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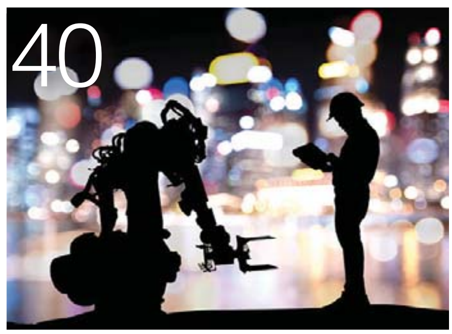

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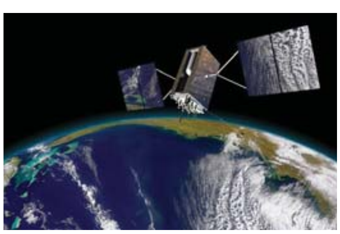

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Editorial

DAVID MALINIAK | Editor

dmaliniak@endeavorb2b.com

Wi-Fi 6 (and 6E) to the Rescue?

Working from home these days, are you? Well, that's where many more of us than ever before find ourselves lately. For those who are new to the WFH game, it will likely become permanent.

The trend toward WFH means an explosion in the need for wireless connectivity, and that means even more reliance on Wi-Fi than ever. According to high-end Wi-Fi provider Plume Design, some 22.6 million people were active online during the workday prior to the coronavirus crisis. Now, about 46.2 million users are flooding the data pipelines.

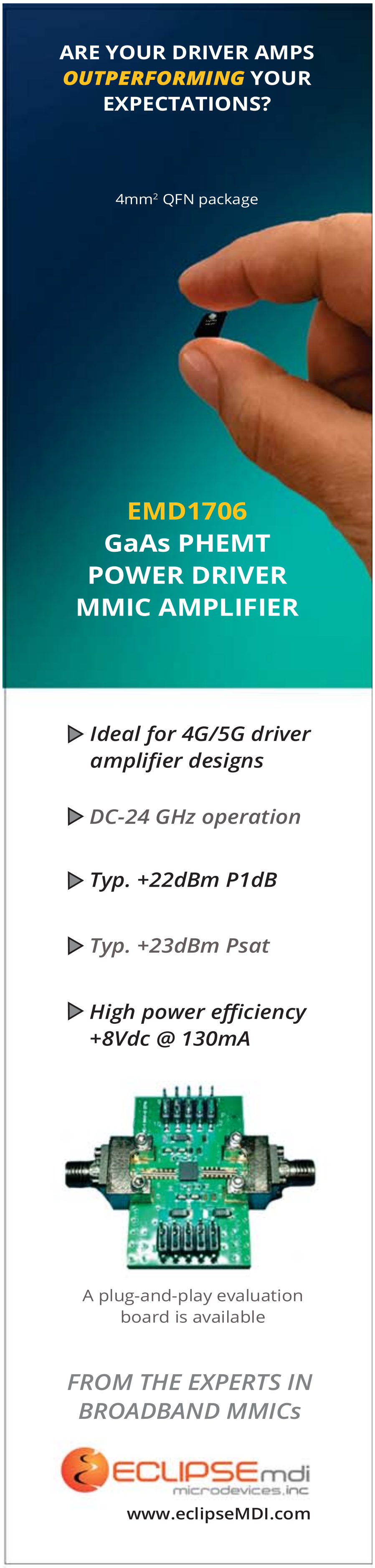
Many of our devices and routers support the prevalent Wi-Fi 5 standard (a.k.a. "the standard formerly known as 802.11ac" now that the Wi-Fi Alliance has shifted to simply numbering the standards rather than using their unwieldy IEEE monikers; I, for one, applaud the move). But what if Wi-Fi 5's 3.5-Gb/s maximum data rate, 256-QAM limit on subcarrier modulation, and four spatial streams can't cut the mustard?

The Wi-Fi standard has already evolved beyond Wi-Fi 5. Wi-Fi 6 is with us and promises to alleviate the growing connectivity logjam. It offers numerous improvements over its processor: With eight spatial streams and 1024-QAM subcarrier modulation, Wi-Fi 6 now sports a maximum data rate of 9.6 Gb/s.

Perhaps even more importantly, Wi-Fi 6 brings a much better approach to structuring and scheduling traffic. It supports modulation schemes like orthogonal frequency-division multiple access (OFDMA) as well as multiple-user MIMO on both uplink and downlink traffic. With more and more smart devices connecting to networks via Wi-Fi (think lightbulbs and thermostats), we can certainly benefit from a smarter approach to traffic control.

Moreover, there's yet another hope for a remedy to our connectivity problems: more available spectrum. Wi-Fi today operates on about 70 MHz of the 2.4-GHz band and about 500 MHz of the 5.8-GHz band. But regulators in the U.S. and Europe are preparing to open the entire 6-GHz band to unlicensed traffic. Indeed, the FCC has unanimously voted to do so, adding some 1.2 GHz of bandwidth for the forthcoming Wi-Fi 6E (for Extended) edition of the evolving standard.

So, for those of us working from home, there's hope for respite from the day when our iPhones aren't competing with lightbulbs for a piece of the router's attention. mw



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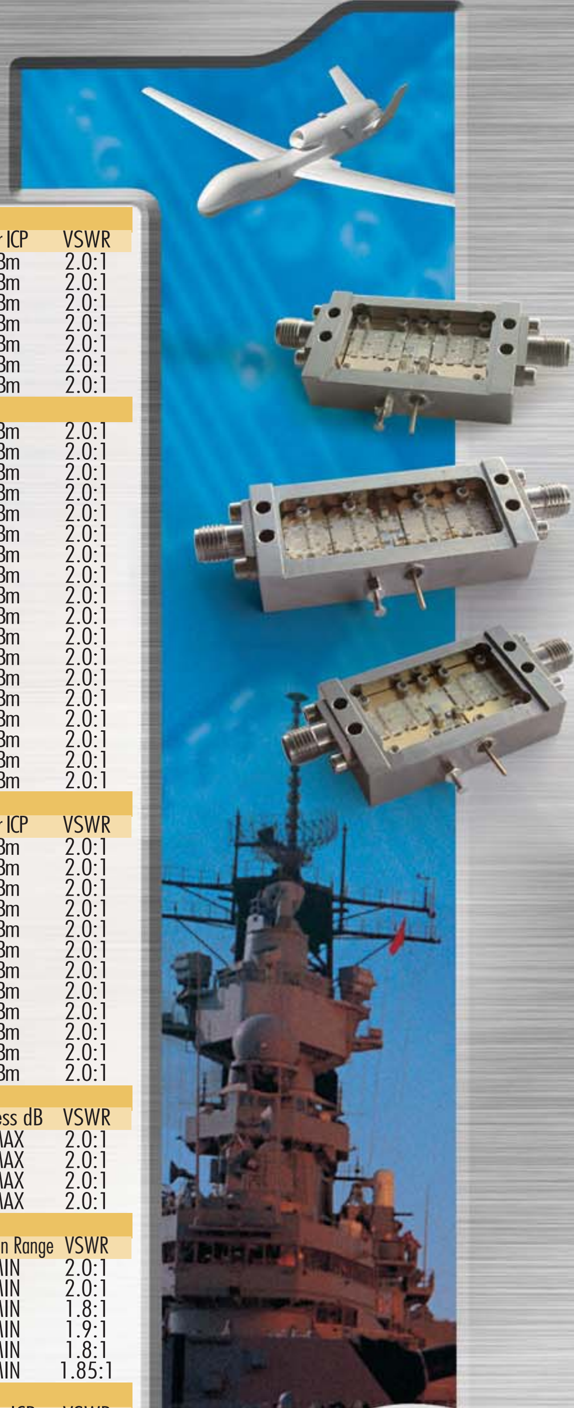

OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

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

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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2020's Perfect Storm: Wi-Fi 6, BLE, and AI?

The debut of Wi-Fi 6 and the explosion of AI hardware, networks, and tools will open new markets and spur future technology trends.

https://www.mwrf.com/technologies/systems/article/21130447/2020s-perfect-storm-wifi-6-ble-and-ai

Analyze 5G Urban Scenarios with Ray Tracing

This "Algorithms to Antenna" blog installment shows how you can use ray tracing to analyze 5G communication links in an urban environment.

https://www.mwrf.com/technologies/systems/article/21128896/algorithms-to-antenna-analyze-5g-urban-scenarios-with-ray-tracing

Common PCB Soldering Problems to Avoid

Soldering can make or break a PCB, both figuratively and literally. This article offers basic tips and nine specific problems/mistakes to look out for when doing a soldering job.

https://www.mwrf.com/materials/article/21126700/common-pcb-soldering-problems-to-avoid

How EFC Over-Specification May Be Costing You

Specifying more electronic frequency control (EFC) than you need, when it comes to crystal oscillators, could actually be hurting your pocketbook.

https://www.mwrf.com/technologies/components/article/21129646/how-efc-overspecification-may-be-costing-you

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News

COVID-19's Impact on the SEMICONDUCTOR MARKET

JIM HANDY | Analyst, Objective Analysis

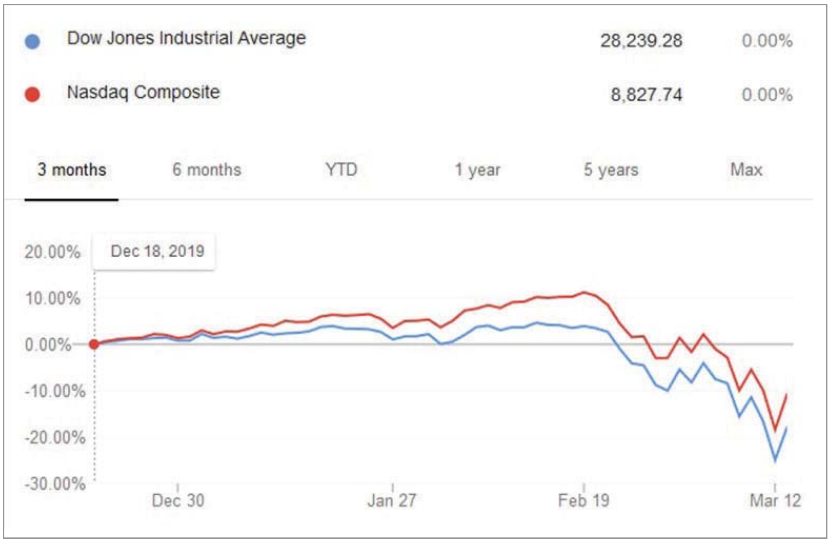
In mid-March, the U.S. stock market was still trying to understand what was happening with the global coronavirus pandemic, having lost nearly 20% of its value in one week. Cooling-off periods (also called "Circuit Breakers") automatically stopped overheated trading at different intervals.

Market indexes fell sharply, as shown in a chart from Google Finance, which shows the relative performance over the first part of the year for both the Dow Jones Industrials and NASDAQ *(Fig. 1)*. It's been a roller-coaster ride since that date, with the market rising sharply last week.

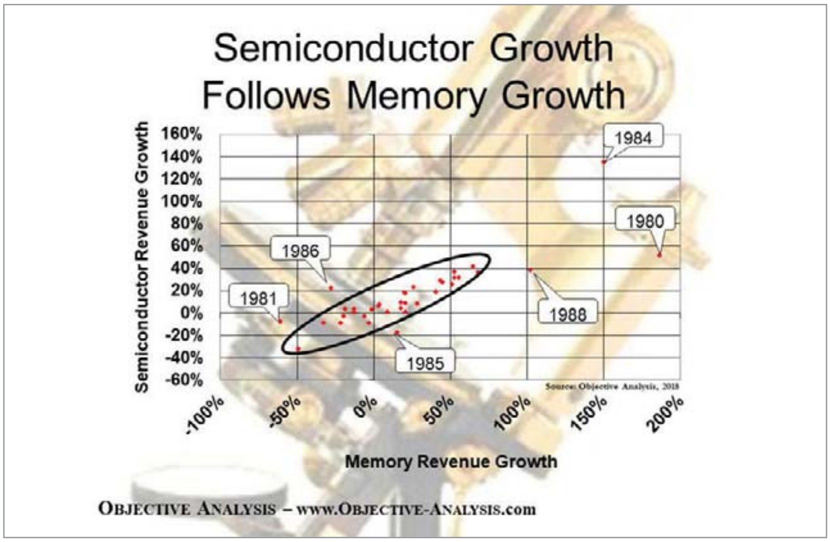
In this time of great financial uncertainty, what does it mean to the chip market?

Since The Memory Guy *(www.thememoryguy.com)* is an engineer by training, I can't easily explain what's happening to the global economy, but my background as a semiconductor industry analyst gives me clarity about what's most likely to happen in the chip market. My aim here is to provide an extremely abbreviated version of the story that I'm now telling in detail to my clients. It's today's version of the story that I always tell when forecasting semiconductors since the market regularly repeats the same cycles.

The line of thought, which I will explain, is the same one that has led to the fact that the Objective Analysis semiconductor forecast has been the most consistently accurate forecast in the industry for the past 13 years. It's a fact that



1. The chart shows the relative performance of the Dow Jones Index and NASDAQ over the January to mid-March timeframe.



2. This scatter chart compares the total semiconductor growth to memory growth. Mist points fall within a narrow range.

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WHERE MEMORIES GO, SEMICONDUCTORS FOLLOW

There's a very strong relationship between memory revenue growth and overall semiconductor revenue growth. *Figure 2* illustrates this fact.

The points show memory revenue growth vs. total semiconductor revenue growth for every year from 1974-2018. With the exception of six years in the 1980s, the points all fall within the range outlined in the orb. This relationship simplifies the task of creating a semiconductor forecast.

Memories are the more volatile portion of the semiconductor market: If you know what memories are likely to do, then you can predict semiconductor revenues.

DEMAND-DRIVEN DOWNTURNS ARE RARE

I used to tell my clients that demand-driven downturns occurred regularly every 15 years, and that all other downturns were caused by over-investment. Demand downturns occurred in 1970, 1985, and 2000. The pace has recently picked up, with demand-driven downturns in 2009 and 2015. All other semiconductor cycles have been the result of excess capital spending.

This isn't commonly believed, since chip makers usually blame demand for every downturn.

MEMORY BITS GROW PREDICTABLY

Figure 3 plots DRAM gigabyte shipments starting in 1991 (red), with a trend line (black) illustrating the gradual slowing of memory bit growth. It's on a semi-logarithmic chart, since a linear chart would look like a hockey stick. In a semi-log format constant growth shows up as a straight line.

Note the call-outs for the Internet Bubble Burst in 2000 and the Global Economic Crisis of 2008-9. While demand did indeed dip in 2009 (from being slightly over trend), it's relatively difficult to pinpoint a specific drop from the Internet Bubble Burst. Another demand drop, in 2015, shows up on this chart, too, but isn't called out.

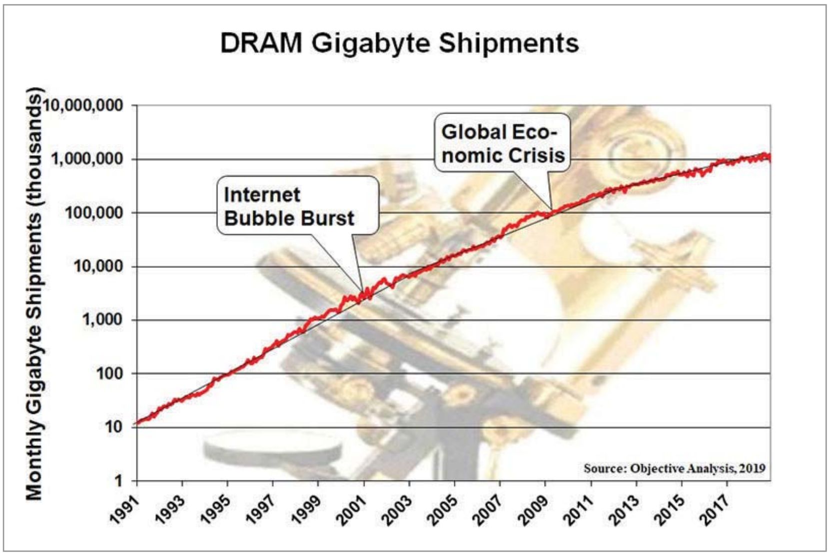
COVID-19 is almost certain to cause a demand lapse similar in magnitude to the dips in 2009 and 2015, and that lapse will trigger an oversupply.

