptive for the residential market as operators look to limit cost on that segment. On the other hand, VoLTE, is strengthening the business case for enterprise femtocells, aligning well with the overall LTE growth," continues Ali.

**Although femtocell solutions make a strong case for small-to-medium enterprise, there is fierce competition from other in-building solutions to capture the medium-to-large enterprise market.** The Distributed Radio System (DRS), in particular, has established a growing market with solutions from major small cell vendors like Alcatel-Lucent, Ericsson, and Airvana. A DRS solves problems that arise from clustering small cells including interference, handover, and scalability. Yet conventional femtocell networks still maintain the advantage in terms of cost and ease of deployment.

—ABI Research  
abiresearch.com

### Data Captured by IoT Connections to Top 1.6 Zettabytes in 2020

A new report from ABI Research estimates that the volume of data captured by IoT-connected devices exceeded 200 exabytes in 2014. **The annual total is forecast to grow seven-fold by the decade's end, surpassing 1,600 exabytes—or 1.6 zettabytes—in 2020.**

Principal Analyst **Aapo Markkanen** says, "The data originating from connected products and processes follows a certain journey of magnitudes. The yearly volumes that are generated within endpoints are counted in yottabytes, but only a tiny fraction of this vast data mass is actually being captured for storage or further analysis. And of the

captured volume, on average over 90% is stored or processed locally without a cloud element, even though this ratio can vary greatly by application segment. So far, the locally dealt data has typically been largely inaccessible for analytics, but that is now starting to change."

In terms of deployment architectures, **the IoT is currently undergoing a major paradigm shift from cloud computing toward edge computing.** On one hand, this shift is opening up edge-based data to meaningful analysis, by distributing the analytic workloads across the network. On the other hand, it is also shoring up the cloud-level capabilities by making the transmitted data more actionable, by enriching and contextualizing the payloads.

Practice Director **Dan Shey** adds, "Edge computing is a huge challenge for the entire IoT value chain, as we can see from the way that cloud platforms, analytics vendors, and gateway suppliers are scrambling to collaborate with each other. It is also a great opportunity for various software and hardware players that have been working towards this goal even far before the IoT as a concept became fashionable. Names like AGT International, Eurotech, Kepware Technologies, OSIsoft, and Panduit are all examples of firms whose background in distributed intelligence allows them now to expand their target market, even significantly."

—ABI Research  
abiresearch.com

### Tech Breakthroughs Fuel Wireless Sensor Network Growth

The global wireless sensor networks market is highly dynamic with rapid technological developments strengthening their use case in a myriad of applications. Need for real-time data monitoring and analysis in factory automation is the primary driver for wireless sensor networks. End users are also comfortable employing wireless devices for less critical functions such as tracking production flow and quality. Cloud connectivity and development of newer wireless protocols have strengthened deployment.

New analysis from Frost & Sullivan finds that **the market earned revenues of \$1.20 billion in 2014 and estimates this to reach \$3.26 billion in 2020 at a compound growth rate of 18.1 percent.**

"All industries, apart from consumer electronics and goods, deploy wireless sensor networks for monitoring," said Dr. **Rajender Thusu**. "The **building automation, supply chain, defense, materials handling, and food and beverage sectors use wireless sensor networks for tracking and tagging in addition to monitoring.**"

—Frost & Sullivan  
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## ► In the News



DARPA has awarded prime contracts for Phase 2 of Tern, a joint program between DARPA and the U.S. Navy's Office of Naval Research (ONR). **The goal of Tern is to give forward-deployed small ships the ability to serve as mobile launch and recovery sites for medium-altitude, long-endurance unmanned aerial systems (UAS).** These systems could provide long-range intelligence, surveillance and reconnaissance (ISR) and other capabilities over greater distances and time periods than is possible with current assets, including manned and unmanned helicopters. Further, a capacity to launch and retrieve aircraft on small ships would reduce the need for ground-based airstrips, which require significant dedicated infrastructure and resources. The two prime contractors selected by DARPA are AeroVironment, Inc., and Northrop Grumman Corp.

**"To offer the equivalent of land-based UAS capabilities from small-deck ships,** our Phase 2 performers are each designing a new unmanned air system intended to enable two previously unavailable capabilities: one, the ability for a UAS to take off and land from very confined spaces in elevated sea states and two, the ability for such a UAS to transition to efficient long-duration cruise missions," said **Dan Patt**, DARPA program manager. "Tern's goal is to develop breakthrough technologies that the Navy could realistically integrate into the future fleet and make it much easier, quicker and less expensive for the Defense Department to deploy persistent ISR and strike capabilities almost anywhere in the world."

The first two phases of the Tern program focus on preliminary design and risk reduction. In Phase 3, one performer will be selected to build a full-scale demonstrator Tern system for initial ground-based testing. That testing would lead to a full-scale, at-sea demonstration of a prototype UAS on an at-sea platform with deck size similar to that of a destroyer or other surface combat vessel.

\* \* \*

**DARPA's Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV) program seeks to develop a new type of unmanned surface vessel**



**that could independently track adversaries' ultra-quiet diesel-electric submarines over thousands of miles.** One of the challenges that the ACTUV program is addressing is development of autonomous behaviors for complying with the **International Regulations for Preventing Collisions at Sea, known as COLREGS.** Substantial progress has been made in developing and implementing those behaviors. Currently, ACTUV's system for sensing other vessels is based on radar, which provides a "90 percent solution" for detecting other ships. However, radar is less suitable for classification of the type of other vessels, for example determining whether the vessel is a powered vessel or a sailboat. Additionally, one of the requirements of COLREGS is to maintain "a proper lookout by sight and hearing."

To help augment ACTUV's capability for sensing and classifying other vessels, and to reduce reliance on radar as ACTUV's primary sensor, DARPA has issued a Request for Information (RFI) about currently available technologies that could help ACTUV and future unmanned surface vessels perceive and classify nearby ships and other objects. DARPA is specifically interested in **sensor systems and image-processing hardware and software** that use passive (electro-optical/infrared, or EO/IR) or non-radar active (e.g., light detection and ranging, or LIDAR) approaches. The goal is to develop reliable, robust onboard systems that could detect and track nearby surface vessels and potential navigation hazards, classify those objects' characteristics and provide input to ACTUV's autonomy software to facilitate correct COLREGs behaviors.

\* \* \*

For decades, the United States has successfully countered the threats of competitor nations by harnessing advanced technologies to create exceedingly robust and capable military platforms. But as advanced technologies have become more readily available to adversaries on commercial markets, the Nation's focus on ever more complex weapons systems has become not just a strength but also a weakness. Effective as they are, U.S. military systems today are often too expensive to procure in the



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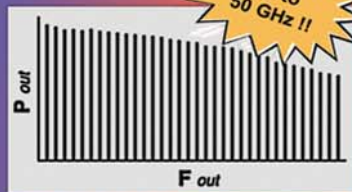
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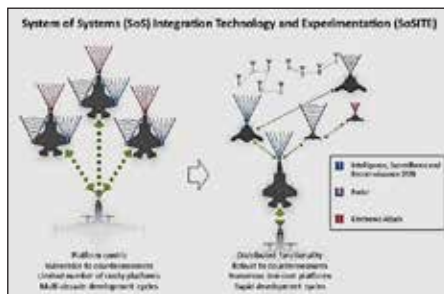


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## In the News



quantities needed, and may take so long to develop that the electronic components they contain are obsolete by the time they become operational.

To address these challenges as they apply to airborne platforms, DARPA has kicked off the **System of Systems (SoS) Integration Technology and Experimentation (SoSITE)** program. SoSITE aims to develop and demonstrate concepts for maintaining air superiority through novel SoS architectures—combinations of aircraft, weapons, sensors and mission systems—that distribute air warfare capabilities across a large number of interoperable manned and unmanned platforms. The vision is to integrate new technologies and airborne systems with existing systems faster and at lower cost than near-peer adversaries can counter them.

\* \* \*

**Versatile Power** announced the addition of **Saelig Company**, Fairport, New York., to its list of authorized distributors of Versatile Power's new family of **BENCH Programmable Power Supplies**. The Versatile Power **BENCH** series are compact, programmable, DC power supplies and are nearly half the cost compared to the industry's leading producer of power supplies.

"Saelig is well known in the North American region and, since its founding in 1988, has earned a reputation for having unique OEM products and excellent customer service. This distribution arrangement offers

a perfect addition to our resources to acquaint the test and measurement community to our new family of **BENCH Programmable Power Supplies**," commented **Jerry Price**, CEO of Versatile Power.

\* \* \*

Five additional **on-demand webinars** have been added to [ni.com/awr](http://ni.com/awr) that showcase **NI AWR Design Environment™ software capabilities**. These webinars, which examine various challenges for power amplifier and antenna design, are presented by industry experts that rely on NI AWR Design Environment to deliver best-in-class solutions. For more info, go to: [awrcorp.com/awr-support/training-center/webinar-archive](http://awrcorp.com/awr-support/training-center/webinar-archive).

\* \* \*

**NI (formerly AWR Corporation)** announces a new application note titled "**Using NI AWR Design Environment Load-Pull Simulation for the Designer of Wideband High-Efficiency PAs**" that explores the design of power amplifiers (PAs) leveraging load-pull technology within NI AWR Design Environment™ software, specifically that of Microwave Office.

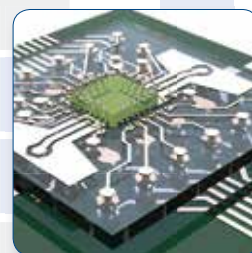
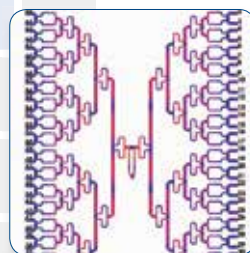
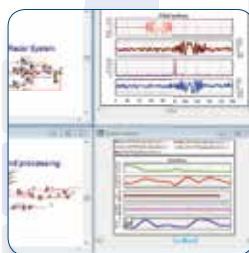
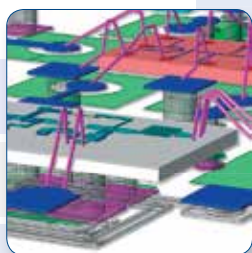
Using a Cree CGH40010F gallium nitride high-electron mobility transistor in a Class F PA at 2000 MHz as the example circuit, the application note details how power-added efficiency is maximized by optimizing source and load pull at the fundamental frequency, plus second and third harmonics.

Additionally, the ability of the load-pull technique to inspect transistor voltage and current waveforms helps users gain confidence in their high performance designs. The application note is found online at [awrcorp.com/solutions/technical-papers](http://awrcorp.com/solutions/technical-papers).

Get info at [www.HFELink.com](http://www.HFELink.com)



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# ► Featured Products



## HEMT

Cree's CGHV40050 is an unmatched, gallium nitride (GaN) high-electron-mobility transistor (HEMT). The CGHV40050, operating from a 50-volt rail, offers a general-purpose, broadband solution to a variety of RF and microwave applications. GaN HEMTs offer high-efficiency, high-gain and wide-bandwidth capabilities, making the CGHV40050 ideal for linear and compressed amplifier circuits.

**Cree**  
cree.com



## Data Recorder

Ultraview Corp. announced a 14-bit 2/4-channel 400MSPS multi-terabyte-deep-storage data acquisition system for demanding uses in which extremely long analog/RF waveforms need to be observed with high SNR for timespans of up to an hour (up to 2 Hours for 10TB model), such as SIGINT, RADAR, missile testing, communications systems and antenna testing, and more.

**Ultraview**  
ultraviewcorp.com

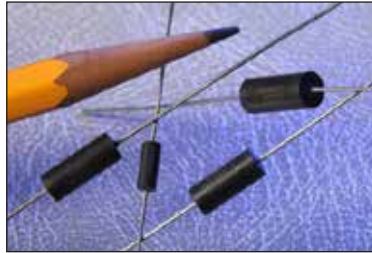


## Amp Subsystem

Mini-Circuits' AVM-273HPK+ is a MMIC amplifier subsystem consisting of a MMIC amplifier and an auto-voltage sequencing mod-

ule. The MMIC amp is designed using 0.15µm PHEMT technology and provides very wideband performance, medium power and unconditional stability. Its outstanding isolation enables it to be used as a wideband isolation amplifier or buffer amplifier.

**Mini-Circuits**  
minicircuits.com



## RF Inductors

Gowanda Electronics announced five new RF inductor series for military applications. The series that achieved QPL status and the seven MS numbers they address include: MRLF19M (MS90539), MLRF21M (MS90542 and MS14052), MLRF22M (MS90540), MLRF24M (MS90541) and MLRF28M (MS75103 and MS91189).

**Gowanda Electronics**  
gowanda.com



## Circuit Assemblies

Molex introduced its new High-Speed Low-Loss Flex Circuit Assemblies, made using DuPont™ Pyralux® TK flexible circuit material. The assemblies are ideal for electronic data transmission applications such as servers and high-end computing, storage servers and signal processing.

**Molex**  
Molex.com

## ELINT Detector

Norden Millimeter introduced a channelized activity detector for



EW, SIGINT, COMINT and ELINT applications. It operates in the 6 to 18 GHz frequency range and has 12 independent 1 GHz wide simultaneous detection channels. The channel outputs are DC voltages log linear to ±1.0 dB over a 60 dB dynamic range.

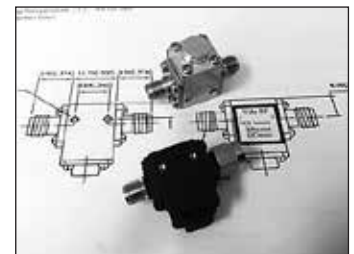
**Norden Millimeter**  
nordengroup.com



## Transistor

RFMW announced support for NXP's BLF2425M7LS-250P. This efficient LDMOS transistor is internally matched for broadband performance from 2400 to 2500 MHz, supporting ISM (Industrial, Scientific and Medical) applications. The earless, ceramic package adds to the excellent thermal stability, creating a 250 watt CW power transistor to meet the needs of innovative RF power generation.

**RFMW**  
rfmw.com



## Isolator

VidaRF offers the 30 - 40 GHz Coaxial Isolator Model VCI-300400 which is a rugged body with S/Steel (K) connectors; if required, sealed and painted to meet IP63 standards. Operating temp -15 to +55C. Other



# isola

## RF/Microwave Materials & Resources

- ▶ **IS680** materials offer a complete laminate materials solution for single- and double-sided printed circuit designs and are a cost-effective alternative to PTFE and other commercial microwave materials. Dk available from 2.80 to 3.45.
- ▶ **I-Tera® MT RF** materials are available in 0.010", 0.020" and 0.030" in 3.38, 3.45 and 3.56 Dk.
- ▶ **I-Tera® MT** materials are suitable for both high-speed digital and RF/microwave designs. A full compliment of cores and prepregs allowing flexibility in design is available in core thicknesses from 0.002" to 0.018". I-Tera MT has been used in designs up to 24 GHz.
- ▶ **TerraGreen®** halogen-free, very low-loss, thermoset materials are available in a variety of laminate and prepreg offerings. This material is inexpensive to process – improving your company's bottom line, as well as the environment.
- ▶ The revolutionary **Astra® MT** ultra low-loss thermoset laminates are a replacement for PTFE. Astra MT is available in core and prepreg for double sided, multilayer and hybrid designs using isola 185HR, 370HR or IS415. Astra MT has been used in designs up to 77 GHz.

	RF/MICROWAVE MATERIALS				
	IS680	I-Tera® MT RF	I-Tera® MT	TerraGreen®	Astra® MT
Tg	200°C	200°C	200°C	200°C	200°C
Td	360°C	360°C	360°C	390°C	360°C
Dk @ 10 GHz	2.80 - 3.45	3.38, 3.45 & 3.56	3.45*	3.45*	3.00
Df @ 10 GHz	0.0028 - 0.0036	0.0028, 0.0031 & 0.0034	0.0031*	0.0030*	0.0017
CTE Z-axis (50 to 260°C)	2.90%	2.80%	2.80%	2.90%	2.90%
T-260 & T-288	>60	>60	>60	>60	>60
Halogen free	No	No	No	Yes	No
VLP-2 (2 micron Rz copper)	Available	Available	Available	Standard	Standard
Stable Dk & Df over the temperature range	-55°C to +125°C	-55°C to +125°C	-55°C to +125°C	-55°C to +125°C	-40°C to +140°C
Optimized global constructions for Pb-free assembly	Yes	Yes	Yes	Yes	Yes
Compatible with other Isola products for hybrid designs	For use in double-sided applications	Yes	Yes	Yes	Yes
Low PIM < -155 dBc	Yes	Yes	Yes	Yes	Yes

\* Dk & Df are dependent on resin content NOTE: Dk/Df is at one resin %. Please refer to the Isola website for a complete list of Dk/Df values. The data, while believed to be accurate & based on analytical methods considered to be reliable, is for information purposes only. Any sales of these products will be governed by the terms & conditions of the agreement under which they are sold.

### RF Conversion Service

- ▶ Isola's **Design Review Service** can facilitate your conversion to Isola's RF/microwave products and get you to market faster with the newest, ultra-low-loss materials.
- ▶ As part of this new service, Isola's technical staff will provide turn-key calculations, testing, characterizations and material recommendations to assist PCB fabricators and OEMs in converting to Isola's RF-materials, which will help overcome the current material shortages of other vendors and accelerate time-to-market. The design review service also addresses the perceived conversion issues when migrating from a currently used material to an Isola material.

<http://www.isola-group.com/conversion-service>



### FREE! Impedance and Power-Handling Calculator

- ▶ Isola's free **Impedance and Power-Handling Calculator** predicts the design attributes for microstrips and striplines based on the design's target impedance and dielectric properties of the company's RF, microwave and millimeter-wave laminate materials.
- ▶ This software tool provides a design or an equivalent dielectric constant to facilitate modeling for PCB designers to predict impedance and other design attributes. The software computes changes in the effective dielectric constant due to dispersion at higher frequencies. The software then computes the total insertion loss—a measure of power lost through heat for power handling calculations, including the dielectric loss, conductor loss, and the loss due to the surface roughness. The main factors affecting the typical power-handling capability of a material are its thermal conductivity, the maximum operating temperature, and the total insertion loss.

<https://isodesign.isola-group.com/phi-calculator>

[www.isola-group.com/RF](http://www.isola-group.com/RF)



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## Featured Products

frequencies and connector configuration available upon request.

**VidaRF**  
[vidarf.com](http://vidarf.com)



### Power Amp

Model SBB-0132732526-KFKF-SB is a bench-top broadband power amplifier operating from 1.0 to 26.5 GHz. It provides 25 dB small signal gain and a minimum +25 dBm output power over the entire frequency range. It is designed to use 100 - 240 V AC power directly from power line for laboratory use.

**SAGE Millimeter**  
[sagemillimeter.com](http://sagemillimeter.com)



### Waveform Amplifier

The TS250 waveform amplifier amplifies current or voltage or power for driving heavy loads. It is ideal for many test and measurement applications such as LDO and amplifier PSRR test, battery simulator, op-amp CMRR measurement, high-frequency electromagnetic coil driver, general function generator amplifier, transient response test, four-quadrant power supply, lab power amplifier, and more.

**Accel Instruments**  
[accelinstruments.com](http://accelinstruments.com)

### Cable Assemblies

D-COAX introduced  $\leq 1$ ps skew matched and phase stable high performance flexible coaxial cable assemblies through 65 GHz. The standard assemblies deliver excellent return loss and low insertion loss. Cable Pairs are ideal for: Signal Integrity; Channel Model-



ing; Jitter Measurements; BERT; Differential Measurements; VNA measurements.

**D-COAX**  
[d-coax.com](http://d-coax.com)



### EW App Note

Keysight's new app note, "Assembling Cost-effective Development and Verification Solutions for EW Systems," presents two off-the-shelf alternatives that can address the simulation requirements of subset scenarios for a system under test (SUT). The proposed alternatives offer greater versatility because the constituent instruments can be easily used for other measurement tasks.

