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EDITORIAL MISSION:
To provide the most current, accurate, and in-depth technical coverage of the key emerging technologies that engineers need to design tomorrow's products today.

ELECTRONIC DESIGN (ISSN 0013-4872) is published monthly by Penton Media Inc., 9800 Metcalf Ave., Overland Park, KS 66212-2216. Paid rates for a one-year subscription are as follows: $120 U.S., $180 Canada, $240 International. Periodicals postage paid at Shawnee Mission, KS, and additional mailing offices. Editorial and advertising addresses: ELECTRONIC DESIGN, 1166 Avenue of the Americas, New York, NY 10036. Telephone (212) 204-4200. Printed in U.S.A. Title registered in U.S. Patent Office. For subscriber services or to order single copies, write to Electronic Design, PO Box 2100, Skokie, IL 60076. POSTMASTER: Send change of address to Electronic Design, PO Box 2100, Skokie, IL 60076. Canadian Post Publications Mail agreement No. 40612608. Canada return address: IMEX Global Solutions, P.O. Box 25542, London, ON N6C 6B2.

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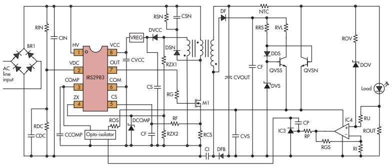

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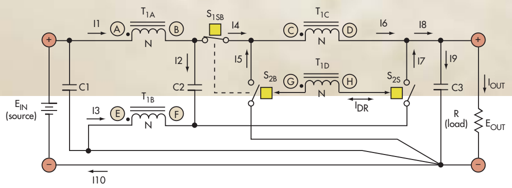

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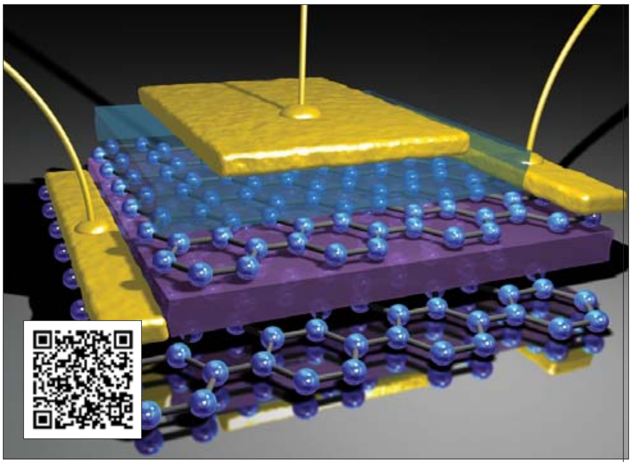

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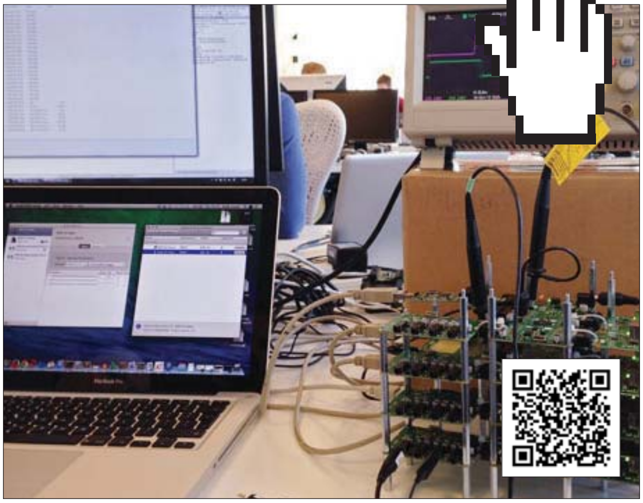

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LOU FRENZEL | Communications Editor
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Is Moore's Law Really Over For Good?

No, not yet. But it can't go on forever. The number of transistors on a chip has doubled about every two years for almost five decades. Smaller transistors can fit into smaller spaces, making it possible to put more circuitry on the same size or a smaller chip. We also have seen higher digital speeds, high-frequency RF circuitry, lower power consumption, and lower costs. But as devices get smaller, we approach the atomic level of the materials, meaning the downward scaling will come to an end.

Adam Brand and Gigi Lai of Applied Materials say that Moore's law will continue, at least for now. Scaling to smaller transistor geometries will not be as easy, though. CMOS scaled nicely down to about 28 nm but smaller sizes have presented leakage, materials issues, and limits in the processing equipment. Right now we are at the 22-nm node with 14 nm in the wings.

New architectures and geometries have emerged in response. The new circuitry is more 3D or vertical. Imec's smaller FinFET design enables CMOS at the 22-nm level. Also, indium gallium arsenide (InGaAs) or indium phosphide (InP) can be used with the silicon to make the transistor faster and smaller. IBM is exploring the use of InGaAs with silicon germanium (SiGe) to produce smaller and faster CMOS devices. Chip-stacking techniques offer some promise as well. Such techniques could help scale CMOS down to the 7-nm node. Are you ready for 0.5-V dc supply voltages and 200- to 300-mV thresholds?

But that's not all. New processes are also necessary. To date, the biggest factor in limiting the downward scaling has been the photolithography process that translates the design patterns into the masks that are used in deposition and etching. Immersion lithography and double patterning have helped, but the ultimate solution appears to be extreme ultraviolet (EUV) lithography. EUV has been in the works for years and is still not ready. It is expected to be available in 2015 and beyond.

For many years the processors and memory chip businesses have driven Moore's law. Today, the mobile and wireless business is driving the need for faster and smaller chips that consume less power. That trend will continue to rely on Moore's law.

The continuation of Moore's law is possible, but it will be more complex and more expensive. We might see the traditional two-year interval extend to three years to enable the industry to develop more complex materials, processes, and equipment. The costs will be excessive, creating an economic slowdown as well. Costs are already making Intel delay its 14-nm fab in Chandler, Ariz., because of low PC processor sales. Yet there is both hope and an agenda as the industry works to keep the good times going. ed

Energy Zarr

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Protect High-Power DC Systems Against Arc Failures

With the increased deployment of high-power dc systems such as those used in electric vehicles, wind turbines, photovoltaic plants, and other large-scale energy harvesters, there is a growing concern over arcs forming across insulators that do not self-extinguish. Damage caused by high-power arcs can be extensive as well as extremely dangerous. These issues are driving technology for sensing the presence of arc formation in high-power systems.

BACKGROUND

Arc formation was first observed in the early 1800s by both Sir Humphry Davy, who is generally acknowledged for the discovery, and a Russian experimental physicist named Vasilii Vladimirovich Petrov, whose work predated Davy's. It has been a focus of study since that time and applied in a wide range of industrial applications such as welding, machining, metallurgy, chemistry, and lighting.

However, arcing can have an unintentional dark side in high-power systems. It can vaporize conductors, ablate surfaces, explode insulators, start fires, and cause severe injury. This is due to the high power present in the system and the phenomenon related to the formation of an arc.

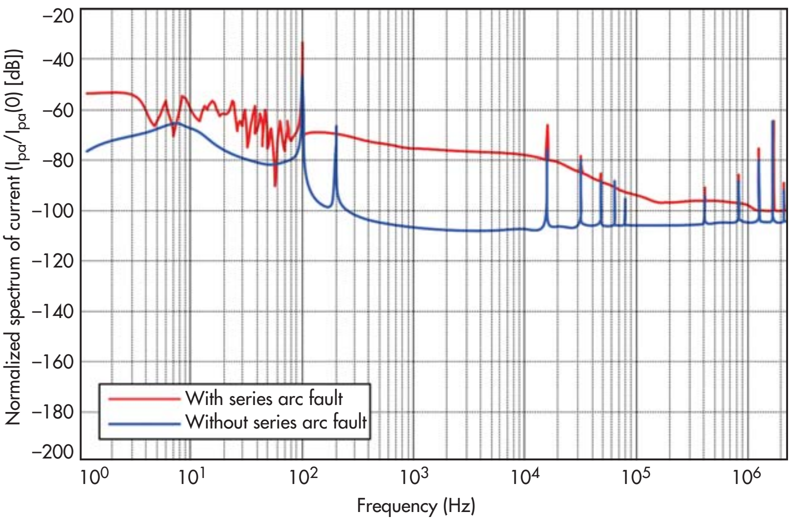
Arcs are formed when an insulator, typically a gas such as air, breaks down under a strong electric field, allowing the conduction of electric current via plasma formation. Interestingly, the resistance of the current path through the arc produces heat, which ionizes more gas, resulting in an improved conduction path and reducing the voltage between the ends of the arc. This is also known as a negative resistance, which lets the current increase unbounded limited only by the source of the current. This phenomenon in part is what makes arcing so dangerous.

ARC FAULTS

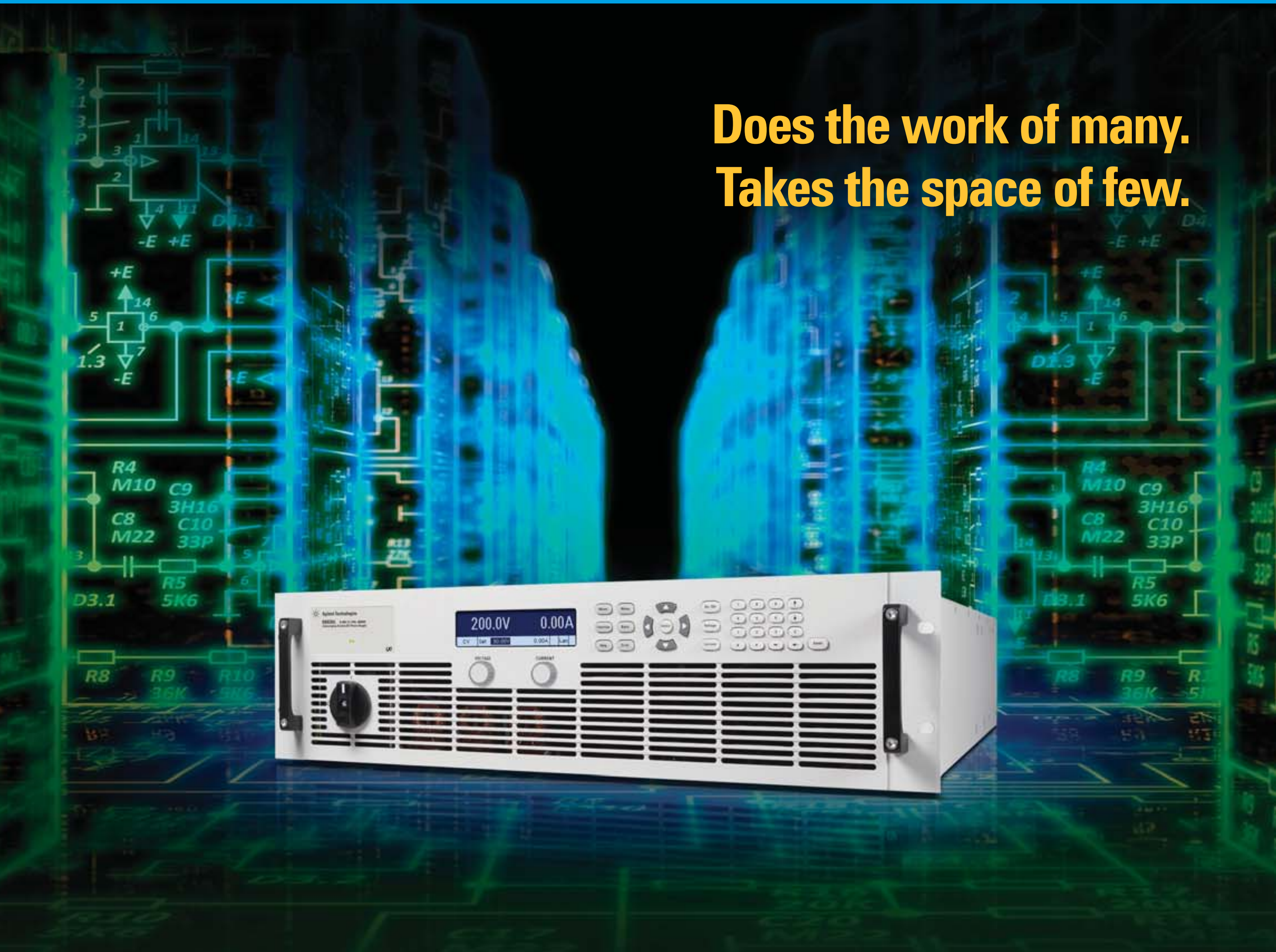
The plasma that forms within the arc is extremely hot and can exceed 35,000°F (19,400°C). This is hot enough to vaporize metal, leading to what is known as an arc blast. The explosive nature is the result of rapidly expanding plasma and molten metal as well as high levels of radiant emissions ranging from the far infrared to ultraviolet. Nearby objects (including people) will absorb this radiant energy or be struck by the rapidly expanding shockwave, which can result in severe damage or injury.

There are two types of arc faults: parallel and series. Parallel arc faults occur in parallel with the load (or to ground for most dc systems). This looks like an increase in load current and is the most dangerous since nothing but the source is limiting the current flow. A series arc fault occurs when the conductor to the load breaks or is opened in some way (as in a switch). The load limits the current in this type of arc fault, but it also can be dangerous due to plasma formation.

Circuit breakers and fuses often are used to prevent catastrophic damage from these types of events, but they are slow to operate



There are key differences between the RF signatures of both a steady-state dc load with random noise and the same system with an arc fault. Conducted RF energy notably increases in the presence of an arc fault from dc to roughly 1 MHz. (from "Arc faults in photovoltaic systems," by Christian Strobl and Peter Meckler, Innovation & Technology, E-T-A Elektrotechnische Apparate GmbH)



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due to the nature of their design. Other methods can be used to quickly detect an arc fault and shut down equipment to prevent damage. Systems can implement optical detection where photodiodes are used to pick up the emission spectrum of an arc fault. Another method is to use acoustic detection, much like listening for thunder. Both of these methods suffer from various implementation issues and can be extremely complex or, in some cases, ineffective.

Optical methods rely on the placement of photodiodes near potential arc locations such as near insulators. This can add significant complexity to a system where there could be a large number of potential locations arcs could form. Some manufacturers of optical arc detection systems use cables that include optical waveguides built into the insulation (which is transparent) to carry the optical arc signature back to a detector that can process the signature and interrupt the power flow if an arc is detected.

Acoustic detection must wait for the arc signature wave front to reach the sensor that only travels at the speed of sound, which depends on the medium. Detectors often utilize piezoelectric transducers connected directly to bus bars to pick up the shockwave's ultrasonic signature. This can have significant safety issues, and isolating the sensors can be problematic.

DETECTING RF ARC SIGNATURES

Another method of detection relies on the electrical noise induced into the transmission line when an arc forms. Arcing has significant broadband energy with a notable increase from dc to roughly 1 MHz *(see the figure)*. Since modern ac inverters often also have unintended conducted and emitted radiation in this spectrum (50 kHz to 100 kHz) as well as other manmade and natural phenomena such as lightning, a significant amount of signal processing is needed to differentiate an arc occurring in the system from some external event that is unrelated.

This method relies on coupling through a transformer or coil to the series conductor, which provides a significant advantage in simplicity. As dc current flows through the conductor, the noise caused by arcing modulates the current, providing a way to sense the arcing event anywhere along the transmission line. A problem with this method is that the signature dissipates over distance, so monitoring for arcing far from the sensor is an issue.

Systems that use this technique must look for an increase in energy across a section of the emission spectrum with an amplitude envelope that matches that of the arc formation. This requires filtering and significant signal processing to remove false signatures caused by lightning, power inverters, and other random noise found in high-power electrical systems.

ARC FAULT DETECTION SYSTEMS

Incorporating in-line arc fault detection technology into PV or other high-power dc systems can be a daunting task. First, the system must be isolated from the high-power dc rails via an isolation transformer, which will suffer from a low magnetizing inductance, limiting the ac signal level from the transmission line. This requires the signal to be amplified and filtered to remove large ac signals such as 50/60-Hz power transmission and inverter or switching regulator noise. Since many inverters operate below 50 kHz, a good section of the spectrum to examine is between 50 kHz and 100 kHz. Above 200 kHz, the signal is lost in the high-power conductors, which were never designed to carry high-frequency ac signals.

The problem here is that marine and other radio operators with extremely high-power transmitters also use this band. Given the size of many high-power dc installations such as a photovoltaic system, the cabling picks up these high-power continuous wave transmitters masking the minute signature of arc formation. Due to the presence of these signals, an analog-to-digital converter (ADC) front end requires an extremely wide dynamic range approaching 100 dB. A practical system requires a 16-bit ADC.

Once the signals are acquired and properly digitized, the data needs to be processed by performing various signal processing (such as fast Fourier transforms, or FFTs) to isolate the low level signature of arc formation from those of interferers and random noise. This requires some processing power along with DSP functions to accelerate the FFT calculations. In the end, those calculations determine if the signal present is actually an arc forming or simply the keying of a transmitter or distant lightning.

CONCLUSION

With knowledge of the complexity required to design in-line arc detection systems, semiconductor manufacturers such as Texas Instruments have developed complete reference designs that incorporate the entire signal chain and back-end processing to simplify the design process. For example, RD-195 is a reference design for detecting arcs in high-power PV systems. It is available as a complete circuit card, software, and manual and can greatly reduce the design time required to implement this type of arc fault detection.

The formation of arcs in high-power systems can be extremely dangerous and lead to severe damage, if not controlled. Sensing when an arc is forming in a timely manner is paramount to interrupting the power flow before damage can occur.

In-line monitoring for arcs has many advantages. The technology to build systems that use this technique has been simplified through the development of reference designs where the complete solution is available, making implementation faster and far easier than starting from scratch.

REFERENCES

For more about arc detection, visit www.ti.com/arcdetect-ca.

For more information about TI reference designs, visit www.ti.com/tidesigns-ca.

RICHARD ZARR is a technologist at Texas Instruments focused on high-speed signal and data path technology. He is a member of the IEEE and holds a BSEE from the University of South Florida as well as several patents in LED lighting and cryptography.

LOU FRENZEL | COMMUNICATIONS EDITOR

Deal Pushes Wireless Charging Closer To The WPC Standard

Wireless power charging often uses a charging pad with a built-in transmitter and one or more coils, driven by a USB port or an ac adapter. A smartphone with an internal receiver coil is placed on the pad. Some wireless charging products offer a sleeve or adapter with a coil that slips on the back of a smartphone without an internal coil. (courtesy of PowerbyProxi)

The idea for using wireless power transfer to charge batteries has been around for years. While a few smartphones boast wireless charging capability, the technology has been waiting on the threshold of wider adoption. Now, PowerbyProxi and Texas Instruments have announced an agreement that should move it forward.

The lack of a single standard has inhibited widespread use, though three standards organizations are vying for acceptance: the Alliance of Wireless Power (A4WP), the Power Matters Alliance (PMA), and the Wireless Power Consortium (WPC). The IEEE is also involved with its Wireless Power and Charging Systems Working Group (WPCS-WG) and hopes to move toward a single standard if possible.

All of these charging methods are based on inductive coupling. A transmitter driving a primary winding in a charging base creates a magnetic field that induces a voltage into a nearby secondary winding and receiver inside a smartphone, tablet, notebook PC, or other portable electronic device. Most configurations use a flat charging base with one or more transmitter coils, and the device to be charged lies on top *(see the figure)*. The PMA and WPC standards use an ac frequency in the 100-kHz to 200-kHz range while the A4WP uses a more efficient resonant solution on the 6.78-MHz industrial, scientific, and medical (ISM) band frequency.

The technology licensing agreement between PowerbyProxi and TI could mean a shift toward the WPC standard, which is known as Qi (pronounced "chee"). PowerbyProxi is a New Zealand intellectual property (IP) firm with more than a hundred patents in the wireless charging space. TI makes a complete line of Qi transmitter and receiver chips, such as the bq500412 transmitter, which can be used to build charging pads of the 5- or 12-V variety with up to three primary coils and comply with the WPC 1.1 standard.

TI and PowerbyProxi initially will focus on developing and delivering a resonant solution compatible with the WPC Qi standard. PowerbyProxi's wireless power IP can work across any standard being used and developed globally. With the agreement, TI can add a new, broader range of wireless charging products based on PowerbyProxi IP. Consumers are ready and waiting for these fully integrated wireless charging features on mobile products. ■

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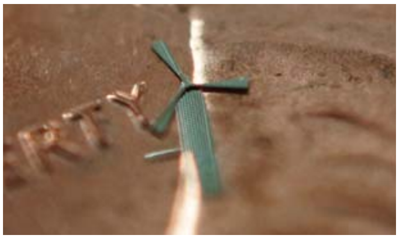
MICRO-WINDMILLS Power Portable Devices

GIANT WINDMILLS NOW COMMAND the landscape in the quest for renewable energy resources. Researchers at the University of Texas Arlington, however, are taking the technology behind these titan turbines and shrinking it to power portable electronics. Measuring 1.8 mm at their widest point, hundreds of these micro-windmills could be embedded in a sleeve for a cell phone *(see the figure)*.

Developed by Smitha Rao and J.C. Chiao, the windmills blend origami concepts into conventional wafer-scale semiconductor device layouts so 3D movable mechanical structures can be self-assembled from 2D metal pieces utilizing planar multilayer electroplating techniques that have been optimized by WinMEMS Technologies Co.

"The micro-windmills work well because the metal alloy is flexible and Smitha's design follows minimalism for functionality," Chiao said.



Measuring 1.8 mm at their widest point, micro-windmills developed at UT Arlington could be used to charge portable electronics.

WinMEMS became interested in the MEMS research and started a relationship with UT Arlington. The university will hold the intellectual properties, while the company will explore commercialization. UT Arlington has applied for a provisional patent.

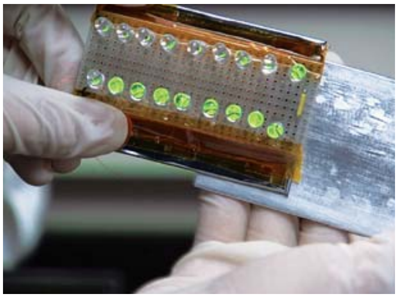
The micro-windmills operate under strong artificial winds without any fracture in the material because of the durable nickel alloy and smart aerodynamic design. Typical MEMS materials would be too brittle. They can be made in an array using batch processes.