Throughout this history, growth has resumed as soon as the calamity was brought under control. Objective Analysis expects a COVID-driven demand shortfall that will last less than a year. This may be followed by a short period of unusually high consumption driven by pent-up demand.

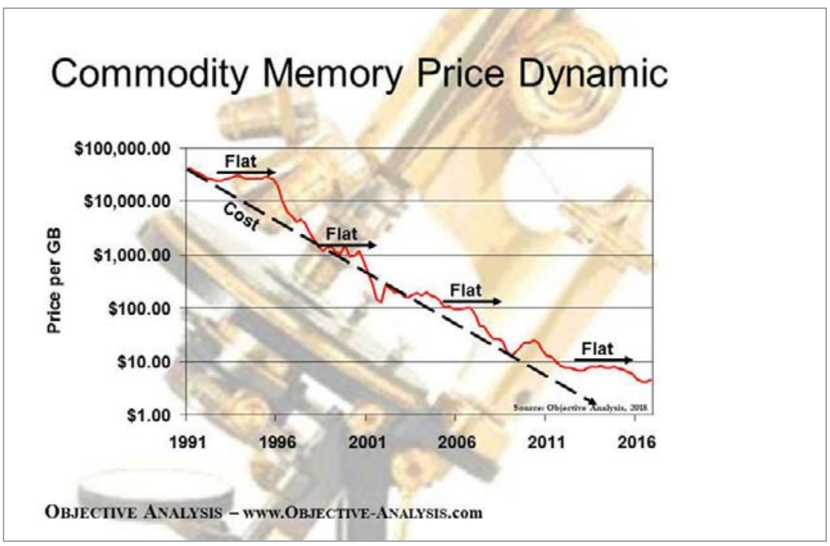
After that, long-term gigabyte consumption will return to its previous growth rate.

MEMORY PRICING IS ALSO PREDICTABLE

It's a little more difficult to predict memory prices, but it's not all that difficult. Memory prices tend to flatten during a shortage and collapse to cost at the onset of an oversupply. If you under-



3. Shown is the history of DRAM gigabyte shipments.



4. The price (red), cost (black dashed line), and arrows indicate the flat periods.

stand what cost is, and if you know when shortages and oversupplies are likely to occur, then you can predict prices.

A historical chart *(Fig. 4)* explains the phenomenon.

DRAM price per gigabyte history trend line: With today's events causing a demand shortfall, the result will be an oversupply, and that will cause prices to fall to cost. Once demand catches up with supply, prices will rise above cost.

THE MARKET WILL EVENTUALLY RECOVER

What this leads us to is an expectation that 2020 will be a down year in the chip market, yet this is something that Objective Analysis was already predicting based on excessive capital spending in 2018. The anticipated CapEx-driven oversupply will be accompanied by a demand downturn that will cause more immediate damage to semiconductor revenues.

This situation will not last. Since demand is likely to rise back to the trend line, then the future shortage that we have already been predicting is likely to happen on time, driven by insufficient capital spending. The net impact of COVID-19 will be to cause an earlier downturn in 2020 than would have otherwise occurred, but the impact is unlikely to go beyond that.

FOR MORE IN-DEPTH INFORMATION

Objective Analysis's regular clients get a far deeper look into this analysis and much better insight that allows them to plan around such predictable results of unpredictable phenomena like the COVID-19 pandemic. Readers who aren't already clients of ours are welcome to contact us to explore ways that we can help you to outperform your competition using a deeper understanding of the market to assist in your planning.

We also express our sympathy to those already impacted by the pandemic, as well as those yet to be impacted. Such events are a true test of our strengths as human beings, but we should emerge stronger as a result of the ordeal. ■

LoRa ALLIANCE INTRODUCES Certification Affiliate Program

TO MAKE ITS INTERNET OF THINGS (IoT) device certification more accessible and pervasive, the LoRa Alliance has launched a Certification Affiliate option for certifying devices with the LoRaWAN standard. The new option provides non-members of the LoRa Alliance a path to obtaining LoRaWAN device certification.

The LoRa Alliance, which backs the open LoRaWAN standard for the IoT low-power, wide-area networks (LPWANs), offers a certification program that includes full protocol testing, as well as interoperability and RF performance tests, which are critical for open global standards. The Certification Affiliate program will increase the number and breadth of LoRaWAN Certified devices available in the market to serve the IoT needs of companies and users around the world.

The Certification Affiliate program allows any device manufacturer to certify its products, ensuring they meet end-user requirements for dependability, interoperability and security as defined by the LoRaWAN standard. While membership in the Alliance remains the most affordable path to certification, membership may not be an option for some OEMs.

Under the Affiliate Certification program, companies receive the following benefits:

- The use of the LoRaWAN Certification Test Tool (LCTT), a precertification test tool allowing device manufacturers to test their product at their

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own facility prior to sending the device to an authorized test house for certification.

- One license for the LCTT is included in the affiliation fee per year, and affiliates have the right to purchase additional licenses.
- Use of the LoRaWAN Certified logo on their certified products in compliance with LoRa Alliance policies.
- Have certified products included in the LoRaWAN Showcase online catalog of certified products.
- Receive LoRa Alliance communications regarding certification.

Historically, companies were required to be a member of the LoRa Alliance to certify their devices. The organization still encourages companies to become members of the LoRa Alliance, as the cost to certify is lower and there are many more benefits for member companies. ■

LoRa ALLIANCE, lora-alliance.org

mmWAVE SYNTHESIZER Serves LO, Beamforming Needs

IF YOU'RE IN THE MARKET for a local oscillator (LO), beamforming device, or a precision reference clock for a high-speed data converter in applications such as test and measurement, optical networking, or data acquisition, Renesas Electronics' 8V97003 millimeter-wave (mmWave) synthesizer may be the answer.

Developed with an eye toward emerging applications above the 6-GHz carrier frequency, including broadband wireless, microwave backhaul, and 5G radios, the 8V97003 delivers a rare combination of wide frequency range (171.875 MHz to 18 GHz), ultra-low output phase noise (-60.6 dBc at 20 kHz to 100 MHz at 6 GHz) and high output power over its entire frequency range.

The wide frequency range enables customers to use a single 8V97003 in place of multiple synthesizer modules, reducing area and cost. High output power eliminates the need for an external driver, further reducing complexity and overall power consumption without compromising performance. The ultra-low output phase noise makes it an excellent choice for 5G and other wireless applications as it enables superior system level signal-to-noise ratio (SNR) and error vector magnitude (EVM). As a reference clock for high-speed data converters, 8V97003 maximizes system performance by improving SNR and spurious-free dynamic range (SFDR).

Mass production quantities of the 8V97003 are available now in a 7 x 7-mm, 48-lead VFQFPN package. ■

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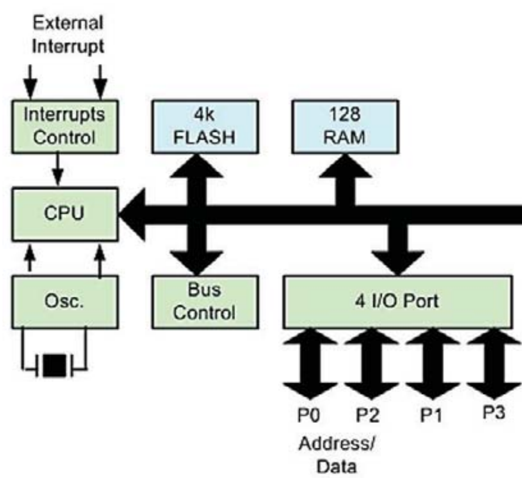
Opportunities and Challenges for Next-Gen Semiconductor Integration

This article explores challenges and solutions to the pace of integration and increased performance needed for tomorrow's embedded applications, and how system-in-package fits into it all.

In the 70 years since the transistor was invented[1] and 60 years since the integrated circuit (IC) was invented,[2] we have taken the computer out of large rooms and put them into our pockets. It's been an amazing time where we have been able to impact every aspect of society with the innovations enabled by these two moments in history. Now we're in the process of taking the computer out of our pockets and putting it into our clothing, into our bodies, and into our imaginations. At the same time, we have completely removed the need for wires when communicating with other people throughout the world. Instead of having to fly halfway around the world for a face-to-face conversation, we can do that instantaneously with the push of a button. Now instead of suffering from "jetlag", we instead suffer from "netlag." It's amazing now to find ourselves on the threshold of computers talking and listening to us in the same ways we communicate with other people. Computers, of course, now talk to each other without human intervention. One can only guess what will be next.



1. The first microcontroller was developed in 1971 by Texas Instruments, which had a block diagram similar to the one shown.

These advances have created several challenges (or should we say opportunities) for electronic designs and therefore the semiconductor industry:

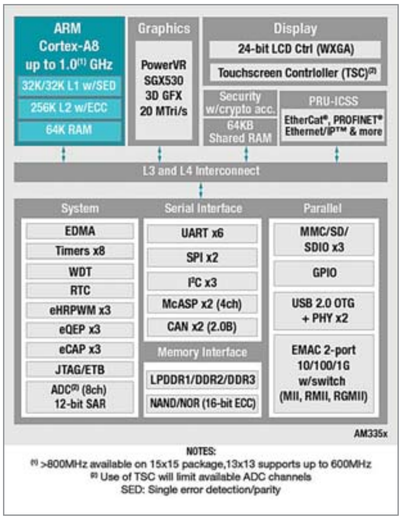
1. The focus of electronic design has moved from the component to the system.
2. The demand for performance has outstripped our capacity and capability.
3. The demand for ultra-low power (e.g., long battery life) has become the new performance metric.
4. There's a continuous demand for faster product introduction cycles.
5. The innovation enabled by using technology no longer requires us to understand the technology we're using.

In this article, we'll discuss the opportunities that are ahead for the semiconductor industry and how they will drive the next round of innovation. Then we'll propose an idea on how to enable the next round of innovation. Finally, we'll make some concluding remarks as to our view of that exciting future.

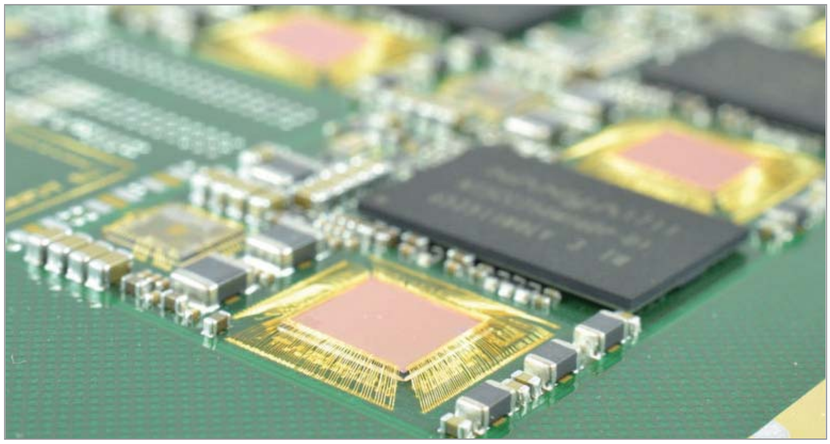
OPPORTUNITY

One of the interesting evolutions that has occurred in the semiconductor industry is the move in focus from the component to the system. That is, instead of just creating components, which can then be used to create systems, the focus is to now create a system design and then determine the optimal set of components needed to implement that system. This may seem to be a subtle change, but is a valuable insight to help us continue the integration path Dr. Gordon Moore envisioned in 1965.[3]

If we look back at early microprocessor and microcontroller devices, they had very little integrated memory and typically had no industry-standard peripherals *(Fig. 1)*. Compare that to



2. The block diagram represents Texas Instruments' AM335x Arm Cortex-A8 based microprocessor system-on-chip.



3. System-in-package integrates a diverse set of semiconductor components and passives into one package, miniaturizing the hardware while also simplifying design and manufacturing.

contemporary microprocessors *(Fig. 2)*, which are complete systems with all (yes using the word "all" is a bit of an overstatement) of the memory and peripherals needed for a complete computer system.[4]

However, the pace of integration and increased performance in processor systems haven't exactly kept up with the demand for performance from the software and embedded-systems designers as they grow hungrier for more every year. The performance demands at the beginning of the microcomputer era to create new audio or video products were well within the state of the art of semiconductor technology.

But we're now seeing opportunities in fields such as artificial intelligence (AI), machine learning, image understanding, and cloud computing stretching the limits of contemporary performance. Not only are these applications demanding exponentially more performance, they also want better integration of heterogeneous components such as FPGAs, GPUs, hardware accelerators, and processors for targeted applications. These demands are driving the performance requirements well beyond Moore's law.[5]

At the same time, we're seeing computer systems shrinking, with the end goal being the concept of "smart dust".[6] To make this possible, the focus changes from driving performance to reducing power dissipation so as to, in the end, power these devices using as little energy as body heat.[7]

During the past 10 years, with the advent of smart devices, the electronics consumer industry has been in a constant state of competition that has driven semiconductor innovation to an unprecedented level. With the design services market segment forecasted to grow with a 7.24% CAGR between 2018 to 2023,[8] there has been a consistent demand for ways consumer electronics companies could reduce/eliminate the effort they have to invest to introduce new products by abstracting the menial tasks of system design.

Finally, the most interesting aspect of the opportunities ahead is the ability to use technology without the need to deeply understand it. Platforms like Arduino,[9] Raspberry Pi,[10] and BeagleBone[11] have made it possible for creative non-engineers to take advantage of the technology to innovate in their areas of passion. As this non-technical creative community begins to create new requirements for semiconductor devices, it's important to make sure those requirements are met in a meaningful way. The goal is to eliminate the increasingly higher barriers of entry that surround electronic design and manufacturing.

THE SYSTEM-IN-PACKAGE SOLUTION

The key to successfully create any solution is to first find the need to be realized and then find the technology that makes it possible. For the semiconductor industry, this solution needs to enable system designers and product developers to simplify product design while offering them what they need in terms of performance and features, essentially addressing each of the opportunities described earlier. We argue that the solution lies in system-in-package (SiP) *(Fig. 3)*.

There are fundamental requirements that the proposed SiP solution should satisfy, without which its usefulness is limited. The requirements are:

- The integration of diverse active semiconductor components and passive components into one system where the active components could be microprocessors, memories, specialized processing devices, analog circuits, power management, and sensors.
- The miniaturization of the resulting implementation and system footprint.
- Scalability allowing for low-volume opportunities to high-volume

opportunities without a cost burden to either end of the scale.
- The ability to provide system-level hardware sub-modules of often-used subsystems. You might call this sub-system-in-package (SSiP).
- Quick, low-cost, prototyping and testing alternatives through flexibilities in design and interconnection methodologies.

This is where the concept of "what is good in the world of semiconductors" complements the concept of "what is good in the world of systems." For example, the concept of fan-out wafer-level packaging (FO-WLP)[12,13,14] has been developed to allow the creation of semiconductor devices that shrink feature size of the IC beyond the physical constraints of a system design. The result is taking semiconductor die that are too small to use as a system-level component and putting them in larger packages, made up of low-cost materials, which are large enough to be used in system designs. The size of these larger packaged components enables them to be used on printed circuit boards (PCBs) to create custom systems.

This currently existing technology is one proposed solution that addresses some of the opportunities that we discussed. Though it's a step in the right direction, it doesn't satisfy all of the requirements of a system component. It partially addresses the complexity of design and manufacturing issues, but doesn't allow for miniaturization or higher level of integration, both of which can be addressed in a SiP solution. As we discuss more about the proposed SiP solution in our series, we will delve into how each of these requirements can be satisfied *(Fig. 4)*.

Finally, it's important to characterize the target areas and markets for SiP technology, as the semiconductor industry is also vastly diverse in its requirements. These requirements may sometimes include specialized functionalities and custom hardware that might not fit within the SiP framework. But, advances and improvements to the existing SiP architecture can help address most use cases. The goal of this article series will be to make a compelling value proposition for system-in-package technology

4. SiP technology can solve a lot of existing electronics design and manufacturing issues, allowing for faster and easier development of electronics.

while addressing how it beats the challenges presented by the opportunities introduced in this article.