**Keysight Technologies**  
[keysight.com](http://keysight.com)

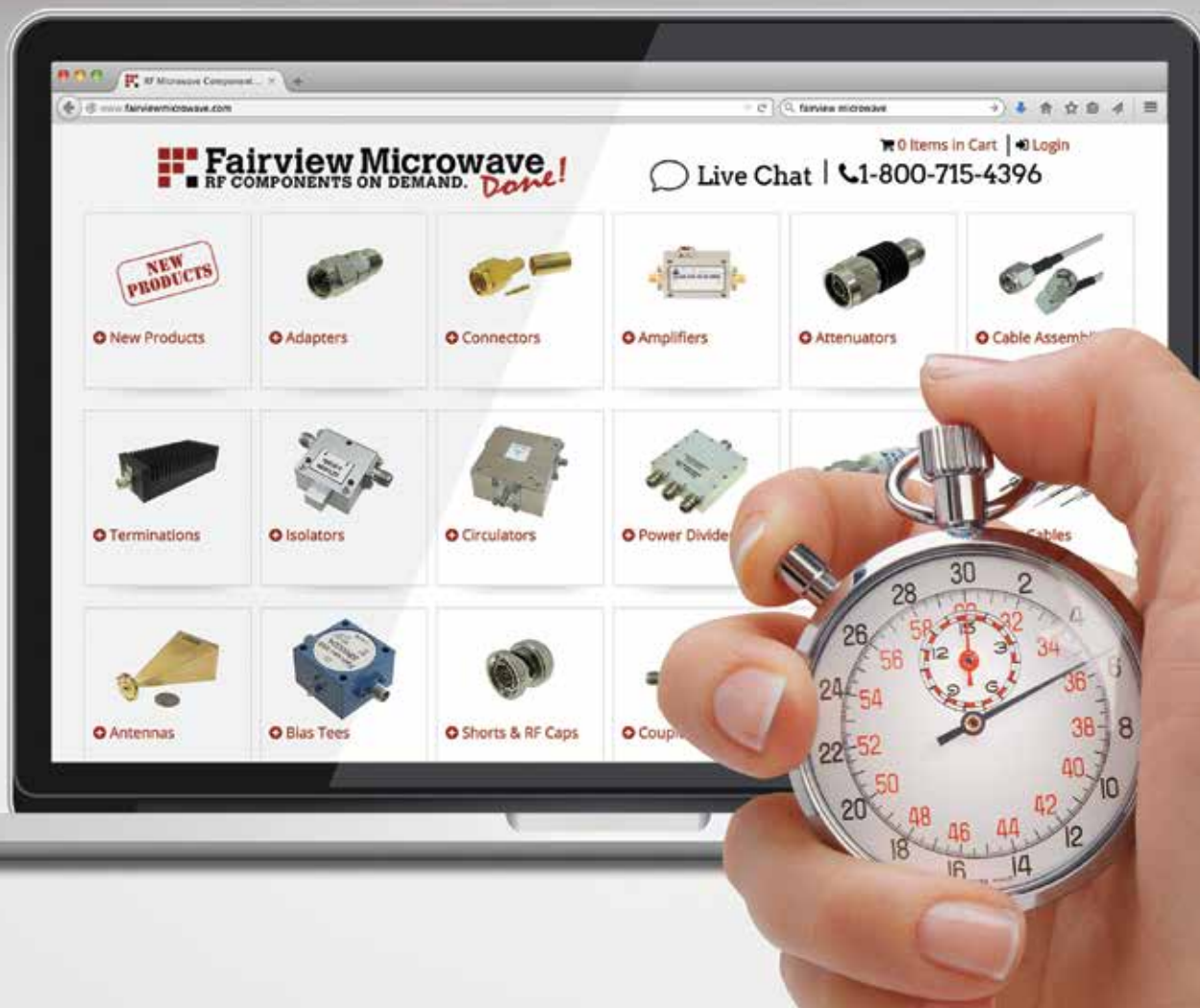


### VCO

Crystek's CVC055CCQ-3500-3500 VCO operates at 3500 MHz with a control voltage range of 0.3 V~4.9 V. This VCO features a typical phase noise of -115 dBc/Hz @ 10 KHz offset and has excellent linearity. Output power is typically +6 dBm. Engineered and manufactured in the USA, it is packaged in



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# ► Featured Products

the industry-standard 0.5-in. x 0.5-in. SMD package.

**Crystek**  
crystek.com



## Bandpass Filter

ERF-5W™ has been redesigned to minimize size, weight, power consumption and cost while covering the entire military tactical radio band of 30 to 520 MHz and maintaining high in-band RF power handling (5 watts). It is commonly used in UAV Communication Relay Payload applications. SWaP-C reductions include a new size: 4.7" x 6.8" x 1.0" (119.4 x 172.7 x 25.4 mm) and new weight: 14.08 oz. (399 g).

**Pole/Zero**  
polezero.com



## Amplifier

Comtech PST announced the release of a solid state Class "AB" linear amplifier which operates over the full 6-18 GHz frequency band and delivers a minimum of 50 watts. The amplifier uses the latest Gallium Nitride (GaN) technology and is packaged in a standard rack mountable enclosure measuring 19" x 22" x 3.5".

**Comtech PST**  
comtechpst.com



## Coupler

Mini-Circuits' ZUDC20-183+ is a 50Ω, 20dB, Up to 50W, 0.5 to 18 GHz, Directional Coupler that features: ultra wide frequency range, 0.5 to 18 GHz; good coupling flatness, ±0.5 dB typ.; good directivity, 22dB typ. up to 4 GHz; good VSWR, 1.3:1 typ.; DC

current pass through input to output. Applications: cellular; lab use; WiMax; ISM; GSM; PCN.

**Mini-Circuits**  
minicircuits.com



## Multiplier

Model SFA-154SF-S1 is a broadband X4 active multiplier with output frequency covering 50 to 66 GHz. With an RF input signal from 12.5 to 16.5 GHz and power level of +3 dBm, it can deliver +16 dBm power in the frequency range of 50 to 66 GHz. The harmonic suppression is -20 dBc typically. It draws 380 mA current from a +8 Vdc DC power supply.

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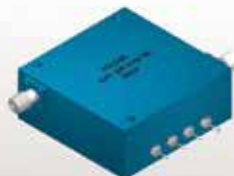
**Power Dividers, DC-60 GHz**  
2-32 Way



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Single and Dual, to 60 GHz  
High Power, to 2500 watts



**Hybrids, to 40 GHz**  
90° & 180°



**Attenuators, to 18 GHz**  
Digital, Analog, Linearized



**Bias Tees, to 85 GHz**  
30 KHz to 85 GHz



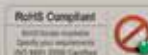
**Switches, to 18 GHz**  
SP1T-SP8T



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1.8 to 12.5 GHz



**\$556**  
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### EP2C+

- ✓ Tiny size, 4 x 4mm
- ✓ 1.1 dB insertion loss
- ✓ 1.85W input power handling
- ✓ Good port-to-port isolation, 16 dB
- ✓ Low amplitude unbalance, 0.2 dB
- ✓ Low phase unbalance, 6°
- ✓ DC current passing up to 0.4A

## MMIC Amplifiers

Ultra-Low Noise, High IP3  
1.1 to 4.0 GHz



**\$276**  
ea. (qty. 1000)

### PMA2-43LN+

- ✓ Ultra-low noise figure, 0.46 dB
- ✓ High IP3, up to +33 dBm
- ✓ High gain, up to 23 dB
- ✓ P1dB up to +19 dBm
- ✓ Low power consumption, +5V, 51mA
- ✓ Tiny size, 2 x 2mm

## MMIC Mixers

Wideband 2200 to 7000 MHz



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ea. (qty. 1000)

### MDB-73H+

- ✓ Tiny Size, 4 x 4mm
- ✓ Low conversion loss, 8 dB
- ✓ High L-I Isolation, 46 dB
- ✓ High L-R Isolation, 39 dB
- ✓ IF bandwidth, DC to 1600 MHz
- ✓ LO power, +15 dBm
- ✓ Usable as up and down converter

## MMIC Mixer-Amplifiers

Wideband 2200 to 7500 MHz



**\$10<sup>25</sup>**  
ea. (qty. 1000)

### MDA4-752H+

- ✓ Integrated mixer, LO amplifier, and IF amplifier in one package
- ✓ Tiny size, 4 x 4mm
- ✓ High L-I Isolation, 61 dB
- ✓ Hi R-I Isolation, 51 dB
- ✓ Conversion gain up to 9.7 dB
- ✓ IF Bandwidth, 30 to 1600 MHz
- ✓ LO power, 0 dBm

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## Pondering on Power Measurements

By Joseph Cahak

Reviewing the various methods of measuring RF power.

A power measurement is a scalar quantity and is a measure of power detected. These measurements can be made in a variety of ways. Most of us are familiar with the notion that voltage (volts) multiplied by current (amps) is power (watts) and power multiplied by time is energy. At DC or low frequencies these power measurements from the current or voltage are relatively easy and not very complicated. As we get to higher frequencies the typical means of measuring voltage or current breakdown are not accurate. The power measurement inaccuracies are due to the frequency response of the detectors at high frequency and also the impedance match of the detectors as well as the instantaneous frequency response of the detector network. All power sensors are broadband sensors. They cannot discriminate between individual signals in a multiple signal environment. These signals can add or subtract from the total power as a combination of the power depending on whether the signals are in or out of phase.

Power measurements in the RF and Microwave frequency range are typically made with thermistor-, thermocouple- or diode-based instruments. The thermistor- or thermocouple-based power sensors are most accurate for “true” or RMS power. True power is properly integrated (modulation envelope) over time to give the “true” power no matter the waveform shape. If the

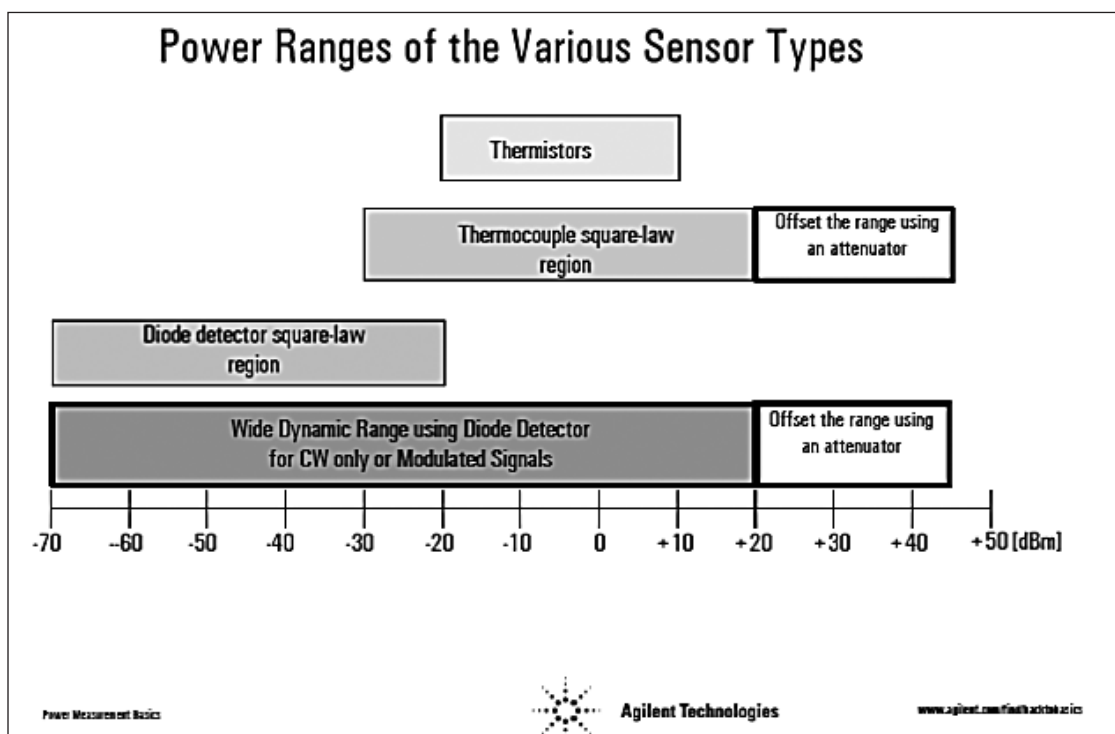


Figure 1 • Power sensor type and range. Courtesy Keysight Technologies.



# 100W POWER AMPLIFIERS

## 700-2700 MHz



**\$8,995<sub>each</sub>**

### **48 dB Gain, $\pm 1.7$ dB Flatness**

*Output power up to 100W with consistent performance across a wide frequency range for a fraction of the cost of competitive products!* Mini-Circuits' new HPA-272+ high power rack mount amplifiers are ideal for a wide variety of high power test applications including EMI, reliability testing, power stress testing, and burn-in of multiple units at once. This model provides 48 dB gain with  $\pm 1.7$  dB gain flatness over its entire frequency range and 89 dB reverse isolation. Housed in a rugged, 19-inch rack-mountable chassis, the amplifier operates on a self-contained 110/220V power supply and includes internal cooling, making it easy to use in most lab environments. Extensive built-in safety features include over-temperature protection and the ability to withstand opens and shorts at the output.\* They're available off the shelf for an outstanding value, so place your order on [minicircuits.com](http://minicircuits.com) today for delivery as soon as tomorrow!

\*at 3 dB compression point.





# Power Measurements

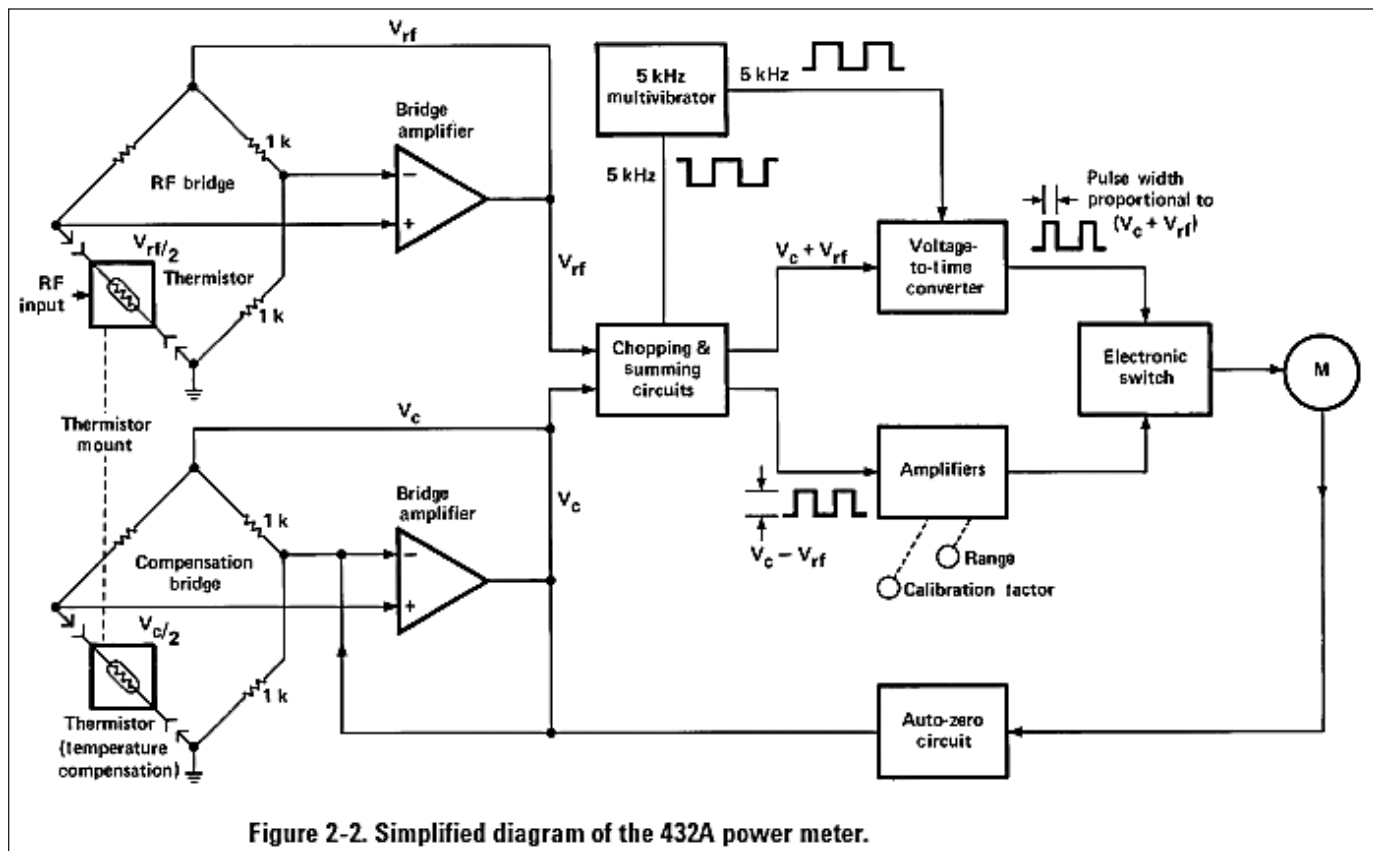


Figure 2-2. Simplified diagram of the 432A power meter.

Figure 2 • Thermistor Power Meter Schematic. Courtesy Keysight Technologies.

signal is a CW (continuous wave) signal that does not vary in signal strength or frequency, the measurement is relatively easy and the RMS value is easy to compute. In the case of more complicated modulated signals or complex waveforms, computing or measuring True RMS power gets more difficult and complicated. To better understand this we will review the methods of measuring RF power.

## Thermistor and Thermocouple Devices

The most accurate method of measuring True RF power is with a device called a thermistor or a thermocouple. These devices convert RF power to thermal power (heat) and the thermal power is converted to a resistance or a voltage difference measurement that can be measured and converted to the power measured. There are issues associated with this method of measuring RF power.

The first issue with this method is a limited dynamic range that it will accurately measure over. Most of the sensors in the market today that use thermistor-based sensors have a measurement range of -30 to +20 dBm. Some measure higher power levels with an attached calibrated attenuator. Microprocessors and EEPROM cali-

bration tables are used to perform power correction for temperature and frequency response.

With RF power to thermal conversion, there is a small time lag for the thermal response from the RF power. While this is a small sensor with a small thermal mass in the sensor, nonetheless this equates to a small lag in the power response. This property will affect accuracy of rapidly varying signals, and signals with complex modulation. Finally, there is a frequency response associated with the sensor and also the impedance match of the interface to the sensor. These responses can be calibrated and removed using a cal factor for the sensor.

## Diode Devices

Another method of measuring power is with a diode sensor. These diode sensors have a faster response time than thermistor-based sensors, but due to the diode characteristics, they have more impedance match issues than the Thermistor. The diode has low impedance compared to the 50 ohm characteristic impedance of most RF instruments and RF networks in use today. This means that some form of matching network must be used to improve the match into the sensor and DC isolation (blocking). These components have frequency sensitivity.