The fabrication cost of one device is the same as making thousands on a single wafer, enabling mass production of inexpensive systems. Chiao noted that thousands of windmills could be mounted on the walls of houses or buildings to harvest energy for lighting, security, sensing networks, and wireless communications. ■ **RICHARD GAWEL**

TRIBOELECTRIC GENERATORS Harvest Power

RESEARCHERS AT THE SCHOOL of Materials Science and Engineering at the Georgia Institute of Technology are harvesting energy using triboelectric effect technology, or contact electrification. Processor Zhong Lin Wang and his students there are taking advantage of the triboelectric effect to harvest small amounts of energy, essentially turning static electricity into something useful. They can power LEDs and other devices using the harvested energy *(see the figure)*.

Static electricity is a form of the triboelectric effect. It occurs when some materials are rubbed together and the friction generates static electricity. Walking over a rug on a dry day and touching a metal doorknob is shocking, but not too useful. Georgia Tech researchers can turn this shock into manageable power that could drive sensors and mobile devices.



Triboelectric generators that harvest energy from friction between two different types of materials can power LEDs. Researchers at Georgia Tech say a square meter of these generators could provide 300 W.

The approach uses two modes of operation. In one, two materials are brought into contact with each other. In the other, two materials slide against each other. The amount of energy is tiny. But like most energy harvesting technologies, the collection of these small amounts enables useful work to be done, whether it's lighting an LED or running a microcontroller.

The triboelectric generator has increased power output density by a factor of 100,000. In theory, a square meter could provide 300 W. Originally, the team at Georgia Tech was investigating piezoelectric generators, which use movement and different underlying technology. Triboelectric generators are a laboratory phenomenon now, but practical uses are on the near horizon. ■ **BILL WONG**

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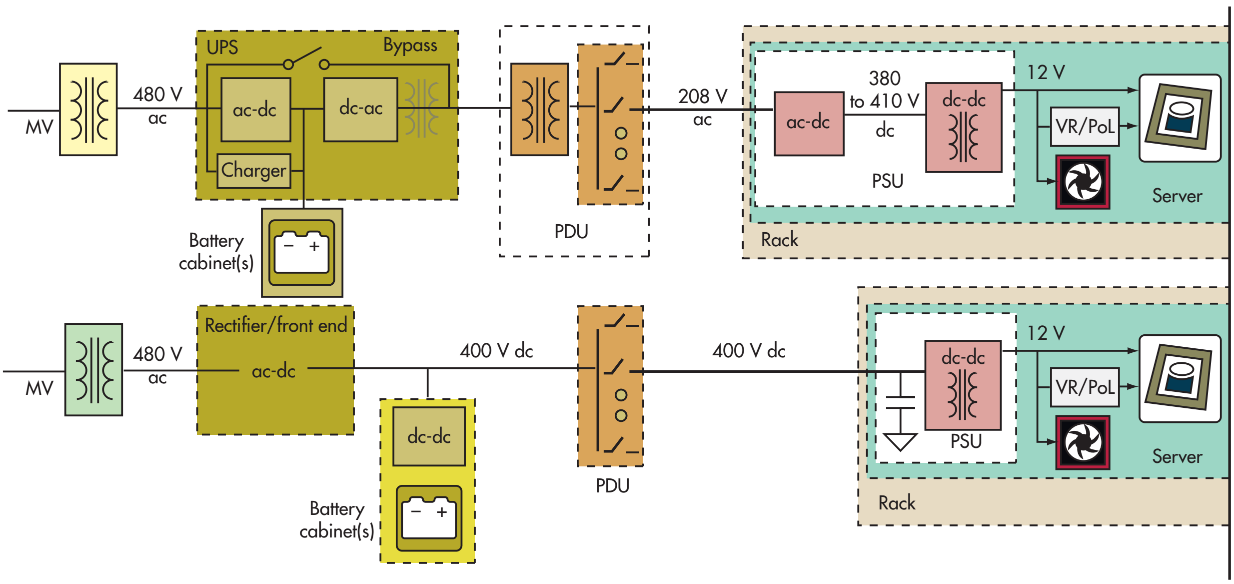
400-V DC DISTRIBUTION



1. The top illustration represents the customary 480-V ac power distribution chain; the bottom, the 400-V dc approach. In the dc delivery system, the power path is much more streamlined. It removes a dc-ac inversion stage in the UPS and an ac-dc rectification stage in the power supply unit. The transformer in the power distribution unit is also eliminated.

V

Switching regulators for dc power buses are common in smaller-scale systems, so why not data centers?

IN THE DATA CENTER GETS REAL

Power distribution in data centers used to emulate the architecture of old telephone central offices. A "rectifier" would step down and rectify the ac from the power line and use it to charge banks of batteries that provided an unregulated 48 V dc, which was distributed around the facility to run the telephone equipment in the racks.

Since at least 2007, data-center engineers have been talking about distributing 400 V dc (sometimes 380 V). Data centers are bigger and use a lot more power than telco central offices. At a minimum, higher voltage distribution would mean lower I^2R losses and/or thinner power-distribution cables.

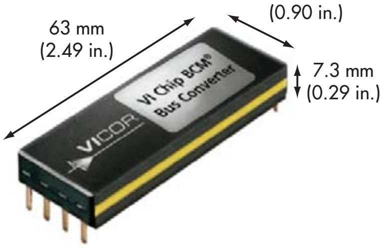
As data centers have grown in size and as cloud computing looks more and more economically viable, the use of 400 V has started to gain traction. In addition, one semiconductor company has released the missing silicon link in the chain. There is now a 400- to 12-V switching buck regulator device with efficiencies in the high 90s.

POWER IN THE DATA CENTER

As the use of the cloud for data storage grew in the early years of the 21st century, two issues related to electrical power emerged. One was the sheer power drain in kilowatt hours associated with a data center, not just for the transaction processing alone, but also for dealing with the waste heat generated by rows and rows of cabinets housing dozens of blade servers. The other was the incredibly rapid di/dt demands of the blade processors in those servers as their cores shifted among operating states.

The highly regulated voltage rails for core, peripherals, and memory in each processor might run on something like a volt. However, that volt would have to be tightly regulated in the face of changes in current demand on the order of multiple amps per second as the processors changed operating states.

Power sourcing led to the siting of new data centers close to power-generating facilities, which cut the cost of delivered power. Inside the data center, the issue was power distribution: how to get it from the utility drop to the ICs inside each blade server. The generally accepted solution was the Intermediate Bus Architecture (IBA). An IBA implementation has three stages:



2. One key to the power-handling capability of Vicor's CHiP package technology is that it can be fitted with heatsinks on top and bottom and both long sides.

- A front-end supply in the equipment rack steps down and rectifies the ac mains voltage from the power company to semi-regulated 48 V dc. It isolates the boards and circuits downstream from the lethal characteristics of the ac mains.
- Each board in the system has its own step-down supply, or bus converter, that changes the front end's 48 V to 12-, 8-, or 5-V bus voltages. The actual voltage is a tradeoff between the efficiency of the buck regulator at the point of load (POL) and the bus IR drop and I^2R losses.
- The bus voltage is stepped down and regulated by non-isolated buck converters termed point-of-load (POL) converters located at each load.

Most IC companies adopted IBA. Vicor created a different approach that it called Factorized Power. Vicor intended Factorized Power for a wider range of applications than data centers, but the data center was a candidate from the beginning. The approach is based on very efficient non-regulating, isolated POL-like chips at the load while moving the regulation function upstream.

Factorized power introduces its own terminology. The isolated voltage transformation modules (VTMs) are located at the load. Upstream, preregulator modules (PRMs) provide the actual regulation based on feedback from the VTM. The PRM adjusts the factorized bus voltage to maintain the load voltage in regulation.

VTMs function as current transformers. They multiply the current (or divide the voltage) by a "K" factor. This takes place with essentially a 100% transformation duty cycle, so there's no loss of efficiency at high values of K. Thus, the bus voltage can be (and is) greater than 12 V. PRMs can operate with input voltages from 1.5 to 400 V and step up or step down over a 5:1 range, with a conversion efficiency up to 98%.

Despite its design elegance, sole-sourced Factorized Power never displaced IBA, which was supported by many competing IC companies whose products were priced competitively.

Many engineers, including *Electronic Design*'s emeritus editor-in-chief Joe Desposito, argued that swapping 48 V dc, a separated or safety extra-low voltage (SELV) according to international standards bodies, for 400 V dc, capable of pushing a lot of current, was never going to be popular. Actually, it's coming faster than you think.

What's interesting is the thinking behind it, the equipment that's already available, and the fact that Vicor has just released a regulator device that works with its Factorized Power V-chips to handle what's been a "missing link." It's a high-current 400- to 48-V dc step-down device in a small package.

400-V HISTORY

The document most cited with respect to 400-V dc distribution in data centers was presented at the 29th International Telecommunications Energy Conference (INTELLEC) in 2007: "Evaluation of 400V DC distribution in Telco and Data Centers to Improve Energy Efficiency" by Annabelle Pratt, Pavan Kumar and Tomm V. Aldridge.[1] Most of the chips in those blade servers were Intel's, and regulating the voltages for the power rails on those chips had been the driver for distributed power architectures.

In 2010, Intel published a somewhat shorter white paper based on the con-

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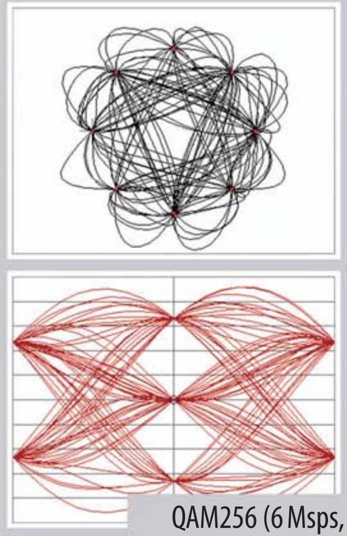
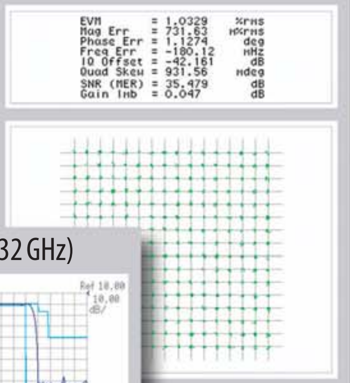

TETRA (π/4 DQPSK)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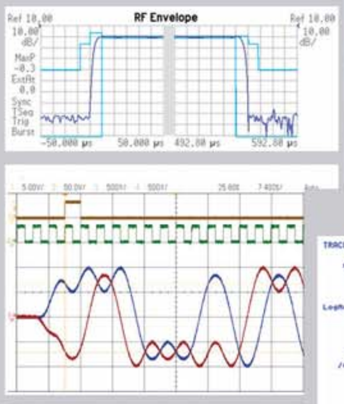
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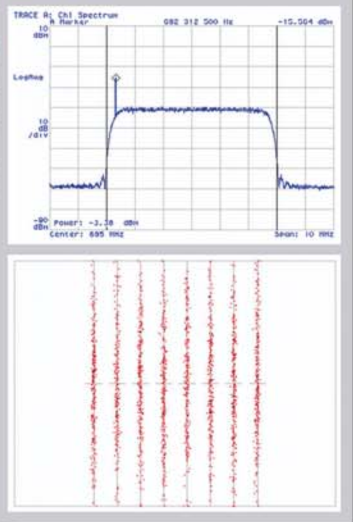
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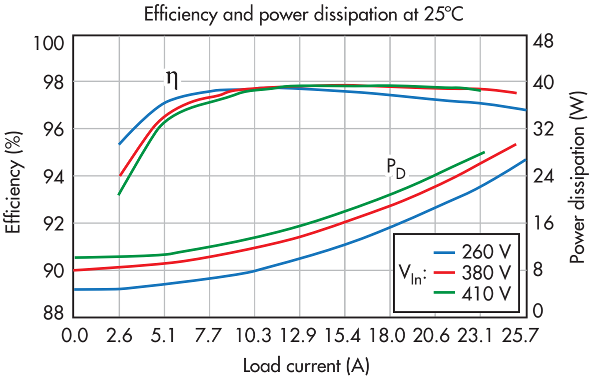
ference paper: "Evaluating 400V Direct-Current for Data Centers," with the subtitle: "A case study comparing 400 Vdc with 480-208 Vac power distribution for energy efficiency and other benefits," by the same authors, plus Dwight Dupy and Guy AlLee.[2]

The 2010 paper described an in-depth case study conducted by Intel in conjunction with EYP Mission Critical Facilities, which is now an HP Company, and Emerson Network Power for a 5.5-MW data center. The study concluded that energy savings of approximately 7% to 8% could be achieved over high-efficiency, best-practice 208 to 480 V ac with a 15% electrical facility capital cost savings, 33% space savings, and 200% reliability improvement.

According to Intel, 255 to 375 W is required at the input to the data center to deliver 100 W to the electronic loads. Anywhere from 50 to 150 W is used for cooling. About 50% of the power that's left is lost in front ends, power distribution units and cabling, power supply units, voltage regulators, and the server fans used inside the cabinets that hold the blade servers. Better efficiency is possible with 400-V dc power delivery because it eliminates three power conversion steps and enables single end-to-end voltage throughout the data center.



3. Low-load efficiency is another strength of Vicor's BCM

WHY 400 V IN PARTICULAR?

Previous studies also have identified 400-V dc power distribution as the most efficient. According to the 2007 IEEE paper, 15 different nominal voltages have been proposed, and Intel recognizes the need for flexibility. Nevertheless, having said that, 400 V dc does offer some particular advantages.

No phase balancing is required, which reduces the complexity of power strips and wiring. No synchronization is required to parallel multiple sources. There are no harmonic currents to worry about, eliminating the need for power factor correction (PFC) circuits. It can use fewer breakers (up to 50 percent for this case study) because of fewer power conversion stages. And, it simplifies wiring since only two conductors are required.

Also, a link voltage of approximately 400 V dc already exists in today's ac power supplies, as well as in the bus in light ballasts and adjustable speed drives (ASDs) that often are used to power fans and pumps in the data center. Because 400 V dc builds on the existing components in high-volume production server and desktop power supplies, the lowest power supply cost is ensured by not increasing the voltage any higher.

Uninterruptible power supply (UPS) systems typically use a higher voltage dc bus of 540 V dc, which can easily be redesigned to support 400 V dc. Additionally, the spacing requirements per the IEC 60905-1 standard for power supplies are the same for universal input (90 to 264 V ac) power supplies and for dc power supplies with a working voltage below 420 V dc. This is advantageous, as it would allow the reuse of high-volume designs in existence for ac power supplies.

Furthermore, 400 V is well within an existing 600-V safety limit. It operates over standard 600-V rated wiring and busing systems. Commercial solutions are already emerging. And finally, it is simpler and more efficient to connect to renewable energy sources such as photovoltaics, fuel cells, and wind turbines with variable frequency generators, since they also already have a higher-voltage dc bus at a voltage in this range.

THE ANALYSIS

Researchers from Intel, Emerson Network Power, and EYP Mission Critical Facilities, a data-center design services firm that was acquired by HP, applied the 400-V dc model to an extension of an existing data center to add three additional modules. The details are in the original paper and the white paper. The exercise was to compare a 480-V ac design with a 400-V dc design *(Fig. 1)*.

In the traditional ac approach, a central UPS constitutes the front end. Incoming power is rectified and feeds a backup storage system. The dc then is inverted back to ac and sent to the distribution unit, where the voltage is stepped down to 208 or 120 V, which is distributed to the server cabinets.

A power supply in each server rerectifies the 208 V ac to a dc voltage between 380 and 410 V dc, which is subsequently buck-converted down to 12 V dc. This voltage then is routed directly to the hard drives, which are not fussy about regulation. It is regulated down for the ICs in each server as well.

The Intel analysis also included a dc-dc converter between the battery and 400-V dc distribution bus, but noted that the batteries can be connected directly to the bus. The analysis also showed that the equipment for a dc data center would require only about two-thirds the space of an ac facility, freeing up more room for servers.

When the alternatives were modeled, the researchers obtained the results noted above. The dc approach produced a 7.7% energy savings with a 50% load and 6.6% savings at an 80% load. In dollars saved per year, that's $150,000 for a 5.5-MW data center operating at 50% load. (That was the calculation for the conditions prevailing in 2007.)

In terms of reliability, calculations showed a twofold improvement in availability over five years, with a calculated probability of failure of 6.72% for the dc distribution versus 13.63% for ac distribution. (Those are the numbers from a standard reliability calculation.)

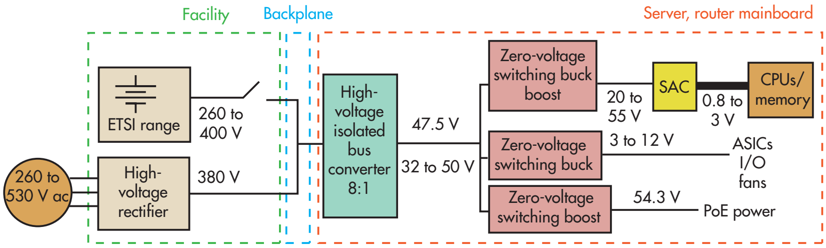
SAFETY

Whether it's ac or dc, 400 V will hurt. Placing yourself across 400 V pushing hundreds of amps won't leave a whole lot to bury. Yet ac or dc, 400 V is what we already have in data centers. "Current data centers with conventional UPS systems, which contain batteries as their backup energy source, are operating with dc bus voltages at the UPS at about 540 V dc," Intel said in its white paper.

"Operation and maintenance personnel are presently familiar with voltages at these levels, and the use of a 400-V dc system is not more hazardous than what is presently used. It is known that the use of higher ac or dc voltages inside of the data-center racks and cabinets may expose data-center personnel to voltages with which they are not normally familiar," according to the paper. "In the U.S., however, any nominal voltage above 50 V is considered hazardous to personnel, and when one is using or working with a higher voltage than this, the same precautions and personal protective equipment are mandatory."

DATA-CENTER DESIGN UPDATE

Unfortunately, the Intel study is from the 2007-08 timeframe. Data-center design has been evolving, but more in terms of server design than in power distribution. The IEC 61850 standard,



4. Compare the power flow through a dc distribution system using the BCM with the upper and lower flow representations in Figure 1.

which came out after the Intel documents, deals with the design of automated electrical substations. It's part of the IEC Technical Committee 57's reference architecture for electric power systems.

The standard's abstract data models can be mapped to various data protocols that run over TCP/IP networks and substation local-area networks (LANs) using high-speed switched Ethernet. In part, it's about making many of the power distribution elements discussed above part of the Internet of Things.[3]

A new model for data centers replaces the old model of aisles and aisles of cabinet racks filled with blade servers sitting on raised computer floors and cooled by internal fans pushing cooled room air produced by rooftop air conditioners. It recognizes that the average cell phone boasts approximately the memory capacity and processing power of an old-fashioned blade server.

Moreover, lacking a disc drive, the cell-phone-style server is perfectly happy at elevated temperatures. Consequently, new data centers can operate "in the dark" like modern semiconductor fabs, with much denser arrays of servers, operating in closed cabinets whose internal temperatures can be allowed to rise to much higher temperatures than would be comfortable for human workers, while the external environment is maintained at temperatures that are suitable for only occasional visits from real people. That doesn't change the economics of distributing power via 400-V dc, but it does make some of the construction simpler.

FOUND: THE MISSING LINK

In January, Vicor announced the first 400-V dc to 48-V dc (nominal) bus converter module to use its CHiP ("Converter Housed in Package") module technology. The BCM380y475x-1K2A30's dc input range is 262 to 410 V dc. Its nominal output voltage is 47.5 V dc, but it can be set for any output footage from 32.5 to 51.25 V.

Rated for 1200 W, the module can handle up to 1500 W peak. In OEM quantities, unit pricing is $120. Dimensionally, it's roughly 2.5 inches long, an inch wide, and something less than a third of an inch tall *(Fig. 2)*. The key to its size and power-handling capability is the CHiP package technology, introduced at last year's APEC conference.

Efficiency peaks at 98% and remains in the mid-90s down to 10% of rated load *(Fig. 3)*. The BCM is designed to be used with Vicor's other V-Chip devices. In other words, it provides a step-down stage that's followed by the more familiar upstream regulation controlled by the current transformer at the point of load *(Fig. 4)*. Beyond that, the company provides instructional videos, an evaluation board (BCD380x475x1K2A30), and graphic design tools. ed

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2. "Evaluation 400V Direct-Current for Data Centers," Tomm Aldridge, Annabelle Pratt, Pavan Kumar, Dwight Dupy, Guy AlLee, Intel Labs
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Quad 4-A Regulator Offers Parallel Output Flexibility

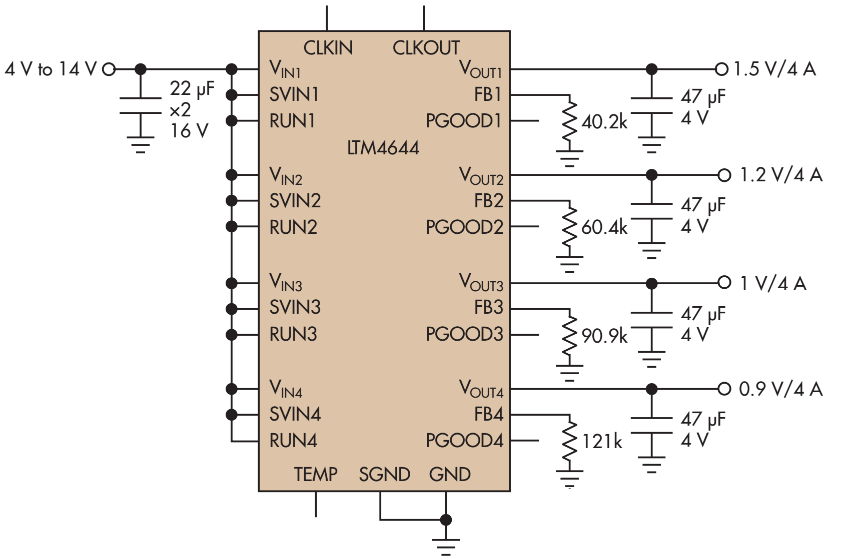
In one surface-mount package, a micromodule with four 4-A switching regulators supports the multiple power needs of FPGAs, SoCs, ASICs, and other similar devices.

FPGAs, systems-on-chip (SOCs), and ASICs serving in telecom, datacom, medical diagnostics, and industrial equipment require several voltage rails to power the core, multiple I/O, auxiliary rail, and other supporting circuitry. Also, designers are under constant pressure to reduce the voltage regulator footprint on the printed-circuit board (PCB). What's the solution?