LOOKING AHEAD

Significant levels of semiconductor integration have already been achieved, and consumers are already benefiting from this through smaller and better performing smartphones and other electronic devices. As we develop new ways of 2.5D and 3D integration that reduce cost and increase manufacturability, it's important to look at the bigger picture in terms of needs and technologies and to connect them in a meaningful way.

The bigger picture for electronic system design would be to have a design flow that's both systems-centric (SiP and PCB) and component-centric (SoC). The system-centric portion of the design flow requires the ability to integrate various semiconductor devices that are each manufactured with its own optimized process, along with hundreds of passive devices.

Finally, the overall design flow from IC creation to system creation needs to economically scale up or down (both volume and cost) without burdening either end of the design flow. We will see in future articles in the series how system-in-package technology provides a perfect sweet spot to solve many design and manufacturing problems while addressing new opportunities and requirements. mw

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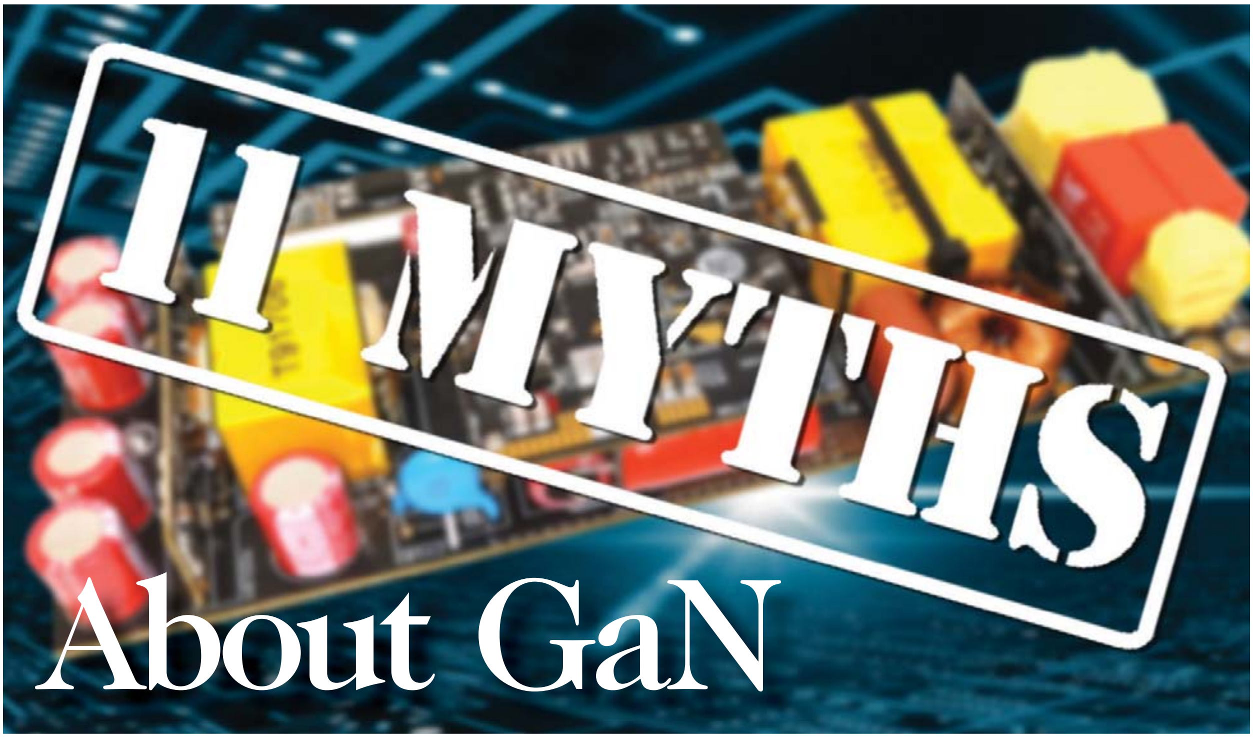
AJAY HARI | Applications Manager, ON Semiconductor



Wide-bandgap materials such as gallium nitride (GaN) have emerged as technologies to take electronic performance to the next level. So, what's "real" about GaN and what's a myth?

Components based on gallium nitride (GaN) offer a range of important benefits versus silicon devices, including smaller size allowing for greater power-density circuits, improved efficiency, reduced switching losses, better power handling, and several other performance attributes. These factors are critical to meeting the increasingly demanding high-power, high-density needs of today's designs in applications ranging from USB Type-C/PD-enabled consumer products like adapters to telecom and industrial applications.

However, myths about GaN have emerged, too. Let's take a closer look.

1. GaN IS ALL ABOUT HIGH-FREQUENCY OPERATION, PRIMARILY TO REDUCE THE SIZE OF THE PASSIVE COMPONENTS

GaN HEMTs (high-electron-mobility transistors) have excellent $R_{DS(on)}$ * Q_g figure of merit (FOM). Depending on the voltage and current rating, FOM can be somewhere between 4X to 10X lower than that of a superjunction (SJ) FET. Therefore, GaN is suitable for high frequency of operation. Most of the early adopters of GaN have focused on high-frequency operation and hence reduction in the size of the passive components. Some passive components, especially magnetic technology, haven't evolved as much as semiconductor technology, thereby making the proliferation of GaN difficult.

An often-ignored area is the advantage that a better FOM brings at traditional frequencies of operation. Utilizing a lower-$R_{DS(on)}$ GaN HEMT can reduce the conduction losses and push the efficiency up. Often, this incremental increase in efficiency, coupled with innovative packaging, is all one needs to push the power-density curve up in the short to medium term.

2. THERE'S NO PLAY FOR GaN AT LOW-FREQUENCY OPERATION

For the reasons mentioned above, GaN is often portrayed to benefit only at high frequency. However, topologies such as totem-pole PFC (TPFC), in which there's no body diode and hence no reverse-recovery effect, bring a tremendous advantage *(Fig. 1)*. In fact, this feature of GaN enables the TPFC to operate in continuous-conduction mode, which wasn't previously possible. The TPFC topology can be run at frequencies <150 kHz and could result in efficiency gain of 1 to 2% in a 500-W PFC by eliminating the diode bridge. This improvement in efficiency

and elimination of the bridge diode, along with its corresponding heatsinks, enables higher power density even at low-frequency operation.

3. GaN IS EXPENSIVE

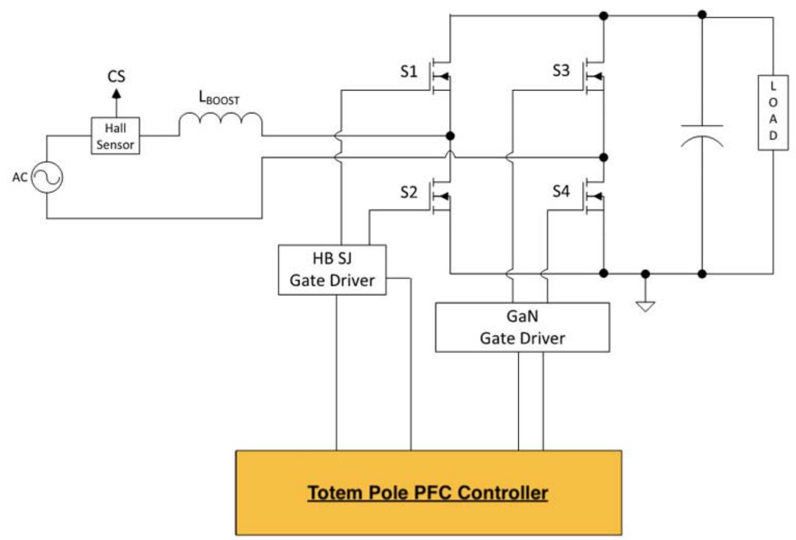
The notion that GaN is expensive stems from the initial price being quoted by various semiconductor vendors. GaN HEMT can realize the same $R_{DS(on)}$ as a SJ FET in less than half the size, resulting in more die per wafer. Once the initial startup costs are recouped, GaN will be cheaper than a SJ FET.

4. GaN WILL BE FIRST COMMERCIALIZED IN A HIGH-END NICHE APPLICATION

This is yet another myth propagated by the initial mistake of chasing extremely high-frequency operation. GaN has started to make inroads especially into the USB Type-C/PD and other consumer applications that are high volume but not very high reliability or critical like automotive applications.

5. THE GaN ECOSYSTEM IS STILL NASCENT

This GaN ecosystem is evolving. Almost all of the semiconductor vendors are offering or plan to offer enhancement-mode GaN (eGaN) gate drivers or gate driver plus GaN HEMT in one package. For instance, there's a complete ecosystem today that implements a TPFC, and it didn't exist a few years ago.



1. The totem-pole PFC (TPFC), operating in CCM, is enabled by GaN HEMTs due to its lack of body diode and, hence, reverse recovery. This topology is employed at power levels >500 W, but using GaN reaps efficiency and power-density benefits even at lower switching frequencies.

6. GaN'S GATE VOLTAGE NEEDS TO BE TIGHTLY CONTROLLED

First-generation eGaN HEMTs needed tight control of gate voltage and suffered long-term degradation or worse blowups in the product validation phase if the gate saw some voltage transients. But the latest-generation GaN HEMTs can handle larger gate voltage transients for a short period of time during turn-on phase, simplifying gate-driver design and layout.

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PTRAN-100M18G-SDLVA-SFB-3UVPX-10HP-MAH-MX

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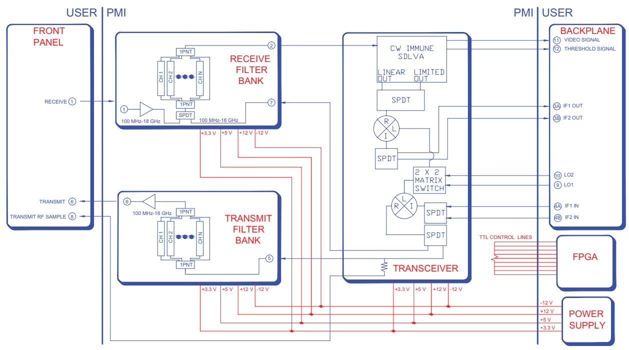
PMI Model No. PTRAN-100M18G-SDLVA-SFB-3UVPX-10HP-MAH-MX is a transceiver that covers the frequency range of 100 MHz to 18.0 GHz and fits into a 3U open VPX form factor utilizing the high speed VITA 67 RF connector. This unit up-converts a 100 MHz to 4.0 GHz transmit signal to the 2.0 to 18.0 GHz range and down-converts a 100 MHz to 18.0 GHz received signal to the 100 MHz to 4.0 GHz intermediate frequency range for analog to digital conversion. A receive filter bank incorporates a 2-way absorptive switch to select an input, along with two 6-way switches allowing one of six filter paths to be chosen. A filter bank is used also on the transmit path, with two 6-way switches allowing one of six filter paths to be chosen. The unit is designed to attach to an FPGA controller card allowing for a total solution in a 10 HP (2”) form factor.

- 100 MHz to 18.0 GHz Transceiver
- Integrated Up and Down Converters
- IF up to 4 GHz
- Time Gated SDLVA for Pulse Blanking
- -80 to -10 dBm Input Dynamic Range
- Customizable Switched Filter Banks
- 0 to +10 dBm Transmit Power
- 100 ns Switching Speed
- Less than 30W Power Consumption
- Customizable Switch Filter Banks
- Over 100 dB of Isolation between Tx and Rx
- 300% smaller than individual single function components
- Fits into a 3U open VPX form factor utilizing the high speed VITA 67 RF connector.
- CW Immunity
- Unit Size: 6.299” x 3.937” x 1.915”

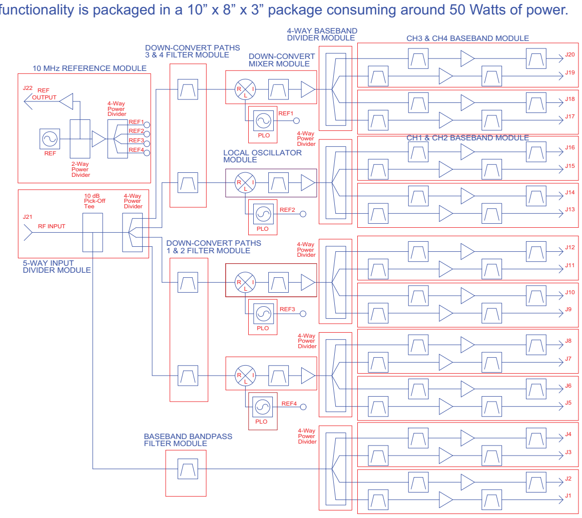


PRX-20-1G18G-850M-SFF

https://www.pmi-rf.com/product-details/prx-20-1g18g-850m-sff

PMI has developed a channelized receiver covering 1 to 18 GHz instantaneously in 20 channels. IF frequencies between 1 and 4.4 GHz are output and ready to be digitized. The receiver is designed to cover a 60 dB dynamic range using a built-in internal 10 MHz reference to lock the internal LO’s used in down-converting the signal into the necessary frequency bands. The reference is also output at a +20 dBm level to be used for synchronization. All of this state-of-the-art functionality is packaged in a 10” x 8” x 3” package consuming around 50 Watts of power.

- 1.0 to 18.0 GHz Channelized Receiver
- -58 to +2 dBm Input Dynamic Range
- 60 dB Output Spurious Free Dynamic Range
- 20 Output Channels, IF Frequencies of 850 MHz BW from 1 to 4.4 GHz (4 Filtered Thru Path and 16 Down-Converted Paths)
- Overall Gain of 0 dB +/-3 dB
- 10 MHz Output Reference with output stability of +/-1 PPM
- Input and Output SMA RF Connectors and 9 Pin D-Sub male for Power
- Less than 50 W Power Consumption
- Unit size : 10.0” x 8.0” x 3.0”



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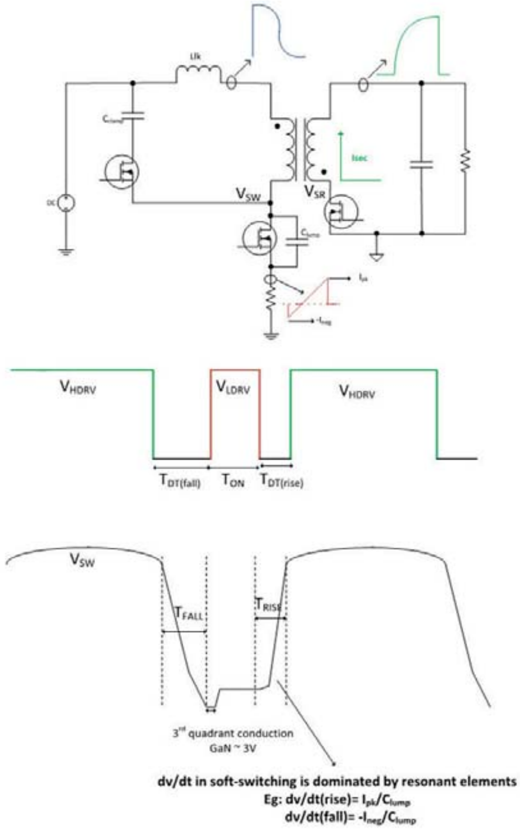


2. This active clamp flyback topology is operating in soft-switching condition. In soft-switching topologies, switch node dv/dt is dictated by circuit parasitics, resulting in lower dv/dt than hard-switching topologies.

7. GaN DRIVERS NEED TO ALWAYS HANDLE EXTREME DV/DT

A persistent myth among the semiconductor companies is that GaN half-bridge drivers need to handle extreme dv/dt on the order of 200 V/ns, since the parasitic capacitances of the GaN HEMT is low. In fact, in most resonant topologies that achieve zero voltage switching (ZVS), resonance is primarily dictated by the transformer characteristics and the lump capacitances on the switch node *(Fig. 2)*. Even while operating at high frequency, the dv/dt rarely if at all crosses 100 V/ns.