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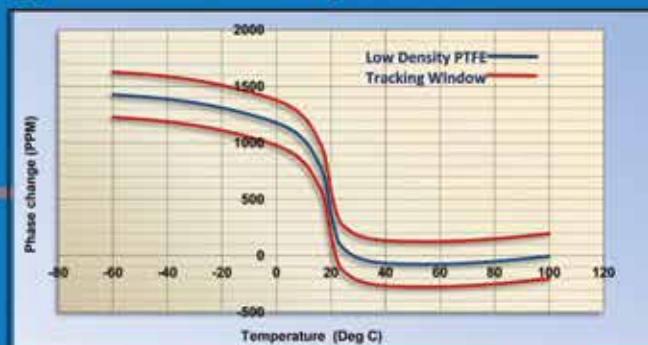
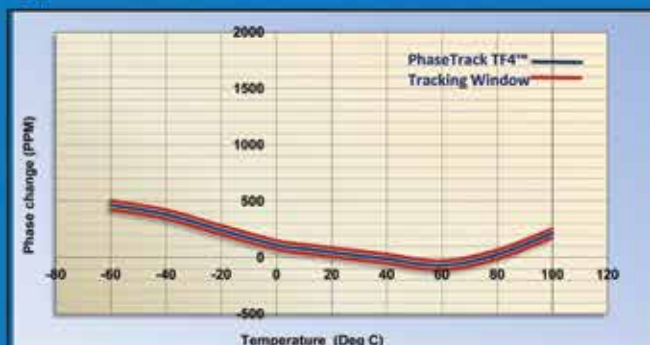


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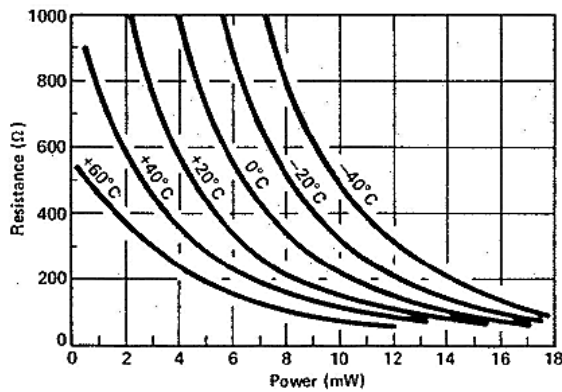
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# Power Measurements

## Thermistors

Characteristic curves of a typical thermistor element



Power Measurement Basics

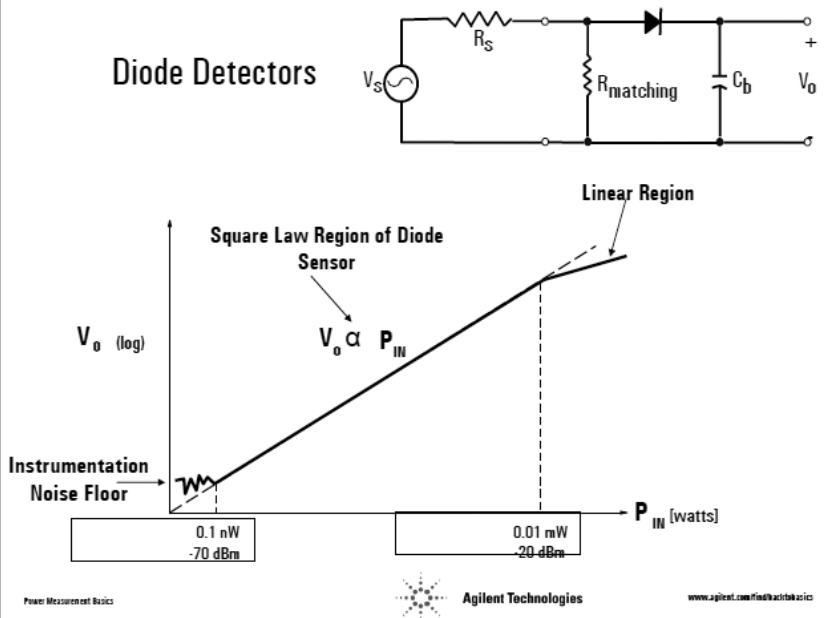


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Figure 3 • Thermistor temperature response. Courtesy Keysight Technologies.

## Diode Detectors



Power Measurement Basics



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Figure 4 • Diode Power Sensor. Courtesy Keysight Technologies.

The diode is sensitive to VSWR and is more prone to measurement error due to these issues. Another issue is the non-linearity of the diodes. What that means is at higher power levels the diodes conduct and the current is no longer square law proportional to the voltage of the detected signal. This has ramifications with measuring complex signal environments. Recall the power equation from voltage:

$$\text{Power} = \frac{V^2}{R} = I^2 * R$$

This implies that while the diode is in the square law region the voltage output from the rectification is directly proportional to the power in that region only. Outside that region, the power is not directly linear to voltage.

Making power measurements in the quasi and linear regions of the diode response is *less* accurate when the signal input is modulated with wide bandwidth signals or multiple tone signals. To make these measurements, the instrument must have the dynamic measurement power range and the frequency response to be quantifiable, repeatable and correctable. For the diode sensors, extensive EEPROM correction tables are used for the frequency, signal levels and temperatures at which the power measurements will be made. In many cases these corrections are not adequate for very wideband devices such as Ultra Wideband USB or some of the other digital modulation formats. Most sensors have an instantaneous bandwidth that they can respond to which typically range from 10 MHz to 30 MHz for most power sensors available on the market. This is not important for most measurement markets. With modulation formats wider than this and higher in power than the square law region, pulsed power or sensor instantaneous bandwidth can have varying amounts of error. Recall the comment above regarding operation above the square law region. The trick that can be used to gain some level of better power accuracy for modulated signals with diode sensors is to keep the power within the square law region (-70 to -20 dBm).

Analog Devices has recently come out with a replacement for the Schottky diodes to measure power. The ADL6010 is a coplanar input for measuring power from 500 MHz to 50 GHz. It features built-in linearization for added accuracy.

## DSP Devices

One trend in communication power measurements is to use DSP (digital signal processing) architecture to process the signals and get a better measure of power with complex formats and frequency components. These can also provide the ability to measure the peak or envelope power and crest power on multiple tones or modulated signal measurements. They can also offer wider bandwidths than traditional sensors. Capability is only limit-



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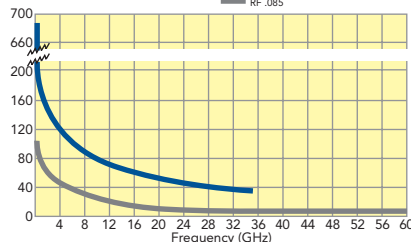
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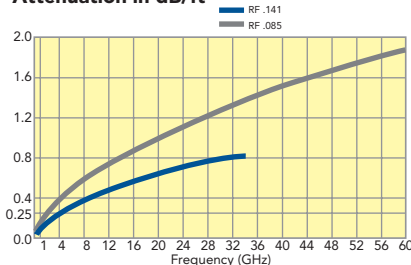
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# ► Power Measurements

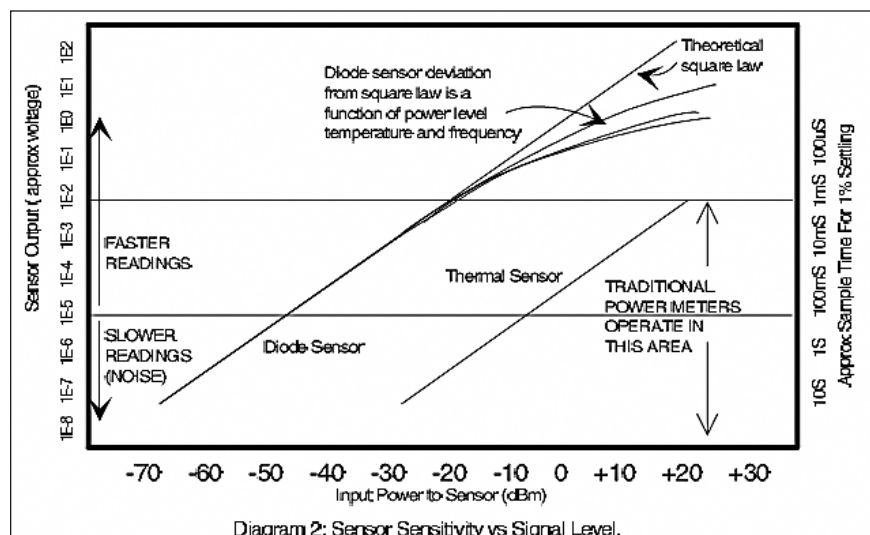


Figure 5 • Universal Power Sensor Range. Courtesy Anritsu Company.

ed by the sampling rate, bit depth and accuracy of the ADC's or Sigma-D samplers.

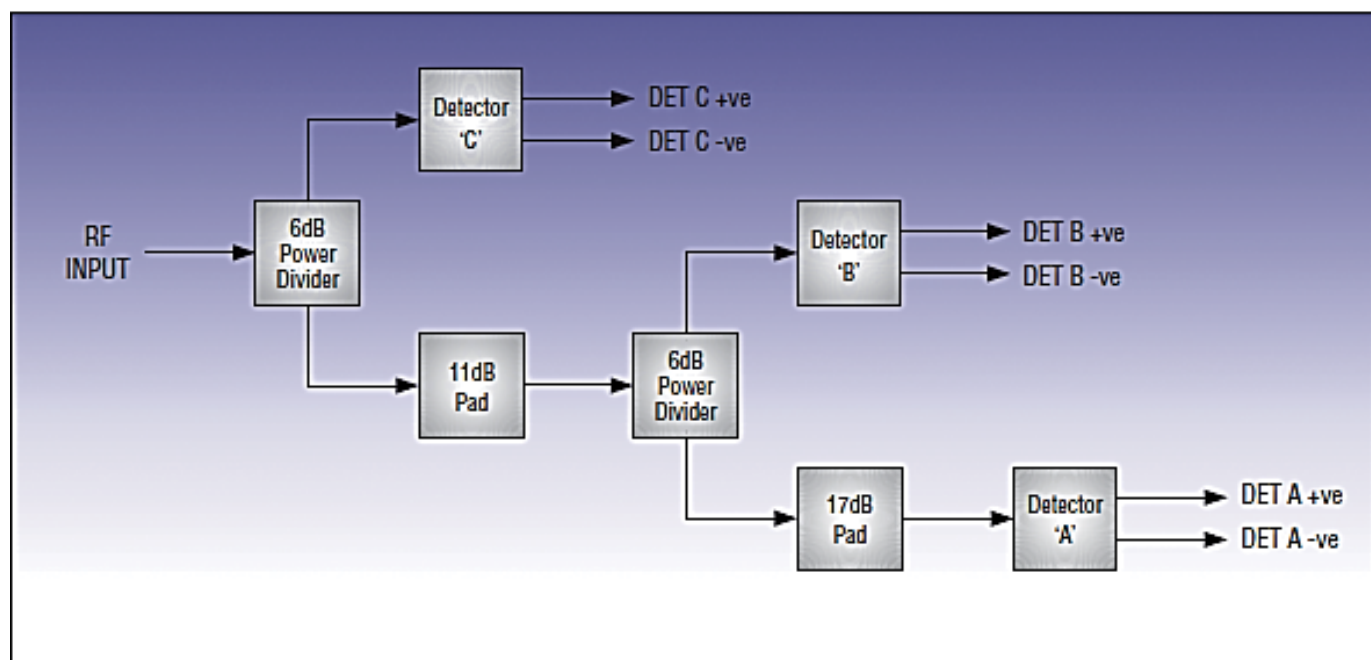
## Peak Envelope Power and Peak or Crest Power

Other RF power measurements are peak envelope power (PEP) and peak or crest power. These are used to measure the power of multi-tone and digitally modulated waveforms to get the instantaneous power maximum of

the system. There are many instances where a power measurement that takes the peak power value of the envelope is needed. All digitally modulated waveforms, AM and single sideband (SSB) use this measurement. The peak measurement is also the crest power, which would be compared to the average power to calculate the crest factor of the RF device, which is the ratio of the peak power level above average power. These peaks can damage power amplifiers if not contained in amplitude.

## Instantaneous or Video Bandwidth

Instantaneous or video bandwidth (VBW) is the response after rectification of the signal and the detection circuitry response and ability to integrate the RMS power. This video modulated rectification result is used to calculate the power. If the detection circuitry downstream of the rectification has poor frequency response, the accuracy of the power measurement will degrade. Typical video bandwidth range is 10 MHz up to 100 MHz video or instantaneous bandwidth. The user must be aware of the signal measurement equipment requirements to account for this signal band-



*Anritsu's MA2480A series Universal Power Sensors use a unique architecture with three cascaded diode pairs, dividers and attenuators. One of the diode pairs is within its square law region, ensuring true average power measurements of any input signal.*

Figure 6 • Universal Wide Power Range Sensor. Courtesy Anritsu Company.



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# Power Measurements

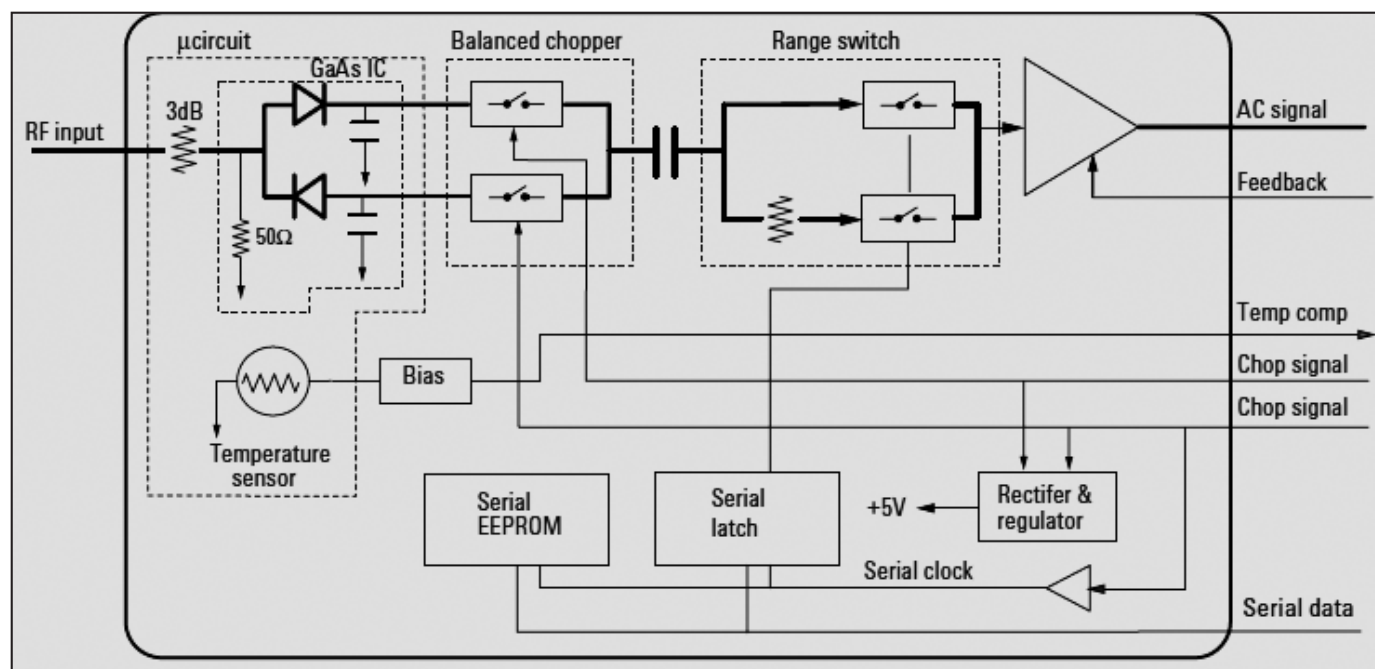


Figure 7 • E4412/13 Sensor Architecture. Courtesy Keysight Technologies.

width and to thereby ensure accurate power measurements of modulated signals. If measuring pulsed power the Video or instantaneous bandwidth should be at least 5x the pulse repetition rate.

## Measurement Accuracy

The quality or accuracy of the power measurement depends not only on the power sensor calibration factors previously mentioned. Another significant source of measurement error is the sensor impedance match and the match of the device port under test. This mismatch error is

computed with the formula  $\text{MismatchError} = 10 \log(1 \pm \rho_g \rho_l)^2$ . The + and – represent the max and minimum mismatch for the measurement mismatch loss of power measured  $\rho_g$  and  $\rho_l$  are the generator and load reflection coefficient..

## About the Author:

Joseph Cahak is currently employed at Silanna Semiconductor as an RF Test Engineer. He began his career in 1983 at defense contractor Watkins-Johnson Company, Palo Alto, Calif., working on the bench and worked his way up to ATE Specialist working with

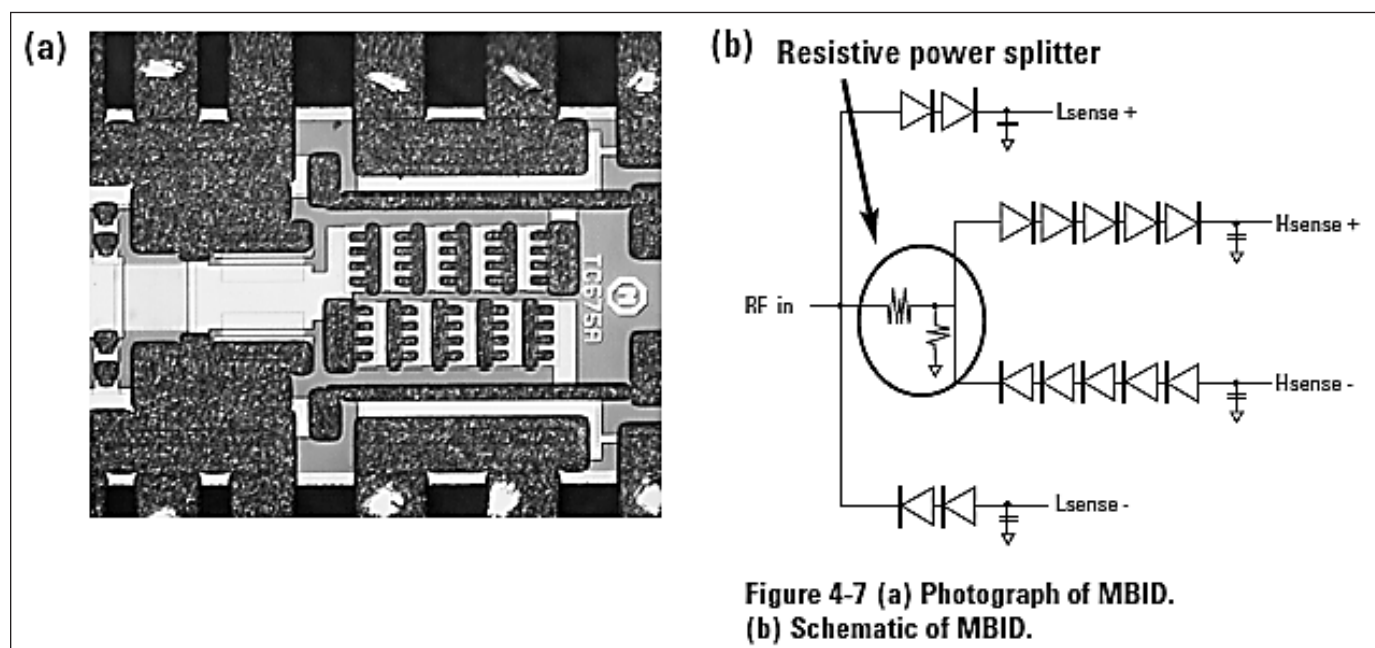


Figure 8 • Sensor for E4412/13 Power Sensor. Courtesy Keysight Technologies.