Linear Technology's LTM4644 µModule (micromodule) combines four switching regulators to support most if not all the power needs of modern digital systems in one surface-mount package. It also is compatible with the 5-V and 12-V intermediate bus voltages common in these applications. It can provide four individual 4-A outputs or a single 16-A output by paralleling the regulators.

BY THE NUMBERS

The LTM4644 integrates four separate constant frequency controlled on-time valley current-mode regulators, power MOSFETs, inductors, and other supporting discrete components *(Fig. 1)*. Each of the four separate regulator channels can deliver up to 4-A continuous output with a few external input and output capacitors. With a 4-V to 14-V input, each regulator provides precisely regulated output voltage programmable from 0.6 V to 5.5 V via a single external resistor. Using an external bias voltage, the module can operate from as low as a 2.375-V input. The regulator includes output overvoltage and overcurrent fault protection.



1. At 60°C ambient temperature and 200-LFM cooling and no heatsink, an LTM4644 with 4-V to 14-V input provides four outputs rated at 4 A: 1.5 V, 1.2 V, 1 V, and 0.9 V.

Each converter in the µModule *(Fig. 2)* houses dc-dc controllers, power switches, inductors, and compensation components in a 9- by 15- by 5.01-mm ball-grid array (BGA) package *(Fig. 3)*. Only eight external ceramic capacitors (1206 or smaller case sizes) and four feedback resistors (0603 case size) are required to regulate four independently adjustable outputs. Separate input pins enable the four channels to be powered from different or common supply rails.

The operating frequency of the LTM4644 is optimized to achieve a compact package size and minimum output ripple voltage while maintaining high efficiency. The default operating frequency is internally set to 1 MHz. In most applications, no additional frequency adjusting is required. If any operating frequency other than 1 MHz is required, the µModule regulator can be externally synchronized to a clock from 700 kHz to 1.3 MHz. The four channels operate at 90° out-of-phase to minimize input ripple whether at the 1-MHz default switching frequency or synchronized to an external clock.

The µModule's phase-locked loop (PLL) consists of an internal voltage controlled oscillator and a phase detector. All internal top MOSFET turn-ons then can be locked to the rising edge of the same external clock. The external clock frequency range must be within ±30% around the 1-MHz set frequency. A pulse detection circuit is used to detect a clock on the CLKIN pin to turn on the PLL. During the regulator startup, the PLL function is disabled.

Configurable as a single (16 A), dual (12 A, 4 A or 8 A, 8 A), triple (8 A, 4 A, 4 A), or quad (4 A each) output regulator, the LTM4644's flexibility enables system designers to rely on one simple and compact µModule regulator for the variety of voltage and load current requirements. At an ambient temperature of 55°C, the LTM4644 delivers up to 13 A at 1.5 V from a 12-V input or up to 14 A with 200-LFM airflow.

With current-mode control and internal feedback loop compensation, the LTM4644 has sufficient stability margins and good transient performance with a wide range of output capacitors, even with all-ceramic output capacitors. Current-mode control provides the flexibility of accurate current sharing when paralleling any of the separate regulator channels.

With a built-in clock interleaving between each two regulator channels, the LTM4644 could easily employ two-plus-two-, three-plus-one-, or four-channel parallel operation, which is flexible enough in a multi-rail point-of-load (POL) application like an FPGA *(Fig. 4)*. Furthermore, the LTM4644 has CLKIN and CLKOUT pins for frequency synchronization or polyphasing multiple devices, which allow up to eight phases cascaded to run simultaneously.

Current-mode control also provides cycle-by-cycle fast current monitoring. Foldback current limiting is provided in an overcurrent condition to reduce the inductor valley current to approximately 40% of the original value when VFB drops. Internal overvoltage (OV) and undervoltage (UV) comparators pull the open-drain PGOOD output low if the output feedback voltage exits a ±10% window around the regulation point. Continuous conduction mode (CCM) operation is forced during OV and UV conditions except during startup when the TRACK pin is ramping up to 0.6 V.

Pulling the RUN pin below 1.1 V forces the controller into its shutdown state, turning off both power MOSFETs and most of the internal control circuitry. At light load currents, discontinuous conduction mode (DCM) operation can be enabled to achieve higher efficiency compared to continuous conduction mode (CCM) by setting the MODE pin to SGND. The TRACK/SS pin is used for power supply tracking and soft-start programming.

A diode-connected PNP transistor monitors the module's junction temperature. If the junction temperature reaches approximately 160°C, both power switches will turn off until the temperature drops about 15°C. The LTM4644 is specified for operation over the –40°C to 125°C internal temperature range.

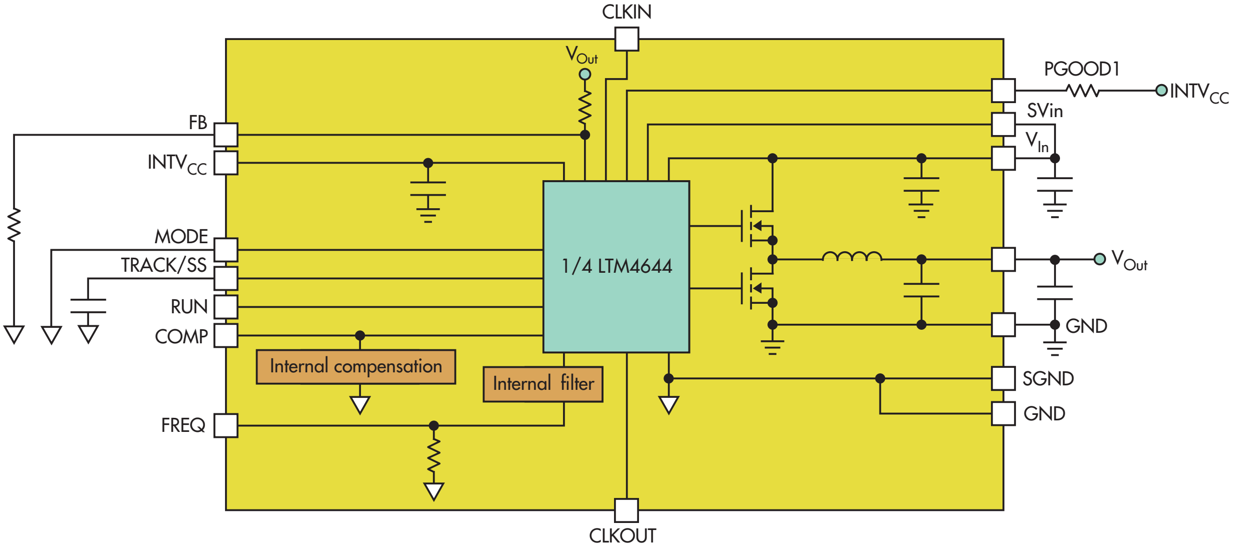
The LTM4644 module should be connected to a low ac-impedance dc source. For each regulator channel, a 10-µF input ceramic capacitor is recommended for RMS ripple current decoupling. A bulk input capacitor is only needed when long inductive leads, traces, or not enough source capacitance compromises the input source impedance. The bulk capacitor can be an electrolytic aluminum capacitor or polymer capacitor.

With an optimized high-frequency, high-bandwidth design, only a single low-ESR (equivalent series resistance) output ceramic capacitor is required for each regulator channel to achieve low output voltage ripple and very good transient response. The system designer may require additional output filtering to further reduce output ripples or dynamic transient spikes.

A multiphase power supply significantly reduces the amount of ripple current in both the input and output capacitors. The RMS input ripple current is reduced by, and the effective ripple frequency is multiplied by, the number of phases used (assuming that the input voltage is greater than the number of phases used times the output voltage). The output ripple amplitude is also reduced by the number of phases used when all of the outputs are tied together to achieve a single high-output-current design.

The LTPowerCAD Design Tool is available to download online for output ripple, stability, and transient response analysis and calculating the output ripple reduction as the number of phases implemented increases by N times. You can download the LTPowerCAD Design Tool at www.linear.com/solutions/LTPowerCAD.

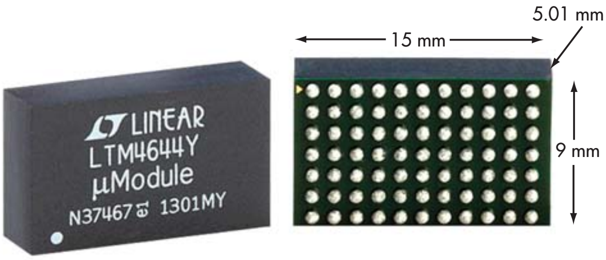
The LTM4644 µModule is an inherently current-mode controlled device, so parallel modules will have very good current sharing. This will balance the thermals on the design. Tie the RUN, TRACK/SS, FB, and COMP pins of each paralleling channel together. The TRACK/SS pin provides a means to either soft-start of each regulator channel or track it to a different power supply. A capacitor on the TRACK/SS pin programs the ramp rate of the output voltage. An internal 2.5-µA current source will charge the external soft-start capacitor toward the $INTV_{CC}$ voltage.



2. A typical converter circuit houses dc-dc controllers, power MOSFET switches, an inductor, and compensation components. It requires only two external capacitors and two resistors for each independently adjustable output.

The open-drain PGOOD pins can be used to monitor each valid output voltage regulation. This pin monitors a ±10% window around the regulation point. A resistor can be pulled up to a particular supply voltage for monitoring. To prevent unwanted PGOOD glitches during transients or dynamic V_{Out} changes, the LTM4644's PGOOD falling edge includes a blanking delay of approximately 52 switching cycles.

The LTM4644 module internal compensation loop for each regulator channel is designed and optimized for low-ESR ceramic output capacitors. In case bulk output capacitors are required for output ripples or dynamic transient spike reduction, an additional 10-pF to 15-pF phase boost capacitor is required between the V_{Out} and FB pins. The LTpowerCAD Design Tool is available for control loop optimization.



3. A 9- by 15- by 5.01-mm BGA package houses the LTM4644's dc-dc controllers, power switches, inductors, and compensation components.

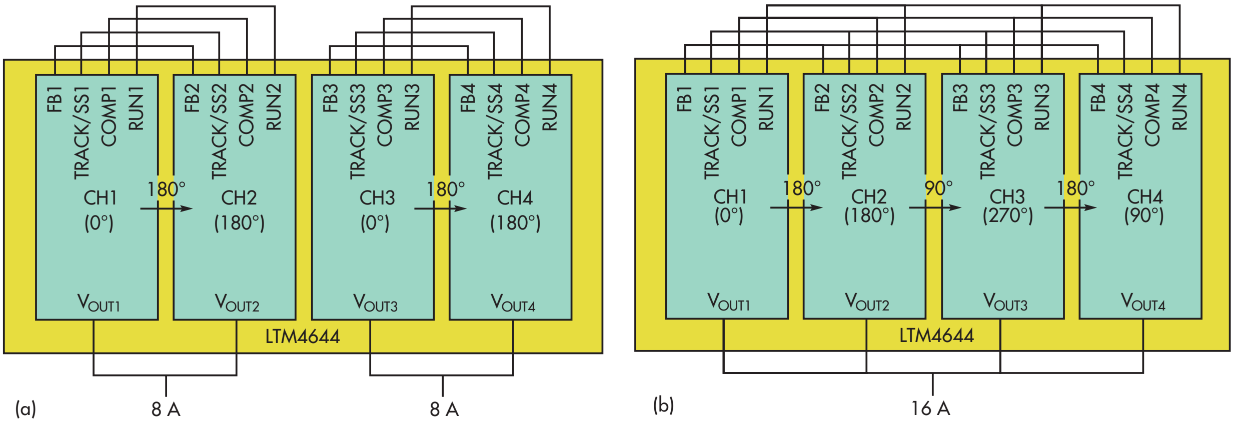
The LTM4644 modules do not provide galvanic isolation from V_{In} to V_{Out}. There is no internal fuse. If required, a slow-blow fuse with a rating twice the maximum input current needs to be provided to protect each unit from catastrophic failure. The module does support thermal shutdown and over-current protection.

LAYOUT

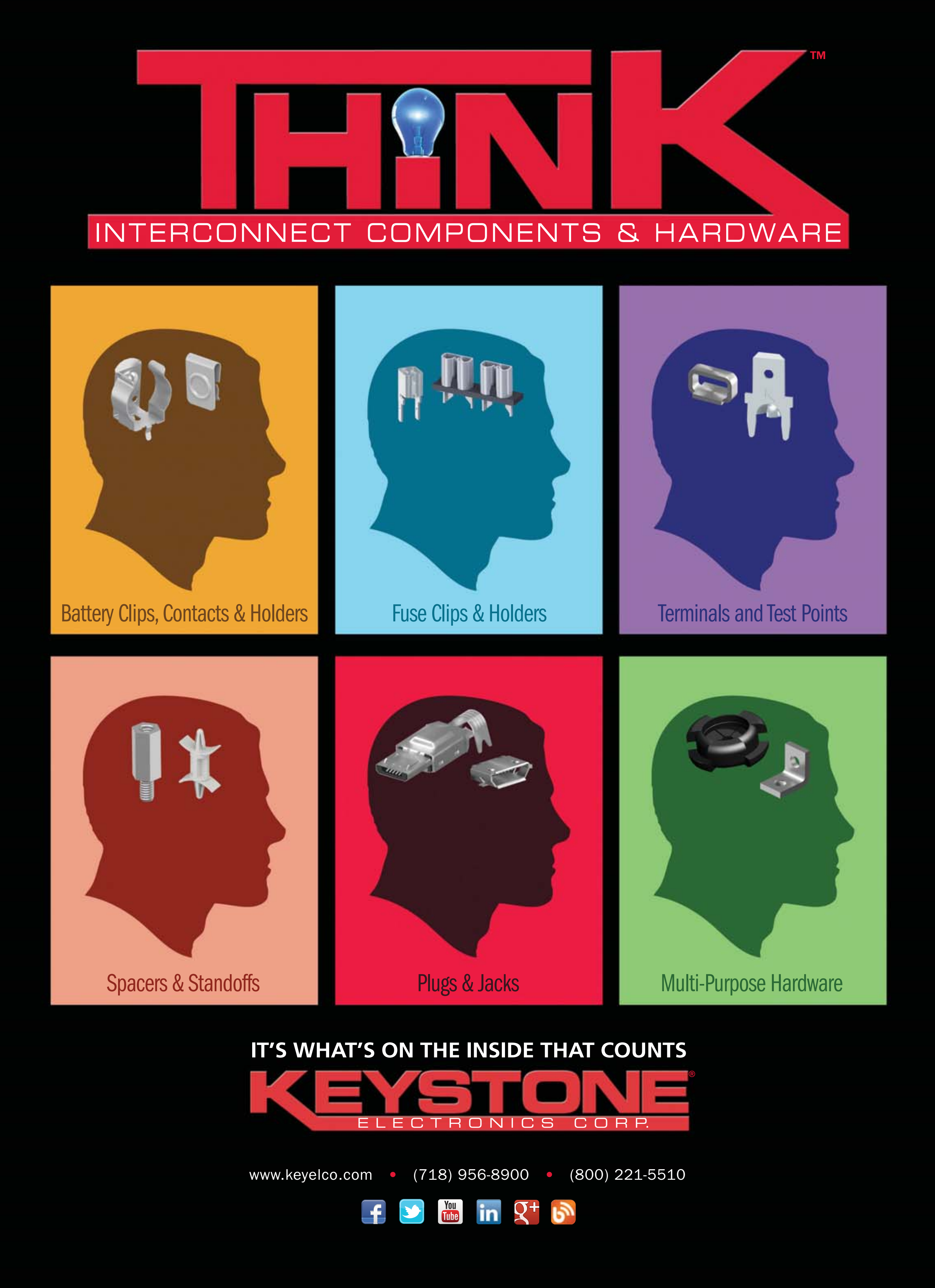
The highly integrated LTM4644 makes the PCB layout very simple and easy. But to optimize its electrical and thermal performance, some layout considerations are still necessary:

- Use large PCB copper areas for high-current paths, including V_{IN1} to V_{IN4}, GND, and V_{OUT1} to V_{OUT4}. It helps to minimize the PCB conduction loss and thermal stress.
- Place high-frequency ceramic input and output capacitors next to the V_{In}, GND, and V_{Out} pins to minimize high-frequency noise.
- To minimize the via conduction loss and reduce module thermal stress, use multiple vias for interconnection between the top layer and other power layers.

- Do not put via directly on the pad, unless they are capped or plated over.
- Use a separated SGND ground copper area for components connected to signal pins. Connect the SGND to GND underneath the unit.
- Place a dedicated power ground layer underneath the unit.
- For parallel modules, tie the V_{Out}, VFB, and COMP pins together. Use an internal layer to closely connect these pins together. The TRACK/SS pin can be tied a common capacitor for regulator soft-start.



4. Parallel circuit configurations enable 8-A and 16-A outputs. In a 2+2 configuration, V_{OUT1} and V_{OUT2} are connected in parallel and V_{OUT3} and V_{OUT4} connect in parallel to provide two 8-A outputs (a). In a four-channel configuration, V_{OUT1}, V_{OUT2}, V_{OUT3}, and V_{OUT4} are connected in parallel to provide one 16-A output (b).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Understanding GaN-Based Power Devices

Technologies based on this breakthrough material are beginning to outperform their silicon-based brethren.

When it comes to power electronics, circuit designs usually are based on the performance and cost of the available semiconductor devices. Topologies are developed to take advantage of the capabilities of the active power devices and to mitigate their deficiencies. Active devices represent a significant fraction of the total system cost, so their number often is minimized.

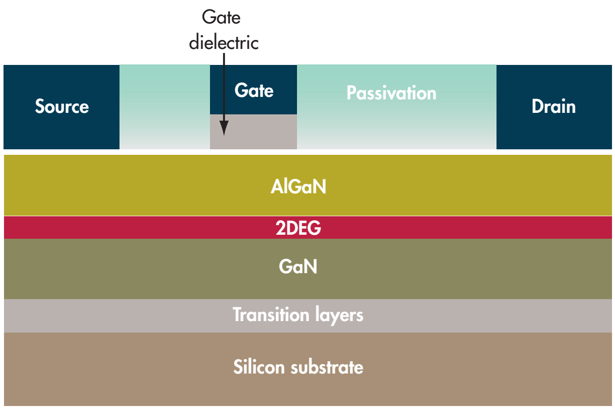
As a result, single-switch circuit topologies such as the flyback are popular. Despite the well-documented performance disadvantages, half-bridge topologies often are used instead of full bridge as well. Relatively expensive magnetic and dielectric components are sometimes used to reduce the voltage stresses exerted on the semiconductor devices, allowing for reduced voltage ratings and thereby lower costs.

Complex control circuitry is used to implement resonant topologies to mitigate power losses induced by slow switching speeds. Significant volumes of capacitive and inductive elements are used to provide necessary quiescent output voltage levels while maintaining relatively low switching frequencies, again to avoid the consequences of the semiconductor devices' poor switching speeds.

When significant advances in power semiconductor devices occur, subsequent radical changes are driven in circuit topology designs and their market adoption, such as the development of switched-mode power supplies after the introduction of commercially viable power MOSFETs. For example, the development of highly dense MOSFETs made the voltage regulator modules used to power modern processors viable.

The improved performance provided by super-junction MOSFET switches has enabled, at least in part, the rapid expansion in the use of power factor correction circuits. Similarly, the development of highly efficient insulated gate bipolar transistors (IGBTs) has largely enabled the use of energy-efficient inverterized motor systems.

The next wave of power electronics will use devices based on gallium nitride (GaN), specifically the GaN-AlGaN (aluminum gallium nitride) high electron mobility transistor (HEMT). These devices provide many benefits compared to silicon-based incumbents in a variety of power conversion applications such as class-D audio amplification and inverterized motion control, as well as ac-dc and dc-dc power supplies.



1. In the structure of a basic AlGaN-GaN HEMT, the gate-modulated resistor is formed at the heterojunction of the two top III-nitride layers.

THE FUNDAMENTALS

Efficiency, density, and cost can be directly related to the power device properties of conduction loss and switching loss of the semiconductor switches used. With MOSFETs, they're called on resistance ($R_{DS(on)}$) and switching charge (Q_{SW}). For an IGBT, they're $V_{CE(on)}$ and (E_{On}+E_{Off}), respectively.

The lateral nature of the AlGaN-GaN HEMT provides for less terminal overlay capacitances and therefore less switching losses than the incumbent vertical silicon-based devices. In addition, the shorter drift regions in the HEMT, made possible by the larger bandgap (e.g., 3.3 eV) of GaN compared to silicon (e.g., 1.1 eV), together with the high electron mobility of the two-dimensional electron gas (2DEG), provide for lower specific on resistance. Therefore, the AlGaN-GaN HEMTs are inherently superior to silicon-based devices for power conversion applications.

Essentially, the GaN HEMT is a gated resistor *(Fig. 1)*. The conduction path is formed near the interface between the top

GaN and AlGaN layers. Due to the difference in the polarizing nature of the two films, net positive charges are effectively located at this interface. These charges produce a localized low-energy well in the conduction band edge. The highly polarizing nature of the AlGaN crystal further produces a built-in potential across the film.

When this potential exceeds a critical value (i.e., 1.5 to 2 V), atoms (presumably Al) near the surface of the film are ionized. The resulting free electrons are collected in the well of the band structure at the AlGaN-GaN interface. These electrons do not strongly interact with either the GaN or AlGaN lattices, forming a 2DEG, exhibiting high mobility (i.e., >2000 cm^2/VS, compared to a silicon MOS inversion mobility of 1500 cm^2/VS). In this way, 5 – 10 x 10^{12} electrons per cm^2 can be incorporated in the 2DEG, providing a sheet resistivity of 300 to 500 Ω/sq.

The passivation of the AlGaN surface provides for the stability of the 2DEG. Ohmic contacts are made with the 2DEG through the passivating and surface AlGaN layers. Historically, this has been accomplished through an aluminum/titanium (Al/Ti) bi-layer capped with gold/titanium (Au/Ti) to promote mixing and prevent corrosion.

But to make the devices cost-competitive with silicon-based alternatives, gold-free ohmic contact processes are required. Contact resistances of 0.2 to 0.5 Ω mm then can be commonly achieved, with reported values as low as 0.05 Ω mm. Reported devices have achieved linear source-drain resistances of 2 to 3 Ω mm (30 V) and 10 to 20 Ω mm (600 V).