8. THIRD-QUADRANT OPERATION CAN BE PREVENTED BY PARALLELING A DIODE

The voltage drop while GaN is conducting in the third quadrant (also called reverse conduction from source to drain) is on the order of –2 to –4 V, depending on the device and bias condi-

The voltage drop while GaN is conducting in the third quadrant (also called reverse conduction from source to drain) is on the order of −2 to −4 V, depending on the device and bias conditions. Hence, many engineers assume that paralleling an external diode can improve the efficiency.

tions. Hence, many engineers assume that paralleling an external diode can improve the efficiency. Often, this isn't possible—GaN conducts very fast and the parasitic inductance present in the diode package makes it impossible for the current to steer through it.

9. NEGATIVE TURN-OFF VOLTAGE IS A MUST FOR eGaN

While negative turn-off voltage can protect the eGaN from inadvertently turning back on during transients, it's not necessary, especially if the layout follows all of the standard protocols. In fact, many of the eGaN gate drivers available in the market don't feature negative turn-off voltage as it adds cost and complexity.

10. IT ISN'T POSSIBLE TO HAVE DV/DT CONTROL OF GaN DEVICES

This myth stemmed from the days of cascoded GaN HEMTs, where it wasn't easily possible to control the turn-on and turn-off speed. eGaN behaves similarly to a SJ FET. Gate-drive circuitry can be tuned to control dv/dt.

11. ALL NEW WIDE-BANDGAP (WBG) MATERIALS WORK SIMILARLY

GaN and silicon carbide (SiC) are both wide-bandgap materials. They are exciting for multiple reasons, but their characteristics, application space, and gate-drive requirements are different. SiC will compete with IGBTs in the high-power space and very-high-voltage space (≥ 650 V). Meanwhile, eGaN will compete with SJ FET at all power levels from 40 to 650 V. mw

ROBERT MEILLEUR | VP of Operations, Corry Micronics

Ceramic Feedthrough Filters: Winning the Finite EMI Fight

In today's world, nearly all electronic devices have wireless-connectivity features built into them, and they rely on transmitting and receiving RF or microwave signals from one device to another.

From laptop computers to home-security systems, the transmission and reception of RF or microwave signals from one device to another is crucial. The term used to identify the energy in these transmissions is electromagnetic radiation. Such radiation is around us everywhere, all the time, at frequencies ranging from 3 kHz to 300 GHz.

When electronic devices have internal operating processes that rely on signals in this RF frequency spectrum, unintended results may occur if the ever-present RF or microwave electromagnetic radiation interacts with the device. This occurrence is otherwise known as electromagnetic interference (EMI).

EMI is a serious concern for devices that are externally powered (ones that have a plug) or require signal wires that need to extend outside the device (signal wires that might attach to sensors or input/output devices). The wires that connect to power sources, or I/O points, can act as antennas that will allow EMI to be received (coupled onto them) and enter the device. Once inside the device, EMI can then cause the device to perform improperly.

The most common way to prevent EMI from interfering with these devices is by installing feedthrough filters on their signal and power lines.

FEEDTHROUGH FILTERS DEFINED

A feedthrough filter is a component that has a capacitive element built around a central conductor. Capacitors are reactive components, meaning they conduct electrical energy at different rates based on frequency. At very high frequencies, capacitors act like a short circuit, allowing RF energy to pass through them freely. At very low frequencies, they act like an open circuit, not allowing any RF energy to pass through them.

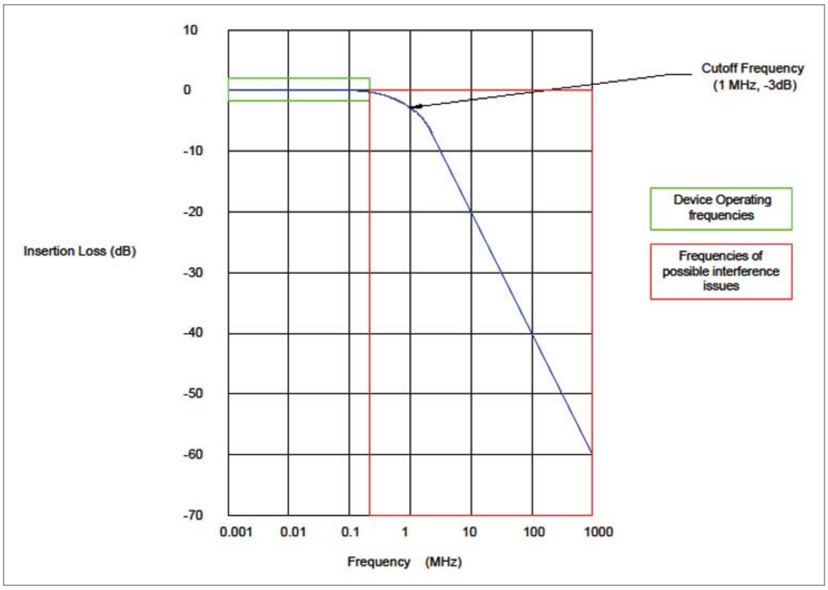
Since the capacitors are built around a center conductor that passes through the case and into the device, they're often called low-pass filters. This is because they allow lower frequencies to enter the device with very little loss, while shunting high frequencies through the capacitors.

Feedthrough filters are built using a dielectric material that can be shaped into a circular form. This may be in the form of a discoidal (donut shape) or in a tubular form *(Fig. 1)*. These shapes allow for the center conductor to pass through and attach to them in the center. This creates the "+" connection to the capacitor element. The outer diameter of this form is the "–" connection to the capacitor element, which is typically attached to an electrical ground point of the device.

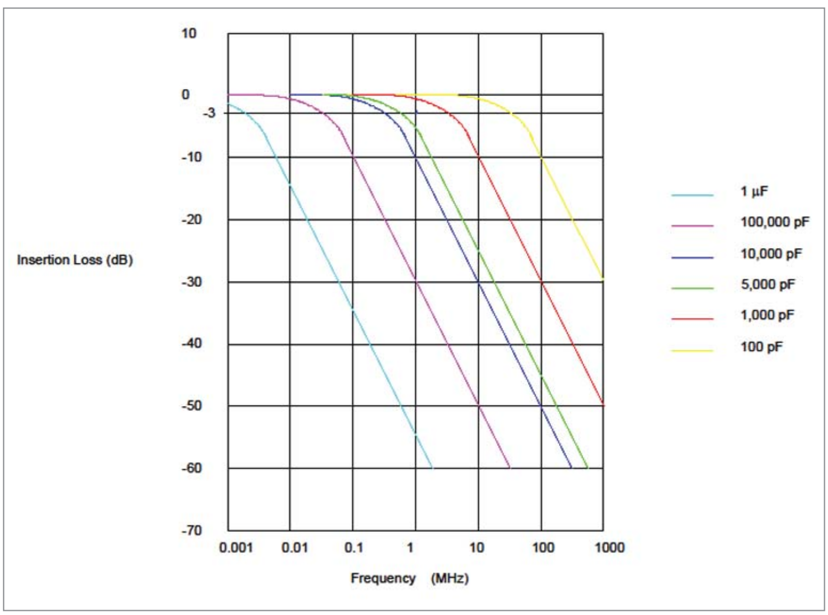
Many different types of material can be used to make the capacitor, but the most common material today is ceramic

1. The tubular shape allows for the center conductor to pass through and attach to the center.

2. Many different types of material can be used to make the capacitor, but the most common material today is ceramic.



3. The cutoff frequency needs to be above the operating frequencies of the device.



4. The selection of the proper circuit for your device depends on the insertion-loss requirements.

(Fig. 2). This is due to its ability to have relatively high dielectric constants and high working voltage capabilities.

CERAMIC FEEDTHROUGH FILTERS: BASIC REQUIREMENTS

When reviewing the use of low-pass filters to prevent EMI, a few basic requirements are common to all applications:

- Cutoff frequency
- Insertion loss
- Power requirements

To incorporate a feedthrough filter into a design, you must be familiar with two sets of frequencies. The first set includes frequencies that the device utilizes internally for its operation. For example, if a switching power supply is used, the switching rate may be from a few hertz to over 2 MHz. The second set includes frequencies that will cause unintended operation of the device if it's exposed to EMI. Typically, the interfering frequencies will be higher than those at which the device operates.

Cutoff Frequency

The cutoff frequency is the frequency at which the filter starts eliminating the unwanted EMI. This is defined as the frequency at which the filter removes 1/2 of the radiation energy level, or 3 dB, which is more commonly referred to as 3 dB of insertion loss.

The cutoff frequency needs to be above the device's operating frequencies, but it must also be low enough to eliminate as much of the higher frequencies

Capacitance (pF)	Dielectric Type		Cutoff Frequency
	Tubular	Discoidal	
100	*Yes*	*Yes*	*50 MHz*
1,000	*Yes*	*Yes*	*5 MHz*
5,000	*Yes*	*Yes*	*700 KHz*
10,000	*Yes*	*Yes*	*500 KHz*
50,000	*No*	*Yes*	*70 KHz*
100,000	*No*	*Yes*	*50 KHz*
1,000,000	*No*	*Yes*	*3 KHz*

5. The cutoff frequency is mainly determined by a simple variable.

as possible. *Figure 3* shows a device that has internal operating frequencies of up to 300 kHz *(see the green box)*. Within these frequencies, all I/O lines must be able to operate with minimal signal loss. The red box (above 300 kHz) represents frequencies that could potentially pose issues with EMI. For this device, the cut-off frequency was set at 1 MHz.

Insertion Loss

The term insertion loss refers to the filtering capabilities of the feedthrough filter at a given frequency. The MIL-STD-220 test standard is globally recognized for the characterization of these types of filters and their insertion-loss capabilities. Not all circuits are the same in terms of input or output impedance. This standard normalizes the measurement in a balanced 50-Ω test system.

When measured in this test system, the insertion loss of the feedthrough filter can be plotted versus frequency, which is normally shown on a log scale. Insertion loss is reported in decibels (dB). The formula for insertion loss is:

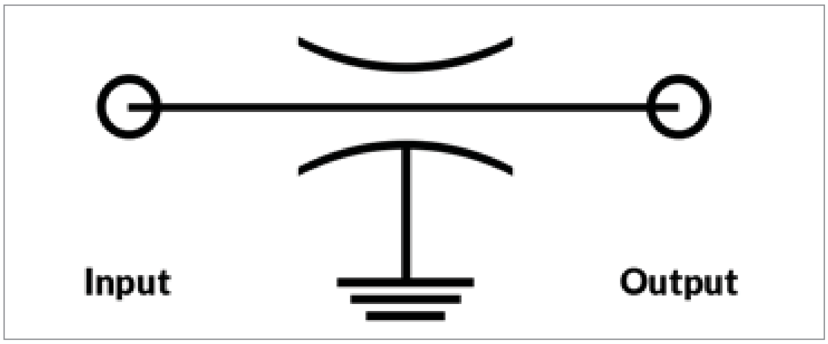
$$\text{Insertion Loss} = 10\ \text{Log}_{10}\ (P_{out} / P_{in})$$

where P_{out} = power level at the output of the filter, and P_{in} = power level at the input of the filter.

For every 3 dB of insertion loss, the power level of that frequency allowed through the filter and into the device is reduced by 50%. Common feedthrough filters today have insertion-loss values of 40 dB or more at 100 MHz. At 40 dB, the feedthrough filter is removing 99.99% of the RF energy.

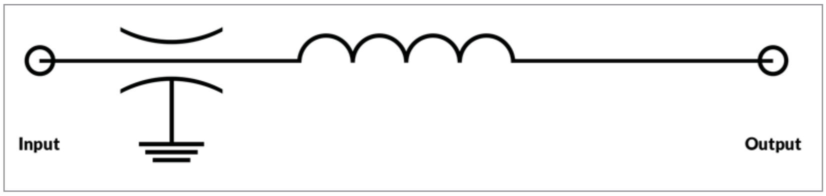
Power Requirements

The other basic requirement when selecting the right feedthrough filter for your device involves the power



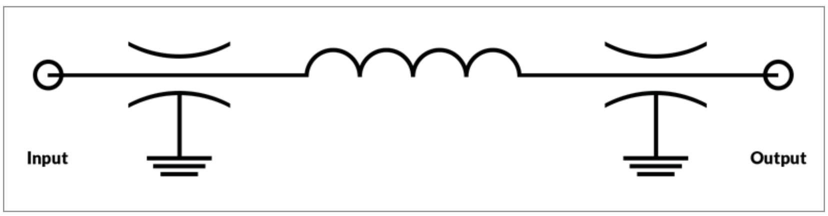
6. A "C" circuit is comprised of a single feedthrough capacitor on a center conductor.

requirements (voltage and current). The feedthrough filter must be able to operate at the input voltage of the device for power connections, or the signal voltage for signal lines. It also must have a center conductor that's large enough to handle the current level required by the device. Most center conductors are made of copper; standard wire gauge amperage charts can be used for design purposes.

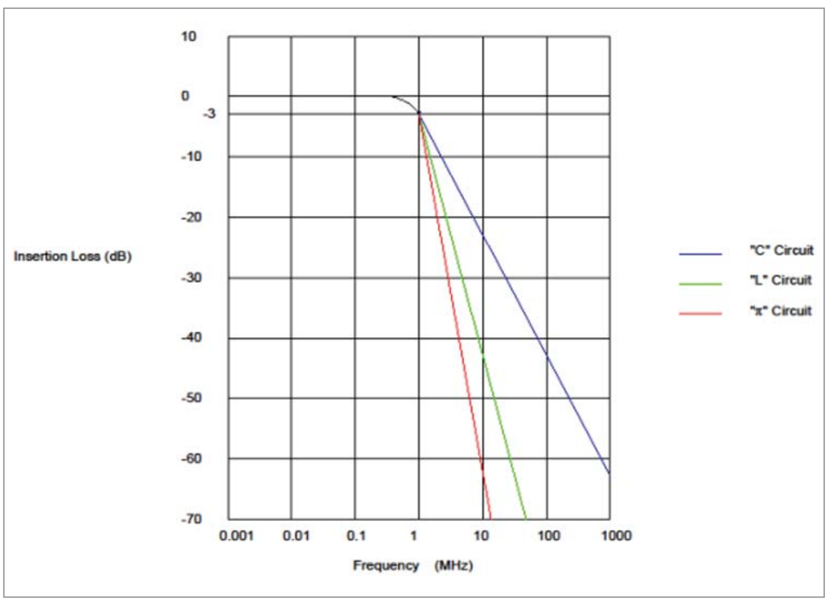


7. An "L" circuit adds an additional series of inductive elements to the "C" circuit.

A "π" (Pi) circuit is two "C" circuits separated by a series inductive element (same as an "L" circuit with an additional "C" circuit added after the inductive element) *(Fig. 8)*.



8. A π (Pi) circuit is two "C" circuits separated by a series of inductive elements.



9. These circuits all have different insertion-loss frequencies.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Ceramic feedthrough filters come in a variety of packages to suit the individual needs of different types of applications. These range from individual component types for single-line applications to multi-line products suited for applications that have many lines to protect against EMI.

CERAMIC FEEDTHROUGH FILTERS: CIRCUIT OPTIONS

In feedthrough filtering, there are three common circuit types: "C", "L", and "π" (Pi). All three circuit types can be made with the discoidal or tubular type dielectrics mentioned earlier. Selecting the proper circuit for your device depends on the insertion-loss requirements *(Fig. 4)*. First, set the proper cutoff frequency, and then determine how fast the optimal amount of insertion loss is needed after the cutoff frequency.

Setting the Cutoff Frequency

For feedthrough filters, the cutoff frequency is mainly determined by a simple variable – the total capacitance of the filter. Typical design values for capacitance versus cutoff frequency are shown in *Figure 5*.

Selecting the Circuit Type

A "C" circuit consists of a single feedthrough capacitor on a center conductor *(Fig. 6)*. This circuit type will provide an insertion-loss slope after the cutoff frequency of approximately −20 dB per decade of frequency. However, as with all capacitors, there will be a point of self-resonance that will alter this slope. There will also be a frequency at which there will be a limit to the filter's ability to provide any additional insertion loss. The typical industry-standard maximum stated insertion loss for "C" and the other two circuit types is around −70 dB.