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# ▶ Power Measurements

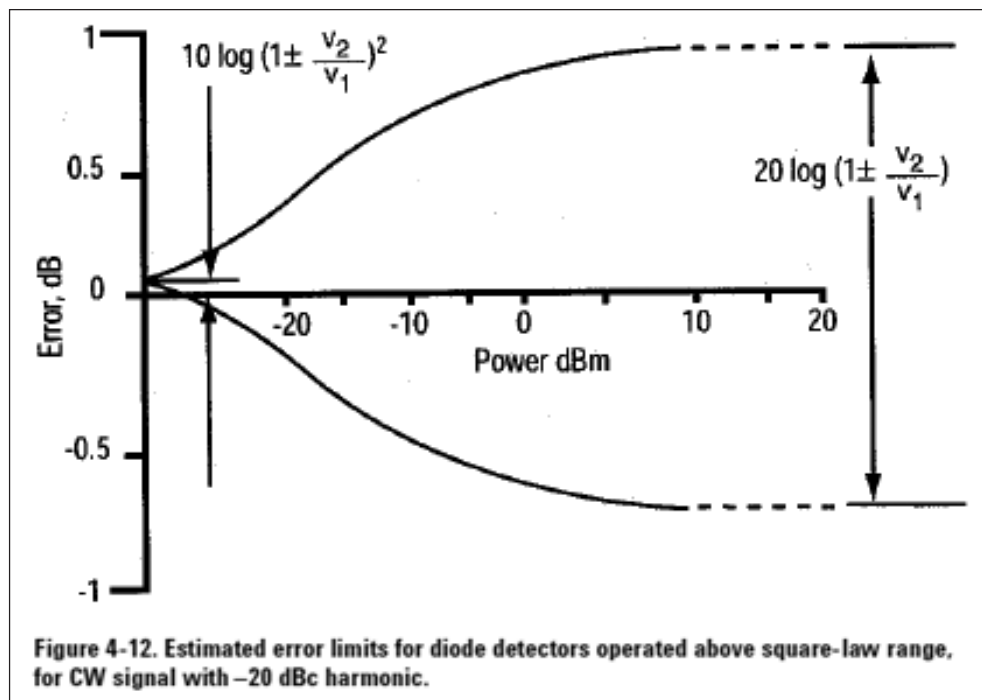


Figure 9 • Diode Sensor Error with harmonic signal present. Courtesy Keysight Technologies.

Microwave Converter Subsystems. From there he moved on to Harris Microwave Semiconductor/Samsung Microwave Semiconductor as an RF Test Engineer and gaining test experience in GaAs Semiconductor testing. He then moved to Remec Wireless to work on transceivers and subsystems test. Following that was a slew of contract positions building ATE test solutions. Besides lifetime self and scholastic education working toward electrical engineering and computer science/programming degrees, he also maintains a consulting business to develop test and other software products for web-based sale. Joseph's flagship product, AstroCalculator, was developed to aid his Astronomy hobby. RfCalculator is a tool for test development and elec-

tronics in general. He can be reached at: Sunshine Design Engineering Services, 23517 Carmena Rd, Ramona, CA 92065. 760-685-1126; AstroCalculator.com; SunshineDesign@cox.net.

This article was originally published at [rfcafe.com](http://rfcafe.com).

## Keysight Technologies (formerly Agilent) Application Notes:

4 Steps for Making Better Power Measurements App Note 64-4D 5965-8167E

Fundamentals of RF and Microwave Power Measurements (Part 1) 1449\_1\_5988-9213EN

Fundamentals of RF and Microwave Power Measurements (Part2) 1449\_2\_5988-9213EN

Fundamentals of RF and Microwave Power Measurements (Part 3) 1449\_3\_5988-9213EN

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Power Measurement Basics 5965-7919E

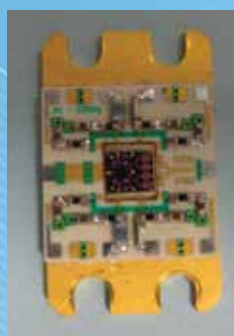
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AM004047SF-2H*	0.05-4.0	33	47	44	25, 90	0.5, 0.9	EAR99
AM006044SF-2H*	0.05-6.0	22	44	42	30, 60	0.4, 1.0	EAR99
AM206542TM-00!	2.0-6.5	25	42	20	28	0.96	3A001.b.2.a
AM010130TM-00!	0.05-13.0	13	33	15	28	0.24	3A001.b.2.b

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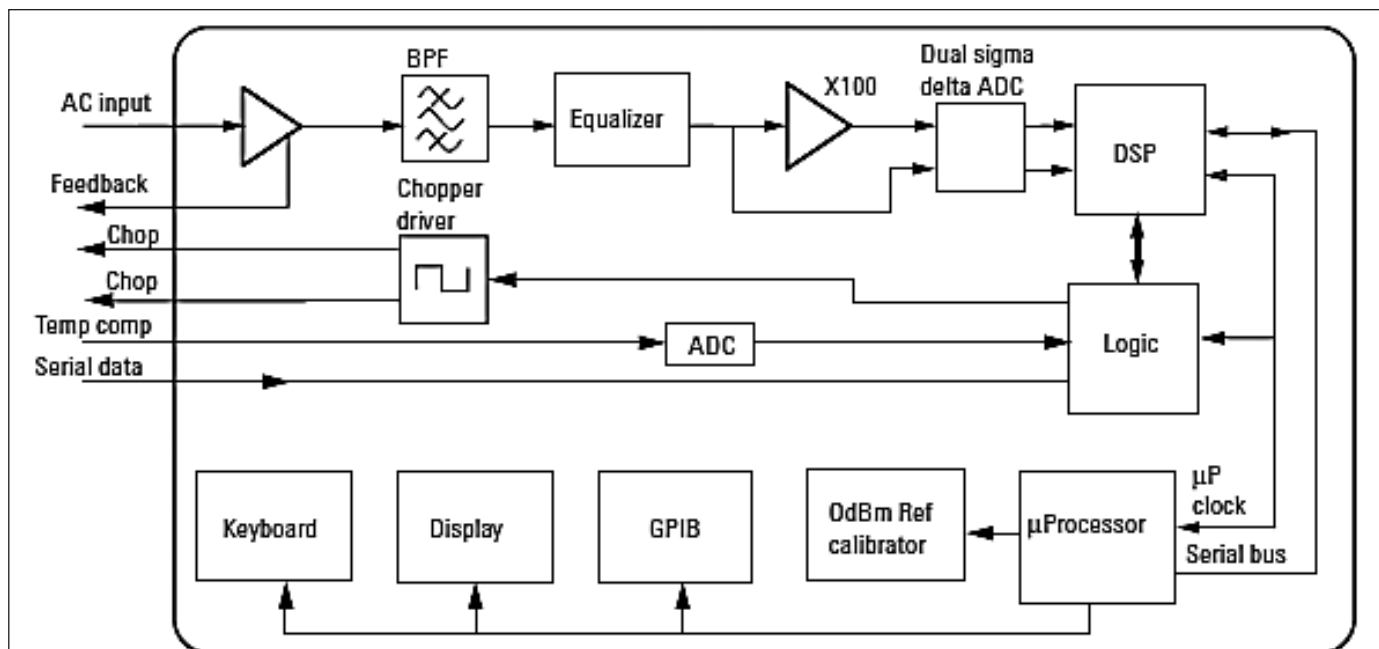
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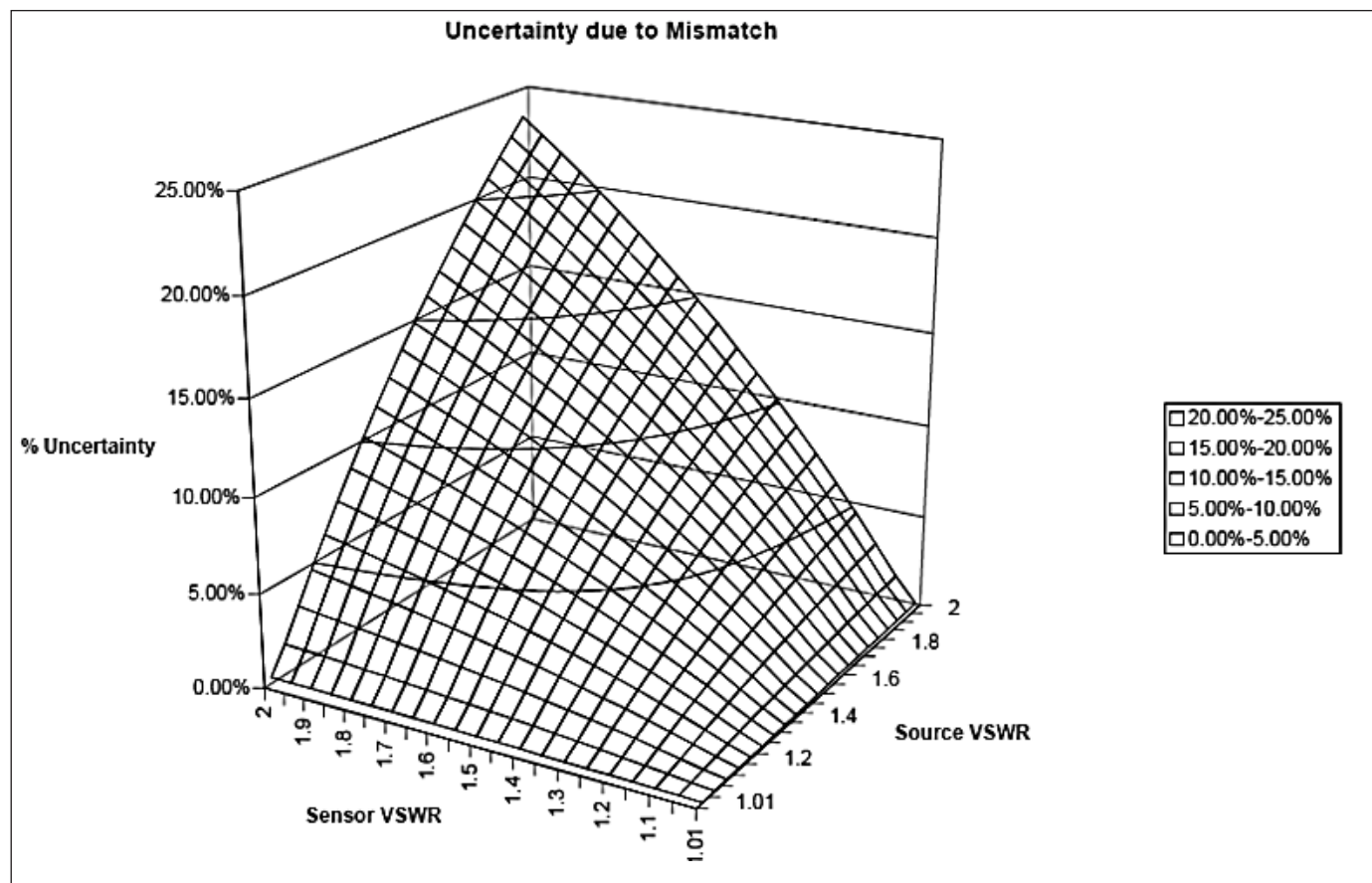


## ► Power Measurements



**Figure 4-11.** Simplified schematic of E4418B shows the transition to digital signal processing (DSP) architecture.

Figure 10 • DSP Power Measurement. Courtesy Keysight Technologies.



**Figure 11 • Power Mismatch Curves for Anritsu Detector.** Courtesy Anritsu Company.



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# Eliminate High-Speed ADC Flicker Noise with Chopper Upgrade

By Tommy Neu

ADCs are moving into more advanced CMOS process nodes.

Modern high-speed analog-to-digital converters (ADCs) are primarily moving into more advanced CMOS process nodes to increase sampling rates and reduce power consumption as much as possible. However, this move away from traditional, bipolar transistor-based ADC designs comes with a big drawback. The low frequency  $1/f$  noise or flicker noise of CMOS transistors is significantly worse compared to that of bipolar transistors.

The  $1/f$  noise corner of bipolar transistors is around 100 kHz, while for CMOS transistors it ranges anywhere from ~10 MHz to ~1 GHz, depending on the process geometry. The cause of flicker noise is complex. A simplified model is based on the trap density in the oxide-silicon surface. Electrons get into the traps, but get released at a lower frequency. If the trap density is reduced for the same amount of carriers, flicker noise will be reduced as well, because the probability of carriers getting into the traps reduces. Therefore, the  $1/f$  noise corner moves lower in frequency. The amount of carriers stays constant, if the width-to-length (W/L) ratio of the transistor stays constant. Alternatively, trap density is reduced by increasing the area. As such, a lower  $1/f$  noise corner requires an area increase (larger transistor size) with the same W/L ratio.

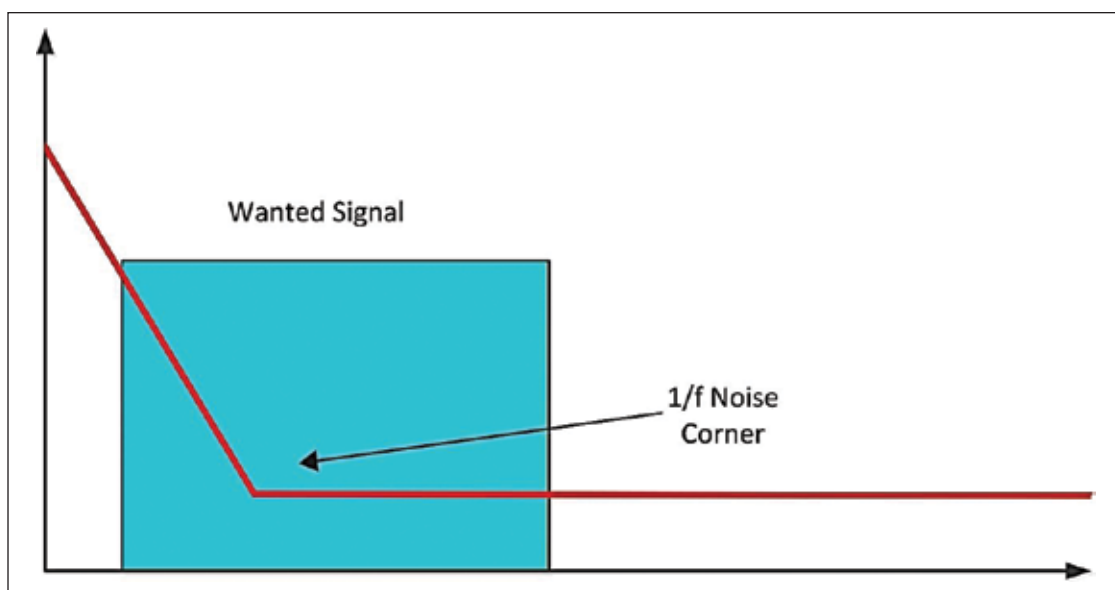
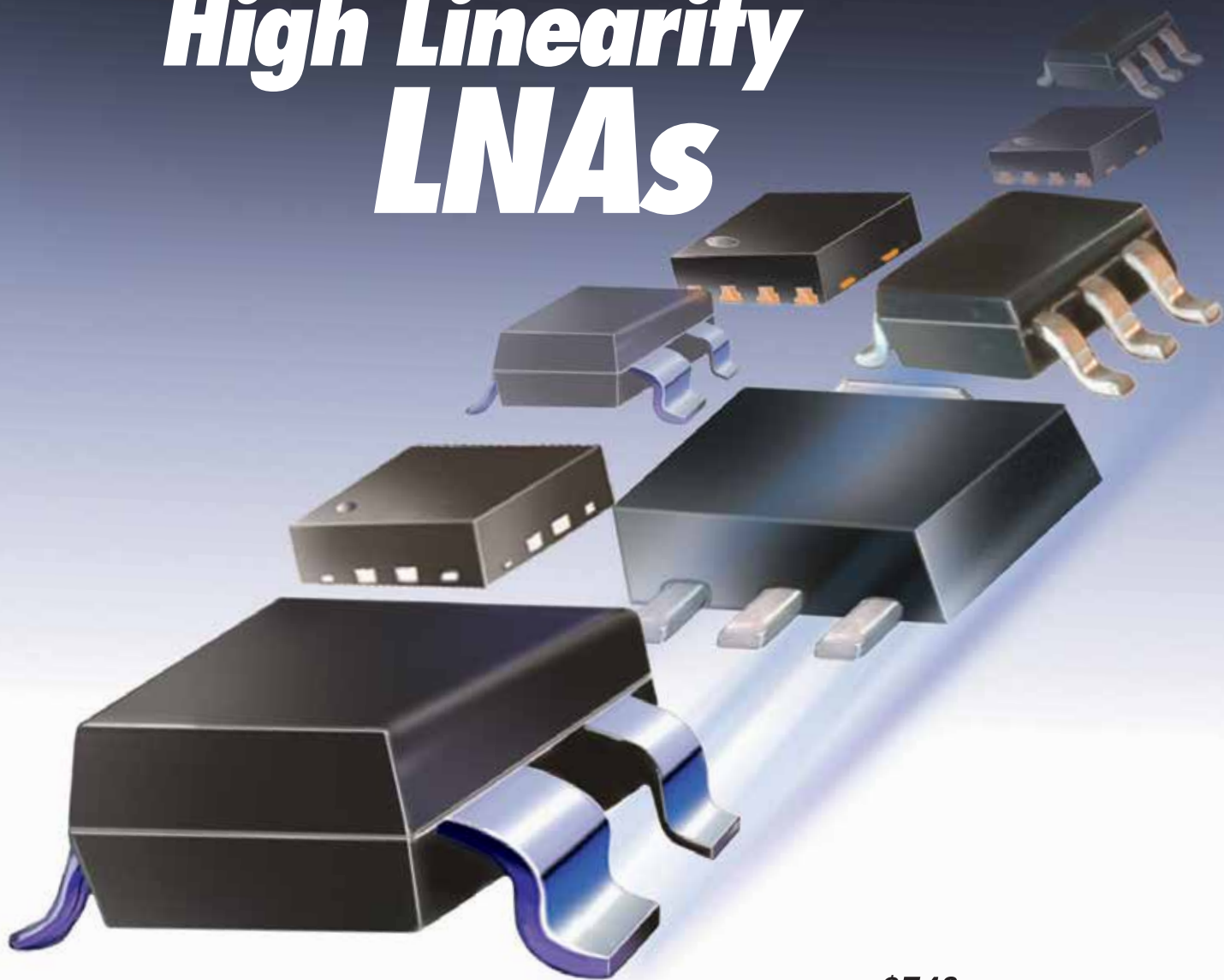


Figure 1 • Wanted signal in the presence of  $1/f$  noise.