Resistance is modulated through a field-effect inducing gate electrode. In the past, a metal-semiconductor (Schottky) gate was often used, especially for microwave amplifier applications. However, this structure is far too leaky (e.g., mA/mm of gate width) for use in power devices, where the typical device involved 100 to 3000 mm of gate width.

Therefore, state-of-the-art GaN HEMTs generally use insulated gate structures that exhibit far less leakage (e.g., pA/mm of gate width). To accommodate the large surface fields induced between the edge of the metallic gate electrode and the 2DEG, field plates must be engineered above the surface AlGaN layer. A highly effective fast switch then can be constructed for power conversion applications.

THE DIFFERENCES

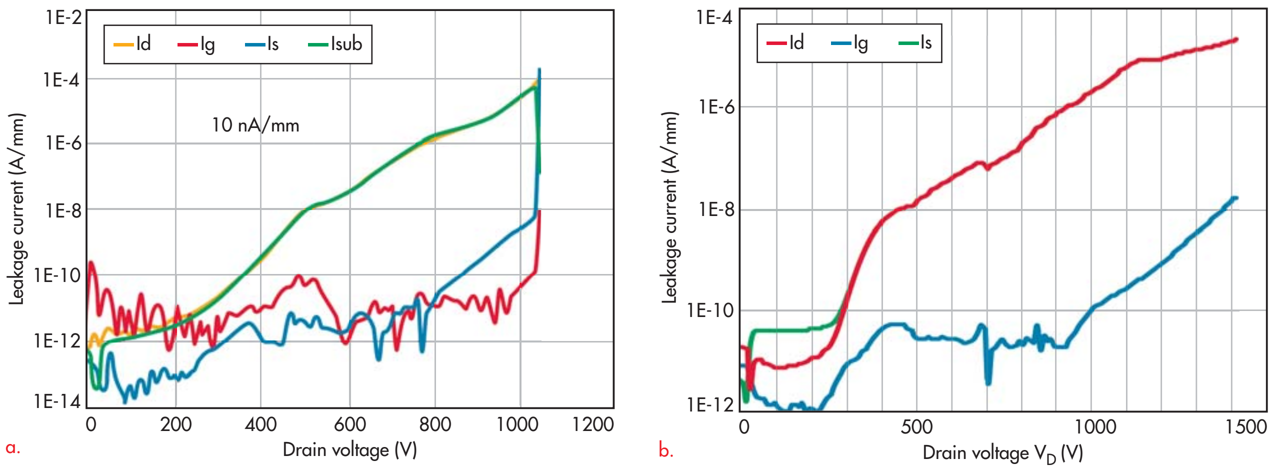
Several important differences in behavior between such lateral AlGaN-GaN HEMTs and incumbent commonly used silicon-based power switches are key to their performance in application circuits.

One fundamental difference is the absence of a p-n junction in the GaN HEMT. In fact, spatially resolved p-n junctions in such GaN-based lateral HEMTs are technically impractical since AlGaN and GaN are unstable at temperatures above about 900°C, except in a growth environment. Even with a passivation layer of silicon nitride (SiN), the GaN or AlGaN material will disassociate at the surface, causing severe surface roughness, voids, and highly non-stoichiometric regions.

As the effective annealing of implantation damage, or the incorporation of dopants by implantation or diffusion, requires temperatures well in excess of 900°C, such strategies are ineffective in the formation of high performance p-n junctions. The absence of a p-n junction has at least two dramatic consequences for the behavior of AlGaN-GaN HEMTs.

First, no minority carriers are involved in the device's operation. This is in stark contract to the behavior of MOSFETs, especially superjunction-based devices, as well as IGBTs. In

2. The measured reverse biased leakage currents of a representative 600-V rated GaN HEMT from International Rectifier can be charted as a function of applied drain bias with the substrate grounded (a) and the silicon substrate floating (b), exhibiting an intrinsic surface dielectric breakdown voltage of greater than 1400 V.



both cases, the minority carriers that are injected into the drift region during the on state must be removed from the depletion region when the device is reverse biased, before current flow stops.

Significant energy loss results, in addition to noisy ringing of the application circuit response during device switching, requiring sophisticated dead-time control as well as expensive filtering circuitry. In turn, this limits the applicability of superjunction MOSFETs, for instance, away from hard switching applications and sets a maximum operation frequency for both superjunction MOSFETs and IGBTs (e.g., less than 100 kHz).

The AlGaN-GaN HEMT does not suffer from these effects. Consequently, it switches much more cleanly with far less noise generation and the ability to operate at much higher frequencies (e.g., more than 1 MHz). This enables the reduction in filtering components, making the system smaller, lighter, and less expensive.

The reduced switching time reduces power losses. Also, the AlGaN-GaN system comprises wider-bandgap materials, so it's intrinsically capable of higher temperatures. The HEMTs therefore have reduced cooling requirements, often eliminating the need for heatsinks. Or, they can operate with a higher ambient cooling medium (air or liquid).

The second major effect of the absence of a spatially resolved p-n junction is the lack of a switch-voltage diode clamp. In commonly used silicon-based power MOSFETs, a built-in diode clamps the source-drain voltage during, for instance, the back EMF-induced (electromotive force) voltage spike generated when switching current through an inductive element.

A p-n diode affords the possibility to non-destructively pass large currents, effectively clamping very large power sources. This is due to the phenomenon of multiplicative carrier generation (avalanche) across the energy gap in the presence of a strong electric field. The relatively short distances present in the reverse biased p-n junction depletion region enables such a field.

This clamping diode has been very effectively used in power conversion applications, providing significant robustness for the use of silicon-based power devices. The limitation to this clamping mechanism occurs when the current through the semiconductor is sufficient to overcome the doping level and make a portion of the p-n junction intrinsic. At this point, a condition of thermal runaway from Joule heating will destroy the device. This often is called the device's avalanche capability. AlGaN-GaN HEMTs have no p-n clamping junction, so they have no avalanche capability.

Another significant difference is that commonly used (discrete) silicon-based devices collect the current vertically through a bulk drift region between the gate and drain, compared to the near surface drift region of the lateral HEMT. The silicon device then dissipates the Joule heating of the ohmic conduction losses in a much (e.g., 100 times) larger volume of material. The local temperature rise, under short-circuit conditions, is far less in the vertical current collection case.

In addition, the vertical conduction case provides for the electric fields to be contained in the volume of the semiconductor material. This is not the case in the lateral HEMT, where the highest fields are present above the 2DEG, especially in the overlying dielectric layers, just beneath the gate/field plate conductors.

The absence of spatially resolved p-n junctions exacerbates the surface fields, since the conductive field plates induce much sharper discontinuities and therefore higher peak electric fields than can be achieved with the relatively smooth transitions provided by the presence of a semiconductor junction. The combination of these two differences means that the AlGaN-GaN HEMT is not characterized by the same tradeoff between drift length/doping (specific on resistance) and the avalanche breakdown critical field as commonly used silicon-based power devices.

The equivalent design criteria for the lateral HEMT is the time-dependent dielectric breakdown of the insulating layers (including the AlGaN barrier) above the 2DEG. As such, reliable devices will operate below half of the breakdown field strength of these insulating layers. Therefore, there is significant headroom for voltage spikes between the rated operating voltage and the actual breakdown voltage of the HEMT device for a 600-V rated power HEMT from International Rectifier *(Fig. 2)*. Typically, 5% to 10% of headroom is provided for silicon-based devices between the drain-source operating voltage rating and junction breakdown.

The AlGaN-GaN HEMT, then, represents a key departure in terms of materials, device structure, and performance compared to incumbent silicon-based power devices. ed

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VICTORIA FRAZA KICKHAM | DISTRIBUTION EDITOR | victoria.kickham@penton.com MARCH 2014

Top Distributors Sharpen Their Focus On Asia

Electronics distributors respond to changing dynamics in Asian markets.

ELECTRONICS DISTRIBUTORS ARE RESPONDING to market changes across Asia with a variety of strategies, ranging from online expansion to physical growth that will allow them to cover a wider geography, especially in China where many manufacturers continue to move inland. An increase in research and development in some countries also is helping to grow business on the design side of the equation. It all adds up to new business opportunities and revenue growth for some of the industry's largest distributors.

Global Purchasing spoke with three such companies to learn about their growth strategies and identify the latest customer trends in the area. Avnet's Stephen Wong, president of Avnet Electronics Marketing Asia; Digi-Key's Chris Beeson, executive vice president of sales and supplier development; and Newark element14's James McGregor, director of supplier management, all weighed in on the latest trends among customers in Asia.

AVNET: WHERE BUSINESS IS GOING TO BE

Much of the secret to success for Avnet Electronics Marketing is anticipation. In the last six to seven years, the distributor has invested in developing new locations in inland China, anticipating the now well-established migration from coastal cities to inland ones among many manufacturers doing business in the country today. Avnet has more than 50 locations across

Continued on Page 42

Product Innovation, Assembly Work Drive Connector Sales

Customer demand for specialty products and services keeps connector suppliers busy in 2014.

VALUE-ADDED SERVICES ARE DRIVING growth at Peerless Electronics, a distributor of electromechanical and interconnect products based in Bethpage, N.Y. Business is picking up in all customer segments, says Dave Rome, chief marketing officer. The company's investment in custom assembly work and other services are keys to capitalizing on today's slower economic growth, he adds.

Looking at connectors in particular, Rome points to Peerless' connector assembly work, which many customers are taking advantage of due to downsizing at their own companies and the desire to focus on more complex manufacturing processes. The trend is a natural extension of the distributor's increasing role as a service and solution provider, Rome adds.

"[Our value-added business] is growing tremendously," he explains. "There are a lot of customers out there who are doing things they shouldn't have to do. When we take over some of their assembly work, they can focus on the more complicated processes."

Peerless Electronics took another step in the service direction recently with two new quality

TE has expanded its VITA 66.1 series, introducing the new ruggedized optical backplane interconnect system designed for high-bandwidth applications.

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Top Distributors

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Asia—more than 30 of them in China. "The potential business in the western part of China is [great]," Wong explains. "Having established there well ahead is to our advantage."

Wong says this is key to Avnet's strategic growth in Asia, a market he expects to perform well for the company in 2014.

"And we need to work hard in terms of servicing the customers, working with suppliers, and investing our resources and money and time in the right place," Wong explains. "I feel much better [about the economy] than [I did] six months ago. This year will be a good year."

Wong emphasizes the importance of developing a strong infrastructure in China that lets companies serve customers in the way they want to be served. As with customers everywhere, consistent service, reasonable pricing, and supply and design chain services are all important. There is also a growing emphasis on integrity of supply.

"Avnet has a very strong reputation in Asia as being a high-integrity company," says Wong, emphasizing the growing importance on such issues among suppliers, customers, and employees.

Also playing into this is a shift in the Chinese economy in which domestic consumption and research and development are becoming more important. "Customers in China now have R&D [and] they invest in their brand," Wong explains. "They want good product [and] insist on getting [that] product from franchised distributors for that reason."

DIGI-KEY: NOT ONLINE ONLY

For Minnesota-based Digi-Key Corp., the region's growing interest in doing business with well-known, global companies is helping the firm move beyond the largely virtual presence it has had throughout Asia over the last several years. The distributor has had support centers in place in Japan, Korea, and Hong Kong for some time, but just opened its first major location in Shanghai in December. Beeson says the locations will help Digi-Key build momentum in the region and follow up on 2013's 15% growth with similar gains.

"We're just now becoming a little less virtual and [have a] more physical presence [in Asia]," Beeson explains, pointing to efforts to develop in China especially. "We're still relatively 'light touch' in the area, but we see a very large engineering opportunity for us" in Asia-Pacific.

Digi-Key's efforts to enhance customer payment options are helping as well. The company now conducts business in the local currency, the Chinese Renminbi (RMB), and other local payment forms such as China's UnionPay system.

"That gives us the ability to reposition [our] website orientation, have some technical resources there—which are all enhancements to our market positioning," Beeson explains, noting that it is easier to solve technical problems and provide customers with resources when you have a stake in the community.

Engineers' increasing reliance on the Web for research and purchasing combined with a growing need to purchase more components from a single source in a short time frame also play into the hands of larger, global distributors. Especially with today's shorter product lifecycles, design engineers are challenged to respond more quickly to the demands of time management. Beeson argues that design engineers can fulfill their needs more quickly via Digi-Key's broad inventory selection and ability to get products anywhere in the world within two to four days. These are supply chain demands the electronics channel as a whole is continually working to improve.

It's also important to consider that Asia is a market traditionally served by traders or agents, which don't necessarily have the capabilities of more traditional, global distributors, Beeson adds.

"Those models really don't lend themselves to a single spot where I can go and get a broad array of products off the shelf," he says. "[Ours] is an enhancement to the model that the region has dealt with historically."

ELEMENT14: CHINA AND BEYOND

Newark element14's McGregor likewise sees an increasing need for the services of large, western distributors throughout Asia, especially in China, which he says will continue to be a growth driver for the company. Newark element14 is well established throughout Europe and North America, and it has been focusing on building business in Asia-Pacific over the last five years, he says.

"It remains very much a bright spot within element14—a region that's performing very well for us," McGregor says, pointing to the distributor's business in mainland China as well as India, Australia, New Zealand, and elsewhere across the region. He agrees that integrity of supply is a growing trend that bodes well for element14 and its peers.

"We see that becoming a more important issue for certain customers in Asia—certainly in New Zealand and elsewhere, but particularly in China. Customers are choosing suppliers with many locations, a good reputation [and so forth], making sure it's a quality product and that it's traceable," McGregor says.

Newark element14 has worked to establish a solid footprint in Asia-Pacific, combining locally based sales and service with regional inventory locations that allow it to deliver products within two days throughout the region. McGregor notes the area's diverse customer base as well. Newark element14 focuses on customers with short-run production needs in China, supports research and development and the integration of software and hardware in India, and works with small-scale manufacturers in key markets such as mining and telecommunication in Australia.

"[This] speaks to the breadth of our engagements with our customers across the region," McGregor explains. "Having that local sales and market presence as well as regionally based inventory has really helped." ■

Product Innovation
Continued from Page 41

standard certifications. The company's value-added staff is now certified to the MIL-STD-2000A for soldering electrical and electronic assemblies. Members of the staff also are CIS Certified IPC Specialists, meeting the J-STD-001 soldering certification.

IPC J-STD-001 has become particularly important, Rome says, as the leading authority for electronics assembly manufacturing.

Rome says the certifications illustrate Peerless' ongoing effort to enhance and expand its service offering. In addition to assembly and soldering work, the distributor offers bar coding, packaging, and splicing services. It also builds circuit breaker panels and provides custom printing on a wide range of products.

"It's all become much more complex," Rome explains, noting that when he joined Peerless in 1978 it had two employees doing basic assembly work. Today, the distributor has nearly 20 employees and a host of high-tech machinery dedicated to value-added work.

In addition to services, two other key trends rule the connector market: the desire for lighter, faster interconnect products and the demand for more online resources. Looking at product innovations, Rome points to the fiber optic market in particular, noting TE Connectivity's ongoing updates to the VITA-66 product line.

TE expanded its VITA 66.1 series recently, for instance, introducing the new ruggedized optical backplane interconnect system designed for high-bandwidth applications such as high-definition video and images, as well as for computing applications that require optical infrastructure. TE says the new system is ideal for a wide range of industries and applications, including embedded computing, ruggedized military applications, commercial aerospace, and the geophysical industry.

Rome says the VITA 66 line is in strong demand, especially among defense and aerospace customers, which he says are faring better than most media reports indicate these days.

"People say it's dead," Rome says of the defense market. "It's not dead. It's not showing the growth potential of some other industries, but it's not as dormant

Semiconductor Market To Grow 7% In 2014

Tablet and cell-phone applications remain top drivers in the IC market.

THE GLOBAL SEMICONDUCTOR MARKET is set to grow 7% in 2014 following 5% growth last year, according to industry researcher IC Insights, which released its McClean Report 2014 in January. Although steady improvement is expected across the market, IC Insights leaders note that such growth is still considered slow in an industry accustomed to double-digit gains.

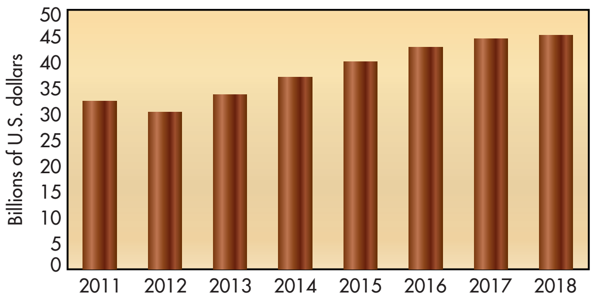
"This year looks pretty good. Not great, but better than last year," said IC Insights president Bill McClean. "Really good growth in this industry is double-digit. Anything else is just okay."

A sluggish worldwide economy is largely to blame. McClean pointed to ongoing problems in the Eurozone in particular as keeping market conditions less than stellar. Positive economic indicators in the United States combined with growth in emerging markets will help keep conditions moving in the right direction, however.

"If the world economy cooperates, it should be a good year," McClean said.

Top-growing markets for ICs, in particular, continue to be tablet microprocessor units (MPUs) and cell-phone app MPUs, followed closely by NAND flash and DRAM markets.

A separate industry report released in early February pointed to growing strength in industrial electronics markets. Researcher IHS said the worldwide market for industrial electronics semiconductors ended 2013 on a positive note, rising 11% to $33.7 billion. IHS says it expects that momentum to continue, predicting 34% growth to $45 billion worldwide over the next five years *(see the figure)*.



The industrial market will have a considerable effect on the industry with 34% growth to $45 billion predicted worldwide over the next five years. *(courtesy of IHS Technology)*

"The market's persuasive bounce-back is due to a strengthening global economy, coupled with higher purchasing confidence across all geographical regions," said Robbie Galoso, principal analyst for industrial electronics at IHS. "While the field may not sound as sexy or attention-grabbing as some of the more popular markets around, like wireless or consumer, there is no underestimating the power or sheer breadth of its applications, ranging from home automation to the medical field, to energy, to aeronautics and military purposes, and much more." ■

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Power Experts Ponder Moore's Law
And Today's Technology

Moore's Law continues to enable ever more computing power. The integration of billions of transistors on a single die in multicore processors and other advanced devices such as ASICs and FPGAs, even if supply voltages are down to 1 V or less at the core of the chip, has meant that current demand is beginning to exceed 100 A at the point of load (POL).

Experts from three companies that operate at the cutting edge of power technology recently discussed this increasing challenge for power system architects: Chance Dunlap, senior marketing and applications manager at Intersil; Mark Adams, senior vice president at CUI; and Patrick Le Fèvre, marketing and communications director at Ericsson Power Modules.

ELECTRONIC DESIGN: With power requirements for many of today's ICs rising above 100 A, what challenges arise for engineers who are tasked with designing the architecture?

DUNLAP: With increasingly power-hungry ICs, the classical problems of power supply design continue to exist: how to increase system efficiency, minimizing power loss in an ever-shrinking footprint. This is compounded with output voltages continuing to decline and load steps increasing with the use of smaller geometry processes. As a result, a power supply that could meet the system requirements for transient response and output regulation a few years ago may not pass the latest specifications.

ADAMS: In addition to the extremely tight restrictions and performance metrics required by the IC, when you start to reach these levels, two key design issues are space and thermal management. The available board space isn't increasing, but the power density and requirements are. So how do you manage a complicated design without just adding additional phases, which add space? Furthermore, the required intelligence and tighter performance tolerances that are needed mean you're not only dealing with analog signals, ground planes, and power paths.

LE FÈVRE: The high currents now required to power FPGAs, ASICs, and multicore processors is not new. Despite the large number of non-isolated power modules being available on the market, these products might not always be suitable to power network-packet, traffic-manager, and fabric-interface processors, which all require different interfaces and communication protocols. One example is the way Intel specifies the output voltage setting through the voltage identification (VID) table, which is not necessarily the way that many system designers would want it. Designing a multiphase voltage regulator is not necessarily a challenge. What is more difficult is making it even smaller than before, while also making it easy to parallel with full monitoring and control via PMBus 1.2 or PMBus+ 1.3 specifications.

ED: What challenges does this trend pose for power companies?

While today's top processors enable new innovations, they also require much more power than their predecessors. Chance Dunlap of Intersil (a), Mark Adams of CUI (b), and Patrick Le Fèvre of Ericsson Power Modules (c) are on the front lines of this battle to meet the market's performance and energy needs.

ADAMS: Chip designers typically create reference designs to support their core voltage requirement by working at a discrete level. For them it is important to keep their "perceived" total bill-of-materials cost low. This works for the few OEMs that drive large volume and have the support of power engineers and semiconductor FAEs to assist in the design. Yet there is a large portion of the customer base that doesn't have that luxury and relies heavily on modules for these high current requirements. Thus, getting a hold of this information is critical. Without it, we'd be shooting in the dark—is the requirement 100 A, or is it actually 120 A? To better address this challenge, we've started to partner closer with our customers and work with chip vendors to better understand future power requirements, ensuring our products meet these critical performance metrics.

LE FÈVRE: Multiphase POLs have been on the market for decades. But outside of the well-defined Intel VRM specifications, power requirements for network processors represent a number of challenges. These include selecting the best controller embedding the latest features such as dynamic loop compensation, active current sharing, and the ability to communicate with the board power manager to optimize the voltage to meet traffic conditions. Few controllers available today meet all these requirements, although some recently introduced semiconductor products are opening up interesting opportunities. Another challenge will be the implementation of PMBus+, which is expected soon, but will require chipmakers to update firmware as soon as the final specification is released. Another challenge will be how to manage boards and systems having to carry PMBus 1.2 and PMBus+ units. It could be that power companies to have to provide dual-mode compliance, which could be extremely challenging.

DUNLAP: For Intersil, this means the continued evolution of IC architectures to enable power supplies with faster transient response and improved regulation. But with the increase in performance also comes the challenge of creating a power supply that can be developed with faster time-to-market with high reliability. As a result, the focus has been on developing products that provide a compensation-free system.

ED: Is this trend changing the way you approach the priorities and tradeoffs within your latest designs?

LE FÈVRE: High-current POL regulation is part of our technology roadmap and very much aligned with what network processor manufacturers expect from power supply manufacturers. In this respect, our priorities are not changed. However, because of the relative uniqueness of advanced control ICs, it is strategically important to select the right partner early on in the design phase and work in tight cooperation to co-develop our respective products.