An "L" circuit adds an additional series of inductive elements to the "C" circuit *(Fig. 7)*. These additional elements can be an inductive coil or a slip on a ferrite shielding bead over the cen-

10. SMT filters have a maximum capacitance of 8,200.

13. The maximum capacitance of a bolt-style filter will vary depending on its VDC, power rating, and circuit type.

11. Solder-in filters have a maximum capacitance of 50,000.

12. Press-in filters have a maximum capacitance of 50,000.

tral conductor. By adding one of these additional elements, the cutoff frequency stays the same, but the slope of insertion loss increases by another 20 dB per decade. Self-resonance will still be present at the same frequency as if this were a "C" circuit. The magnitude that the resonance will have on limiting the insertion loss will be diminished.

A "π" (Pi) circuit is two "C" circuits separated by a series inductive element (same as an "L" circuit with an additional "C" circuit added after the inductive element) *(Fig. 8)*. By adding this third element, the cutoff frequency stays the same, but the slope of insertion loss increases by another 20 dB per decade over the "L" circuit (to 60 dB per

Individual Line Feedthrough Filters					
Type	Maximum Capacitance (pF)	Working Voltages (VDC)	Current Ratings (A)	Circuit Types	Notes
SMT	8,200	100	20	"C"	
	4,000	100	10	"π" (Pi)	
Solder-In	50,000	100	7	"C", "L"	Hermetic available
Press-In	50,000	100	7	"C"	
Bolt-In	4,000	200	1	"C"	#0 Thread
	50,000	50	10	"C", "L"	#2 - #4 Thread
	100,000	100 - 1,500	Up to 25	"C", "L", "π" (Pi)	#8 - 1/4" Thread, Hermetic available
	5,000	2,500	Up to 200	"C", "L", "π" (Pi)	5/16" - 5/8" Thread

14. The maximum capacitance varies depending on the type of feedthrough filter you use.

Multiple Line Feedthrough Filters					
Type	Maximum Capacitance (pF)	Working Voltages (VDC)	Current Ratings (A)	Circuit Types	Notes
Terminal Block	30,000	300	30	"C"	2 - 8 position
	5,000	300	30	"L", "π" (Pi)	
D-Sub	50,000	200	5	"C", "L", "π" (Pi)	9, 15, 25, 37, and 50 pin
Mil-Circular	50,000	200	15	"C", "L", "π" (Pi)	Mil-C-38999 and similar
Filter Plate	5,000	100 up to 500	5 up to 25	"C", "L", "π" (Pi)	Standard Bolt-in, up to 60 pin, 0.100" and 2 mm Spacings, Custom designs available
	50,000	50	10	"C", "L"	Standard Clip-In, up to 26 pin, 0.100" and 2 mm Spacings, Mini-Clip (10 position) also available

15. When there's a need to filter multiple I/O or power lines, multiple-line components are available.

decade). This circuit type eliminates nearly all the effects of self-resonance on insertion loss *(Fig. 9)*. For discoidal type dielectrics, this circuit type is made from three separate components. For tubular dielectric types, these are made with just two components, with both capacitors being made on a single dielectric tube.

CERAMIC FEEDTHROUGH FILTERS: PACKAGE OPTIONS

Ceramic feedthrough filters come in a variety of packages to suit the individual needs of different types of applications. These range from individual component types for single-line applications to multi-line products suited for applications that have many lines to protect against EMI.

Individual-Line Applications

Individual feedthrough filters are most commonly installed directly into the case of the device. This is done by either soldering the case of a solder-in type or bolting a bolt-in type directly into a threaded hole (or using a nut and lock washer in a clearance hole) on the case. Internally, the same installation methods can be used through partition walls or floor openings between device sections.

Figures 10-13 show the various package types for individual-line feedthrough filters. *Figure 14* reveals

16. The maximum capacitance of a terminal block will vary depending on its circuit type.

17. Filtered mil-circular connectors have a maximum capacitance of 50,000.

their corresponding capacitance value, power ratings, and circuit types.

Multiple-Line Applications

When there's a need to filter multiple I/O or power lines, multiple-line components are available *(Fig. 15)*. Terminal blocks, D-sub connectors, and mil-circular connectors are commonly used on case installations *(Figs. 16-18)*. Filter plates are typically used for internal filtering on partition walls or floor openings between device sections *(Fig. 19)*. These designs are all suited to match industry standard mating connectors and hardware. mw

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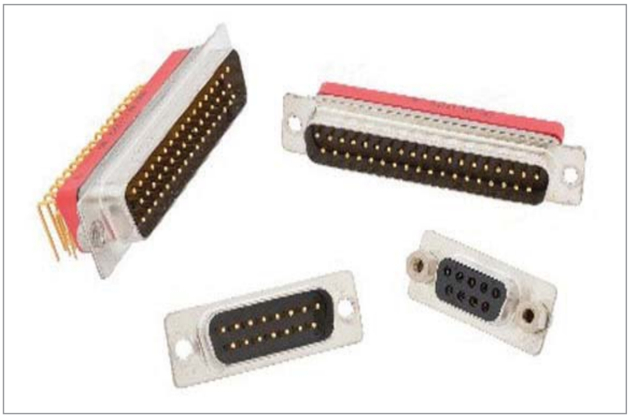
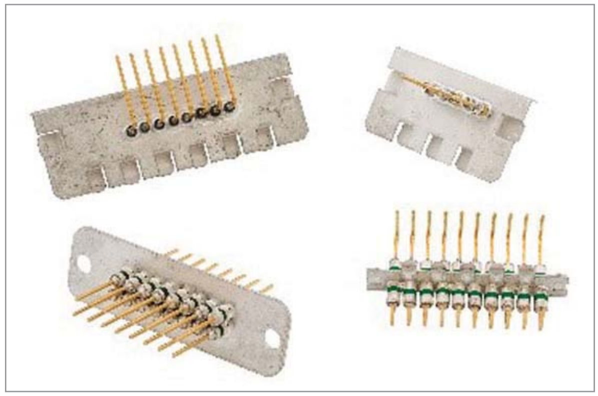


18. D-sub connectors have a maximum capacitance of 50,000.



19. Filter plates have a maximum capacitance of either 30,000 or 5,000.

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Start Your 5G Journey Now with 4G LTE

Lost amid the noise around 5G is that well into this decade, 4G LTE will remain the strongest contender for IIoT solutions, even as we prepare for the 5G era.

1. A cyber-physical system is a fundamental building block of Industry 4.0.

2. Not only will LTE networks be available for another decade or more, they're expected to continue their evolution well into the 5G era.

It's hardly news that we're at the cusp of the fourth industrial revolution. The Internet of Things (IoT), artificial intelligence, ubiquitous wireless connectivity, mixed reality, blockchain, autonomous vehicles, the cloud—these and countless other recent developments are changing the way industries operate. The promise: the merger between digital and physical systems into the Industrial Internet of Things (IIoT) —a cyber-physical system that's a fundamental building block of Industry 4.0 *(Fig. 1)*.

In the limelight and often polarizing is 5G. To some, the fifth generation of cellular communication technology is overhyped. Others are preparing to upend their industries to get in on the action as early adopters. Somewhere in between, the more cautious are investing in 5G to gain the experience needed to create new products and solutions that they can offer to their customers once the dust settles and the technology is mature.

Precisely because of all the hype, this confusion is hardly a surprise. With the industry-relevant facets of 5G still a few years from widespread adoption, traditionally conservative industries will be tempted to hold off investments into the IIoT until the new standard in 3GPP's Release 17 is fully implemented. After all, why pour money into 4G LTE—a technology that seems to be on the verge of becoming outdated—when a technological revolution is in the making?

There's just one thing: Far from obsolescence, 4G LTE still gains traction and will continue to grow its footprint for years to come, dominating the market for even longer. In fact, 4G LTE networks will complement and even underpin 5G networks as they take root.

A point that tends to get lost amid the noise around 5G is that well into this decade, 4G LTE will remain the strongest contender for IIoT solutions *(Fig. 2)*. In this article, we'll lay out why. We'll also look at how best to prepare for the new 5G era and explore ways to start tapping into the value 5G will bring—using today's 4G LTE technology.

A GAME-CHANGER... EVENTUALLY

There's no doubt that 5G will be transformational and that much of the hype surrounding it is warranted. It even stands a chance of living up to its lofty ambition of fundamentally transforming the role cellular communication technologies play in society, culminating in an "Internet of Everything," built on several disruptive innovations:

- 5G adds new spectrum bands, including sub 1 GHz and mmWave (>24 GHz), to expand capacity.
- It offers up to 1-GHz channel bandwidth in mmWave bands to achieve ultra-high broadband speeds.
- It introduces a new radio interface (5G NR) that's versatile enough to serve diverse needs.
- It will require a new core network with small cells, network slicing, network virtualization, edge computing, and more to meet requirements and tailor performance to industry-specific requirements.

Defined by 3GPP, the standardization body responsible for defining global cellular-communications standards, 5G's specifications cater to diverse new use cases that are relevant in industrial applications. Ranging from a new generation of human-machine interfaces to automated manufacturing to ubiquitous sensing and cloud connectivity, each use case can be enabled using the right balance between 5G's three fundamental pillars:

- Enhanced mobile broadband (eMBB) will deliver data-transfer rates in excess of 10 Gb/s while increasing capacity by three orders of magnitude.
- Ultra-reliable, low-latency communication (URLLC) will target an astounding reliability of up to 99.9999% with latencies in the milliseconds.
- Finally, massive machine-type communication (mMTC) will further extend the promise of today's low-power, wide-area networks (LPWANs), delivering sporadic data with low power requirements and at low cost.

A STAGGERED ROLLOUT

That's a lot to look forward to. But

3. Data is gaining in strategic value as an enabler of real-time quality control, predictive maintenance, integrated supply and distribution chains, workforce monitoring, and more.

fully rolling out 5G around the globe will take time. We'll see mobile network operators align their schedules with the business cases they consult in their respective markets, as well as with their willingness and capacity to make the required investments. Moreover, 3GPP isn't releasing the 5G specifications in one fell swoop for all industries. Instead, each new release brings additional features to the technology.

3GPP Release 15 was mostly about making possible eMBB and its high-speed data transfer, primarily targeting consumer markets. Release 15 was further broken down into three sub-releases. The first, focusing on the non-standalone (NSA) implementation of the technology on the back of 4G LTE networks, was put on a fast track and delivered in late 2017. Major mobile network operators (MNOs) have since brought the technology to key markets in urban areas.

The second sub-release, which deals with the standalone implementation of 5G, was finalized in mid-2018. The final sub-release followed in early 2019, adding several technical enhancements. Because MNOs are still busy rolling out 5G NSA, it could still be a few years before we see commercial rollouts of the standalone variant.

3GPP Release 16, slated for the first half of 2020, will finally address the two pillars that most impact the connected industry: URLLC and, finally, mMTC. URLLC, in particular, will require dedicated network implementation. Release 17, scheduled for the last quarter of 2021, will further expand these pillars.

A SMOOTH TRANSITION FOR LPWANS

To ensure the longevity of today's LPWAN solutions, which are only beginning to ramp up, the 3GPP consortium is going out of its way to ensure a smooth migration path from 4G LTE to 5G technologies.

Not only will LTE networks be available for another decade or more, but they're also expected to continue their evolution well into the 5G era, future-proofing investments with further improvements in power consumption, performance, device size, features, and cost. Backwards compatibility will ensure that 4G LTE solutions continue to deliver even as 5G goes mainstream. And "legacy" LPWAN devices, which work on today's 4G networks, will be made compatible with 5G networks.

This explains why some industries are embracing advances provided by 4G LTE to streamline their operations, increasing their efficiencies and growing their productivity. It's a trend that will only accelerate as we enter the 5G era, changing the entire logic on the factory floor, where a heavily fragmented market of wired technologies still dominates today.

Today's manufacturing sites, for example, are made up of "connectivity islands" separated by gateways at the field level. Because existing technology standards are fragmented and, consequently, lack interoperability, simply getting different industrial networking technologies to connect requires a series of protocol translations.

Contrast that to Industry 4.0's promise of full transparency across all processes and assets at all times, with seamless communication between goods, production systems, supply and distribution chains, people, and processes, all on the back of unified, robust, and reliable wireless connectivity.

NEW EMERGING BUSINESS MODELS

But it isn't just operations that are being redefined. Entire business models are being shaken up, driven by facilitated access to data *(Fig. 3)*. Generated faster than ever—across industrial verticals—it's gaining strategic value as an enabler of real-time quality control, predictive maintenance, integrated supply and distribution chains, workforce monitoring, and more. This fundamentally changes the ways industries operate.

A case in point: Industry 4.0 is accelerating the speed of business under the slogan, "Today's order is tomorrow's delivery." It's simultaneously reversing the decades-old trend of centralized mass production: Demand for mass-produced goods that are customized down to the individual unit can only be met on time if production capacity moves closer to the end customers.

Full traceability is just as disruptive: Thanks to Industry 4.0, operation managers can know the exact source of each piece used in every single device they produce. Even when deployed, devices can be continually monitored, revealing weaknesses in the manufacturing process that can be addressed to improve the quality of future products. And customers reap the benefits of a new level of data- and insight-driven service and support.

Moreover, by embracing technologies that don't require wired connectivity, Industry 4.0 makes manufacturing more agile and more versatile. Easier to deploy than the wired solutions of the past, LPWAN and 5G technologies reduce the investment needed to gather huge amounts of sensed data. They accelerate implementation in existing and new installations. They deliver higher quality information and improve operator safety. And finally, they're much more flexible to implement and easier to scale.

LIFTING INDUSTRIAL AUTOMATION TO NEW HEIGHTS

Tapping into this pool of data and translating it into actual benefits will require a new, more holistic way of thinking about the flows of resources, goods, and people, as well as of supply, production, and distribution chains.

Not to mention the operation and maintenance of all the machines and other installations, and the safety and wellbeing of the people involved.

Setting up and running this new way of communicating between goods, production systems, and processes will require extensive human thinking and supervision and a deeper understanding of all aspects of the production process. Likewise, rationalizing processes on the conveyor belt will demand more sophisticated planning, creation, and process management, combined with a move to strengthen local production capacity.

The culmination of this holistic approach—the marriage between operational technology (OT) and information technology (IT)—will be the digital twin, a virtual representation of all relevant information about the manufacturing process. As digital twins mature, they will progress both in scope and depth. They will tie together increasingly more detailed data on resources, products, and assets, as well as information on the status and performance of the operational infrastructure, the machines, and even external supply chains.

PRIVATE NETWORKS: A STEPPING-STONE ON THE WAY TO 5G

It will, however, be years before the industry-relevant facets of 5G are rolled out on public networks. In the meantime, non-public networks, owned and operated by enterprises or professional service providers, will be the quickest way to solve the challenges of reliability, availability, low turnaround time, and data privacy.

Already available using 4G LTE, non-public networks give companies the possibility to adjust network parameters and radio spectrum utilization to meet industry-specific needs. These private networks can enable mission-critical applications, ultra-low latencies, ultra-high data-transfer rates, or an extra level of safety that rival those offered by 5G.

Manufacturing sites, warehouses, supply chains, and logistics are obvious beneficiaries of private networks. To the extent that they leverage wireless connectivity at all, manufacturing sites tend to be made up of a patchwork of technologies that can't be integrated into a single platform, limiting the complexity of applications that they can enable. 4G LTE and later 5G private networks offer a new level of versatility, scalability, and ease of implementation.

Several countries have begun to reserve spectrum specifically for industrial private cellular networks. Germany has reserved spectrum in the range from 3.7 to 3.8 GHz, with Sweden likely to follow suit. Japan has reserved spectrum at 2.4, 4.5, 4.6, and 28.2-29.1 GHz, while the UK has reserved spectrum at 1.8, 2.3, 3.8-4.2, and 24.25-26.5 GHz.

On request, the German Federal Network Agency is allocating frequencies for a limited period of up to 10 years, with annual fees in the four- to five-digit ranges (Euros) based on the requested bandwidth, the duration of allocation, and the coverage area. It's an attractive offering that hasn't been universally welcomed by mobile network operators, not least because it cuts a significant slice out of the frequency spectrum.