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PMA-5455+	50-6000	14.0	0.8	33	19	40	1.49
PMA-5451+	50-6000	13.7	0.8	31	17	30	1.49
PMA2-252LN+	1500-2500	15-19	0.8	30	18	25-55 (3V) 37-80 (4V)	2.87
PMA-545G3+	700-1000	31.3	0.9	33	22	158	4.95
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PMA-5453+	50-6000	14.3	0.7	37	20	60	1.49
PSA-5453+	50-4000	14.7	1.0	37	19	60	1.49
PMA-5456+	50-6000	14.4	0.8	36	22	60	1.49
PMA-545+	50-6000	14.2	0.8	36	20	80	1.49
PSA-545+	50-4000	14.9	1.0	36	20	80	1.49
PMA-545G1+	400-2200	31.3	1.0	34	22	158	4.95
PMA-545G2+	1100-1600	30.4	1.0	34	22	158	4.95
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# ► Flicker Noise

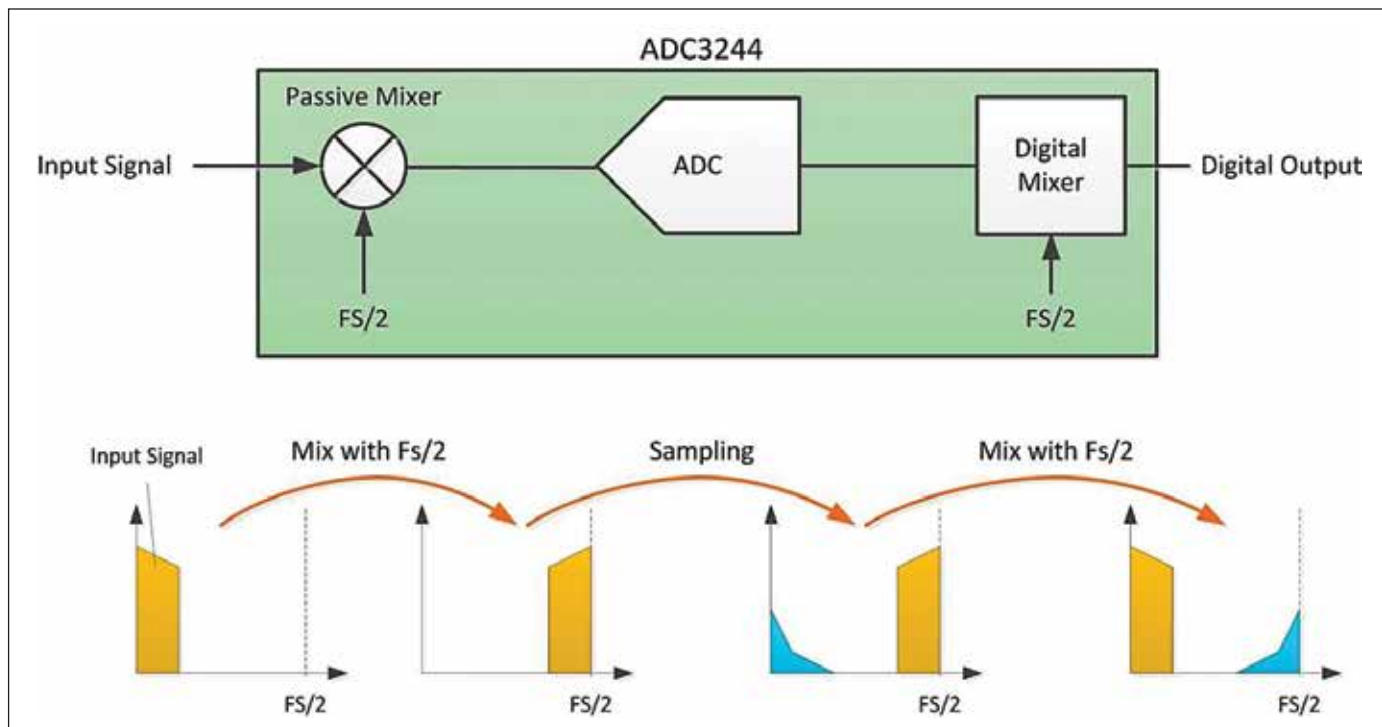


Figure 2 • Chopper implementation in a high-speed data converter.

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## Higher Noise Corner

Unfortunately, moving into smaller process geometries goes in the opposite direction, resulting in a higher  $1/f$  noise corner. This severely impacts the performance of systems utilizing information contained in the area of close-in phase noise around DC. For example, motor controllers of high-power and precision motors use frequencies and its harmonics of only a few hundred kilohertz (kHz). Zero intermediate frequency (OIF) complex receivers may employ carriers with only tens of kHz offset. Thus, the  $1/f$  noise performance of the high-speed ADC is crucial for these applications. As a result, modern high-speed CMOS ADCs, such as the 14-bit, 125-MSPS ADC3244, get outfitted with design enhancements like an internal analog chopper front-end, which combines the low-power CMOS ADC with very good  $1/f$  noise performance.

## Chopper Front-End Circuit Implementation

Chopper circuits have been used for more than 30 years. Nowadays a 'chopper' refers to many different switching circuits. Originally, the chopper was used to convert a fixed DC input to a variable DC output voltage. The idea of using a chopper circuit with CMOS ADCs is based on the same concept where the unwanted  $1/f$  noise is transferred to a different frequency, as far away as possible from the wanted signal itself (typically to the Nyquist limit) (**Figure 1**). The ADC in our example uses an analog, passive mixer prior to the actual



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Frequency: DC to 50 GHz  
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Frequency: DC to 18 GHz  
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### Type "N" Features:

Frequency: DC to 11 & 18 GHz  
Ruggedized construction for repeatability & reliability, Captivated Center Contact, Low VSWR & Insertion loss, Cable Connectors for various semi-rigid & flexible cables. Receptacle configurations including threaded & flanged.





### 2.92mm Features:

Frequency: DC to 40 GHz  
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Ruggedized construction for repeatability & reliability, Phase matched adapters, Captivated Center Contact, Low VSWR & insertion loss, Cable Connectors for various semi-rigid & flexible cables, Receptacle configurations including threaded, PCB & flanged.



### 3.5mm Features:

Frequency: DC to 34 GHz  
Mechanically compatible with SMA & 2.92mm Series,  
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### SMA Features:

Frequency: DC to 18 & 26.5 GHz  
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### TNC(A) Features:

Frequency Range: DC to 18 GHz  
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### VSWR to Return Loss Conversion Chart

VSWR	RL (dB)	VSWR	RL (dB)
1.010	46.064	1.176	21.843
1.020	40.086	1.178	21.753
1.030	36.607	1.180	21.664
1.040	34.151	1.182	21.576
1.050	32.256	1.184	21.489
1.060	30.714	1.186	21.403
1.070	29.417	1.188	21.318
1.080	28.299	1.190	21.234
1.090	27.318	1.192	21.151
1.100	26.444	1.194	21.069
1.110	25.658	1.196	20.988
1.112	25.510	1.198	20.907
1.114	25.364	1.200	20.828
1.116	25.221	1.210	20.443
1.118	25.081	1.220	20.079
1.120	24.943	1.230	19.732
1.122	24.808	1.240	19.401
1.124	24.675	1.250	19.085
1.126	24.544	1.260	18.783
1.128	24.415	1.270	18.493
1.130	24.289	1.280	18.216
1.132	24.164	1.290	17.949
1.134	24.042	1.300	17.692
1.136	23.921	1.310	17.445
1.138	23.803	1.320	17.207
1.140	23.686	1.330	16.977
1.142	23.571	1.340	16.755
1.144	23.457	1.350	16.540
1.146	23.346	1.360	16.322
1.148	23.235	1.370	16.131
1.150	23.127	1.380	15.936
1.152	23.020	1.390	15.747
1.154	22.914	1.400	15.563
1.156	22.810	1.410	15.385
1.158	22.708	1.420	15.211
1.160	22.607	1.430	15.043
1.162	22.507	1.440	14.879
1.164	22.408	1.450	14.719
1.166	22.311	1.460	14.564
1.168	22.215	1.470	14.412
1.170	22.120	1.480	14.264
1.172	22.027	1.490	14.120
1.174	21.934	1.500	13.979



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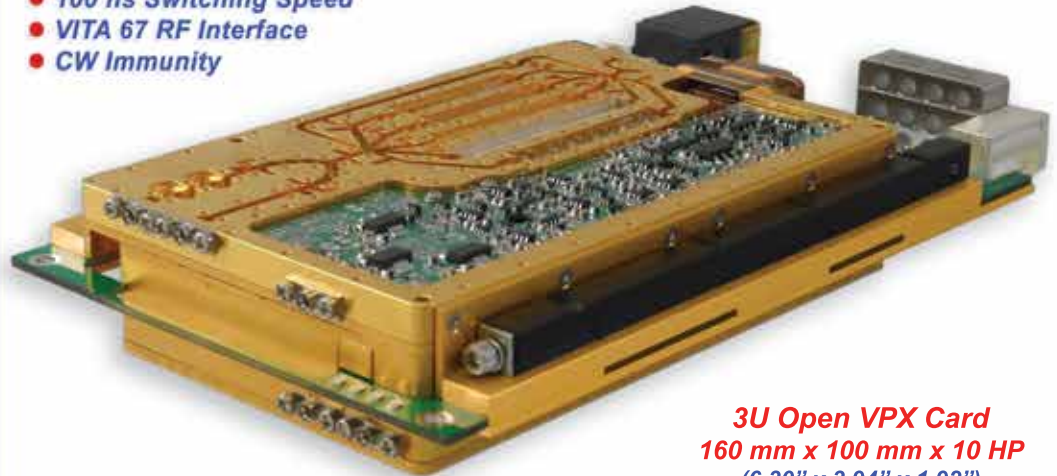
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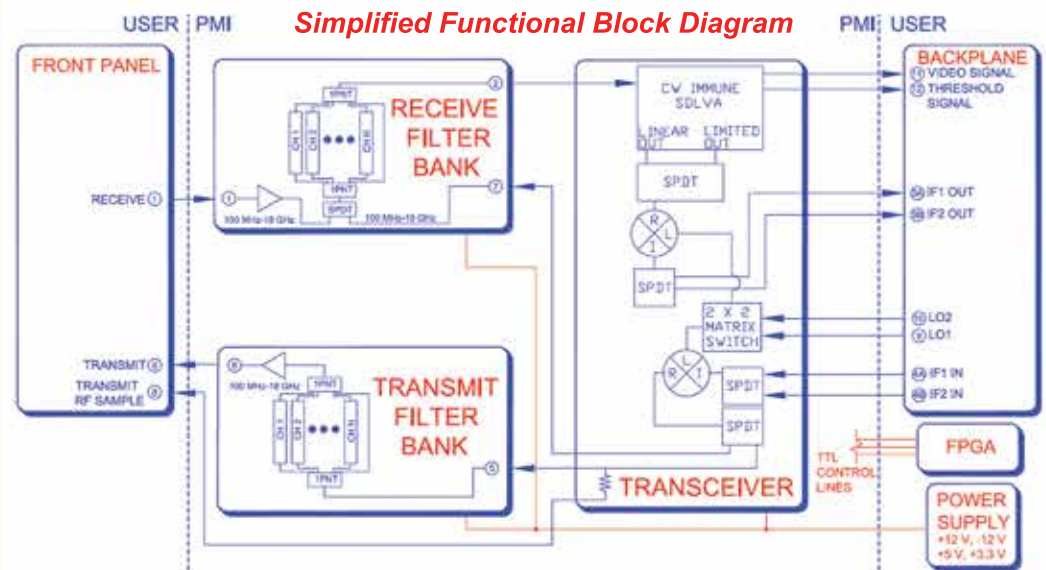
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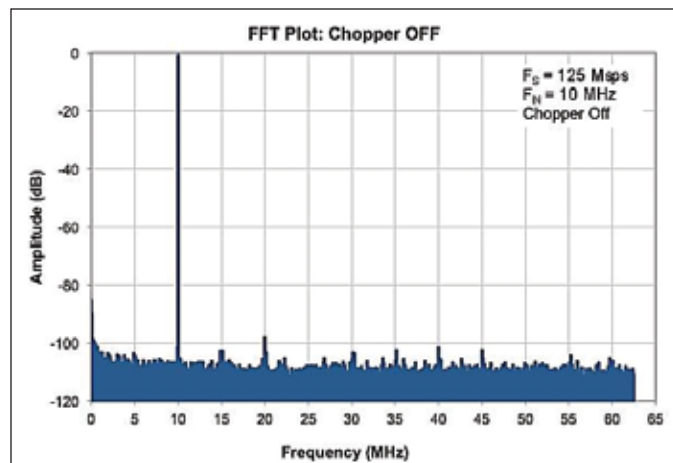


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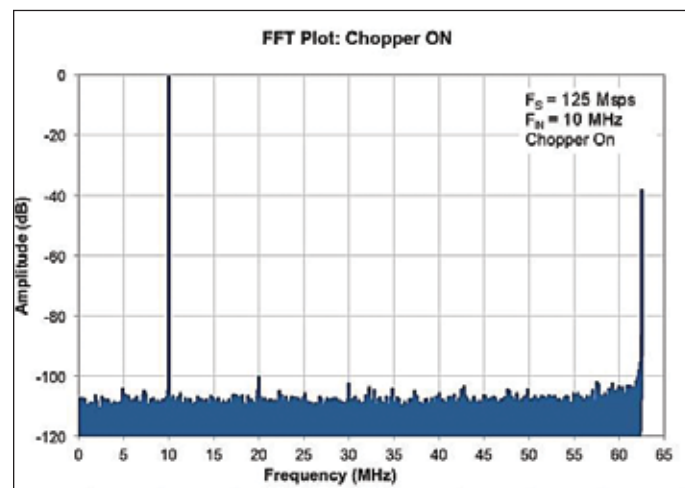
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## ► Flicker Noise



(a)



(b)

**Figure 3 • High-speed CMOS ADC compared with off (a)/on (b) chopper front-ends.**

ADC-sampling network to accomplish this purpose. High-fidelity audio converters use the same concept, but employ a high-resolution (typically 24-bit) delta-sigma ADC, versus a pipeline ADC.

The low-frequency input signal first gets shifted to  $F_s/2$  using an on-chip passive mixer that operates at half the ADC clock frequency. Next the input signal gets sampled, as with any other data converter, except the low-frequency input signal now resides at  $F_s/2$ . In the sampling process, the unwanted  $1/f$  noise of the ADC-sampling network gets added to the spectrum of the input signal. This operation is followed by a mixing block in the digital domain. The output spectrum is mixed once more with  $F_s/2$ , which now shifts the original wanted signal back near DC, and the  $1/f$  noise near  $F_s/2$ . As a result of this exercise, the input signal is where it is expected and unaffected by the unwanted  $1/f$  noise, which is placed on the opposite end of the Nyquist zone (**Figure 2**). At this stage, any  $1/f$  noise contribu-





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tion from the analog front-end signal chain is already combined with the wanted input signal and does not get shifted to  $F_s/2$ .

## Measurement Comparison of Chopper Front-End

A comparison of the fast Fourier transform (FFT) output spectrum of the ADC in our example with the internal chopper enabled and disabled is illustrated in **Figure 3**. The low frequency  $1/f$  noise is clearly visible when the chopper is disabled. Once the chopper is enabled, the flicker noise around DC is shifted to  $F_s/2$ , while the input signal remains untouched at 10 MHz. However, the FFT spectrum also reveals an additional byproduct of the chopper circuit. Besides shifting the input spectrum, the passive mixer generates a tone at  $F_s/2$ , also known as the local oscillator (LO) feedthrough, since the LO input is coupled into the output spectrum. However, when digital post-processing filters are implemented on the data, a likely scenario when analyzing DC and near-DC information, the transposed  $1/f$  noise and LO feedthrough will be rejected.

The low-frequency improvement from the chopper circuit becomes even more obvious when overlaying the two FFT plots directly on top of each other and changing frequency axis to a log scale (**Figure 4**). This reveals the ADC's  $1/f$  noise corner of about 10 MHz, and clearly shows the noise floor improvement between 3 kHz and 10 MHz.

## Disadvantages of Employing a Chopper Front-End

The primary drawback for which a system engineer needs to be cognizant is the LO feedthrough when using a high-speed ADC with a chopper input. A large tone at  $F_s/2$  can potentially limit an automatic gain control (AGC) loop when using a large amount of front-end gain for capturing a very small amplitude input signal. In that application, the LO feedthrough needs to be removed with a digital filter prior to the AGC function.

Since the mixer is passive, the additional power consumption from the chopper is very minimal and no addi-

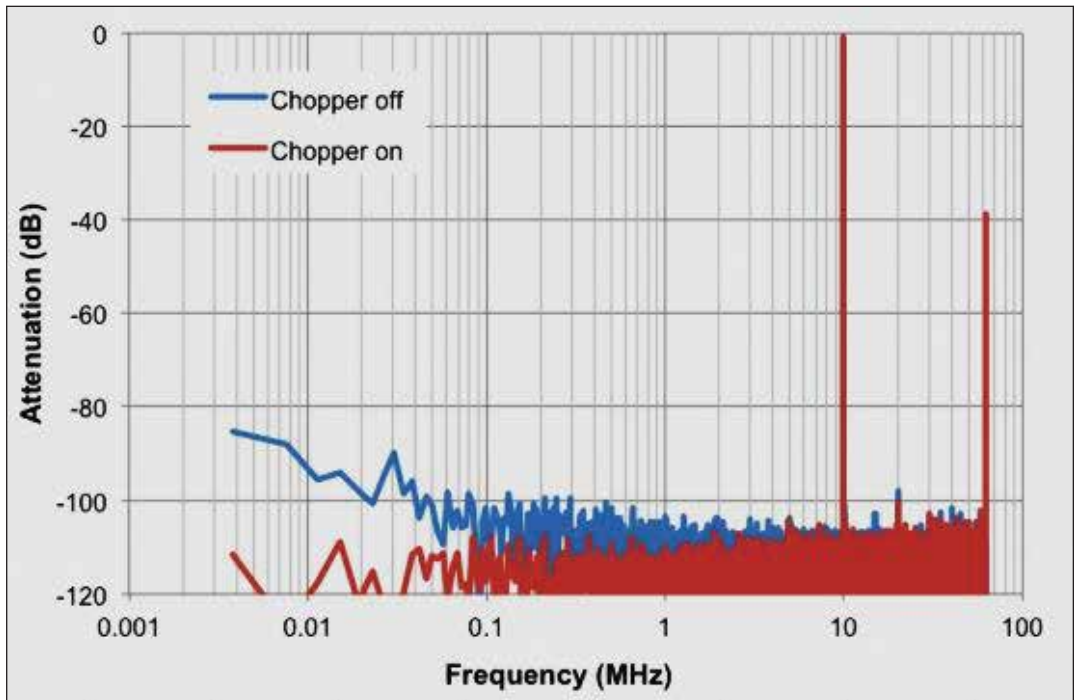


Figure 4. Low-frequency noise comparison between a chopper on and off.

tional signal-to-noise ratio (SNR) or spurious free dynamic range (SFDR) degradation should be expected.

## Summary

As modern high-speed data converters are taking advantage of smaller process nodes for lower power consumption and faster clocking rates, ADC design engineers are implementing circuit enhancements to improve the few disadvantages associated with finer CMOS process geometries. A chopper front-end, as implemented in the ADC3244 for example, is a great way to drastically improve the unwanted flicker noise for applications where information of interest is in the very low frequency range.

## References

1. Razavi, Behzad. Design of Analog CMOS Integrated Circuits, ISBN 0-07-238032-2, McGraw Hill
2. Download the ADC3244 datasheet
3. Here's more information about TI's high-speed data converters
4. TI E2E™ high-speed data converter forum

## About the Author

Thomas Neu is a systems engineer for TI's high-speed data converters group where he provides applications support. Thomas received his MSEE from Johns Hopkins University, Baltimore, Maryland. He can be reached at [ti\\_thomasneu@list.ti.com](mailto:ti_thomasneu@list.ti.com).





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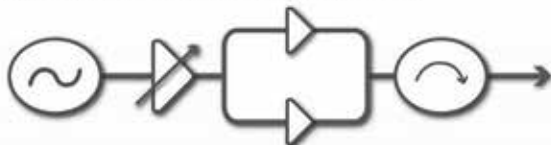


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# MMIC Broadband Feedback Amplifiers

By John E. Penn

## Abstract

A simple design approach for broadband gain stages where noise figure and power efficiency are not a primary driver.

A feedback amplifier is a simple design approach for broadband gain stages where noise figure and power efficiency are not a primary driver. Four variations of a simple one stage feedback amplifier were designed using a 0.13  $\mu\text{m}$  GaAs Pseudomorphic High Electron Mobility Transistor (PHEMT) process from TriQuint Semiconductor. The design and fabrication of these circuits was performed during the Fall 2013 Johns Hopkins University Monolithic Microwave Integrated Circuit (MMIC) Design Course, taught by the author. In these very compact amplifier designs, an external bias was required for the drain supply. A modification to the feedback designs to include a broadband DC supply using a second PHEMT as an active load is also presented, both simulations and layouts.

## Resistive Feedback Broadband Amplifier

One way to achieve broadband gain with an inverting transistor, such as a GaAs MESFET or PHEMT, is to use resistive feedback to achieve octaves or even a decade of bandwidth. Figure 1 shows the simplest schematic of the feedback amplifier with the two key components that can be tuned for the desired return loss, stability, and gain characteristics; the value of the feedback resistor, and size of the transistor. In this case, a MMIC PHEMT can be varied in total periphery (size = width of gate fingers \* number of gate fingers). This simple arrangement ignores the DC bias, but it is a good starting point to simulate the small signal performance without worrying about bias yet.