DUNLAP: With old designs, there used to be a compromise that was made. To ensure stability with the integration of compensation components, power supplies would have to trade off bandwidth and performance. The converse would then hold true. High-performance devices would be complex and require significant time to design and optimize.

ADAMS: Definitely. It means you can't drive designs going forward that serve 90% of the needs and then let the customer figure out the last 10%. You now need to work to solve the most challenging 10% and then figure out how we adapt the design for the other 90%: either create a derivative of that product, backing down on some of the performance, or drive them to be more commercially viable in a high-value situation.

ED: Digital power has received a lot of press for its ability to address complex loading requirements in distributed power architectures. How can digital help address rising current densities at the board level?

DUNLAP: One of the key advantages of digital power is the ability to integrate all the small signal components surrounding the power supply that set up the functionality and performance into the controller IC. With the controller's on-board memory, multiple parameters can be set up and dynamically changed via the PMBus interface.

ADAMS: The biggest way that digital can add value is through the stability and the performance of the supply itself. It isn't going to necessarily allow you to get 100 A at a smaller space. That will come from the design of the power train. But digital will deliver a more controlled 100 A and a tighter power at that 100 A.

LE FÈVRE: The conventional ways of powering boards are changing as systems gain in complexity. Besides offering better switching control within power modules, digital power adds a new level of flexibility that makes complexity simple. ed

Reduce IGBT Gate Drive Design Costs and Space

Introduction

The ACPL-337J is an advanced highly integrated gate drive optocoupler, designed to ISOLATE, DRIVE, PROTECT and FEEDBACK the IGBT's operational status.

It has a rail-to-rail output that can deliver 4A of maximum current capable of driving high power IGBT directly. The integrated DESAT detection protects the IGBT during short circuit condition and the isolated feedback reports this fault to the controller.

In addition to these basic functions, the ACPL-337J integrates more new features to further reduce external discrete components used by designers to improve the system overall power efficiency and reliability. The end result is an easy-to-use, compact and affordable IGBT gate drive optocoupler solution.

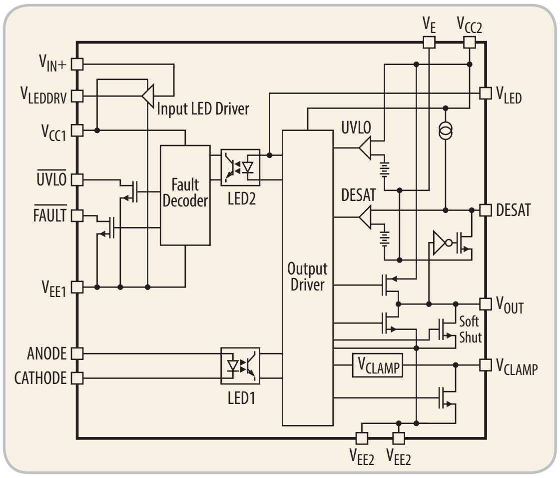

Figure 1. Functional diagram of the ACPL-337J gate drive optocoupler

In the Beginning

Optocouplers are used to provide high voltage reinforced galvanic insulation and noise isolation in inverter or motor drives applications. Basic gate drive optocouplers which can deliver high output current are usually used to charge and discharge the gate capacitance of the IGBT in order to switch the IGBT on or off quickly. A current buffer is sometime used when driving higher power IGBT.

IGBT desaturation sensing circuit, which is made up of discrete components like voltage comparator, constant current source and transistor switches are used to protect the expensive IGBT during short circuit fault. This fault will give feedback to the low voltage controller side through another galvanic isolated path, usually a digital optocoupler.

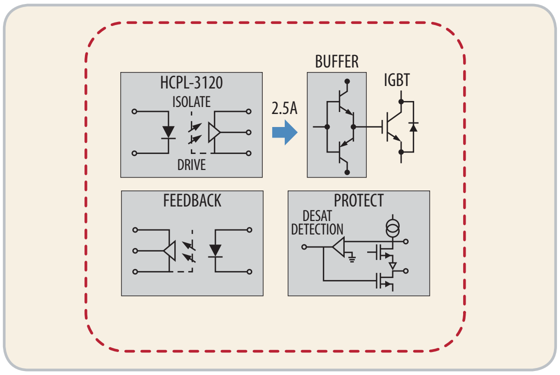

Figure 2. Basic gate driver optocoupler and discrete components to isolate, drive, protect and feedback IGBT's operation status

The First Integration

Avago Technologies first integrated the complete gate drive solution to isolate, drive, protect and give feedback into the HCPL-316J. The HCPL-316J is the first 2.5A gate drive optocoupler with integrated DESAT (desaturation) detection and isolated FAULT feedback.

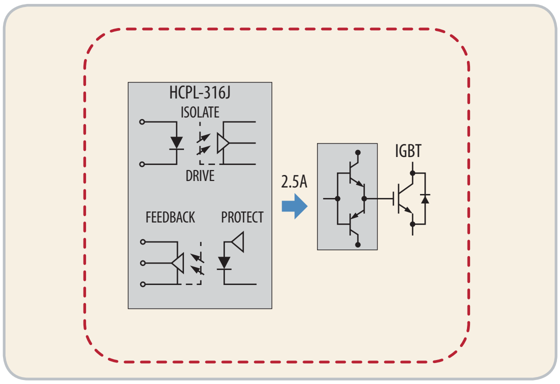

Figure 3. HCPL-316J, 2.5A gate drive optocoupler with integrated DESAT detection and isolated FAULT feedback

To further maximize design flexibility, the HCPL-316J also comes with undervoltage lockout (UVLO) to prevent insufficient gate voltage from driving the IGBT and "soft" IGBT turn-off to prevent high voltage turn off transient stress across the IGBT.

Over the years, designers have been adding more peripheral circuits to meet the increasing demand of higher power, better efficiency and reliability in inverter and motor drives. The circuits include:

To Improve Efficiency

- Current buffer to switch the IGBT faster for lower switching loss
- Higher positive supply to compensate for current buffer voltage drop to achieve optimum gate voltage

To Improve Reliability

- Negative supply to ensure IGBT switch off safely
- Extra blanking current source to prevent false DESAT fault detection
- UVLO feedback to report insufficient supply causing low IGBT gate voltage
- Direct LED drive with split resistors network to improve the common mode rejection ratio (CMRR)

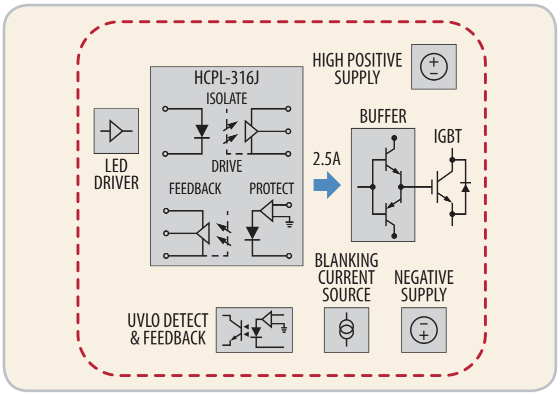

Figure 4. Peripheral circuits to improve the efficiency and reliability of the IGBT gate drive

More Integration

The new ACPL-337J is Avago's response to customer feedback for a compact gate drive optocoupler solution to further integrate peripheral circuits.

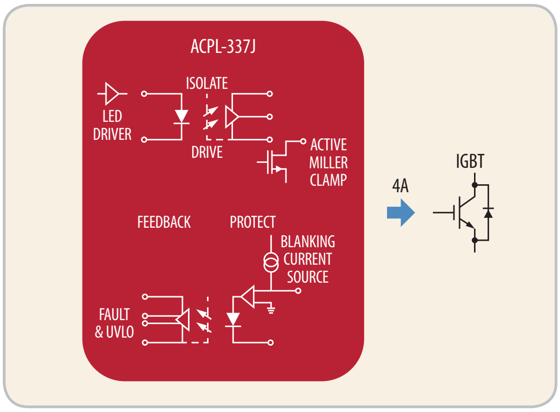

Figure 5. ACPL-337J, a compact gate drive optocoupler solution to simplify the design and board layout

The 4A high output current can be used to eliminate the current buffer and drive the IGBT directly. The rail-to-rail output can reduce the supply voltage and drive the gate of the IGBT without voltage drop. The integrated active Miller clamp can replace the negative supply by shunting parasitic Miller current away and prevent the IGBT from switching on accidentally. The internal DESAT blanking current source is increased by 4 times to charge a bigger blanking capacitor. A bigger blanking capacitor will be able to filter out transient noise more efficiently and prevent false fault triggering. The single isolated feedback path is able carry both DESAT and UVLO fault signal to the low voltage controller side. The controller can use the UVLO feedback as "Ready" signal to begin high voltage IGBT operation or to shut down the operation if the secondary side power supplies go into fault. Lastly, the integrated LED driver allows easy interfacing between the controller and the gate driver. The flexible configuration of the LED driver will allow direct access to the LED to balance its input impedance and improve the CMRR.

Summary

The ACPL-337J highly integrated features reduce external components greatly, providing a complete cost-effective gate drive solution for motor control and power inverter applications.

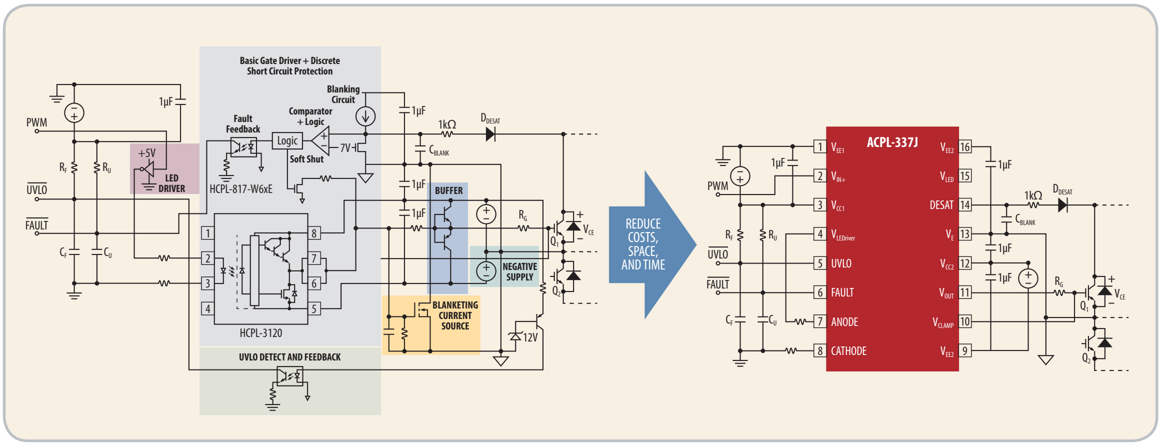

Figure 6. Schematic view, reduce systems costs and board space using ACPL-337J

Contact us for your design needs at: **www.avagotech.com/acpl-337J**

DesignSolution

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Use A Flyback Topology
To Drive Custom LED Lighting

When a lighting application requires a custom array of LEDs, a flyback ac-dc driver can be developed quickly and economically, while providing power-factor correction and dimmability.

LED replacement bulbs include integrated driver electronics using a variety of circuit topologies. But LED light fixtures frequently require standalone LED power supplies, sometimes called modules or bricks, often not produced by the fixture manufacturer. These supplies are available in a wide range of power levels rated at different output voltages and currents to cover many different LED loads.

LED power supplies for light fixtures typically fall within the 30- to 60-W power range, generally requiring isolation, constant output current, a wide input voltage range, high power factor and low total harmonic distortion (THD), short-circuit and open-circuit protection, and electromagnetic interference (EMI) compliance. Dimming by 0- to 10-V control also may be required.

The flyback topology enables a cost-effective platform to provide the desired functionality. This type of converter is based around a control IC. Several types of control ICs are available. These devices include functionality specific to the LED driver in addition to basic switch-mode power supply (SMPS) control. They also vary in associated system complexity, cost, and ease of use. A good control IC to base a design on simplifies the design process through its versatility and ease of interface with surrounding circuits.

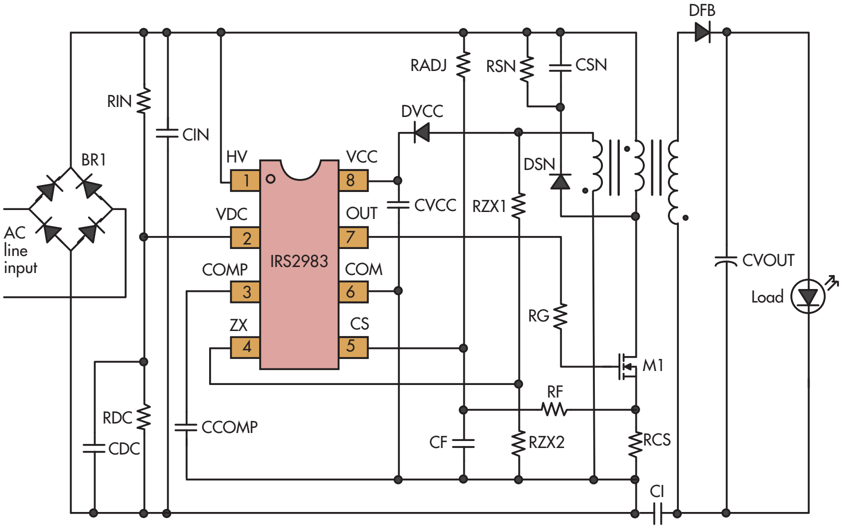
BACKGROUND

A critical factor in creating as efficient a flyback converter as possible is the design of the transformer, which is in fact a coupled inductor. It is necessary to minimize conduction and core losses and essential to minimize leakage inductance, which should be kept below 3% of the actual inductance.

A split primary winding is required to accomplish this, which is constructed by first winding half of the primary on the inside of the bobbin and then winding the secondary and auxiliary windings before finally winding the second half of the primary on the outside.

High leakage inductance leads to larger ringing oscillations at the MOSFET drain, creating increased losses in the snubber network that significantly lower the converter efficiency. Efficiency above 85% should be achievable for most converters. This depends largely on load voltage and current. High current outputs produce greater losses in the output diode.

The flyback converter can provide high power factor and isolation in a single conversion stage using a high-voltage MOSFET. This is done by means of an unsmoothed full-wave rectified primary bus voltage with the converter operating in critical conduction mode (CrCM). The regulating loop speed is slow relative to the ac line frequency so the switching-on



1. A simple fixed-load LED driver doesn't require many components.

time does not vary significantly over the line half cycle.

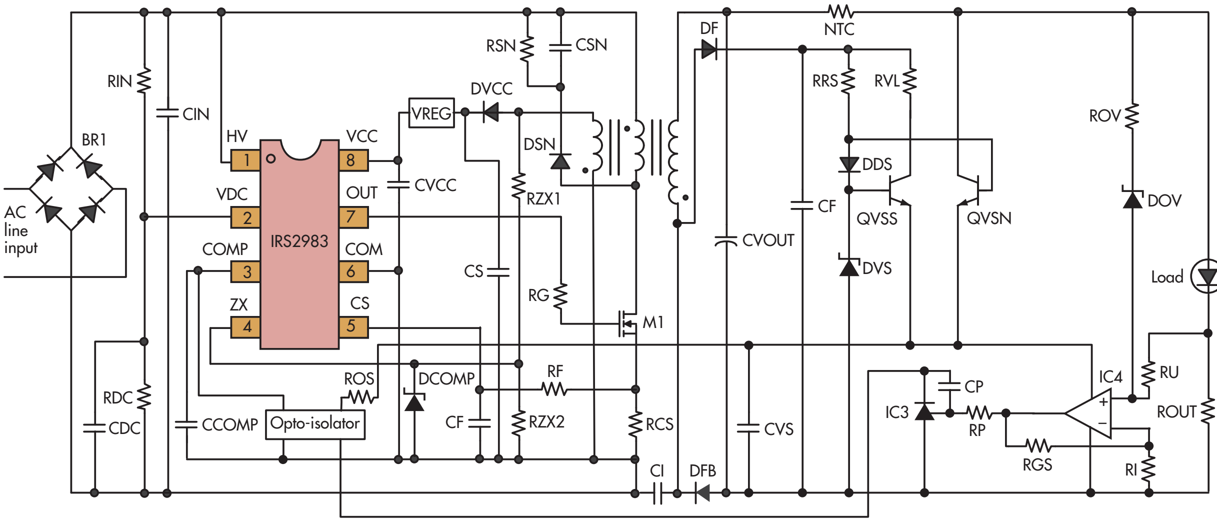
The input current then can remain approximately sinusoidal, providing a power factor above 0.9 over a wide input voltage range with a THD under 20%. Output current must be smoothed by capacitors placed at the output to reduce the low-frequency ripple to an acceptable level. A tradeoff between ripple and capacitor size typically results in ripple in the region of 20%, which does not produce visible flicker in LEDs.

One very important issue in LED drivers is that light output should appear within half a second of applying ac power. Longer switch-on delays are objectionable to most end users accustomed to the almost instant response of the filament lamp.

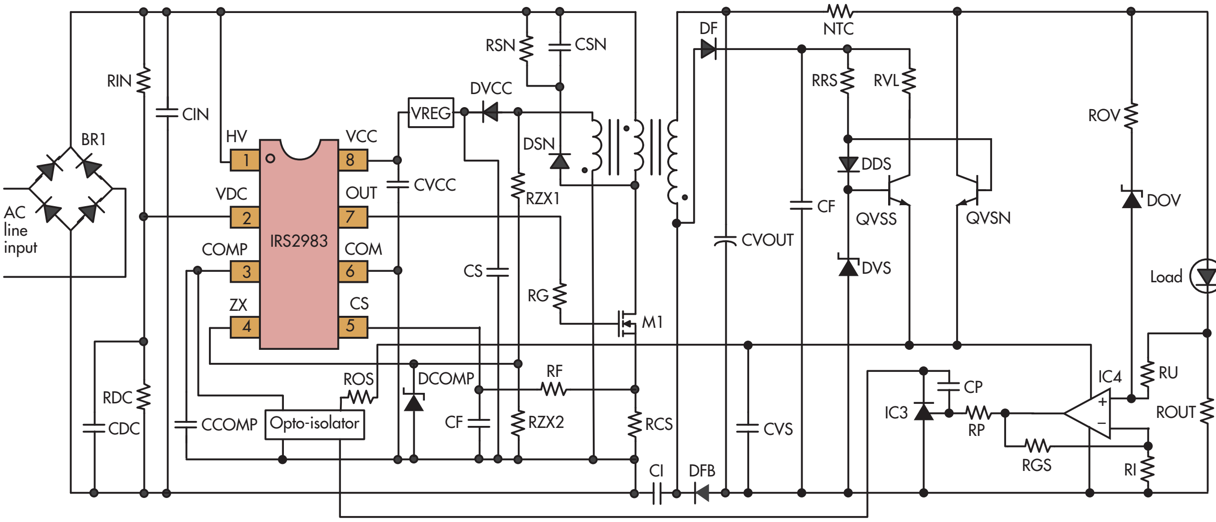
Some IC controllers such as the IRS2983 from International Rectifier accomplish rapid start by means of an on-board high-voltage startup circuit. This circuit is connected to the rectified dc bus to supply a current to V_{CC} at switch-on, enabling the V_{CC} capacitors to charge rapidly and allowing the system to start up. This avoids the need for startup resistors that waste power and introduce noticeable delay on startup at low line voltages.

CURRENT REGULATION METHODS

The first and simplest method uses primary-side regulation. Several LED controller ICs can regulate the LED output current within ±5% over a wide input voltage range. This is done without the need for any feedback loop, so no opto-isolator is required. Control methods vary between different parts. Some provide current regulation for a fixed load, and some can also accommodate some load voltage variation.



2. An advanced LED driver with a current regulating feedback loop can use an opto-isolator for isolation. This converter supplies a constant current over a wide range of LED load voltages.



3. A 0- to 10-V dimmable LED power supply can use an isolated feedback loop with an additional dimming control input.

Primary regulation operates from states such as the line input voltage, MOSFET current, and de-magnetization voltage that can be sensed from the primary side of the converter. These quantities are used to approximate the output current or power. If the output voltage is fixed, the input power is approximately proportional to the input power and can be used to provide regulation.

Open circuit protection is usually provided through the zero-crossing or de-magnetization input, which senses the zero crossing point for the transformer and the reflected voltage shutting off the gate drive if it becomes too high. This way, output components are protected from over-voltage without the need for direct sensing.

Short-circuit protection is provided by collapse of the V_{CC} supply since the auxiliary transformer winding loses voltage when the secondary side is short-circuited. This causes the IC to shut down and then to restart through the high-voltage startup circuit. This cycle continues in hiccup mode until the short circuit is removed *(Fig. 1)*.

The second method, which uses a feedback loop with an opto-isolator, is more complicated and requires more components. It can provide a very accurately regulated output current over a wide output voltage range. While the first method suits fixed-load LED drivers, the second fits drivers that can operate with a range of different loads with the same current rating.

The opto-isolator that is connected to the control IC provides isolated feedback. In the following example, the control IC is configured for closed-loop operation by connecting the input voltage sensing input to 0 V. The COMP pin then becomes a current source connected to the collector of the opto-isolator transistor.

The voltage at this pin determines the switching-on time and therefore controls the output current. The output current and voltage are sensed and compared with a reference by circuitry that's located at the output side. The error signal drives the opto-isolator to close the loop.

The feedback circuit uses an op amp to amplify the dc output current sensed by the shunt resistor ROUT. This allows current sensing with minimal power loss. The developed voltage is amplified so that at the regulated current, the op-amp output reaches the reference level of IC3, a TL431 low-cost but very accurate device with a 2.5-V reference that behaves somewhat like a zener diode.

Loop compensation is provided by the network RP and CP to roll off the gain below the ac line frequency necessary for maintaining a high power factor. A capacitor at COMP is also required to remove noise, which can be 0.1 μF. If the loop speed is too slow, a large current transient occurs at the output at switch-on. If it is too fast, the power factor is degraded.

Over-voltage protection is added by means of DOV and ROV. DOV is a zener diode rated a little above the desired over-voltage shutoff level such that under open circuit conditions, this diode will conduct and force the op-amp output high, driving the COMP pin low through the opto-isolator IC2 and shutting off the gate drive.

Since the ZX input of IC1 is not used in this case for over-voltage protection, a 3.9-V zener diode DCOMP is added to clamp the de-magnetization signal below the ZX protection trigger threshold. This is done to allow the ZX detection to operate over a wide output voltage range without the risk of falsely tripping the ZX protection or missing cycles at low line when the output voltage is low.