SHAPING THE FUTURE OF THE CONNECTED INDUSTRY

At u-blox, we are strongly engaged in shaping the future of the connected industry. As active members of the 3GPP consortium, we participate and contribute to NB-IoT and mMTC standardization. In addition, we are engaged in pilot studies exploring the requirements and performance of 5G technology in industrial use cases.

5G-SMART *(Fig. 4)*, funded by the European Commission, brings together partners from industry (Bosch, ABB, Ericsson, and u-blox among others) and research (Lund University, Universitat Politechnica de Valencia, and Fraunhofer Institute), to evaluate the potential of 5G in real manufacturing environments. And as an active member of 5G-ACIA, we are working with a diverse team of IT and OT industrial partners to ensure the best possible applicability of 5G technology and 5G networks for connected industries, particularly manufacturing and process industries.

4. 5G-SMART, funded by European Commission, brings together partners from industry and research to evaluate the potential of 5G in real manufacturing environments.

START TODAY

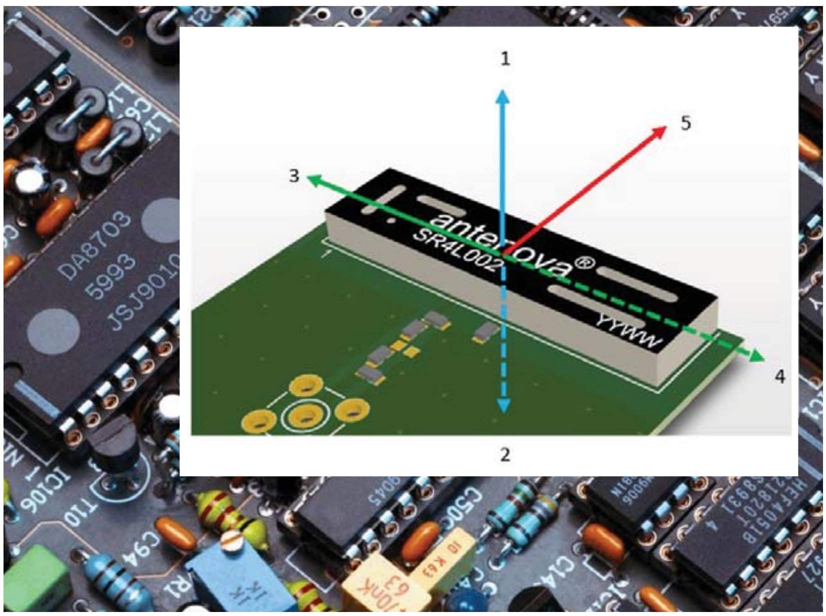
By broadening the scope of applications that are possible with cellular communication technologies, 5G is poised to take the connected industry to the next level. But it will still be several years before the industry-relevant facets of the standard are mature and mobile network operators roll out the infrastructure needed to implement 5G-based solutions.

The good news is that the 3GPP is going out of its way to provide a smooth transition from today's 4G LPWA technologies to their 5G successors. This means that you can embark on your 5G journey today, embrace the possibilities 4G LPWA already offers to enable new business models, and gain a technological head start over your competition that will pay dividends in the long run. mw

GEOFF SCHULTEIS | RF Antenna Application Specialist, Antenova Ltd.

DESIGN TIPS FOR Positioning an Embedded Antenna on a PCB

When integrating an antenna onto a PCB, following the supplier's requirements will get the best performance from the antenna. This article outlines the first steps to designing a PCB that includes an antenna.



1. This image shows how the antenna can radiate in up to six directions (omnidirectional).

Antennas are sensitive to their surroundings. Thus, when there's an antenna on the PCB, the layout for the design should take the requirements of the antenna into account, as this can make a huge difference in the wireless performance of the device. Care should be taken when integrating an antenna into a new design. Even the material, layer count, and layer thicknesses of the PCB can affect an antenna's performance. This article discusses some basic design concepts that will help a designer derive great performance from an antenna.

POSITIONING AN ANTENNA FOR PERFORMANCE

Antennas operate in different modes, and depending on the way an individual antenna radiates, it may need to be placed in a certain position—along the short side of the PCB, the long side, or in a corner.

The corner of the PCB is generally the best place to position an antenna. That's because a corner position allows the antenna to have clearance in five spatial directions, and the feed to the antenna lies in the sixth direction *(Fig. 1)*.

Antenna manufacturers offer a choice of antenna designs that will be suited to different positions, so product designers can select the antenna that fits best into their layout. Often, the manufacturer's datasheet will show a reference design which, if followed, will deliver optimal performance.

Product designs for 4G and LTE usually employ more than one antenna to build a MIMO system. In such designs, where multiple antennas are used simultaneously, the antennas are typically placed on separate corners of a PCB *(Fig. 2)*.

THE KEEP-OUT AREA

It's important not to place any components in the near field immediately around the antenna, as they may interfere with its performance. Accordingly, the antenna specification will state the size of the keep-out area—this is an area near and around the antenna that must remain clear of metallic objects. This will apply to every layer in the PCB. In addition, no components, or even mounting screws, should be placed within this area on any of the layers of the board.

An antenna radiates against a ground plane, and the ground plane is related to the frequency at which the antenna operates. Thus, allowing the correct size and space for the chosen antenna's ground plane is a top priority.

An antenna radiates against a ground plane, and the ground plane is related to the frequency at which the antenna operates. Thus, allowing the correct size and space for the chosen antenna's ground plane is a top priority.

GROUND PLANES

The ground-plane size should also consider any wires used for communication to the device and the batteries or power cable that power the device. If the ground plane is properly sized, it will ensure that the cables and batteries connected to the device have less influence on the antenna *(Fig. 3)*.

Some antennas are ground-plane-dependent, which means that the PCB itself becomes the ground portion of the antenna to operate against in order to balance the antenna currents, and the lower layers of the PCB may affect the antenna's performance. In these cases, it's important not to place a battery or an LCD near the antenna.

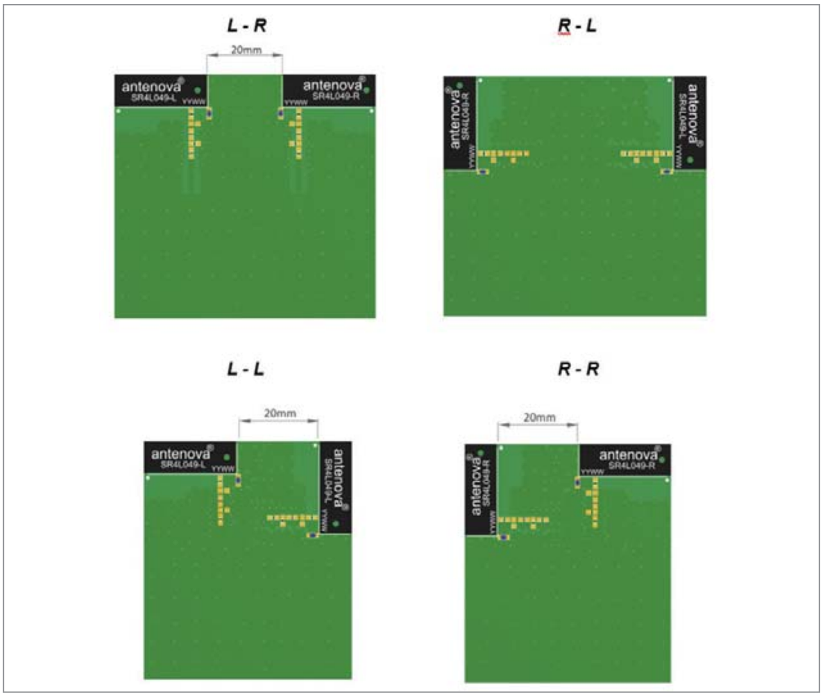
The manufacturer's datasheet should always specify whether the antenna needs a ground plane to radiate, and, if so, the size of ground plane required. This may mean that a clearance area should surround the antenna.

PROXIMITY TO OTHER PCB COMPONENTS

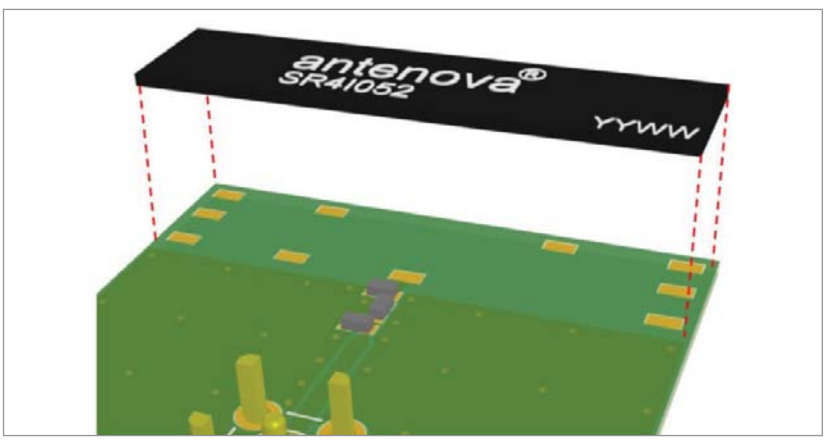
It's vital to keep the antenna well away from other components that might interfere with the way the antenna radiates. Items to be wary of are batteries; LCDs; metal components such as USB, HDMI, and Ethernet connectors; and noisy or high-speed switching components related to switching power supplies.

The ideal distance between the antenna and another component varies according to the height of that component. As a rule, if a line is drawn at an angle of 8 degrees from the base of the antenna, the component will be at a safe distance from the antenna if it's positioned below this line. *Figure 4* shows how this looks with a USB connector.

If other antennas are nearby operating on similar frequencies, the effect may be to detune the two antennas as they affect each other's radiation. We recommend mitigating this by isolating the antennas by at least −10 dB up to 1 GHz and −20 dB for 20 GHz. This can be done by allowing more distance between the antennas or rotating them so that they are placed at 90 degrees or 180 degrees apart from each other.



2. These are examples of two antennas placed for a diversity solution.



3. The keep-out area is simply defined as the same size as the antenna, with 1 to 3 mm of additional clearance below the antenna to the ground.

DESIGNING THE TRANSMISSION LINE

The transmission line is the RF trace that carries the RF energy to and from the antenna to deliver the signal to the radio. The design for the transmission line needs to be 50 Ω or it's possible that it may reflect signals back to the radio and cause a degraded signal-to-noise ratio (SNR), which could possibly desense the radio receiver. The reflections are measured as voltage standing-wave ratio (VSWR). A good PCB design will exhibit a suitable VSWR measurement, which can be measured when the antenna is tested.

We recommend designing the transmission line with care. First, the transmission line should be straight, because if it has corners or bends, these can contribute to losses. It's possible to minimize the noise and signal losses that can affect antenna performance by placing vias evenly along both sides of the trace, as these help to increase performance by isolating noise traveling along nearby traces or ground layers *(Fig. 5)*.

Thinner transmission lines can be more lossy. RF matching components and the width of the transmission lines should be used to tune the antenna to operate at a characteristic impedance of 50 Ω. The dimensions of the transmission line can affect performance, and the transmission line should be as short as possible to allow the antenna to perform well.

A free tool to calculate grounded-coplanar-waveguide (GCPW) transmission lines can be found at *https://blog.antenova.com/rf-transmission-line-calculator.*

HOW TO ACHIEVE BETTER PERFORMANCE?

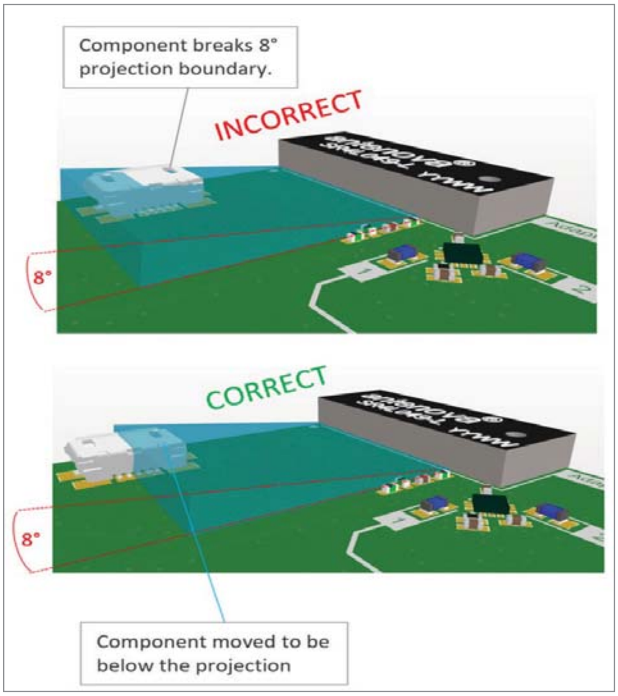
If you allowed for the correct ground plane and placed the antenna in the optimal position, you've made a good start, but more can be done to improve antenna performance. You can use a matching network to tune the antenna—this will compensate somewhat for any factors that might be affecting the antenna's performance.

The key RF components are the antenna, its matching network, and its RF output. A configuration that places these elements in proximity will minimize signal losses. Similarly, if your design includes a matching network, the antenna will perform best if the trace length from the antenna matches that specified in the manufacturer's product specification.

The exterior casing around the PCB may also make a difference. Antenna signals can't travel through metal, so placing the antenna inside a metal case or a case with metallic properties will not be successful.

Likewise, be cautious about placing an antenna close to plastic surfaces, as this can be very detrimental to antenna performance. Some plastics such as glass-filled nylon are lossy and dampen the RF signal to the antenna. Plastic has a higher dielectric constant than air, which can affect signals severely. It means the antenna will register a higher dielectric constant, thus increasing the electrical length of the antenna and reducing the frequency at which the antenna radiates.

We suggest using high-quality FR4 circuit boards—they will be less likely to create any issues with RF performance. mw



4. A line at an angle of 8 degrees from the antenna shows the safe distance between the antenna and another component.

Cover Story

DAVID MALINIAK | Editor

Benchtop RF Power Meter Takes USB Sensors to the Next Level

Boonton's PMX40 RF power meter marries USB power sensors to the benchtop sans computer or the hassles of analog calibration.

Boonton's PMX40 RF power meter retains the best aspects of the traditional benchtop instrument and USB RF power sensors, but combines them to enable new possibilities for RF power measurement.

For many decades, the traditional benchtop RF power meter has been a staple in engineers' toolboxes. Ever present in both the lab and field, benchtop power meters (or wattmeters, as they're sometimes known) are the go-to device for characterizing the performance of transmitters of all descriptions and from top to bottom of the spectrum. Historically, benchtop RF meters have used analog sensors as their input devices with the sensor connected to the measurement unit by an analog cable. Such instruments are quite durable and reliable, and they're still widely used.

Some years ago, USB RF power sensors appeared, representing a new approach to power measurement that encapsulated most of the functionality of the benchtop meter in a device that took the benchtop instrument out of the equation. Instead, the USB RF sensor (which is slightly larger than the analog sensors) delivers its data to a computer. It means a different user interface—rather than the buttons, knobs, and meter movement (or digital display) of the benchtop instrument, a graphical user interface (GUI) on the computer screen displays the sensor's data. The setup involves software that either the user must develop, or the USB RF sensor vendor must supply.

Perhaps no vendor knows more about RF power meters and USB RF sensors than Boonton Electronics. Boonton believes the industry is ready for yet another new approach to power measurement: It would retain the best aspects of the traditional benchtop instrument and USB RF power sensors, but combine them to enable new possibilities for RF power measurement.

Enter the Boonton PMX40 RF power meter, which differs from traditional instruments in that it uses USB power sensors as opposed to the old analog sensors. That's significant in several ways. As a benchtop RF power meter, the PMX40 still captures, displays, and analyzes peak and average power in both the time and statistical domains.

The front panels of many traditional benchtop RF meters are laden with knobs and buttons in addition to a small display. Further, older instruments typically provide inputs for only one or two analog sensors. In contrast, the PMX40's most prominent front-panel feature is a 5-in. multitouch display, providing a more modern UI. Not only that, but it accepts inputs from four USB RF power sensors for multi-channel measurements on any sort of RF signal, be they continuous wave (CW), modulated, or pulses.