If you only have a non-linear model, then it is a good time to add a large capacitor to DC block the drain bias from the gate bias in the feedback path. A 4 pF capacitor was added to the resistive feedback path for these designs. Two basic feedback amplifier variations were created, one used a standard 6x50 $\mu\text{m}$  PHEMT, and the other a smaller 4x38 $\mu\text{m}$  PHEMT. For this process, a large shunt resistor on the gate will provide part of a

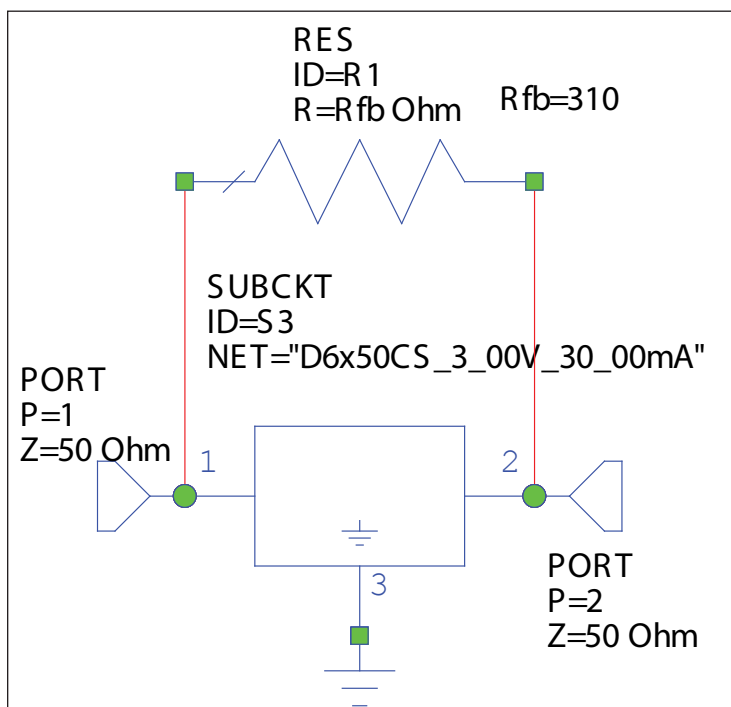








Figure 1 • Simplest Schematic of the Feedback Amplifier.



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## ► Feedback Amplifier

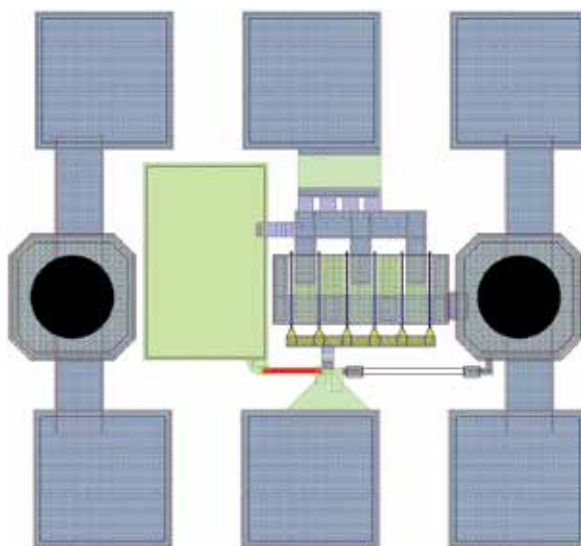


Figure 2 • Compact Layout Plot of 6 x 50um PHEMT Feedback Amplifier (0.5 mm x 0.4 mm).

broadband bias with VGS=0V, while the drain bias was expected to be an external bias tee for these compact layouts; about the size of a PHEMT layout for probe testing (see Figure 2).

### Symmetric Layout of Feedback Broadband Amplifier

Creating symmetry in microwave circuit layout is typically desirable. A new design was laid out with the RC feedback path split into two dual parallel paths which forced a longer connection to ground.

This additional source

inductance was reduced by using two parallel substrate vias (Figure 3). So while the single RC feedback versus the symmetric dual parallel RC feedback design is not quite an “apples to apples” comparison, they both resulted in broadband stable amplifier designs.

### Measured Small Signal Performance

Both the symmetric and single RC feedback amplifiers resulted in nearly identical performance. Figure 4 shows the measured s-parameters and noise figure (green) of the 6x50um PHEMT based amplifiers, resulting in a gain of 16 dB at 1 GHz that gradually drops to 8 dB at 15 GHz. The noise figure was about 1.5 dB from 1 to 6 GHz, gradually rising to 2 dB at 15 GHz. Another pair of the single and symmetric RC feedback amplifier designs was created using a PHEMT of half the size, e.g. 4x38um, which consumes half the DC power of the 6x50um design(s). Performance was similar, though the noise figure was

slightly higher and the gain slope falloff is more gradual as shown in Figure 5.

For the 4x38um amplifier, the gain was measured as 14 dB at 1 GHz gradually dropping to 9.5 dB at 15 GHz. The noise figure was about 1.7 dB from 1 to 6 GHz, gradually rising to 2.1 dB at 15 GHz. These measured results agreed well with the original Microwave Office (MWO) analytical simulations, as well as EM simulations using Axiem, Momentum, and Sonnet. Figures 6 and 7 compare the gain (magenta) and noise figure (blue) mea-

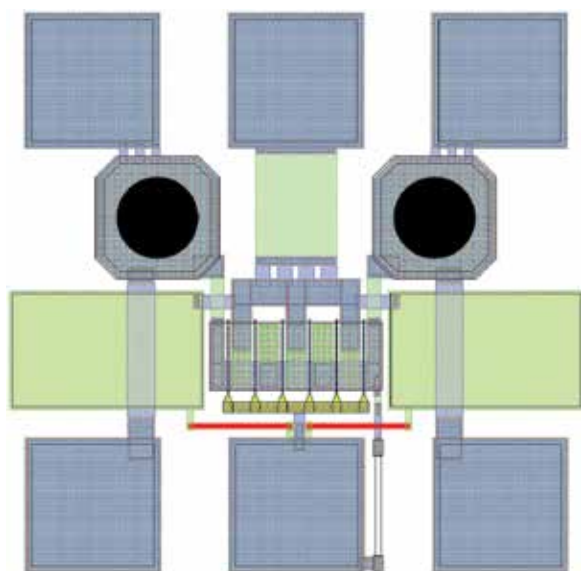


Figure 3 • Compact Layout Plot of 6 x 50um PHEMT Symmetric “Dual” Feedback Amplifier.





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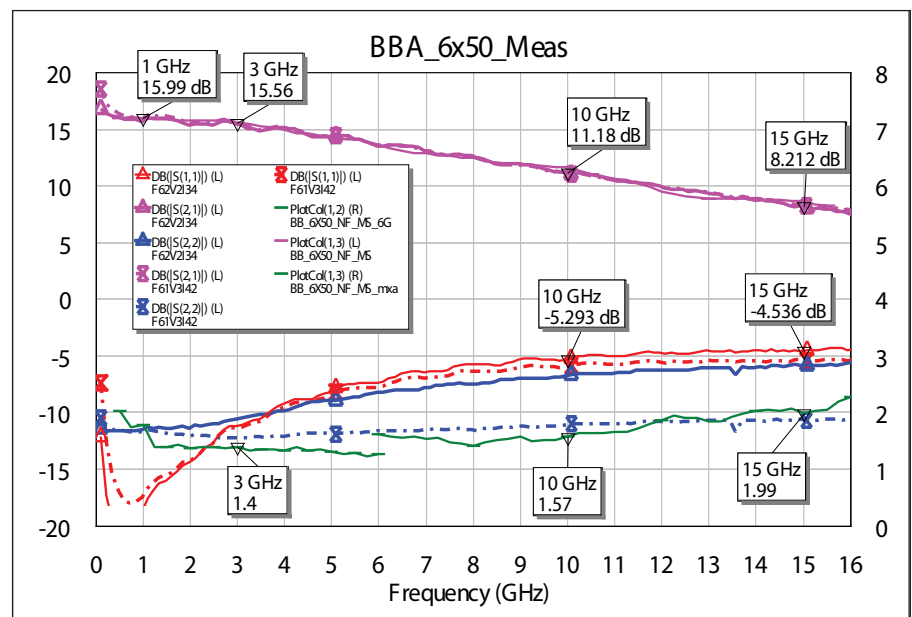
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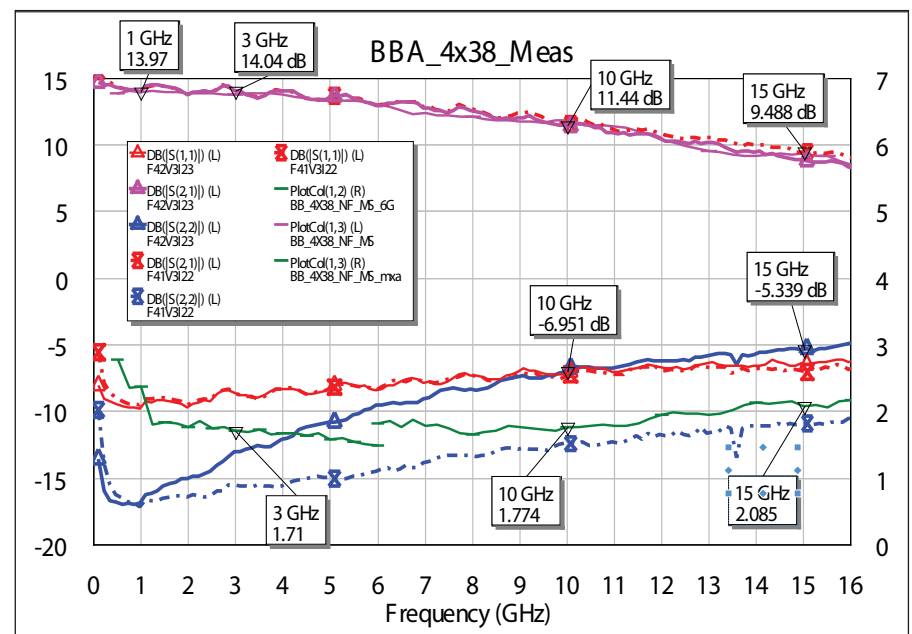



**Figure 4 • Measured Small S-Parameters for Single (1) and Symmetric (2) 6 x 50um Feedback Amplifiers.**

measurements (solid) versus simulations (dotted) for the 4x38um and 6x50um feedback amplifiers. The “break” in the noise figure measurement at 6 GHz is due to using two different instruments for the noise figure measurements, one up to 6 GHz, and the other starting at 6 GHz.

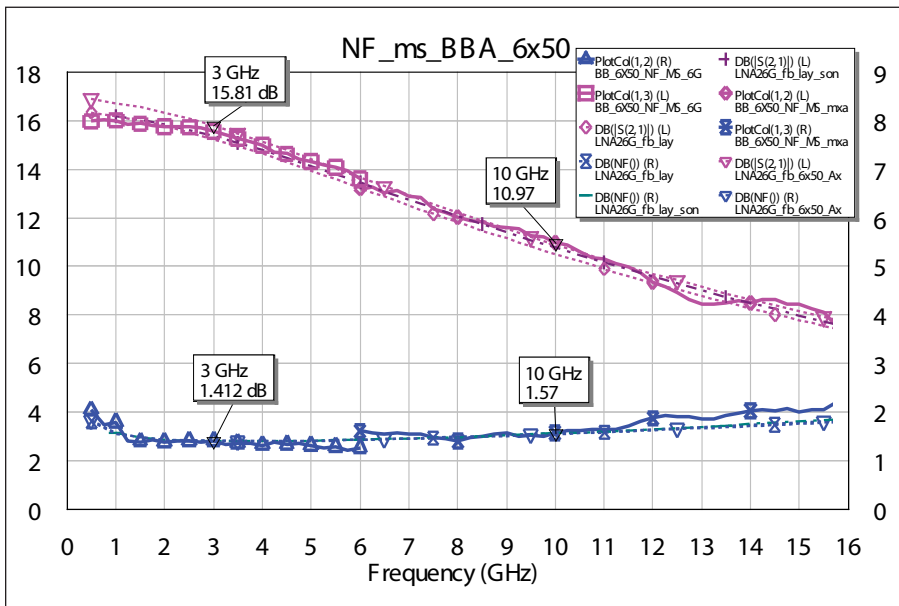
### Broadband DC Supply Using an Active Load (PHEMT)

Biasing of the original broadband feedback amplifiers assumed that the drain DC bias was provided through an external bias tee. The gate bias for these devices was already broadband, supplied by a large shunt resistor (2K) to ground, since these PHEMTs perform well with  $V_{GS}=0V$ . So how do you add a broadband biasing circuit? One solution that keeps the layout compact and provides a bias that is tolerant to variations in processing, is to use a

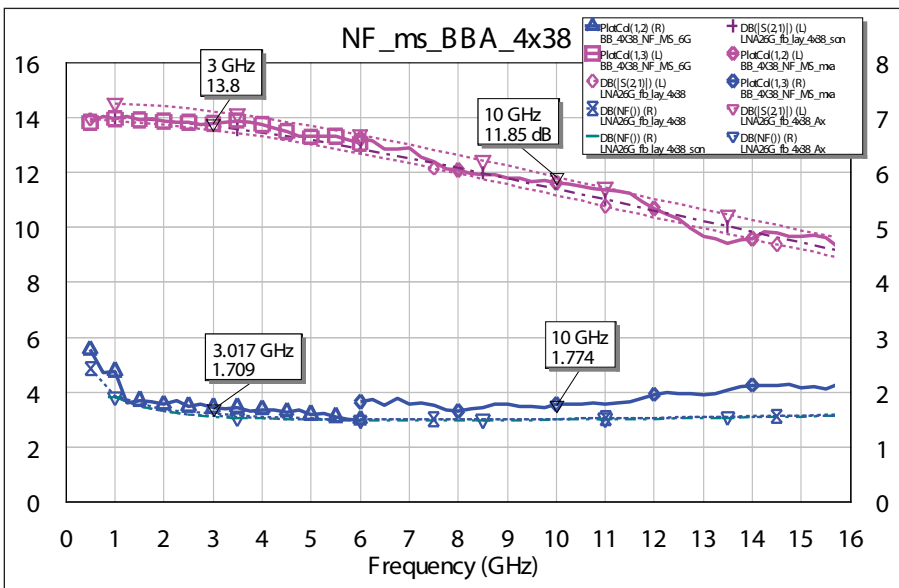


**Figure 5 • Measured Small S-Parameters for Single (1) and Symmetric (2) 4 x 38um Feedback Amplifiers.**





**Figure 6 • Measured (solid) versus Simulated (dotted)--Gain (Red) and NF (Blue) of 6 x 50um Feedback Amplifier.**



**Figure 7 • Measured (solid) versus Simulated (dotted)--Gain (Red) and NF (Blue) of 4 x 38um Feedback Amplifier.**

second PHEMT as an active load to bias the amplifier. The drain voltage can be supplied and split across two equal sized PHEMTs.

Figure 8 shows a simple schematic of the feedback circuit which now has an active load, and two additional capacitors. At the input pad for the drain voltage (Vdd), a shunt cap (4 pf) to ground isolates the RF match from the external DC connection. A second capacitor (4 pf) is used to DC block the drain voltage of the amplifier from the RF output. The size of these capacitors is a tradeoff of size versus the low frequency rolloff of the gain. Also, the active load could be changed to be smaller or larger than the PHEMT used for the amplification. A smaller active load reduces the current consumption and lowers the

noise figure, but makes an unequal split of the Vdd supply voltage, reducing the voltage swing or output power of the amplifier. Conversely, a larger active load increases the current consumption but increases the proportion of Vdd split between the two PHEMTs, thus improving efficiency but with an increase of noise figure. Simulations were performed using an active load of 60% and 150% of the nominal 4x38um or 6x50um size used in the feedback amplifier with little change in the small signal performance, but with a small effect on noise figure.

For example, active loads of 6x30um, 6x50um, and 6x75um, with the 6x50um feedback amplifier resulted in a DC bias ranging from 2.1V at 20 mA, to 3V at 27mA, to 3.7V at 33mA with a 6V Vdd supply. The gain did not change much, but the noise figure at 3 GHz simulated over a range of 1.8 dB, 2.0 dB, and 2.3 dB over these same active loads as the drain current increased. Note that the active load provides a small compact broadband DC bias, but does increase the noise figure from the 1.4 dB in the original designs that required an external drain DC bias.

The use of an active load to bias the broadband feedback amplifier results in a very compact layout, though there is some increase in noise figure, and a rolloff of low frequency gain below 1 GHz, plus a slight drop in gain across the whole band. Figure 9 shows the simulated s-parameters of the broadband DC supplied feedback amplifier (solid) versus the original design (dotted) using an external bias tee. Figure 10 shows the compact

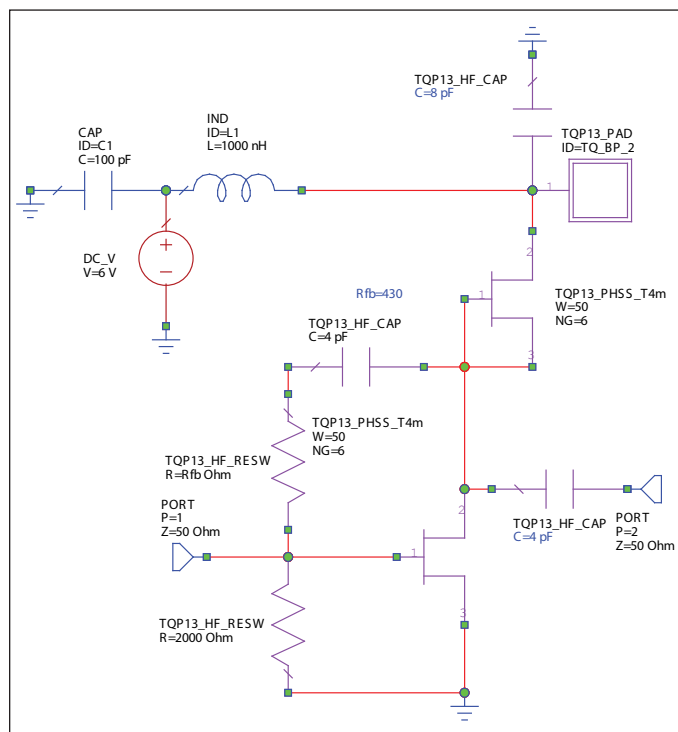
layout with the addition of a Vdd pad (nominally 6V), and the same ground-signal-ground (GSG) probe test RF input and output. Another advantage of the active load is that using another PHEMT for the DC bias makes the amplifier design robust to process variation.