IC4 is a low-cost op amp such as an LMV321, which requires a 5-V supply and can operate down to 2.7 V. For the secondary-side circuitry to operate under short-circuit conditions or with very low-voltage LED loads, a dual-supply circuit is implemented for the op amp and opto-isolator. Under normal operating conditions, the supply is derived from the output through a simple voltage regulator built around QVSN.

The base of this NPN transistor is biased at one diode drop above QVSS so QVSS conducts only when the collector supply to QVSN has fallen below the zener voltage of DDS plus the forward drop of DDS. The collector of QVSN is supplied from the forward phase of the flyback converter, which provides a voltage on CF. This relatively high voltage varies considerably with ac input voltage, so it does not offer an efficient means of supplying the secondary side circuitry. This alternative supply, then, is used only as a backup when the output voltage is not available.

Hot reconnect is sometimes required in LED drivers, meaning the load can be disconnected and reconnected and continue operating normally. This is more problematic than it may initially appear because when the load is disconnected, the output capacitors CVOUT charge to the over-voltage protection level, which may be significantly higher than the rated load voltage.

Discharging a large capacitor through an LED load creates a very high current transient that can destroy the LEDs. To add some protection against this, an NTC thermistor has been added at the output. It's advisable, however, to avoid hot reconnecting of LED loads wherever possible!

As in all switching converters, an EMI filter is necessary at the input. This is based on a standard configuration to attenuate both common-mode and series-mode components of conducted interference below the limits specified by the applicable standard.

CX1 and CX2 are normally equal and should not be too large to maintain the best possible power factor. Since these capacitors introduce phase shift, the larger they are, the more they will reduce the power factor particularly at high line. LF1 and LF2 may be increased as required provided the current rating is sufficient for the converter input current at low line voltage and full load. In some cases, a common-mode choke may be used in place of LF1 and LF2 or even in addition to them if necessary.

Flyback converters generate more emissions than some other topologies due to the asymmetry, ringing, and high dv/dt of the drain voltage. Common-mode noise depends on leakage to earth, which depends partly on PCB layout and transformer construction. CY1 and CY2 are used for further attenuation of common-mode noise, though they require an earth connection, which is not always available and may not be too high since standards do not permit ground leakage exceeding a small amount. This is important to avoid false tripping of ground fault interrupt (GFI) types of protection breakers.

In addition to EMI emissions, immunity should be considered. Both circuits presented include a varistor or voltage-dependent resistor (VDR) connected at the ac input. This is essential to absorb the energy from surges that often appear on the line and can damage the MOSFET or IC if no protection is added. The VDR alone is not sufficient to protect the circuit against surges above 1 kV.

Since the one-stage power-factor correction (PFC) flyback circuit has no dc bus bulk capacitor, there is nothing to absorb a high-voltage surge except for the VDR. Depending on the level of protection required by the application, an additional transil diode may be added across the dc bus. This device acts like a zener diode clamping voltage but can absorb much more energy. A 0- to 10-V controlled analog dimming circuit can be added to the circuit by replacing IC3 with a second op amp *(Fig. 3)*. Isolation already exists at the output, making it convenient to reference the dimming circuitry to the secondary output.

The 0- to 10-V control voltage provides a reference for the current regulation loop so that as this voltage level is reduced, the output current reduces proportionally. IC3 and IC4 are replaced by a dual op amp, which can be a low-cost standard part such as an LM358. The 0- to 10-V dimming system operates by sinking current from an external dimmer or controller, which requires each LED driver to produce a supply voltage a little over 10 V. For this to work, the supply voltage to IC3 can be increased to 12 V by changing DVS.

The values of RDIM1 and RDIM2 are larger than RDPU, which should be large enough to limit the maximum current sourced by the 0- to 10-V control input if it becomes short circuited to a small around 1 mA. This will not pull down significantly on the secondary V_{CC} supply. RDIM1 and RDIM2 form a divider to scale the reference voltage to match the output voltage of IC3B at maximum output current. Loop compensation is placed around IC3A. A simple dimming scheme can provide stable and linear dimming response over a range of ac line input voltage typically down to 5% or lower for a fixed load.

Dimming becomes more complicated if it's required to work over a wide range of line and load. This may prove to be impractical due to the limit of dynamic range available in the flyback converter.

Some control ICs can operate in discontinuous conduction mode under light load conditions such as during dimming. The gate drive then can operate with a very small duty cycle, which would not be possible if the system were still working in critical conduction mode. An IC incorporating this feature should be used for the controller in a dimmable LED driver design.

Whatever variation of the circuit is used, the selection of components determines the thermal performance of the system. A power supply for a lighting application should avoid any component exceeding 70°C in open air after settling at maximum temperature. This will prevent poor reliability and can allow operating life up to 25,000 hours, provided high-temperature-rated long-life electrolytic capacitors are used. Typically, the components that run hottest are resistors, the output diode, the snubber components, and the MOSFET.

For designs where the output current exceeds 0.5 A, a small package output diode (DFB) inevitably exceeds the desired temperature. A larger package such as a DPAK or even TO-220 often is necessary to avoid this. The MOSFET should also be selected with low enough $R_{DS(on)}$ to avoid high running temperature, and the transformer should be large enough to accommodate conductors large enough to keep the resistive losses low.

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Shared, Switched RF Link Enables Multifunction Remote Control For Different Roles

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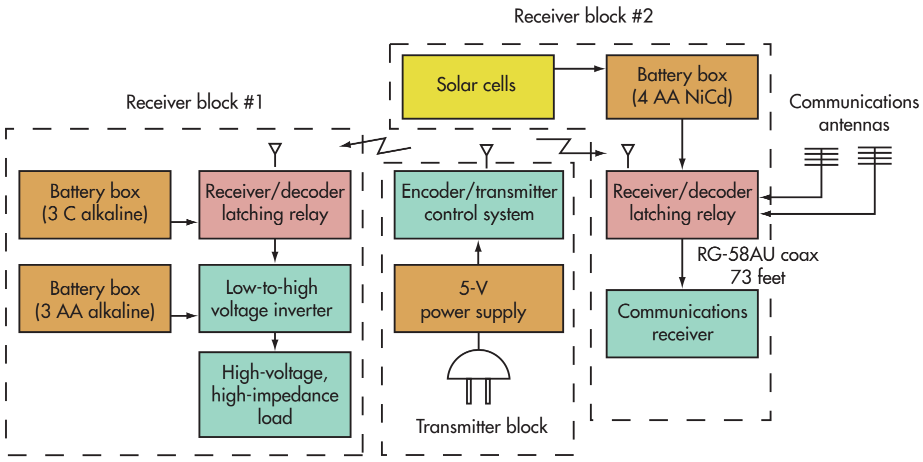
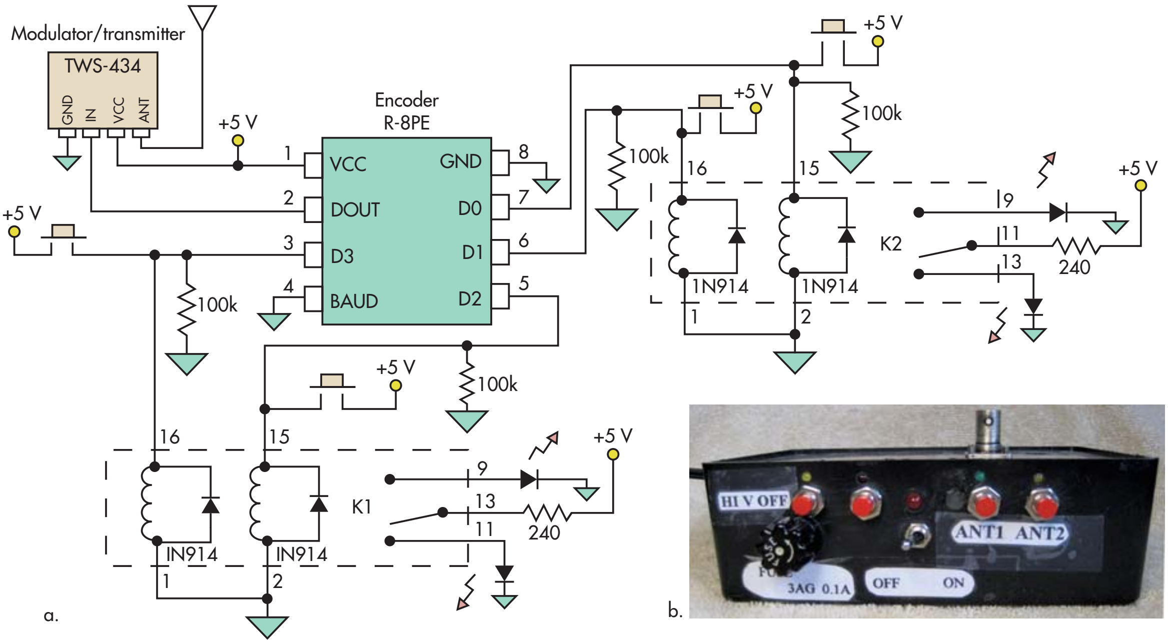
IN MANY INDUSTRIAL and commercial situations, there is often a need to energize or de-energize equipment that is remotely located or select one of two modes of operation for the equipment. This can be done via a hard-wired, RF, or even audio link, each with advantages and disadvantages in cost, reliability, maintenance, ease of installation, and longevity. For this application, a physical link was possible but difficult, so a wireless system was chosen.



1. A single transmitter conveys one of four output commands to two similar receivers. Although similar in design, the receivers serve very different purposes.



2. The transmitter is based on commercially available modules, including a one-of-four encoder, and uses a standard transistor drive configuration for the latching relays.

This two-channel, RF-based control system initiates one of four system activations based on a low-cost, three-module control system that allows the user to control the action of two remote circuits/loads *(Fig. 1)*. The transmitter's low-power, pulse-modulated signal encodes one of four control signals. Both receivers see all signals but only one of the four possible signals activates an output from one of the two receivers *(Fig. 2)*.

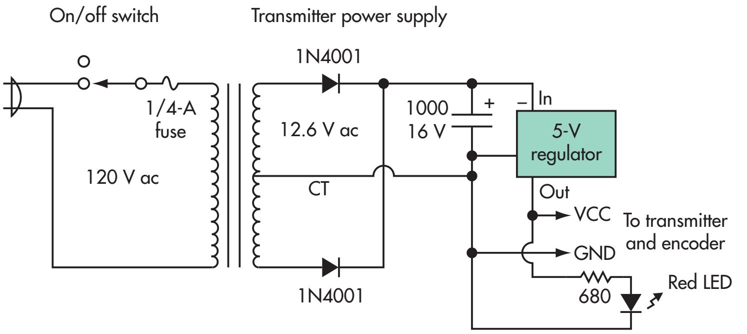
The relays in the transmitter and receivers use the standard low-side switching configuration with a 2N2222 transistor to pull down the ground side of the coil and energize the coil, as well as a 1N914 diode across the coil for protection against inductive spikes when the relay is de-energized. Modules from Reynolds Electronics *(www.rentron.com)* were used to simplify the design.

In the installation, the transmitter is located at the ground-floor level and is powered via the 120-V ac line *(Fig. 3)*. Pushing one of four momentary pushbutton switches activates the transmitter. The transmitter was based on a small, low-cost printed-circuit module (TWS-434) that generates an output at 433.92 MHz and is modulated via a separate R-8PE encoder module. The tested maximum range of the transmitter module with a corresponding receiver module was approximately 200 yards (180 m).

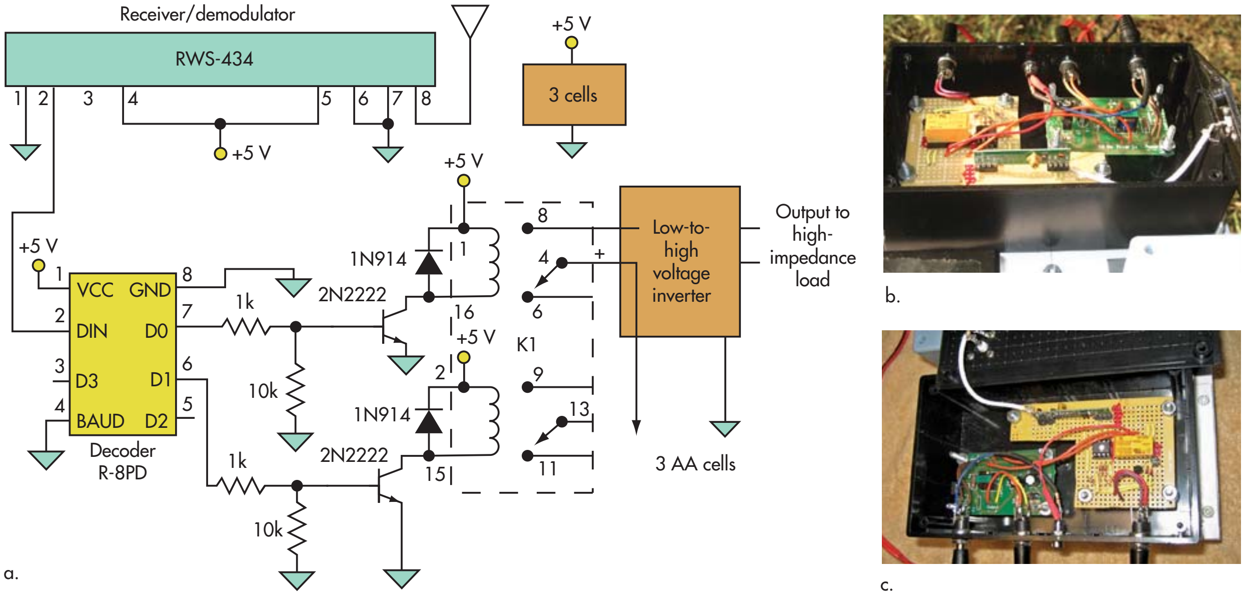
The equipment associated with Receiver Block #1 is located at ground-floor level 32 feet (9 m) from the transmitter *(Fig. 4)*. The role of this module, which consists of an RWS-434 demodulator, an R-8PD decoder, and a latching relay (Panasonic model SDE-SL2-DC5V, a low-power with 36-mA pull-in current) is to enable a user to "chase" invasive wildlife via activation of an operator-controlled "tickler circuit" (a high-voltage, high-impedance module; details not shown).

The two left-most pushbutton switches on the transmitter front panel provide a momentary input to data channels D0 and D1, the "energize" and "de-energize" commands that activate and de-activate the tickler circuit via this receiver *(Fig. 5)*. Latching relays are used so the user does not have to hold the pushbuttons down.

No source of ac-line or solar power was available, so alkaline batteries were used, as the receiver draws only 4-mA



3. Power for the transmitter comes from the 120-V ac line via a step-down transformer and a 5-V low-dropout regulator.



4. The "core" of Receiver #1 is a pair of commercial modules, one for the receiver/demodulator and one for the decoder function, and powered by C-cell batteries. The inverter (circuit not shown) is powered by AA-cell batteries.

DESIGN NOTES

Dual 13A µModule Regulator with Digital Interface for Remote Monitoring & Control of Power

Design Note 524

Jian Li and Gina Le

Digital Power System Management: Set, Monitor, Change and Log Power

Managing power and implementing flexibility in a high rail count circuit board can be challenging, requiring hands-on probing with digital voltmeters and oscilloscopes, and often rework of PCB components. To simplify power management, especially from a remote location, there is a trend to configure and monitor power via a digital communications bus. Digital power system management (PSM) enables on-demand telemetry capability to set, monitor, change and log power parameters.

Dual µModule® Regulator with Precision READ/WRITE of Power Parameters

The LTM®4676 is a dual 13A output constant frequency switching mode DC/DC µModule (micromodule) regulator (Figure 1). In addition to delivering power at a point-of-load, the LTM4676 features configurability and telemetry-monitoring of power and power management parameters over PMBus— an open standard I^2C-based digital serial interface protocol. The LTM4676 combines best-in-class analog switching regulator performance with precision mixed signal data acquisition. It features ±1% maximum DC output voltage error and ±2.5% current read back accuracy over temperature (T_J = –40°C to 125°C), and integrated 16-bit delta-sigma ADC and EEPROM.

The LTM4676's 2-wire serial interface allows outputs to be margined, tuned and ramped up and down at programmable slew rates with sequencing delay times. Input and output currents and voltages, output power, temperature, uptime and peak values are readable. The device is comprised of fast, dual analog control loops, precision mixed signal circuitry, EEPROM, power MOSFETs, inductors and supporting components housed in a 16mm × 16mm × 5.01mm BGA (ball grid array) package.

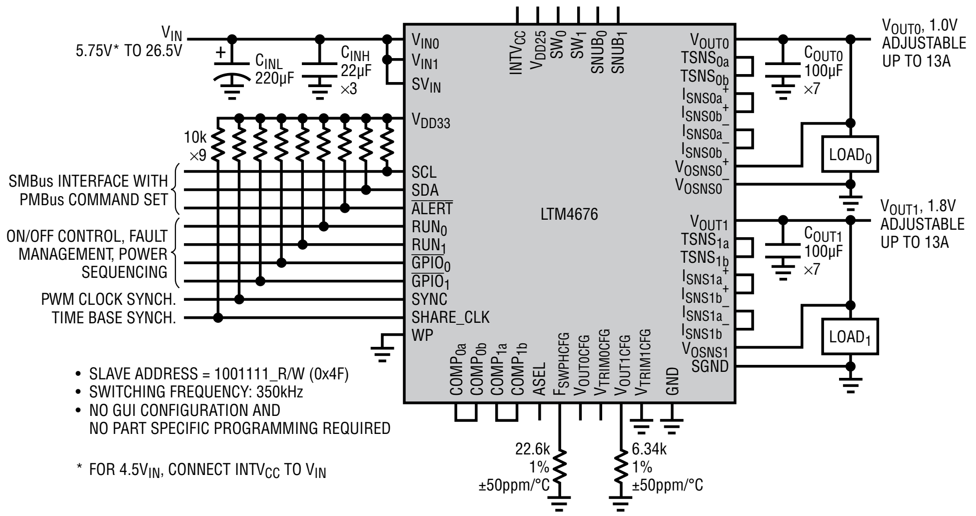


Figure 1. LTM4676: Dual 13A Output µModule Regulator with PMBus Interface

03/14/524

The LTM4676 operates from a 4.5V to 26.5V input supply and steps down V_{IN} to two outputs ranging from 0.5V to 5.4V. Two outputs can current share to provide up to 26A (i.e., 13A + 13A as one output).

Internal or External Compensation

The LTM4676 offers both internal or external compensation, which can optimize the transient response over a wide operating range. Figure 2 shows that the peak-to-peak output voltage is only 94mV with a 50% load step.

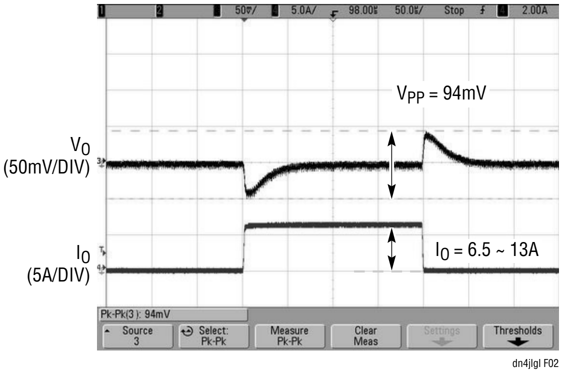


Figure 2. Transient Response of the LTM4676 in Figure 1 at V_{IN} = 12V, V_{OUT1} = 1.8V, I_O = 6.5A ~ 13A

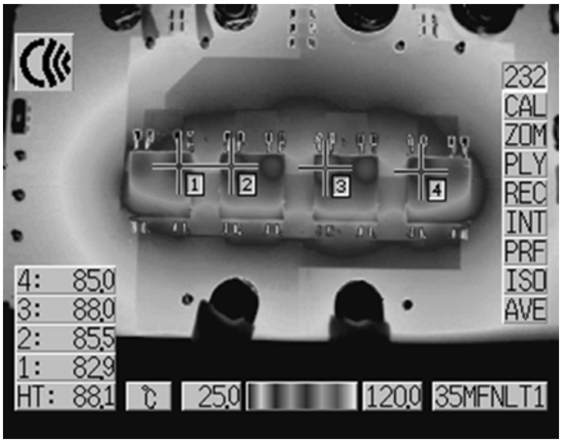


Figure 3. Four LTM4676 Current Sharing: Thermal Picture at V_{IN} = 12V, V_{OUT} = 1.0V/100A, 300LFM Airflow

Current Share for up to 100A at $1V_{OUT}$

The LTM4676 uses a constant frequency peak current mode control architecture, which offers a cycle-by-cycle current limit and easy current sharing among multiple phases. Paralleling modules can achieve much higher output current capability. For example, four LTM4676 μModule regulators can be paralleled to provide up to 100A output current. Figure 3 shows the thermal picture. With 300LFM of airflow, the hot spot temperature rise is only 64.3°C. The even thermal distribution among modules is due to excellent current sharing performance. Figure 4 is a photo of the demo board with four LTM4676 μModule regulators assembled to provide 100A at 1V.

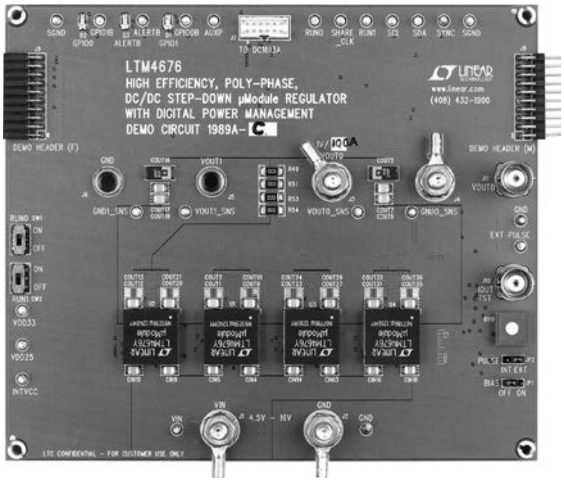


Figure 4. Four LTM4676, Each in a 16mm × 16mm × 5.01mm LGA Package Deliver 100A at $1V_{OUT}$.

Conclusion

Linear Technology's digital power system management (PSM) products provide users with critical power-related data. One can access load current, input current, output voltages, compute power consumption, efficiency, and access other power management parameters via a digital bus. This enables predictive analytics, minimizes operating costs, increases reliability and ensures smart energy management decisions can be made.