In cases such as LTE, 5G, or Wi-Fi, the PMX40 is easily configured for multiple-input/multiple-output (MIMO) measurements. It's also able to perform such measurements in synchronized fashion, giving users a common time reference across all four channels. This makes it easy to determine whether MIMO signal paths are properly timed.

Traditional RF power meters historically have a "reference output" that enables users to mitigate interconnect uncertainties imposed by the analog cables connecting sensors to the meter. Not only do traditional meters require an initial calibration, but as ambient temperatures change and cables are physically moved, users need to stop taking measurements to recalibrate. The all-digital communication between meter and sensor in the PMX40 makes calibrating out cable drops unnecessary; the USB RF power sensors are essentially "plug and play."

But Boonton incorporates a "test source" to verify basic operation of USB RF sensors as a "sanity check" to determine whether the USB sensor is behaving as expected. Don't need the meter for a given application? Then simply use the USB RF sensors independently through a robust application programming interface (API) or complementary UI to gain access to the full palette of sensor features and functionality.

Power meters and USB sensors must intermittently stop acquiring samples to process those they have collected. There are also acquisition interruptions for adding calibration factors, scaling, or formatting for display.

USB RF SENSORS TO MATCH

In some ways, an RF power meter is only as good as the sensors it's paired with. Fortunately for users, Boonton offers several USB RF sensors that seem tailor-made for the PMX40. Chief among them, the RTP4000 and RTP5000 sensors offer what Boonton calls "real-time power processing."

Power meters and USB sensors must intermittently stop acquiring samples to process those they have collected. There are also acquisition interruptions for adding calibration factors, scaling, or formatting for display. With the exception of Boonton, these processes are performed sequentially. During these periods, the meter/sensor isn't collecting data. Something you want to know about may be missed entirely. For example, heating of high-power amplifiers can cause anomalies such as dropouts or droop. Boonton's real-time power processing performs all of those acquisition-interrupting operations virtually in parallel, avoiding sampling interruptions and causing no measurement latency or gaps in data acquisition.

The RTP5000 sensors also offer industry-leading performance on several fronts. At an effective sampling rate of 1 GS/s and 100,000 measurements/s with virtually continuous operation, they enable time resolution of 100 ps. In addition, those 100,000 measurements are of peak, average, and minimum power. So, for a burst or pulse signal, you're measuring the noise floor, the top of the packet or burst, and the average power. Or, you can gate measurements to get peak, average, and minimum power of the burst alone.

Other best-in-class specs for the RTP5000 USB RF power sensors is a video bandwidth of 195 MHz and rise time of 3 ns. If you're measuring, say, Wi-Fi 6 signals with bandwidths of 80 and 160 MHz, you'll need most of that 195-MHz video bandwidth to make accurate peak-power measurements. The fast rise time matters for pulse signals and capture of fast leading edges.

For budget-conscious USB RF sensors, Boonton's CPS2000 family also pairs well with the PMX40 RF meter while also offering best-in-class performance. The sensors have both USB and LAN (with Power over Internet) connectivity, so if you're not using them with the PMX40, they support independent operation. mw

defense electronics

A Special Section to ENDEAVOR'S DESIGN ENGINEERING & SOURCING GROUP

Computer Modeling Provides Material Insights

p| 54

Courtesy: Lockheed Martin

Updated Ground Station Monitors GPS M-Code

JACK BROWNE | Technical Contributor

THE U.S. MILITARY HAS BEEN involved in an extended campaign to modernize its electronic systems, including a system that many civilians rely upon as well, the Global Positioning System (GPS). As part of improved security for the GPS constellation of satellites, the GPS Ground Operational Control System (OCS) is being enhanced for use with Military Code (M-Code) encrypted signals as part of Space Force's M-Code Early Use (MCEU) upgrade.

The upgrade involves working with the Contingency Operations (COps) upgrade from Lockheed Martin and 21 M-Code-capable GPS satellites—including the first two GPS III satellites designed and supplied by Lockheed Martin—until the next-generation ground OCS is available. The upgrade allows the satellites and system to work with M-Code and enhanced user equipment prior to the fielding of next-generation ground control systems, making the military GPS constellation more difficult to hack and jam.

M-Code-encrypted GPS signals help make GPS systems more secure for U.S. Armed Forces and allies. M-Code signals are available on all GPS IIR-M, IIF and III space vehicles and are monitored at Space Force sites with the aid of a software-defined-radio (SDR) receiver developed by Lockheed Martin. Monitoring equipment at these sites includes a commercial-off-the-shelf (COTS) graphics processing unit (GPU) to receive and process M-Code-encrypted signals.

(Continued on page 54)

Technologies Protect Against Drone Threats

GROWING INTEREST IN counter unmanned aerial systems (C-UAS) solutions is one indication of the increasing use of UAS-based approaches to warfare. As small drones are used more for surveillance and countermeasures, drones are also developed as part of electronic countermeasures (ECM) against those drones. One of the suppliers pursuing force protection from drones by means of C-UAS solutions is Citadel Defense, which recently announced $9.2 million in orders during the first two months of 2020 for its compact autonomous Titan C-UAS systems.

The need for C-UAS solutions is expected to extend across military applications as well as in commercial and industrial markets. Citadel Defense Titan C-UAS systems employ a proprietary RF detection method based on machine learning (ML) and artificial intelligence (AI) to identify threat signals. The approach can take advantage of high-speed signal processing for rapid categorization of many different detected radio signals within range and provide the means to detect the threats represented by different small UAS (sUAS) approaches.

"Drones are an asymmetric threat that require unprecedented speed for innovation. Citadel's AI capabilities and responsiveness give customers a cost-effective option that addresses a very large portion of the

(Continued on page 54)

Updated Ground Station Monitors GPS M-Code

(Continued from page 52)

"Our warfighters depend on GPS signals every day for many critical missions, so anything we can do to make these signals more resistant to jamming and spoofing is extremely important—and available today," said Johnathon Caldwell, Lockheed Martin's vice president of Navigation Systems. "The more powerful GPS III/IIIF satellites coupled with Lockheed Martin's upgrades to the GPS ground system are making that possible."

The overall GPS system upgrade includes the development of M-Code-encrypted GPS III satellites, which provide as much as three times the accuracy and eight times the anti-jamming capabilities of existing GPS satellites. The GPS III satellites also provide a new L1C civil signal which is compatible with other international satellite navigation constellations, such as Galileo.

As part of the upgrade, Lockheed Martin is contracted to build and supply as many as 32 GPS III and/or GPS III Follow On (GPS IIIF) satellites to increase positioning accuracy, resolution and reliability. ■

Technologies Protect Against Drone Threats

(Continued from page 52)

sUAS threat," said Christopher Williams, CEO of Citadel Defense. "Strong warfighter references and combat-proven results over the last two years helped secure this order."

The Titan C-UAS systems rely on up-to-date software to respond to new threats and the company updates its software in a timely fashion. If the Titan AI algorithms do not detect and identify a threat immediately, the company can deliver an end-to-end capability in 72 hours that will counter most drones. For the most difficult challenges, it can provide software solutions in less than four weeks for the most complex drone signals. The detection and identification algorithms are backed by adaptive countermeasures to quickly develop a means of jamming or defeating an unwanted drone signal. As Williams explains: "Our AI approach allows us to quickly address new threats without the risks or uncertainty that comes with hacking the drone link." ■


Citadel Defense

Computer Modeling Provides Material Insights


U.S. Army Research Laboratory

MATERIALS ARE WELL KNOWN IN ELECTRONIC DESIGN as part of printed circuit boards (PCBs) and miniature packages for components and semiconductors. But finding out more about how materials bond is leading to the potential development of rugged composites that could make much more rugged military vehicles, such as unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs).

Work by U.S. Army researchers unveiled in the scientific journal *Polymer* is offering polymers filled with carbon nanotubes as a building-block material—not only for protective gear and clothing for soldiers, but also for constructing ruggedized UAVs and UGVs and improving how the unmanned vehicles dissipate energy.

Working at Aberdeen Proving Ground, Md., and assisted by collaborators at the Massachusetts Institute of Technology (MIT) and Drexel University, a research team led by the U.S. Army's Combat Capabilities Development Command's Army Research Laboratory (ARL) is using computer modeling to predict the progression of different materials when combined.

"Our motivation for this research is that there could potentially be a use, as matrix material, for incorporation into lightweight composites in unmanned vehicle systems," said Dr. Yelena R. Sliozberg, a computational materials scientist at the laboratory.

Polyurethanes are composite materials used in a wide range of applications, including as coatings, foams and solid elastomers. They are often used to bond layers of glass and serve as vision blocks on the side windows of tactical vehicles. The research team felt that new composite materials might also help to toughen the tactical vehicles and extend their usable working lifetimes.

"In contrast to traditional thermoset composite performance, poly(urethane urea) elastomers are far less brittle, and they offer unparalleled control over material architecture," said Sliozberg. "Carbon nanotube/polymer composites have desirable electrical and thermal characteristics that exhibit behaviors superior to conventional fiber materials." The research team hopes to learn more about the architectures of the composite materials and convert the computer simulations to real-world material processing, perhaps with the aid of 3D-printing techniques. ■

DAVID MALINIAK | Editor

Moving Toward More Humane Weapons

Will directed-energy weapons be the solution, bringing some sort of answer to the "humane" part of the question that has lingered on since the turn of the last century?

I'VE ALWAYS FOUND THE NOTION OF "humane weapons" somewhat, well, counterintuitive, to say the least. It's not a new idea, of course. There have long been efforts to devise weaponry intended to minimize what's euphemistically referred to as "collateral damage," i.e., casualties and/or property destruction beyond that of a weapon's primary target. Even rubber bullets used for crowd control or tactical anti-riot scenarios can be thought of in this way. Although if you ask anyone who's been on the receiving end of a rubber bullet, they might not agree with their characterization as "humane."

The advent in the late 19th century of automatic weapons, such as the Gatling gun (1862) and Hiram Maxim's machine gun (1885), which could fire up to 500 rounds per minute, so horrified pacifists of the time that the Hague Peace Conference of 1899 sought to tame such instruments by limiting rates of fire. That same Hague conference also addressed chemical weapons by prohibiting use of "poisons and poisoned arms." Somehow, no one got the memo during the First World War, when both sides were spreading chlorine gas over battlefields, inflicting some 1.3 million casualties that may have included as many as 260,000 noncombatants.

The deployment of atomic weapons by the U.S. in Japan during WW2 led to the late 1950s/early 1960s concept of enhanced radiation weapons, which came to be known colloquially as "neutron bombs." These low-yield thermonuclear devices are meant to maximize lethal neutron radiation near the blast while minimizing the blast's city-flattening power. Such weapons were around until the fierce opposition of the antinuclear movement brought about their demise in the early 1990s.

In this edition of *Defense Electronics*, Technical Contributor Jack Browne takes us through the status of directed-energy weapons (DEWs), the latest efforts at "humane weapons." Relying on high-energy lasers or electromagnetic waves, DEWs are beginning to show signs of moving out of the experimental realm and into practical, even portable, field deployment. They're even being tested as defenses against yet another recent attempt at a more humane weapons systems—UAVs or drones. Perhaps DEWs, with their improvements in targeting and overall reduction in broad destructive power, can finally be the humane weapon that the 1899 Hague Peace Conference would have approved. de

JACK BROWNE | Technical Editor

Directed-Energy Weapons Can Save Power—and Lives

Directed-energy weapons—with either EM waves or high-power laser beams—are coming to nondestructively stop enemy threats.

MILITARY WEAPONS, such as guided missiles and rockets with warheads, can be large, dangerous, and imposing. They can stop threats at great distances, but these weapons can also inflict unintended damage to the people and objects in proximity to a target, especially when the aiming process is not exact.

In the hopes of targeting with more precision, the U.S. Department of Defense (DoD) and other armed forces around the world have invested in directed-energy weapons (DEWs) for several decades. Among these somewhat elaborate weapons are systems based on high-energy lasers or electromagnetic (EM) waves. Perhaps after so much "dabbling with technology" and too many dead ends for expensive projects, military systems specifiers and designers seek more practical DEW implementations.

While current DEWs are experimental and at best prototype versions of systems, many branches of the military expect to field practical, perhaps even portable, versions of DEW systems within the next two years. Two leading military systems developers, Raytheon Co. and United Technologies, have credited the DoD's increased interest in DEWs as one of the reasons to merge the two companies into Raytheon Technologies to help meet that two-year plan.

As an example, the U.S. Navy plans to have a laser-based DEW on a warship by 2021. The weapon most likely will be the High Energy Laser with Integrated Optical-dazzler and Surveillance (HELIOS) system. The Navy contracted Lockheed Martin for $150 million (and many possible options) in March 2018 to develop the laser-based DEW system for long-range intelligence, surveillance, and reconnaissance (ISR), as well as a means of bringing down drones or even small boats from a distance. The Navy hopes to make HELIOS part of a guided-missile destroyer in the Pacific Fleet.

1. The Active Denial System (ADS), one of the earliest DEW systems, is designed for stationary installations and being modernized for smaller, more mobile applications. *(Courtesy of Global Security, www.globalsecurity.org)*

Boeing is another early innovator in the area of DEW technology, with more than 40 years of experience in beam control in support of its aircraft. As part of the quest to field DEWs, Boeing's Compact Laser Weapon System (CLWS) has continued to improve during testing.

In a recent series of five tests conducted with members of the U.S. military, the system was able to track and fully engage over 100 separate flying targets successfully. Such consistent experimental performance points to possible deployment in realistic settings for field evaluation. Boeing has developed both 2- and 5-kW versions of its CLWS for mobile and possible portable use.

LASER FOCUS

DEWs typically function by focusing an energy beam (generated either by EM energy or laser) on a small spot on a target, causing intense heating of that spot. When the target is a human, the EM heating effect will generally cause the soldier to reverse tracks before collapsing, but it will not cause permanent harm to the target. With a laser-based DEW, an operator can often select the amount of damage from the laser "shot," even from a considerable distance, such as 500 m.

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For example, when targeting an adversary's jeep, the jeep can be disabled by burning one of the tires or overheating the engine block. For more extensive damage and possible driver/passenger casualties, a DEW operator can target the vehicle's gas tank. Of course, as important as the quality of a DEW's energy beam is the precision with which it is focused and the capability to detect and track a target from a distance, even when both the target and the DEW system are moving.

Perhaps the best-known military directed-energy system is the Active Denial System (ADS) developed by the Non-Lethal Weapons Program (JNLWP) of the U.S. Department of Defense *(https://jnlwp.defense.gov/)*. The ADS *(Fig. 1)* is intended as a non-lethal DEW that sends short bursts of EM energy at a target across distances as far as 1 km and within a target spot size of about 1.5 m. The military counter-personnel system is transportable and can be used for crowd control in civilian settings. Funding for the program behind the DEW began in 1997 and for the system itself in 2002; efforts are now underway to move the system from a largely "experimental" status to a field evaluation process.

Ideally, the ADS can also be made scalable, so that directed mmWave energy can be placed in the hands of soldiers for in-field use. The impact of those high-power, 95-GHz EM waves will be a heating effect on the surface of the skin. The nature of the EM waves, with much shorter wavelengths than those of lower-frequency signals (such as the 2.45-GHz frequency of microwave ovens, which causes deeper, more dangerous heating), ensures only heating of skin surfaces.

The JNLWP is working with the U.S. Army's Research Development and Engineering Command (RDECOM) Armament, Research, Development and Engineering Center (ARDEC) on the modernization of the ADS. They're applying the principles of smaller size, weight, and power (SWaP) to shrink two prototype systems for more effective and efficient in-field use. System-level performance goals for the modernized ADS include a shorter range of about 100 m but with a smaller target spot size of about 0.5 m.

One of the keys to reaching performance goals with SWaP is the use of solid-state technology, such as gallium-nitride (GaN) power amplifiers rather than vacuum-tube amplifiers to boost the 95-GHz signals produced by a gyrotron oscillator. An on-board, laser-based range finder provides the precision targeting coordinates to accurately place the EM beam.