## Summary

Feedback amplifiers can provide very broadband gain with moderate noise figure and efficiency, in a simple compact layout. One simple approach to supplying DC bias over a broadband is to use a PHEMT active load. This approach can also be very small but will have some negative impact on the noise figure and efficiency. For

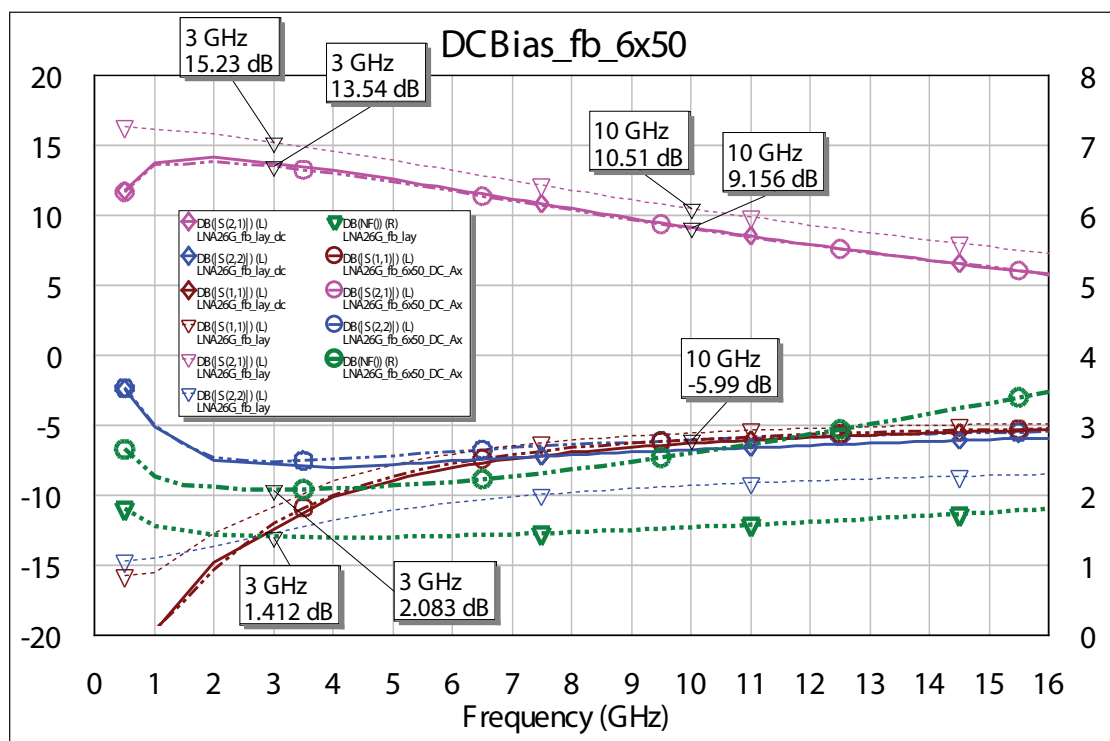


# Feedback Amplifier

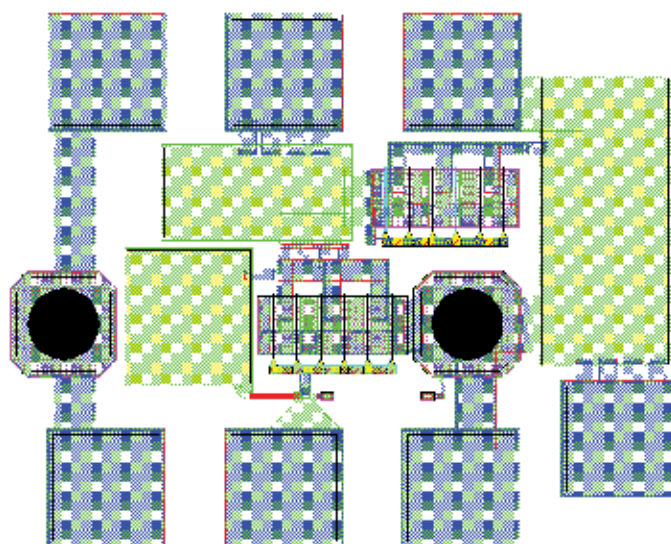


**Figure 8 • Schematic of Broadband Feedback Amplifier with Active Load for DC Bias (Vdd).**

any application requiring a simple broadband gain block where noise figure and efficiency are not primary drivers, feedback is a good approach for the design tradeoff of bandwidth, gain, return loss, stability, noise figure, and efficiency.



**Figure 9 • Simulation of Active Load 6 x 50um/6 x 50um PHEMT Feedback Amplifier.**



**Figure 10 • Compact Layout Plot of Active Load 6 x 50um/6 x 50um PHEMT Feedback Amplifier.**

## Acknowledgements

I would like to acknowledge the support of TriQuint Semiconductor for fabricating designs for JHU students since 1989. Software support for these JHU designs is provided by Applied Wave Research/National Instruments (AWR/NI), Keysight Technologies, and Sonnet Software.

## About the Author

John E. Penn received a B.E.E. from the Georgia Institute of Technology in 1980, an M.S. (EE) from Johns Hopkins University (JHU) in 1982, and a second M.S. (CS) from JHU in 1988. Since 1989, he has been a part-time professor at Johns Hopkins University where he teaches RF & Microwaves I & II, MMIC Design, and RFIC Design. Email: [propenn@gmail.com](mailto:propenn@gmail.com).



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## Product Highlights



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[richardsonrfpd.com](http://richardsonrfpd.com)



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Boonton  
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## Product Highlights

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Keysight Technologies introduced three low-frequency options for its E4982A LCR meter. With these new options, the E4982A is well suited for RF inductor, coil and EMI filter manufacturers that are required to perform impedance testing at various frequencies. The options cover the 1 MHz to 300 MHz (Opt. 030), 500 MHz (Opt. 050) and 1 GHz (Opt. 100) frequency ranges.

Keysight Technologies  
keysight.com



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LadyBug now offers an SMA female connector option on its LB5918A high-accuracy, true RMS 1 MHz to 18 GHz power sensor. The SMA connector (option OSF) is suitable for many applications and is ideal for customers that require an RF cable connection to the sensor. Combined with LadyBug's No Zero Just Measure, patented no-zero no-cal technology, the new connector adds even more flexibility for users.

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S <sub>11</sub> (dB)	Input Match	-15	-15	-10	-8
S <sub>22</sub> (dB)	Output Match	-12	-10	-8	-8
S <sub>12</sub> (dB)	Reverse Isolation	-60	-60	-50	-50
NF (dB)	Noise Figure	9	9	11	14

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## ► Product Highlights



### Frequency Extender Module

OML introduced the Low Power VNA frequency extension series; VxxVNA2-LP. Currently available in waveguide bands from 50 GHz to 110 GHz, this model offers a max output of 0 dBm, typical raw directivity of 37 dB and typical dynamic range of 110 dB. Contact OML for more details.

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## Product Highlights



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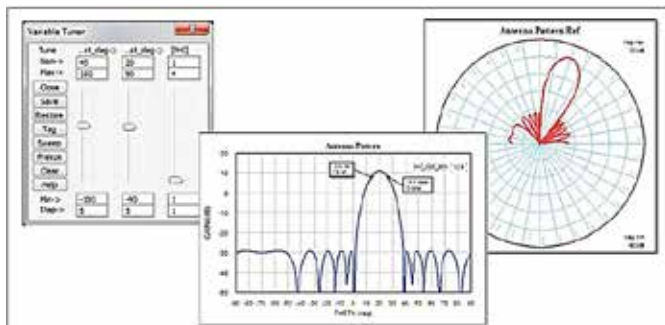
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## Product Highlights



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# Product Showcase



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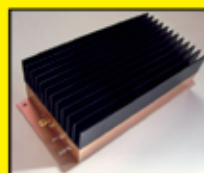
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## ► Product Highlights



### Synthesizer

The popular QuickSyn Lite frequency synthesizers are now extended to millimeter-wave. The new synthesizer modules employ the same revolutionary phase-refining technology that all QuickSyn products use to enable fast switching speed, low phase noise, compact

size, and low cost. They are available in three bands—27 to 40 GHz, 50 to 67 GHz, and 76 to 82 GHz—and are designed to supply medium power output.

**NI Microwave Components**  
[ni-microwavecomponents.com](http://ni-microwavecomponents.com)

## BETTER PRODUCTS / BETTER COMMUNICATIONS

### MECA's New mmWAVE Products

MECA Electronics (Microwave Equipment & Components of America) has served the RF & Microwave industry with equipment and passive components since 1961. Now with expanded capabilities up to 40 GHz including Power Dividers, Couplers, Attenuators, Terminations and Isolators. MECA is a privately held ISO9001:2008 registered global designer and manufacturer for the communications industry with products manufactured in the USA.

A collage of various microwave components from MECA Electronics, including power dividers, couplers, attenuators, and terminations, arranged on a blue and white background. The components are shown in various sizes and configurations, some with SMA connectors and others with different types of connectors. The MECA logo is visible in the bottom left corner, and a QR code is in the bottom right corner.

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### Isolators

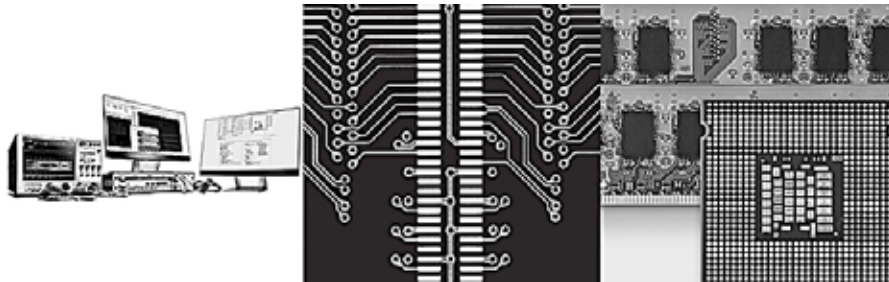
Isolators optimized for excellent performance across Microwave and Millimeter-wave (K, Ku & Ka bands) covering 18.0 - 26.5GHz, 27.0 - 31.0GHz & 26.5 - 40.0GHz in 2.92 mm connectors. Also available are Attenuators, Power Dividers, Terminations & Couplers. Their rugged construction makes them ideal for Telecommunications, Aerospace & Test Equipment systems. Made in the USA – 36 month warranty.

**MECA Electronics**  
[e-meca.com](http://e-meca.com)

Get info at [www.HFELink.com](http://www.HFELink.com)



## ► Product Highlights



### DDR4 App Note

This new application note covers both the challenges and the solutions for DDR4 compliance testing, including specific solution examples. Included are insights into test requirements, accurate testing techniques, and JEDEC standards specifications.

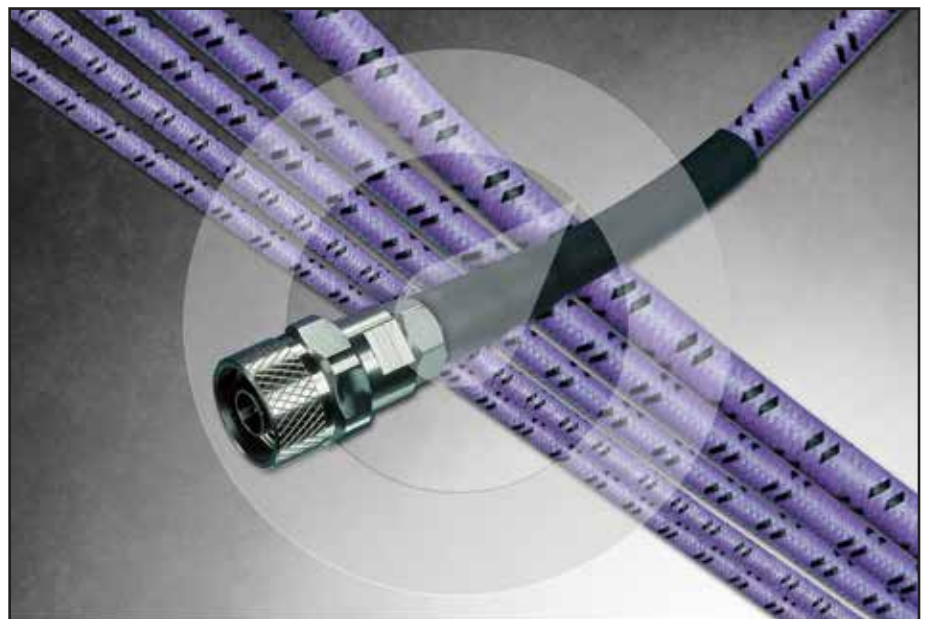
Keysight Technologies  
[keysight.com](http://keysight.com)



### Termination

XMA Corp. announced the release of high frequency terminations with zero outgassing features. A recent independent test performed by Integrity Testing Laboratory (ITL) confirmed a finding that 40 GHz millimeter wave terminations manufactured by XMA meet ASTM Method E 595 Total Mass Loss and Collected Volatile Condensable Material standards.

XMA Corp.  
[xmacorp.com](http://xmacorp.com)



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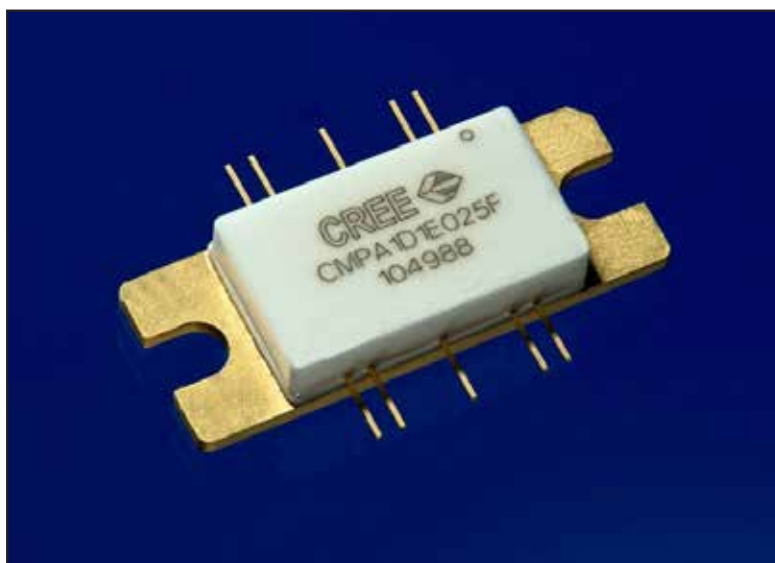


### Antenna

Model SAM-3533532205-28-L1 is a 35 GHz microstrip patch array antenna. It is a linear polarized antenna that implements series-fed power distribution to achieve lowest sidelobe levels. Gain is 22 dBi and beamwidth is 15 degrees vertically and 4.8 degrees horizontally with better than 20 dB sidelobe suppression level. It is construct-

ed with high performance and low loss soft microwave substrates to achieve the best performance.

**SAGE Millimeter**  
[sagemillimeter.com](http://sagemillimeter.com)



### HPA

Cree released the highest power Ku-Band MMIC available on the market. Covering the 13.5 – 14.75 GHz commercial satcom band, the new 30W GaN MMIC two-stage high power amplifier (HPA) will allow the satcom industry to achieve higher power, more efficient Ku-Band

solutions than the incumbent TWT or GaAs solutions utilized today.

**Cree**  
[cree.com](http://cree.com)



## Product Highlights



### Analyzer App Note

A new app note describes measurement techniques using FieldFox handheld analyzers and shows examples for measuring and troubleshooting transmission lines installed in a system. It describes transmission line types, including coaxial cable, two-wire, waveguide and a variety of printed circuit configurations. Also discussed: very long cable insertion loss, gain through frequency translation, waveguide loss, distance to fault, and more.

Keysight Technologies  
[keysight.com](http://keysight.com)



### Synthesizer

The MLBS-Series Bench test synthesizers are ideal for production test sets, laboratory tests and test equipment racks where generation of microwave signals is essential. Frequency coverage is 2 to 20 GHz. Each bench top synthesizer consists of a frequency synthesizer, heat sink, power supply, cooling fans, keyboard, display, USB interface, Ethernet interface and a manual tuning knob.

Micro Lambda Wireless  
[microlambdawireless.com](http://microlambdawireless.com)

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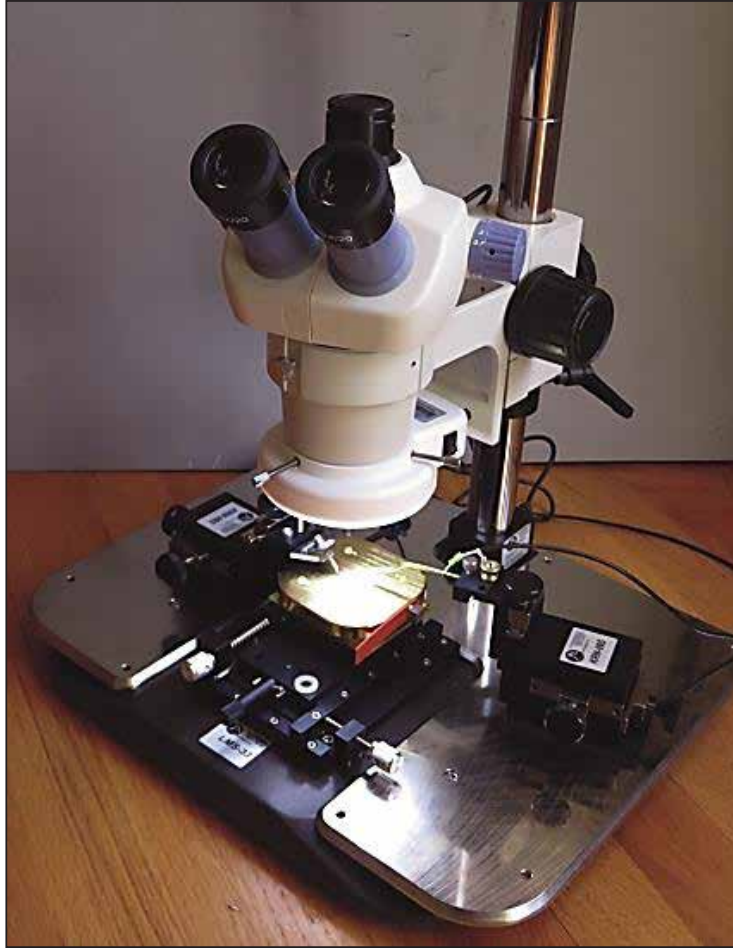
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Get info at [www.HFELink.com](http://www.HFELink.com)





### Laboratory Microprobe Station

J microTechnology introduced a new model of the successful and affordable LMS-27/3X microprobe station product line to enhance the flexibility of microprobing solutions. The most recent introduction has the following features:

- 3" rounded square gold plated shielded and isolated chuck with vacuum stage has 1" of X-Y movement plus 0.090" of Z lift.
- 11.5" X 15" nickel plated steel top plate for magnetic positioners.
- Accessories include a vacuum pump, tubing and tools.
- Shipped in a wheeled, cut foam lined, waterproof shipping container for system safety and storage.
- Compatible with KRN-09S micro positioners with flexibility for either Shielded DC needle probes, Triax probes, coax and microwave probes.

Optics offered for a system include either a Binocular or Trinocular 7X-30X microscope with adjustable intensity LED ring light. Positioners are magnetic mount with 0.5" of fine adjustment travel using ball bearing slides in X-Y-Z. Probe mount for positioner offer a high level of gross height adjustability for setup of non-standard or non-wafer tests. Applications include: chip, carrier and wafer device test and characterization, sample lot verification and qualification, pilot/small lot production test fixture. The basic base system to configure a required test platform, rugged, flexible and affordable.

Turn-key systems or individual components are available, usually from stock.

**J microTechnology**  
[jmicrotechnology.com](http://jmicrotechnology.com)



## ▶ Product Highlights



### Power Divider

VidaRF offers a new 2 way power divider Model: VPD-20180A2, Directional Coupler, VDC-20180A10 and Hybrid Coupler VHC-20180A, SMA S/Steel connectors, operating temp -55 to +85 C. Sealed and painted to meet IP65 standards.

VidaRF  
vidarf.com



### Power Divider

Werbel Microwave's 4PN325 4-way power divider covers 500 - 6,000 MHz continuously with typical 1.5/1.2:1 input/output VSWR, 22-dB typical isolation and precisely tuned for excellent phase balance at all ports. The unit is usable down to 250-MHz with roll-off toward 2:1 VSWR. Rugged, large and heavy all-American construction.

Werbel Microwave  
werbelmicrowave.com



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### LTE Tester

Anritsu Company and EMITE announced that the Anritsu MT8820C Radio Communication Tester has been successfully used in combination with the EMITE E500 Reverberation Chamber and Anite Propsim FS8 channel emulator to test LTE Carrier Aggregation, using 2x2 MIMO and more realistic isotropic Urban-Macro (UMA) fading profiles. The tests were performed for a leading U.S. carrier.