On-demand digital control and monitoring of system power with the LTM4676 eliminates PCB layout and circuit component manipulation and accelerates system characterization, optimization and data mining during prototyping, deployment and field operation.

For demo kits, free download of the LTPowerPlay™ GUI and PSM training videos, please visit www.linear.com and type "PSM" in the SEARCH box.

Data Sheet Download

www.linear.com/LTM4676

For applications help,
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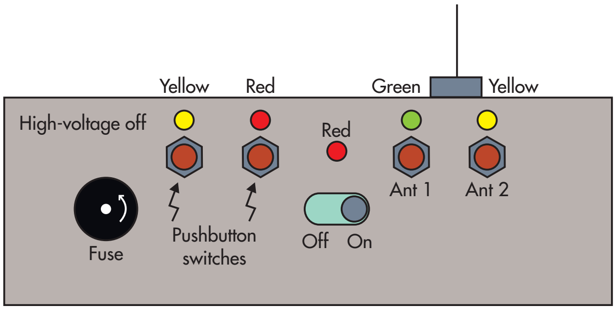


5. The simple front panel with momentary pushbutton switches is the only user interface.

quiescent current. An alkaline C-size cell has an energy rating of about 8000 mAh (according to a Google-researched value), corresponding to a standby battery life of 2000 hours (almost three months) in this application. The AA-size battery life in the inverter is difficult to predict since the low- to high-voltage inverter is mostly in idle mode. To activate and de-activate the tickler, the two left-most buttons on the front panel of the transmitter module are momentarily depressed in sequence.

Receiver Block #2 is used for an unrelated application from the same transmitter *(Fig. 6)*. It enables the user to select the antenna output of one of two co-located antennas on the roof and connect the desired output to a communications receiver via a coax cable.

Though a separate cable for each antenna could have been used, snaking the additional cable needed through two floor levels and two walls was undesirable due to the completion of building remodeling. The solution was to use a data-selection receiver that enables a latching relay to route the signal from one or the other antenna to a common coax.

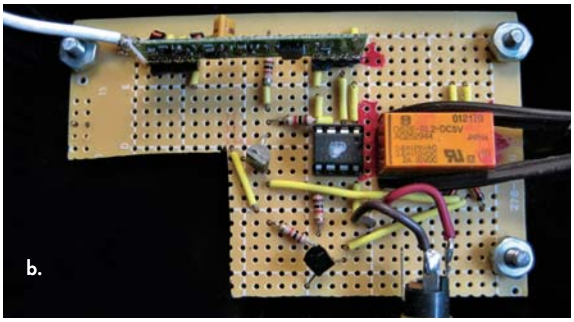
A 120-V ac source to power the receiver circuit and latching relay was not practical, so two solar panels from a surplus electronics dealer feed a battery pack of four AA-size nickel-cadmium (NiCd) cells. To select the output of a particular antenna, the user momentarily depresses one of the two buttons located on the right side of the transmitter panel. This activates either the D2 or D3 inputs to the transmitter encoder and thus generates the corresponding decoder output.

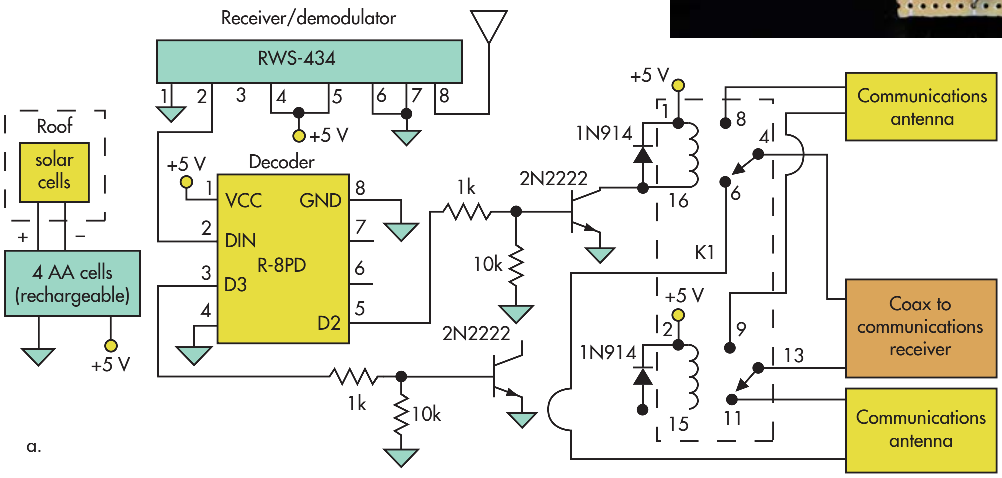
Each of the three antennas was constructed using a UG-88 connector (a male BNC plug) where the center pin was replaced by a 7-in. (18 cm) piece of 0.050-in. (1.3 mm) diameter brazing rod. The brazing rod was epoxied into the connector and a 0.75-in. (20 mm) wooden bead was added to the end of each rod for safety.

ACKNOWLEDGMENTS

The author would like to thank Oscar Ramsey, who did the assembly and assisted in the system testing; David Morrison, Carl Olsen, and Milford Craig for editorial contributions; and Colin White for producing the initial schematic drawings.

WILLIAM RYNONE, PhD, PE, Rynone Engineering, has designed electronics and is presently a technical writer. He taught electrical engineering at the U.S. Naval Academy and Johns Hopkins University. He is also president of the Annapolis Chapter of the Maryland Society of Professional Engineers.





6. Receiver #2 is similar to Receiver #1, but it controls which of two antenna signals goes to a nearby receiver via a coaxial cable.

ROGER ENGELKE | Technical Contributor
reeii@aol.com

SEPIC Fed Buck Converter's
Lowered Losses Elevate Efficiency

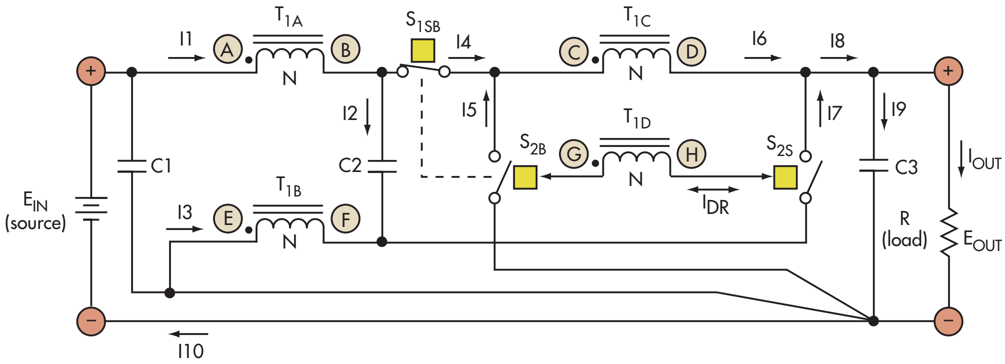
Two critical issues, efficiency and transient response, continue to tag-team the power-electronics arena. CUI takes them on with its patented SEPIC-fed buck (SFB) converter *(see the figure)*. The SFB topology fundamentally improves power-conversion efficiency and transient response while retaining the simplicity and low cost of a synchronous buck converter.

The topology tackles both conductivity losses and switching losses. To overcome the $I^2_{OUT}R$ losses in the buck converter, multiple energy delivery paths are made available to split the load current. It integrates a buck converter into a single-ended primary inductor converter (SEPIC) so it receives energy from the SEPIC inductors. The outputs of both deliver energy to the load in parallel.

When the controlling switch shared by both converters is ON, the buck portion delivers energy to the load while the SEPIC portion stores energy in the magnetic element and feeds the buck portion. When the controlling switch is OFF, both the buck and SEPIC portions deliver stored energy to the load.

An extremely fast, controlled turn-off commutation of the control switch, made possible by a gate-charge extraction (GCE) mechanism inherent in the topology, addresses the significant turn-off loss issue in the buck. Lower voltage and current stresses on the power switches also dramatically reduce their turn-on losses. On the transient response, reduced current level on the integrating inductors and increased reset voltage bring fundamentally faster response from the power stage.

In this non-isolated implementation of the SEPIC-fed buck converter, the commutation switches are shown as ideal switches. They can be implemented as synchronous rectifiers. The SEPIC and buck are combined into a single couple inductor to facilitate energy storage and transfer.



The converter has a voltage-transfer ratio of $E_{OUT}/E_{IN} = (2 - D)$, and it complementarily combines the characteristics of both the buck and SEPIC converters. This reduces voltage and current levels in the magnetic and switching devices, which in turn reduces conduction and switching losses. In addition, a new volt-second structure on the magnetic element boosts the power stage's transient response.

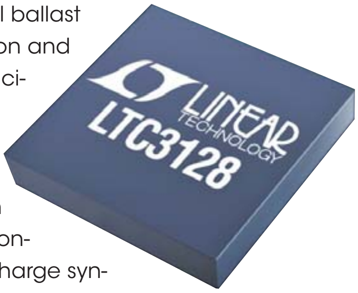
Using a prototype SFB converter at 300 and 500 kHz, testing revealed that despite the relatively high on resistance of the switches that were used and the additional power loss from the current transformer, the device achieved efficiencies of 86.9% at 1 V (at 300 kHz) and 88.0% at 1.2 V (at 500 kHz).

If updated with newer devices that have an on resistance of 1.8 Ω, nearly 835 and 880 mW of conduction losses are saved at 1.0 and 1.2 V, respectively. Furthermore, if the control scheme is changed to voltage-mode control, combined power savings at the switches and transformer would increase efficiency to about 90.0% and 90.9% at 1.0 and 1.2 V, respectively.

The efficiency difference between 300 and 500 kHz is minimal, indicating that frequency-dependent switching losses are relatively small in the SFB converter, smaller than in the buck converter. The overall gains in efficiency lead to reduced input and output capacitances, enhanced power density, and significantly increased reliability. ed

Active Capacitor Balancing Augments Buck-Boost Supercap Charger

THE HIGH-EFFICIENCY LTC3128 buck-boost charger developed by Linear Technology integrates active charge balancing for one or two series supercapacitors. Average current limit can be programmed up to 3 A with ±2% accuracy, preventing power-source overload while minimizing capacitor recharge time. Active charge balancing eliminates dissipative external ballast resistors, which balances operation and charging with mismatched capacitors. A programmable maximum capacitor voltage clamp actively monitors and enforces voltage across each capacitor in the series stack. High-efficiency conversion via low-$R_{DS(on)}$, low-gate-charge synchronous switches minimizes the charging time of storage elements. Input current is controlled over a 0.5- to 3-A programming range, and individual maximum capacitor voltage can be set from 1.6 to 3.0 V. Operating temperature ranges from –40°C to 125°C in 4- by 5-mm quad flat no-lead (QFN) packages and 24-lead thin-shrink small-outline packages (TSSOPs).



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THE CTP 1K series of ruggedized, modular dc-ac inverter systems leverages microprocessor-controlled technology to deliver three-phase, 1000-VA output power with pure sine-wave output voltage. The devices, developed by Absopulse Electronics, offer three-phase outputs of 208, 380, or 400 V rms (line-to-line). Also usable are phase-to-neutral voltages of 115, 220, or 240 V rms. They operate from dc voltages of 24, 48, 110, or 125 V dc. All incorporate protection such as inrush current limiting, reverse polarity, input-to-output isolation, output current limiting with short-circuit protection, and thermal shutdown with auto-resetting. The fan-cooled series delivers 1-kVA continuous power over 0°C to 50°C without derating. Other options include full ruggedizing and conformal coating, customized input and output configurations, remote shutdown or enable, a Form C output fail alarm, and Class B EN55022 electromagnetic interference (EMI) filtering.

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BILL WONG | Embedded/Systems/Software Editor
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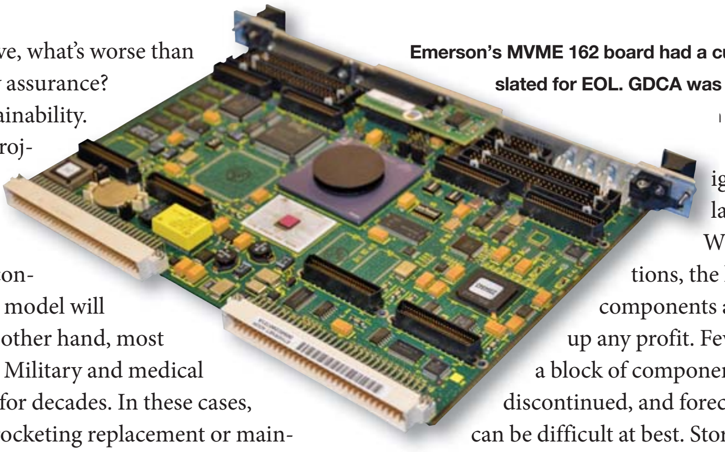
Preparing For Future Obsolescence



Emerson's MVME 162 board had a custom ASIC that was slated for EOL. GDCA was able to transfer the FPGA.

From a designer's perspective, what's worse than having to deal with quality assurance? Answer: planning for sustainability.

This isn't an issue for many projects, like some projects on Kickstarter where a single run of the product is all there is. Likewise, the high turnover in consumer products means the next model will replace the current one. On the other hand, most products have a longer lifetime. Military and medical equipment need to be available for decades. In these cases, price is less of an issue. But skyrocketing replacement or maintainability costs can make new technology more appealing.

Sometimes consumer product companies do think about their original customers. For example, Sony is following in the tracks of other PC vendors by selling its VAIO line. One class of product includes e-readers. Users could purchase e-books from Sony but now they will be directed to Kobo, a competitor that is still in that market.

Things get more difficult when hardware is involved, especially if the hardware is a bit more esoteric. A discontinued inductor or similar component fallout can force a complete redesign to accommodate a replacement part or even a completely new design. This brings up issues associated with a new design such as recertification, which can be a long, risky, and costly process.

WHAT TO DO

GDCA, a firm that specializes in providing companies with proactive sustainment support, has five recommendations for designers:

- Plan sustainment early
- Budget for sustainment
- Identify your high-risk/critical components
- Manage the big picture
- Strategically plan your design refresh

Designers should start early because long-term support can be profitable with proper preparation. Sustainability usually is ignored until it is too late to do anything.

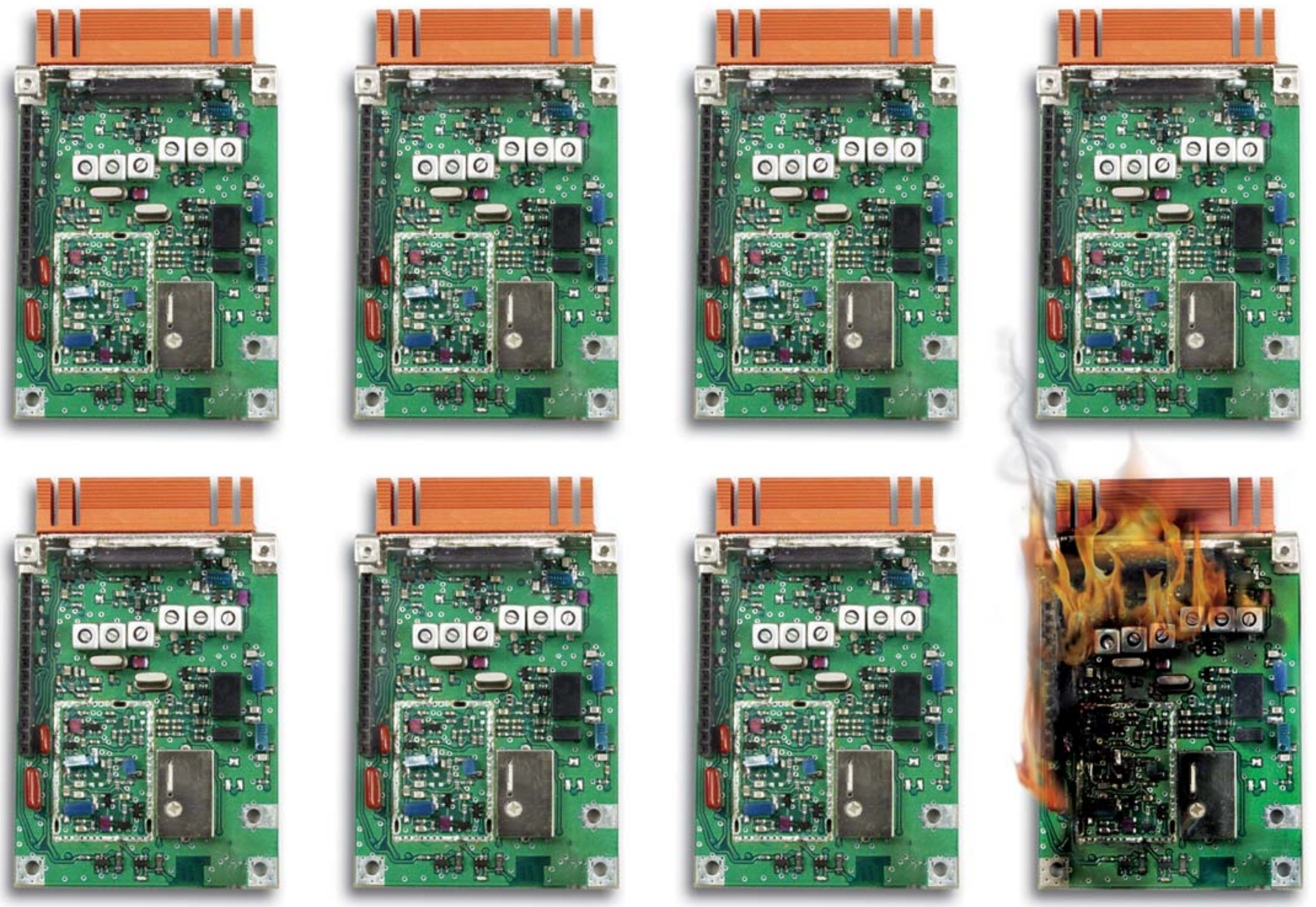
Without these preparations, the higher costs of legacy components and redesigns will eat up any profit. Few can afford to buy a block of components before they are discontinued, and forecasting the amounts can be difficult at best. Storing the components is an issue too. Military products often are stockpiled with a fixed number ordered within a known timeframe.

Sometimes it makes sense to utilize FPGAs to replace discontinued ASICs or microcontrollers as GDCA did for the Emerson MVME 162 (see the figure). In these instances, an FPGA helps considerably. But software compatibility and hardware timing and loading issues also may need to be addressed.

Additionally, vendors need to worry about counterfeit replacement components. Counterfeit components often do not meet the original specs if they even operate properly. This can add to the cost of diagnosing problems. Vendors also need to worry about those who are trying to sell counterfeit versions of their products. Counterfeit components are a problem even with new designs, especially when genuine versions are expensive or have limited availability. This is often the case for end-of-life (EOL) products based on these components. Identifying a source of genuine parts can be critical to supplying systems that work to spec.

Companies can turn to vendors like GDCA to implement IP-authorized products. These products would be based on your designs and software, but they are built and delivered by the third party, which has to worry about issues like component availability.

Identifying high-risk/critical components sometimes takes additional expertise too. For example, components may use materials that are rare or obtained from sources that are affected by war or politics. No one said the job was easy but it can be easier with proper planning. ed



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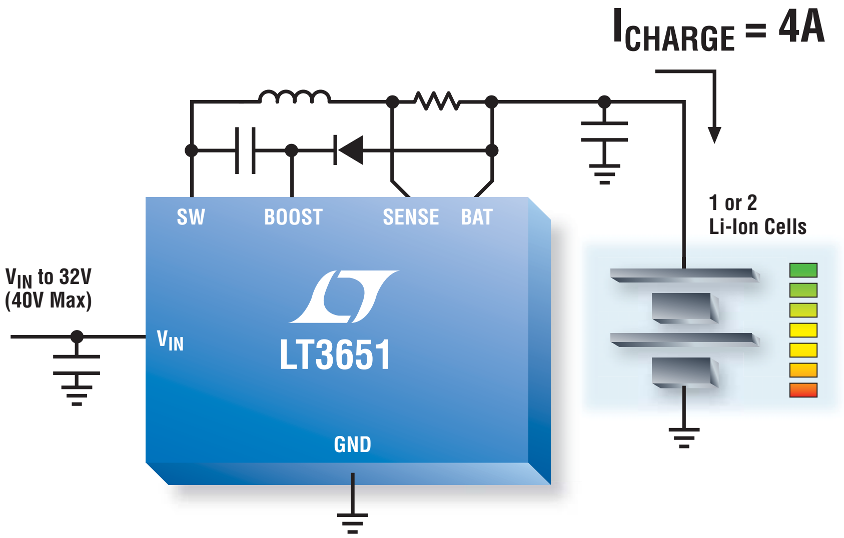

Demo Circuit

Actual Size
23mm x 23mm

High Voltage, High Current, High Efficiency Charger

The LT®3651 enables fast charging of Li-Ion/Polymer batteries by delivering up to 4A of continuous charge current with minimal power loss. This is due to its high efficiency switchmode topology, including on-chip synchronous MOSFETs. Its autonomous operation means no microcontroller is necessary and the device integrates an onboard C/10 or timer charge termination. The LT3651's programmable input current limit with PowerPath™ control regulates charge current to maintain a constant supply current, preventing the input supply from collapsing.

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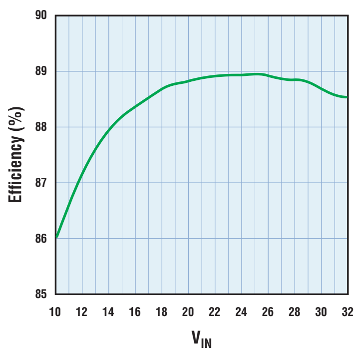
- Wide Input Voltage Range: 4.8V to 32V (40V Max)
- Programmable Switching Frequency: 200kHz to 1MHz
- C/10 or Timer Onboard Charge Termination
- High Efficiency Operation Minimizes Power Loss
- Programmable Input Current Limit
- Compact 5mm x 6mm QFN Package

Efficiency vs V_{IN}



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FEBRUARY/MARCH 2014

CABLES AND CONNECTORS Tie Systems Together

JACK BROWNE | Technical Contributor

INTERCONNECTIONS ARE often regarded as "patches" or "weak links" in military electronic systems. In truth, they are essential components in those systems, required to provide dependable transfers of power, analog signals, and digital signals from one part of the equipment to another. Military and aerospace interconnections must provide mechanical and electrical integrity, performing over wide temperature ranges, and often as part of environments that must endure high levels of shock and vibration.