In hopes of hastening DEWs from the laboratory to the battlefield, the Raytheon Intelligence & Space portion of the company (now Raytheon Technologies) recently showed some of the capabilities of their high-power-microwave (HPM) and high-energy-laser (HEL) DEWs. The respective high-energy beams were directed at one of the more significant threats in need of termination from a distance with a DEW: unmanned aerial vehicles (UAVs) or drones.

The exercises were performed with U.S. Air Force (USAF) personnel at the White Sands Missile Range (WSMR), Ariz., to evaluate the weapons' effectiveness and reliability in such a use case. Ironically, this exercise was performed several years after the U.S. Army did a similar evaluation at the same test facility.

"Drones are a real modern threat. Countering them will need a variety of solutions," said Annabel Flores, vice president (VP) of Electronic Warfare Systems at Raytheon Intelligence & Space. Dr. Thomas Bussing, VP of Raytheon Advanced Missile Systems, added, "After decades of research and investment, we believe these advanced directed-energy applications will soon be ready for the battlefield."

As part of the exercises, drones served as targets either individually or in swarms. Airmen tasked with defeating the drones were given both HEL and HPM DEWs and only one day's training with the weapons systems. The laser-based DEW employs a computer-game-type controller, while the microwave-based weapon uses a joystick to steer the beam.

The HEL weapon system *(Fig. 2)* combines with Raytheon Technologies' Multi-spectral Targeting System of sensors to detect and track the motion of target drones. The sensor and system were mounted on an all-terrain militarized vehicle for mobility. Similarly, the HPM DEW works with sensors capable of providing the targeting information.

These exercises demonstrated that both types of DEW systems are feasible and almost ready for the field. Both systems use different energy sources and can provide different results. The HMP sends out a high-energy microwave beam to disrupt the guidance systems in a drone and can cause even a swarm of drones to fail, whereas HEL-based systems are designed to bring down drones one vehicle at a time. Both DEWs performed flawlessly during the exercises, even when handled by fledgling operators. The exercise was part of the Air Force Directed Energy Experimentation campaign.

SEEING THE LIGHT

Solid-state HEL weapons are achieving much higher output-power levels in much smaller package sizes than chemically-based laser weapons. A 100-kW output level is now seen as a minimum for solid-state HEL systems. For example, Dynetics (www.dynetics.com) and partners received a $130 million contract to build and test a 100-kW solid-state HEL demonstrator weapon *(Fig. 3)* for the U.S. Army Space and Missile Defense Command/Army Forces Strategic Command (USASMDC/ARSTRAT). Partners include Lockheed Martin (which will provide the laser weapons subsystem), MZA Associates, and Rolls Royce LibertyWorks. Dynetics will function as prime contractor, performing final system assembly and test.

Ideally, both HEL and HPM weapons systems will be able to take advantage of solid-state energy sources for smaller, lighter, and even portable DEW systems. Lockheed Martin, for instance, has invested in its Advanced Test High ENergy Asset (ATHENA) HEL weapons system as an effective defense against enemy drones for the USAF.

The laser-based weapon system (*Fig. 4)* was demonstrated late last year at a test range at Fort Sill, Okla. In that demo, the system shot down multiple fixed-wing and rotary-wing UAVs, teaming with a government command-and-control (C2) and radar sensor to detect, track, and disable each drone using a laser beam. The ATHENA system was successfully operated by USAF personnel with little training, pointing out the potential effectiveness of HEL systems as maritime defensive weapons in the future.

This is a small sampling of the work being done by major contractors on HPMs and HELs in support of DEW systems. The move to solid-state technology is a SWaP step in the right direction since these systems depend on several subassemblies, often including secondary lasers in HELs to “illuminate” a target for more precise targeting with the high-power beam. The two-year estimate may be somewhat optimistic for fielding practical DEWs for any branches of the armed forces. However, it’s driving a way of thinking that such weapons systems are no longer part of science-fiction stories, and may become part of saving lives in military conflicts. de

2. This HEL DEW along with an HPW DEW was part of a successful demonstration of DEWs at a USAF exhibition put on a White Sands Missile Range. *(Courtesy of Raytheon Technologies)*

3. Dynetics and Lockheed Martin are among the partners trying to get more from less, working on developing an SSL capable of 100-kW power for mobile/transportable DEW systems. *(Courtesy of Lockheed Martin)*

4. The ATHENA system is a HEL-based DEW designed as a defense against drones. *(Courtesy of Lockheed Martin)*

JACK BROWNE | Technical Editor

L3 Harris Tasked with Modernizing Space Force

This Space Force contract keeps defenses orbiting the planet in search of threats from space.

L3HARRIS TECHNOLOGIES will be looking into space, at least for the next 10 years. The company has been awarded a contract estimated at $1.2 billion over 10 years for the modernization and maintenance of the space infrastructure used by the armed forces to monitor activities and objects in space as possible threats.

The Maintenance Of Space Situational Awareness Integrated Capabilities (MOSSAIC) contract is with the U.S. Space Force Space and Missile Systems Center (a subordinate unit of the Air Force Space Command) and involves support for ground-based space domain awareness sensors and space battle-management command and control capabilities. The MOSSAIC contract is a follow-on program to the Systems Engineering and Sustainment Integrator program won by L3Harris in 2002.

The MOSSAIC contract is an attempt to keep space-based military systems up to date, especially with a growing number of satellites and missile systems in use. *(U.S. Air Force)*

The Space Force Space and Missile Systems Center is a subordinate unit of the Air Force Space Command. With a growing number of satellites, space vehicles and space-based activities, the environment represents an increasing threat for weapons-based systems and the MOSSAIC contract provides for modernization of space-based detection systems and communications of data from those sensors to ground-based control systems. de

JACK BROWNE | Technical Editor

Advanced Radar System is Part of a Rapid Development Plan

Raytheon is racing through deadlines on the development of a next-generation, 360-deg. radar system.

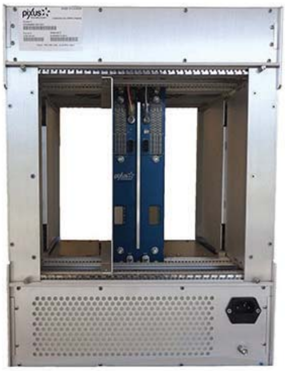
As threats become more complex, the U.S. Army realized that its current generation of radar systems would be incapable of detecting higher-speed signals and weapons, necessitating an improved solution. Fortunately, long-time radar systems supplier Raytheon Co. was up to the task of designing a new kind of radar system, optimized for high-speed signals. The company designed its first Lower Tier Air and Missile Defense Sensor (LTAMDS) radar antenna array within 120 days of the initial work order. It provides a highly sensitive means of detecting complex weapons signals, as from hypersonic weapons.

Indoor testing on the first partially populated LTAMDS radar antenna array was completed just five months from the contract award. Bill Patterson, Raytheon's LTAMDS program director, explained: "The Army set a rigorous and necessary schedule. The timeline...is imperative, because the threat is evolving and proliferating at a blistering pace." He added: "The Army asked for an advanced radar and we're showing them that the radar is on track and on time."

Design and development speed are not properties usually associated with military systems development. But in the case of the LTAMDS radar, the need is for speed—not just in the radar's performance, but in getting it out into the field because of the growing complexity of advanced weapons threats. The deadline urgency impacts all members of the design team and the role they are playing in the nation's defense provides the drive they need to push harder during the design cycles.

The next-generation radar uses an actively scanned array antenna. It is designed to provide 360-deg. detection of threat signals and weapons systems. Its development is part of a $384 million contract for six production systems. Raytheon is teamed with many top electronic companies on the project, including Crane Aerospace & Electronics, Mercury Systems and Kord Technologies. de

System Chassis Now Accepts VITA 67 Backplane Slots for RF Interfaces



PIXUS TECHNOLOGIES NOW OFFERS a new version of its VPXD1000 Series chassis that allows for various VITA 67 backplane slot configurations for RF interfaces over OpenVPX. Such backplane slots make it possible to implement high-speed/high-powered embedded systems. The enclosure enables users to partition for a separate segment for specialty RF devices or Sensor Open Systems Architecture (SOSA) applications. The latest version of the VPXD1000 features a 12.6-in., 63HP-wide size, which allows for backplanes with up to 10 slots at a 1.0-in. pitch. Moreover, designers can utilize one portion of the chassis for a smaller VITA 67 backplane over OpenVPX, as well as a separate segment for housing RF platforms or other devices. The chassis now has removable sidewalls for easy open-frame access, and airflow and cooling can be optimized based on the customers' requirements.

PIXUS TECHNOLOGIES

www.pixustechnologies.com

Inertial Measurement Units Serve Aerospace Navigation Apps

THALES VISIONIX'S NEW NAVCHIP SERIES 3 inertial measurement units (IMUs) are designed to handle the rigors of aerospace navigation systems and other applications, including drone navigation, robotics, camera/antenna stabilization, AR/VR, aiming/alignment, and GPS/INS integration. The NavChip Series 3 has increased performance and accuracy in a critical parameter: bias in-run stability to 3°/hour (typical), and 5°/hour (max), which makes it more competitive for a broader range of applications over the ±16- g operating range. This represents a significant improvement over the previous series, which offered bias in-run stability of 5°/hour (typical) and 10°/hour (max). The NavChip Series 3 IMUs feature a full-scale acceleration range of ±16g and a full-scale angular rate of 2000°/sec. They have an angular random walk of 0.18°/√hour, a velocity random walk of 0.03m/s/√hour, and a very quiet acceleration noise performance of better than 83 µg/√Hz.

THALES VISIONIX

www.intersense.com/navchip

Low-Power FPGAs Tolerate Radiation and Harsh Space Environs

MICROCHIP TECHNOLOGIES has designed a new series of low-power, radiation-tolerant FPGAs targeted at space applications, rugged enough to handle brutal launch processes and the harsh environment of space. The RT PolarFire FPGAs build on the company's successful RTG4 series, and range from 100K logic elements (LEs) to 500K LEs. They integrate 12.7-Gb/s transceivers and consume as little as 50% of the power of competing mid-range FPGAs. The PolarFire series features high-speed serial connectivity with built-in multi-gigabit/multi-protocol transceivers from 250 Mb/s to 12.7 Gb/s. The devices carry up to 481K logic elements consisting of a four-input look-up table (LUT) with a fracture-able D-type flip-flop. There's also support for up to 1600-Mb/s DDR4, 1333-Mb/s DDR3L, and 1333-Mb/s LPDDR3/DDR3 memories with integrated I/O gearing. The FPGA also packs up to 1480 18 x 18 multiply-accumulate blocks with hardened pre-adders and integrated dual PCIe for up to x4 Gen2 endpoint (EP) and root-port (RP) designs.

MICROCHIP TECHNOLOGIES

www.microsemi.com

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440 Rev AD

Embedded Multimedia Chip Endures 60,000 Program/Erase Cycles

ATP ELECTRONICS HAS LAUNCHED the E800Pi embedded multimedia chip, which is based on single-level-cell (SLC) flash memory offering a very high endurance rating of 60,000 program/erase (P/E) cycles. The chip serves applications in harsh and rugged environments, providing ultra-high endurance and performance for rigid industrial requirements. The E800Pi has a wide-ranging temperature threshold and can handle temperature tolerances from -40°C to 85°C. It adheres to the JEDEC e.MMC v4.41 standard, offering support for enhanced features such as Health Report, Field Firmware Update (FFU), and Fast Boot operation. Performance features include Advanced Global Wear Leveling, Page Mode FW architecture technology, Dynamic Data Refresh, AutoRefresh to maintain data integrity, and Early Retirement technology to prevent data loss from weak blocks. It also features SPOR (Sudden Power-Off Recovery), which backs up the firmware in the event of power loss.

ATP ELECTRONICS

www.atpinc.com

Rugged XMC Board Delivers 2.3 TFLOPS of Performance in Little Space

ABACO SYSTEMS HAS ANNOUNCED the new NPV2000 rugged XMC graphics and video board for SIGINT, radar, machine learning, autonomous equipment, and GPGPU applications. The 768 cores of the onboard NVIDIA Pascal P2000 GPU, paired with 4 GB of DDR5 memory, allow the board to run at a peak of 2.3 teraFLOPS (TFLOPS). Integral to the board are three v1.4 DisplayPorts capable of 4K resolution at 60 Hz, which can be converted to DVI or VGA formats with adaptors. Support for the H.265 (HEVC)/H.264 (MPEG-4 AVC) codecs is included, as is support for CUDA, OpenCL, and Abaco's AXIS ImageFlex codecs. The NPV2000 consumes a maximum of 32 W and meets MIL-STD-810G ruggedness standards. The board is available in an air-cooled version with a temperature range of -40°C to +70°C and a conduction-cooled version with a temperature range of -40°C to +85°C.

ABACO SYSTEMS

www.abaco.com/products/nvp2000

MikroBUS-Compatible Interface Modules Speed IoT Development

AT THE HEART of Adesto's new FT Click board is the FT6050 smart transceiver SoC, which makes interfacing to embedded IoT devices a more seamless effort. Through Adesto's mikroBUS and Free Topology (FT) communication technology, the interface modules can connect to and communicate with IoT-enabled devices in industrial environments, including sensor networks, automation networks, and control networks. The FT 6050 SoC natively supports LON, LON/IP, BACnet/IP, and BACnet MS/TP protocol stacks, giving designers a flexible architecture that can communicate with devices and applications from different vendors. As a result, installation time and effort can be reduced and complex networks can be more easily managed. The FT6050 SoC also enjoys support from integrated open system products, including SmartServer IoT's BACnet and LON router and network managers, the IzoT Net Server, and the IzoT commissioning tool.

ADESTO TECHNOLOGIES, www.adestotech.com/embedded-product/ft-click/

Remote Monitoring Devices Leverage LPWANs, NB-IoT, and 4G LTE

NOVA MOBILE SYSTEMS offers a portfolio of tracking and remote monitoring devices. The company's recently launched line of products takes advantage of new technologies, including low-power, wide-area networks (LPWANs), narrowband Internet of Things (NB-IoT), and Cat M1 4G LTE. The devices include multiple sensors and are certified and ready for use with multiple cellular networks, examples of which include the NM826 asset tracker and NMS821 asset tracker. The former includes GPS (location and speed) tracking from anywhere. It comes in a waterproof housing and operates off 4G LTE (Cat M1 and NB-IoT) technologies. Features include message storing and forwarding, a three-axis accelerometer, temperature sensing, and customizable geofencing. The unit also is designed for ultra-long battery life of up to three years with one report per day.

NOVA MOBILE SYSTEMS, https://novamobilesystems.com/asset-trackers

5G Data-Management Suite Packs Forward-Looking Functionality

ENEA IS OFFERING a new option of storing and accessing data on 5G networks. The company's new 5G Management Suite includes functions such as unified data management, a unified data repository, an authentication server function, a policy control function, and an equipment identity register. Yet another new integral feature, called Stratum, provides a common layer data solution that is already being used by several of the world's largest mobile operators. Unlike previous generations of wireless technology, all data silos use a common data layer, allowing applications to communicate efficiently with the same data pool. The data storage can support from 1 to 10 billion data entries and from 1 to 500,000 transactions per second. It also has the added benefit of being open and cloud-native.

ENEA, www.enea.com

Ultra-Small 5G Antennas Target IoT Applications

FRACTUS ANTENNA'S NEW ONE mXTEND antenna booster is a compact antenna with dimensions of 7 mm x 3 mm x 1 mm, making it suitable for 5G IoT applications operating within the 824- to 5000-MHz cellular bands. The small size makes the device slightly larger than the typical grain of rice. On the more technical side, the antennas offer greater than 70% efficiency with a peak efficiency of 86%, 3.9 dBi of peak gain over the frequency range of 3300 MHz to 5000 MHz, and an average gain across the band of 3.2 dBi. Furthermore, they offer an omnidirectional radiation pattern and a linear polarization. The devices are compatible with pick-and-place machines and are offered as a standard product. Targeted applications include IoT devices, tablets, smartphones, sensors, smartwatches, and wearable devices.

FRACTUS ANTENNA, https://fractusantennas.com/one-mxtend-5g-cellular-iot-antenna-2/

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