“We are very happy to have Anritsu’s excellent MT8820C base station emulators integrated in our MIMO OTA Carrier Aggregation RC+CE test platform, as this will certainly add value to our customers,” said David Sanchez-Hernandez, CEO and co-founder of EMITE. “Being able to test LTE CA + MIMO + UMA with a variety of auxiliary equipment units is a novelty worldwide, and brings MIMO OTA testing to a higher level of realism and applicability worldwide.”

The MT8820C LTE One-Box Tester is a multi-format 2G, 3G, and LTE tester with capability for UE calibration, RF parametric testing, and functional testing, including call processing or no-call based testing. Supported formats include LTE-A, LTE, W-CDMA/HSPA CDMA2K up to 1xEV-DO rel. A, TD-SCDMA/HSPA, and GSM/GPRS/EGPRS. The MT8820C provides the most stable and most widely proven implementation of cellular standards for base station emulation and “call box” testing.

EMITE’s unique multicavity mode-stirred source-stirred reverberation chamber solutions (MSRC) provide for a variety of fading scenarios at a fraction of the cost of alternative anechoic chamber-based test solutions. Along with conventional uniform, isotropic Rayleigh and more complex SCME-based fading profiles for MIMO OTA testing, the EMITE solutions are the only ones also offering other standardized fading profiles using the patented Sample Selection technique, something unheard of in the wireless arena until now.

**Anritsu Company**  
**Anritsu.com**



## Product Highlights



### Capacitors

Passive Plus now offers a line of Hi-Q Capacitors available in 4 larger case sizes. Specifically produced for high power / high frequency requirements, these products available in surface mount or leaded configurations that are 100% RoHS compliant and are also available in a Non-magnetic termination.

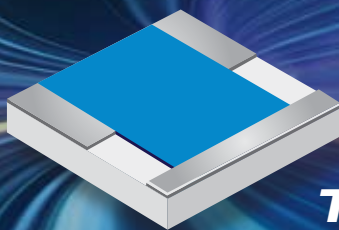
Passive Plus  
[passiveplus.com](http://passiveplus.com)



### SDLVA

Pasternack introduced an all new line of broadband log video amplifiers covering multi-octave bandwidths from 0.5 GHz to 18 GHz. The 5 models being released include 4 Successive Detection Log Video Amplifiers (SDLVA), and 1 Detector Log Video Amplifier (DLVA), which offer a wide input dynamic range, high signal sensitivity, fast recovery times, and excellent temperature stability.

Pasternack  
[pasternack.com](http://pasternack.com)



## Temperature Variable Attenuators

TVAs from the recognized leader in high reliability resistive components offer:

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- Lower signal distortion, phase change and intermodulation compared with active circuit temperature compensation

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## Product Highlights



### VCO

Crystek's CVC055CCQ-3500-3500 VCO operates at 3500 MHz with a control voltage range of 0.3 V~4.9 V. This VCO features a typical phase noise of -115 dBc/Hz @ 10 KHz offset and has excellent linearity. Output power is typically +6 dBm. Engineered and manufactured in the USA, the model CVC055CCQ-3500-3500 is packaged in the industry-standard 0.5-in. x 0.5-in. SMD package.

**Crystek**  
[crystek.com](http://crystek.com)



### Switch

PMI Model No: P2T-500M18G-80-T-515-SFF-4W is a SPDT, Absorptive, PIN Diode Switch that operates over the 0.5 to 18.0GHz frequency range. This switch handles a maximum RF Input Power of 4 Watts CW, a switching speed (On/Off) of 200ns, an Isolation of 70 dB Minimum, Insertion Loss of 3.5 dB Typical, VSWR of 2:1 and the DC power supply is +5, -15vdc. Size is only 1.0" X 1.0" X 0.40".

**Planar Monolithic Industries**  
[pmi-rf.com](http://pmi-rf.com)





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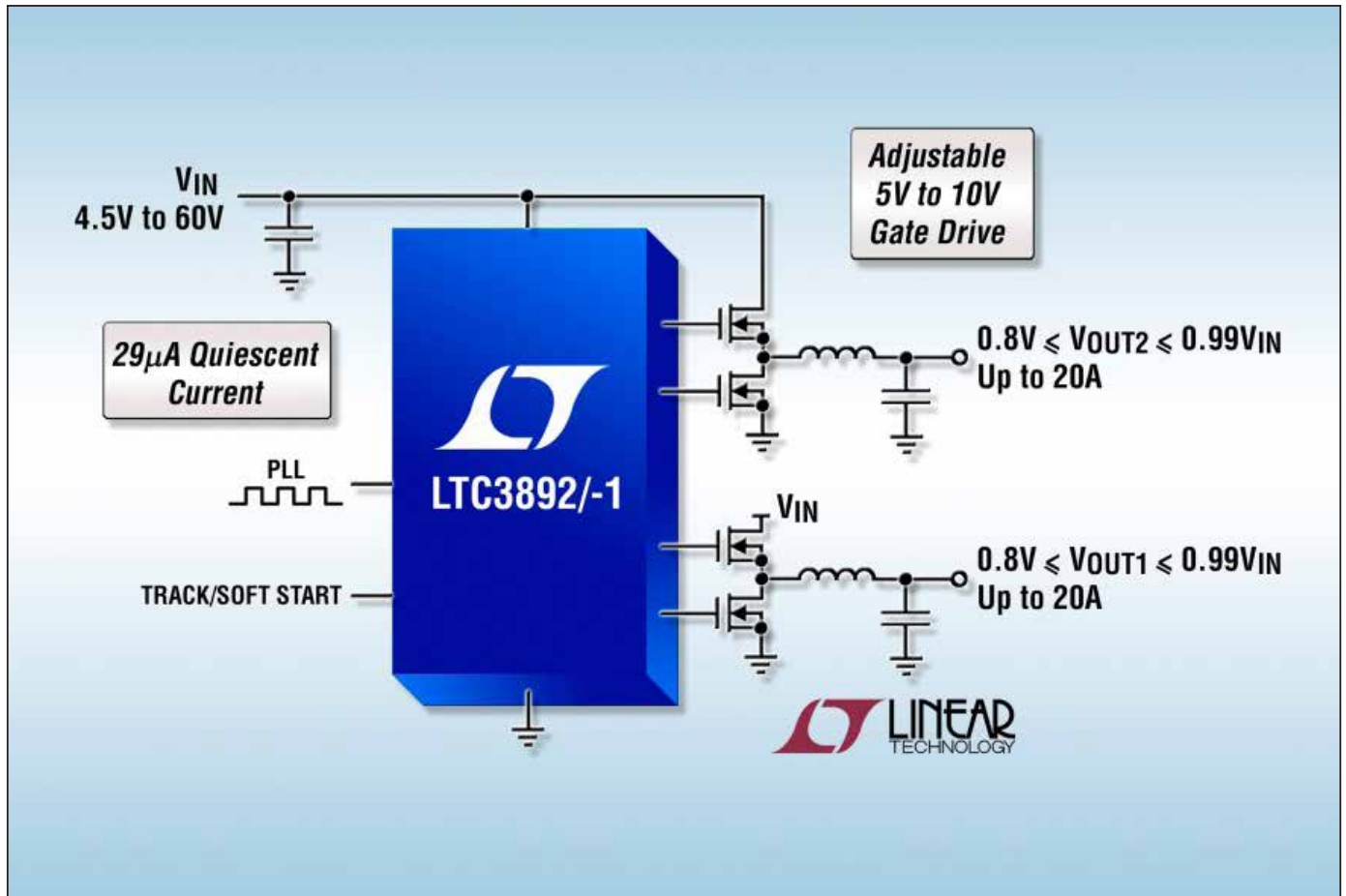
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## Product Focus



### Controller

Linear Technology Corporation announced the LTC3892, a high voltage dual output synchronous step-down DC/DC controller that draws only  $29\mu A$  when one output is active and  $34\mu A$  when both outputs are enabled. The 4.5V to 60V input supply range is designed to protect against high voltage transients, ensuring continuous operation during automotive cold crank and to accommodate a broad range of input sources and battery chemistries. Each output can be set from 0.8V to 99% of  $V_{IN}$  at output currents over 20 amps with efficiencies as high as 96%, making it well suited for 12V or 24V automotive, heavy equipment, industrial control, robotics and telecom applications.

The LTC3892/-1's adjustable 5V to 10V gate drivers enable the use of logic- or standard-level MOSFETs to maximize efficiency. It operates with a selectable fixed frequency between 50kHz and 900kHz, and can be synchronized to an external clock from 75kHz to 850kHz. The user can select from continuous operation, pulse-skipping and low ripple Burst Mode® operation during light loads. The LTC3892/-1's 2-phase operation reduces input filtering and capacitance requirements. Its current mode architecture provides easy loop compensation, fast transient response, fixed frequency operation, excellent line regulation and easy current sharing with paralleled phases for higher current. Output current sensing is accomplished by measuring the voltage drop across the output inductor (DCR) for the highest efficiency or by using an optional sense resistor for high accuracy. Current foldback limits MOSFET heat dissipation during overload conditions. This device is available in two versions; the LTC3892 being the full-featured part with two power good signals, adjustable current limit and fixed 3.3V or 5V output voltage options.

The LTC3892 is available in a 32-lead 5mm x 5mm QFN package and the LTC3892-1 is available in a 28-lead TSSOP package. Four temperature grades are available, with operation from -40 to 125°C for the extended and industrial grades, a high temp automotive range of -40°C to 150°C and a military grade guaranteed from -55°C to 150°C.

Linear Technology  
linear.com



## Product Highlights

### Cavity Filter

RLC Electronics introduced a series of high frequency surface mount cavity filters for small scale, low profile system integration. Designs are created and constructed using proprietary techniques resulting in rugged, stable performance over a full range of environmental stresses. High Q cavity filter performance is available up to 30 GHz with profile height as low as 200mm.

**RLC Electronics**  
[rlcelectronics.com](http://rlcelectronics.com)



### Isolator

Model F3338-3325 is a full band WR28 waveguide junction isolator covering 26.5GHz to 40.0GHz frequency range with 0.6dB maximum insertion loss, 16.0dB minimum reverse isolation, 1.4:1 VSWR at input and output, and can handle 5 Watts of CW power with 2 Watts of reflected power. The RF ports are designed to match to UG-599/U waveguide flanges.

**Wenteq Microwave**  
[wenteq.com](http://wenteq.com)

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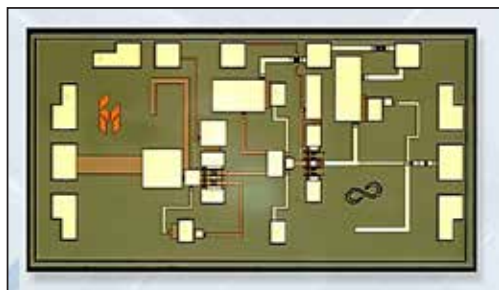
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Get info at [www.HFELink.com](http://www.HFELink.com)



## Product Highlights



### Multiplier

Custom MMIC announced the CMD214, a new 24 to 36 GHz (output) active x2 frequency multiplier in die form. The CMD214 accepts input signals in the range of 12 to 18 GHz and provides output to the second harmonic (24 to 36 GHz) at a level of +17 dBm. Isolations to the fundamental and third harmonics are greater than 32 dBc and 25 dBc, respectively.

**Custom MMIC**  
custommmic.com

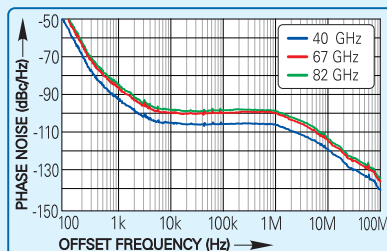
## QuickSyn Synthesizers Now Extended to mmW

Low Phase Noise and Fast Switching  
With USB/SPI Control



We've extended our popular QuickSyn Lite frequency synthesizers to three commonly used mmW bands—27 to 40 GHz, 50 to 67 GHz, and 76 to 82 GHz for high-speed short-range data links, WirelessHD, IEEE 802.11ad, digital radios, automotive radars, etc. QuickSyn mmW frequency synthesizer modules are ideal for demanding application environments like field trials and embedded systems where bulky benchtop solutions were the only choice.

Feature	FSL-2740	FSL-5067	FSL-7682
Frequency GHz	27 to 40	50 to 67	76 to 82
Switching Speed $\mu$ s	100	100	100
Phase Noise at 100 kHz	-108 dBc/Hz at 40 GHz	-105 dBc/Hz at 67 GHz	-103 dBc/Hz at 82 GHz
Power (min) dBm	+17	+17	+10
Output Connector	2.92 mm	1.85 mm	WR-12



[ni-microwavecomponents.com/quicksyn](http://ni-microwavecomponents.com/quicksyn)

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### Attenuator

The 50P-2014 from JFW Industries is a 200-6000 MHz, solid-state variable attenuator with 0-95 dB of attenuation in 1 dB steps. It's designed with USB control (via USB Mini-B connector), so it's perfect for research & development labs or other flexible test environments (JFW software included or .dll file for integration into your own applications supplied upon request).

**JFW Industries**  
[jfwindustries.com](http://jfwindustries.com)



## ► In Memoriam

### Vincent McHenry

The microwave industry lost one of its true pioneers when Vincent J. McHenry, co-founder of OmniSpectra and Southwest Microwave, passed away April 2. He was 86.

McHenry was born on August 30, 1928 in Detroit, Mich. He attended the University of Detroit and subsequently entered the US Army Signal Corps, where he became an instructor in microwave systems during the Korean War. Following his military service, McHenry joined the Bendix Corporation, engaging in the design and testing of microwave components, including a series of miniature components (connectors, ferrite phase shifters, hybrid and directional couplers and terminations) for the Navy's Eagle Missile Radar Guidance

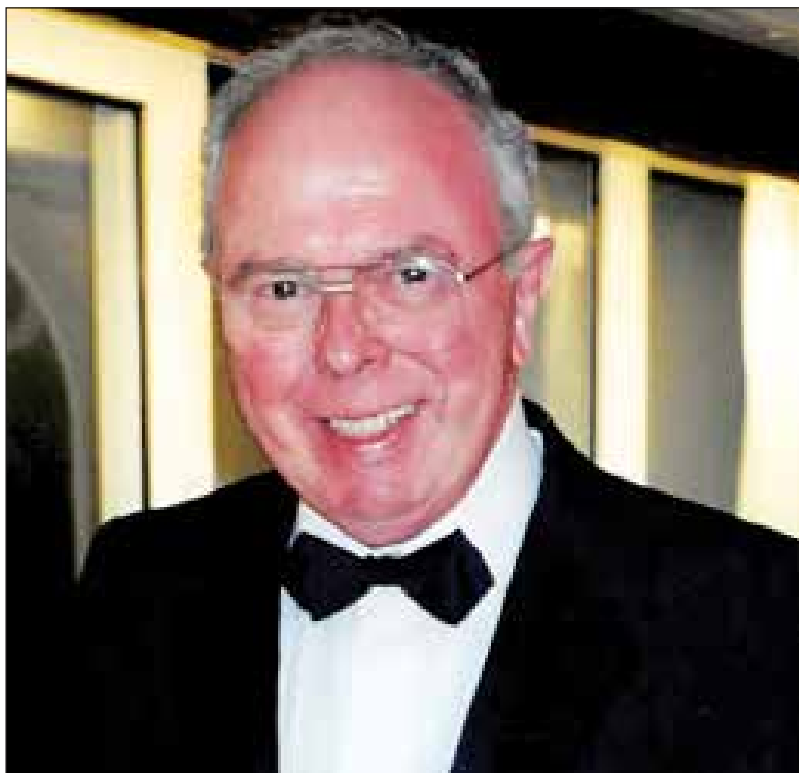
System. McHenry was granted nine patents covering these devices.

While at Bendix Research Laboratories, McHenry investigated the potential of this newly designed miniature coaxial connector, which he concluded in a 1959 report "would be an acceptable addition to any microwave system requiring a compact, low VSWR coupling method." This family of connectors became the prototype for the OSM series at OmniSpectra, Inc., a company McHenry co-founded in 1962. He first served as its New Product Development Manager and later as Vice-President of Sales.

In late 1962, McHenry made another major mark on the industry by filling a longstanding need to upgrade the performance of conventional RF coaxial connectors. Using the engineering principles of the OSM series, he quickly produced a very low reflection, physically short between-series adapter prototype, which led to a complete line of adapters from OSM to other types, including N, C SC, TNC and BNC.

In 1981, McHenry co-founded his most successful venture, Southwest Microwave, where he worked as Director

of Technology for the company's Perimeter Security and Microwave Interconnect product divisions until his passing. During his tenure, McHenry made significant contri-



butions to the design and manufacture of the company's line of microwave sensors, and was instrumental in the development of the company's I N T R E P I D™ MicroPoint™ fence-mounted intrusion detection system. These Southwest Microwave technologies, which earned McHenry several additional patents in the 1970s and 80s, still play critical roles today in the physical security and protection of government and military compounds, utility sites, correctional institutions and industrial facilities worldwide.

McHenry had a sincere interest in Southwest Microwave's employees, considering each of them to be a part of his extended family. His profound influence within the organization encouraged several generations of engineers to follow his path of innovation in RF technology and production design.

In 1997, McHenry won the Institute of Electrical and Electronic Engineers (IEEE) Pioneer Award, a prestigious Microwave industry honor for contributions to the development of electronic or aerospace systems. He was recognized, along with John H. Bryant and another Southwest co-founder, James Cheal, for his leading role in the invention of the Subminiature Type A (SMA RF) Coax Connector. This technology has remained in use for nearly 50 years, and marked a significant achievement in both McHenry's career and the field of Microwave technology to which he dedicated his life.

Vince McHenry was preceded in death by his beloved wife of 38 years, Barbara. He is survived by his sister Irene MacKinnon, his son Dean McHenry, his two daughters Andrea McSweeney and Ann McHenry, six grandchildren, and two great-grandsons.



# ▶ ADVERTISER INDEX

Company	Page	Company	Page
Advanced Switch Technology .....	65	Mini-Circuits .....	21
AMCOM .....	32	Mini-Circuits .....	23
AmpliTech .....	59	Mini-Circuits .....	37
AR Modular RF .....	40	Mini-Circuits .....	53
CEL .....	43	Mini-Circuits .....	62, 63
Cernex .....	18	Molex .....	C3
Coilcraft .....	11	National Instruments .....	5
Cobham Inmet .....	1	National Instruments .....	15
Communication Concepts .....	57	National Instruments .....	78
CST .....	51	Nuhertz .....	60
C. W. Swift & Associates .....	C2	OML .....	58
C. W. Swift/SRI .....		Passive Plus .....	54
Connector Gage .....	35	Pasternack .....	74
Damaskos .....	65	Pasternack .....	75
dBm .....	7	Planar Monolithics Industries .....	39
Delta Electronics .....	41	Pulsar Microwave .....	20
Fairview Microwave .....	19	RF Bay .....	65
GT Microwave .....	69	Richardson RFPD .....	C4
Herotek .....	14	Rogers .....	31
IMS 2015 .....	61	SAGE Millimeter .....	13
Isola Group .....	17	Satellink .....	64
IW Microwave .....	27	Sector Microwave .....	64
Lansdale Semiconductor .....	71	SGMC Microwave .....	45
JFW Industries .....	33	SGMC Microwave .....	center
J micro Technology .....	46	SignalCore .....	38
L-3 Narda Miteq .....	77	Spectrum Elektrotechnik .....	29
Luff Research .....	65	State of the Art .....	73
Luff Research .....	65	Temwell .....	48
Master Bond .....	65	Times Microwave .....	25
MECA Electronics .....	66	Vida Products .....	56
Micro Lambda Wireless .....	9	VidaRF .....	55
Microwave Components .....	47	Wenteq Microwave .....	64
Mini-Circuits .....	2, 3	W. L. Gore .....	67

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