With the complex mix of different signals in modern military electronic systems, the cables and connectors found in those systems range from basic signal and power cables to exotic, multiple-conductor collections that carry every type of energy used by the system. In many cases, if these interconnections fail, the system will fail. Consequently, the reliability of the cables and connectors is extremely important, and the

(continued on p. 22)

ARMORED VEHICLES meet military/medical needs

HANDLING MEDICAL crises in military environments requires a special kind of vehicle, and—as tactical vehicle developer Lenco Industries (www.LencoArmor.com) may have discovered—perhaps more than one type of vehicle. The firm recently introduced its BearCat MedEvac LE and BearCat MedEvac MIL armored tactical vehicles. The former is intended for special weapons and tactics (SWAT) and tactical emergency medical services (EMS), and the latter for Tactical Combat Casual Care (TC3) within the defense sector. Both types of vehicles were designed to provide safe environments for medical teams handling trauma cases within military environments.

Both models are built with military-grade steel armor plating capable of tolerating multiple hits from large-caliber shells, while the ceilings and floors are reinforced with blast and fragmentation protection. The vehicles include ballistic glass windows for additional protection. They are equipped with a full complement of medical supplies and gear, as well as a radio compartment. Each vehicle also boasts a roof hatch, which includes a gunner's stand and gun ports for defensive purposes. In addition to these medical/military vehicles, the firm supplies various ruggedized vehicles to the US Marshals, State Department, and Department of Energy. ■

This militarized medical vehicle is designed to withstand explosives and gunfire while providing life-saving services. [Photo courtesy of Lenco Industries (www.LencoArmor.com).]

(continued on p. 6)

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Find out more at: www.goanritsu.com/mwrfpeace and download our **FREE** Application note: ***Detecting Signals Hidden in Plain Sight***

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Penton
Design Engineering & Sourcing Group

Interconnections Are Not To Be Ignored

CABLES AND connectors cannot be overlooked in any electronics system. As a Special Report in this issue highlights, military and aerospace systems actually grow more dependent on specialized cables and connectors even as the number of different types of signals grows in these systems. Specialized cables and connectors provide a means of keeping the many different types of signals found in these systems properly organized.

Military and aerospace systems often feature a wide range of different signal types: from audio and power through fiber-optic signals, and often with different interconnection requirements. Often, these different interconnection types are bundled together to save space in a system, all the while creating some added challenges for test engineers who must determine the most efficient means of extracting signals from them.

Electrical performance, of course, is among the most-important factors in the selection of an interconnect solution for a military/aerospace system. Nevertheless, it is typically only one of several considerations. As electronic systems are designed to fit into ever-smaller spaces, so too must the interconnections for those systems. Since the diameter of a coaxial cable can be determined by the type of dielectric material used in that cable, the choice of materials for interconnections in military/aerospace applications can play a major role.

Durability is certainly a key capability for interconnections in a military/aerospace system, and connector suppliers are learning to apply such things as self-cleaning connector interfaces to improve electrical contacts. Concerns include consistent mechanical and electrical performance over time, and with challenging environmental conditions.

Successful suppliers of interconnect solutions for military/aerospace systems continue to explore the capabilities of the different building blocks for their products, such as the conductive metals and the dielectric materials. Through knowledge of existing and emerging materials, they are able to push the electrical and mechanical performance limits of different interconnections, while at the same time helping military and aerospace customers to meet some difficult challenges in terms of size, weight, and power. de

JACK BROWNE, *Technical Contributor*

defense electronics
A Penton® Publication

(continued from p. 1)

AFRL Awards GE For 20-Tflops Computer

GE INTELLIGENT Platforms (www.ge-ip.com) has received an order from the Research Information Technology Branch (RITB) of the US Air Force Research Laboratory (AFRL) Information Directorate for a High Performance Embedded Computing (HPEC) system; this system is intended for adaptive learning, large-scale dynamic data analysis, and advanced reasoning functions. The computing system, which is based on powerful graphics-processing-unit (GPU) accelerators from NVIDIA (www.nvidia.com), is meant to provide real-time digital signal processing of high-bandwidth data derived from RF/microwave sensors in support of the US Department of Defense High Performance Computing Modernization Program (HPCMP).

The modular system, which is housed in a 6U OpenVPX rack-mount chassis, builds upon multiple single-board computers based on Core i7 microprocessor cores from Intel Corp. (www.intel.com). The system will be capable of providing 20 trillion floating-point operations per second (20 Tflops), and can be expanded with additional computer modules.

This modular computer system will achieve 20-Tflops processing power in support of next-generation radar systems. [Photo courtesy of GE Intelligent Platforms (www.ge-ip.com).]

Rod Rice, general manager for Military & Aerospace Products at GE Intelligent Platforms, explains that "GE has long been a proponent of GPU accelerators as the optimum approach to solving the toughest problems facing military organizations today." He adds: "GPUs deliver an unbeatable combination of very high performance computing with minimal power consumption and heat dissipation in constricted spaces—characteristics that were key to AFRL awarding GE this order." The HPCMP is a key part of the development of next-generation radar systems, including synthetic-aperture-radar systems, and such computing power is essential to designing these systems. ■

Tactical Radio Earns Top Secret Certification

WARFIGHTERS HAVE gained access to a compact standalone Link 16 radio termination, as the TacNet Tactical Radio (TTR) from Rockwell Collins (www.rockwellcollins.com) has gained final Top Secret certification from the National Security Agency (NSA; www.nsa.gov). The compact, convection-cooled radio complies with MIL-STD-810F and MIL-STD-461E and has an operating range of better than 200 nautical miles. The tactical radio measures just 6.6 × 4.96 × 5.56 in., weighs 9.9 lbs., and operates on +28 VDC.

As Mike Jones, vice president and general manager of Communication and Navigation Products for Rockwell Collins, explains, "The TacNet Tactical Radio opens up Link 16 networked communications to a wide range of new users and gives warfighters the connectivity they need to successfully complete missions with increased survivability."

Measuring a mere 6.6 × 4.96 × 5.56 in. and weighing just 9.9 lbs., the TacNet Tactical Radio (TTR) has received Top Secret certification from one of the US government's most demanding organizations, the National Security Agency.

Link 16 networked radio communications can benefit a variety of different tactical applications, including in unmanned aerial vehicles, rotary-wing aircraft, mobile ground stations, and maritime systems. The tactical radio provides data, images, and digital voice capabilities and is interoperable with multifunction information distribution system (MIDS) and Joint Tactical Information Distribution System (JTIDS) radio systems. ■


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US Army Looks To LGS For Communications

LGS INNOVATIONS (www.lgsinnovations.com), an independent subsidiary of Alcatel-Lucent (www.alcatel-lucent.com), has been named one of the winners of a multiple-vendor, $4.1-billion Communications and Transmission Systems (CTS) contract by the US Army. This five-year, indefinite-delivery, indefinite-quantity (IDIQ) award is designed to seamlessly connect different communications systems for military forces.

LGS Innovations will be competing to provide a wide range of integrated solutions in support of US Army communications systems, providing systems integration; systems engineering and analysis; operations; maintenance; equipment; and system installation. LGS will also offer material procurement; facility and site preparation; outside plant trenching; software support; program management; logistics; technical field assistance; test and evaluation; modeling and simulation; information operations and assurance support; training; and depot support. To meet the requirements of the contract, LGS brings a team of 71 partners with extensive expertise in various areas.

LGS Innovations is also a prime supplier to the US Army's Program Executive Office Enterprise Information System (PEO EIS) Infrastructure Modernization (IMOD) contract, tasked with providing fiber-optic cable and wireless communications links to Army bases and facilities around the world. The program intends to convert existing communications systems from circuit-switched voice technology to a single Internet Protocol (IP) based system. ■

Curtiss-Wright Fuels Navy's Submarines

CURTISS-WRIGHT CORP. (www.curtisswright.com) has been awarded contracts totaling approximately $50 million to supply valves for the United States Navy's Virginia Class Submarines, Ford Class Aircraft Carriers, and Nuclear Propulsion Training Units. The awards, which were received from the Bechtel Plant Machinery, NAVSUP Mechanicsburg, and General Dynamics Electric Boat facilities, will be fulfilled by the Curtiss-Wright Flow Control (www.cwfc.com) facility in East Farmingdale, N.Y. Work has already begun, and will carry through 2017.

David C. Adams, president and chief executive officer of Curtiss-Wright Corp., offers that "we are very pleased to have been awarded these contracts, which continue Curtiss-Wright's longstanding relationships and ongoing support for US naval defense programs." Curtiss-Wright has supported the US Navy for more than 50 years with technologically advanced products, enabling advancements in the US Navy's nuclear submarines and aircraft carriers. ■

EaglePicher Funded For New DoD/DoE Battery Types

BATTERY AND energy-storage specialist EaglePicher Technologies LLC (www.eaglepicher.com) has been awarded a contract from Erico Technologies LLC (www.ericotech.net) to advance energy storage technology. Erico's contract is funded under the US Department of Defense (DoD) Rapid Innovation Fund; it was awarded by the US Corp of Engineers on behalf of the US Northern Command. The contract calls for a system of multiple battery types and control systems to meet present and emerging needs of DoD microgrids.

This new Battery Energy Storage System (BESS) will be based on EaglePicher's patented PowerPyramid hybrid energy storage technology. The solution is to be delivered for testing and evaluation at the US Department of Energy's Energy System Integration Facility (ESIF), located on the campus of the National Renewable Energy Laboratory (NREL) in Golden, Colo. Upon completion of this round of testing, NREL will assist in putting the BESS into service as part of the microgrid at a military base.

The contract calls for a 300-kW, 386-kWh PowerPyramid system capable of microgrid support and on-command response to changing power requirements. The three-tiered battery system incorporates Li-ion, lead-acid, and nickel-iron battery technologies for an appropriate balance of available energy and total power. The system is modular, enabling additional tiers to be added as needed. ■

JACK BROWNE | Technical Contributor

Instruments Aim For Speed And Accuracy

The latest generation of test instruments for military and aerospace applications combines analog and digital signal processing to provide practical measurement power.

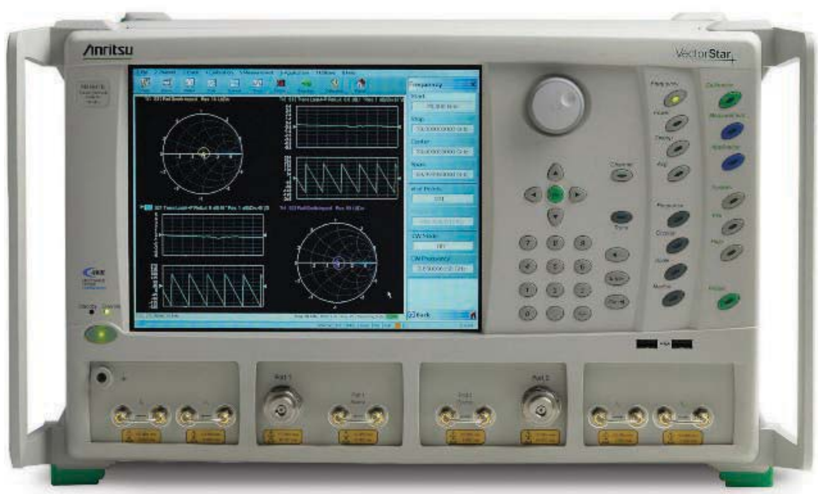
TEST EQUIPMENT typically establishes performance limits for modern military and aerospace electronic systems. Whether it is the resolution and repeatability of a precision vector network analyzer (VNA) in the laboratory, or the reliability of a portable oscilloscope or spectrum analyzer in the field, electronic test equipment gauges the performance of military and aerospace systems—often under a wide range of environmental conditions. For that reason, suppliers of test equipment for aerospace- and defense-related applications are usually trusted names well acquainted with the hostile demands of those applications.

One company well versed in generating and analyzing complex military test signals and evaluating the performance of radar systems is Agilent Technologies (www.agilent.com), which lays claim to a large amount of equipment and educational literature supporting such applications. The firm's model N9342C handheld spectrum analyzer *(Fig. 1)* is an example of the portable instruments contracted by the US Navy from Agilent several years ago for on-site troubleshooting through 7 GHz. The company also offers a handy 21-page application note, "Techniques for Precise Power Measurements in the Field," which provides guidance on the selection of power sensors and making on-site power measurements with Agilent's portable FieldFox handheld spectrum analyzers.

For those involved with characterizing radar systems, the company also offers "Solutions for Wideband Radar and Satcom Measurements," a free six-page application note that tackles evaluations of both commercial and military radar and satellite-communications (satcom) systems using both benchtop and portable, handheld test equipment. It addresses some of the challenges in producing the complex signal waveforms used in military systems (such as pulsed radar signals), as well as how to enlist modern test equipment such as arbitrary waveform generators (AWGs) to produce exotic signal waveforms.

One of the more valuable high-frequency test instruments for military electronics users, the VNA—in particular the MS4640B series from Anritsu Co. (www.anritsu.com)—has been recently upgraded with extended pulse measurement and display capabilities to help with radar measurements. The new Differential View and PulseView capabilities of these VNAs makes them well suited for testing radar and high-speed serial

1. The model N9342C handheld spectrum analyzer runs on a rechargeable battery for on-site troubleshooting of frequency spectrum through 7 GHz. [Photo courtesy of Agilent Technologies (www.agilent.com).]



2. The model MS4647B is a VNA capable of analyzing pulsed signals over a 100-dB dynamic range at microwave frequencies. [Photo courtesy of Anritsu Co. (www.anritsu.com).]

applications. The MS4640B series of VNAs, including model MS4647B VNA (*Fig. 2*), feature 2.5-ns resolution and 100-dB dynamic range. This allows users to view performance perturbations on the rising and trailing edges of a pulse that might have been missed by other measurement systems. Availability of the VNA's internal pulse generator can also help when making radar measurements.

An additional, required, intermediate-frequency (IF) digitizer option provides fast digitization for the PulseView application, as well as four internal pulse generators. The pulse generators can be used to modulate devices under test (DUTs) or one of a series of available modulation test sets. The VNAs are complemented by a graphical user interface (GUI) that makes the radar measurements more straightforward.

The DifferentialView capability in these VNAs (along with an optional, internal second test source) make it possible to measure differential, common-mode, and mixed-mode S-parameters on active components (like amplifiers) under realistic signal conditions. VectorStar VNAs are available in frequency ranges as wide as 70 kHz to 125 GHz, and can be equipped with millimeter-wave modules for coverage extending to 750 GHz.

Rohde & Schwarz (www.rohde-schwarz.us) made news recently by expanding the analysis bandwidth of its FSW family of signal and spectrum analyzers. Originally limited to 320 MHz, they now reach 500 MHz by way of the R&S FSW-B500 hardware option. The analysis bandwidth can be used for measurements on carriers to 67 GHz, making the instruments well suited for tasks in evaluating radar and satcom systems, or even in commercial wireless systems such as fourth-generation (4G) cellular systems. The wider analysis bandwidth allows users to test pulse rise and fall times as short as 3 ns and measure pulse widths as narrow as 8 ns. The signal and spectrum analyzers can also be used for checking the hopping sequences of frequency-agile communications systems, such as tactical radios.

The firm also recently extended its portfolio of oscilloscopes, as will be seen at the upcoming Embedded World 2014 exhibition (February 25-26, Nuremberg, Germany). The latest RTM family of scopes integrate logic, protocol, time-domain, and frequency-domain analysis in a single instrument, at sampling rates to 5 GSamples/s. For those faced with checking switching power supplies, the R&S RTM-K31 and R&S RTO-K31 power analysis options—for the RTM

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NEW USB-1SP4T-A18	1 (SP4T)	0.25	1.2	85	2	795.00
USB-1SPDT-A18	1	0.25	1.2	85	10	385.00
USB-2SPDT-A18	2	0.25	1.2	85	10	685.00
USB-3SPDT-A18	3	0.25	1.2	85	10	980.00
USB-4SPDT-A18	4	0.25	1.2	85	10	1180.00
USB-8SPDT-A18	8	0.25	1.2	85	10	2495.00

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Model	# Switches (SPDT)	IL (dB)	VSWR (:1)	Isolation (dB)	RF P_{MAX} (W)	Price $ (Qty. 1-9)
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RC-1SPDT-A18	1	0.25	1.2	85	10	485.00
RC-2SPDT-A18	2	0.25	1.2	85	10	785.00
RC-3SPDT-A18	3	0.25	1.2	85	10	1080.00
RC-4SPDT-A18	4	0.25	1.2	85	10	1280.00
RC-8SPDT-A18	8	0.25	1.2	85	10	2595.00

*The mechanical switches within each model are offered with an optional 10 year extended warranty. Agreement required. See data sheets on our website for terms and conditions. Switches protected by US patents 5,272,458; 6,650,210; 6,414,577; 7,633,361; 7,843,289; and additional patents pending.

†See data sheet for a full list of compatible software.

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and RTO series of oscilloscopes, respectively—provide the measurement functions and capabilities needed to evaluate modern power-supply performance levels. The same instruments are available with a jitter analysis option for performing jitter measurements on high-speed clock sources.

A general trend in high-frequency test, whether for commercial or military applications, is the adoption of modular instrument configurations. The modular approach simplifies performance upgrades when needed, but also makes it possible to more quickly adapt the format of an instrument to the particular needs of a military measurement application. The LabMaster 10 Zi oscilloscope systems (*Fig. 3*) from Teledyne LeCroy (www.teledynelecroy.com) are designed with this modular flexibility, as well as with some of the latest signal-processing hardware. The company unveiled its first sampling oscilloscope with 100-GHz bandwidth at the recent DesignCon 2014 exhibition in Santa Clara, Calif.

Prior to the 100-GHz instrument's introduction, the firm had developed modular 8-b LabMaster 10 Zi oscilloscope systems with analysis bandwidths as wide as 65 GHz for as many as 40 channels and as wide as 36 GHz for as many as 80 channels, at sampling rates to 160 GSamples/s. The instruments employ sample clocks with 50 fs RMS jitter, 4.9-ps 20%-to-80% risetime, and jitter between channels controlled to a mere 130 fs. The analysis capabilities are backed by as much as 1024 Mpoints of memory per channel.

3. The LabMaster 10 Zi oscilloscope systems were recently extended to a measurement range of 100 GHz. [Photo courtesy of Teledyne LeCroy (www.teledynelecroy.com).]

The high-speed oscilloscopes are based on silicon-germanium (SiGe) chipsets and Teledyne LeCroy's unique LabMaster ChannelSync architecture for greatly elevated sampling rates across multiple analysis channels. The ChannelSync architecture ensures precise synchronization of all acquisition modules, even in large, multiple-channel measurement arrangements.

Not to be outdone in the area of high-performance oscilloscopes, Tektronix (www.tek.com) has developed lines of mixed-domain oscilloscopes (MDOs), which combine time-domain oscilloscope measurements with frequency-domain spectrum analysis, by virtue of built-in spectrum analyzers with either 3.75- or 6-GHz capture bandwidths. The company's MDO4000 instrument can be specified with 16 digital channels, four analog channels with 100-MHz, 350-MHz, 500-MHz, and 1-GHz bandwidth models available, a spectrum analyzer channel with as much as 6-GHz bandwidth, and passive voltage probes with 500-MHz or 1-GHz bandwidth.

The built-in spectrum analyzer can be used in a number of different ways, such as for triggered (on RF power levels) or free-running measurements. It can also be used for a variety of automatic measurements, including channel power, adjacent channel power ratio (ACPR), and occupied bandwidth (OBW) measurements. In line with the needs of military users for transportable solutions, the MDO4000 is supplied in a compact package weighing only 11 lb (5 kg).

> "Suppliers of test equipment for aerospace and defense applications are well acquainted with those applications' hostile demands."

When both the spectrum analyzer and any analog or digital channel are both active, the instrument's display is split into two views. The upper half is a traditional oscilloscope in the time domain, while the lower half shows the spectrum analyzer in the frequency domain. This spectrum view is not a fast Fourier transform (FFT) of a measured analog channel but, rather, the actual measurement from independent spectrum-analysis circuitry. The time and frequency domains can be configured separately for optimum viewing results.

This built-in spectrum analyzer is not a "throwaway" or "add-on" measurement function. It is a high-quality measurement tool with 1-Hz frequency measurement resolution and amplitude accuracy of better than ±1 dB from 50 kHz to 6 GHz, along with spurious response of better than –60 dBc. The analyzer exhibits phase-noise performance of typically better than –104 dBc/Hz offset 1 kHz from the carrier, –111 dBc/Hz offset 10 kHz from the carrier, –113 dBc/Hz offset 100 kHz from the carrier, and –123 dBc/Hz offset 1 MHz from the carrier (assuming a 1-GHz carrier for all phase-noise measurements). The spectrum analyzer can measure input signal levels to +30 dBm (1 W), with a damage level to +32 dBm (1.6 W).

In terms of test-signal generation, the complex modulation formats being used in many military systems are now being produced by flexible signal sources, such as arbitrary waveform generators and frequency upconverters. A number of traditional instrument suppliers, including Agilent Technologies and Anritsu, offer broadband, high-frequency test-signal sources capable of low-noise output signals and usable output levels.

As an example of yet another supplier, Giga-tronics (www.gigatronics.com) recently extended its 2500B Series of microwave signal generators to a frequency range of 100 kHz to 50 GHz through coaxial test output ports. These signal sources can be tuned with 0.001-Hz frequency resolution and with 0.1-deg. phase resolution across a ±360-deg. phase adjustment range. They generate +10 dBm output power at the lower frequencies and as much as +3 dBm output power at 50 GHz.

In addition, Aeroflex Corp. (www.aeroflex.com) recently introduced its GPSG-1000, a low-cost simulator for Galileo and Global-Positioning-System (GPS) systems. It is capable of performing general testing of civilian receivers and limited measurements on military Galileo/GPS receivers. The portable tester, which provides 6- or 12-channel configurations, can simulate environments with mixed GPS and Galileo satellites using 3D positioning capabilities. An operator can enter a 3D position or latitude/longitude/height data to initiate a simulation, and an unlimited number of navigation plans may be saved and recalled under a user-assigned name.

These are just some examples of recent developments in test equipment for military and aerospace applications, with general trends showing more functionality in smaller, lower-power packages. Many of the test equipment suppliers now offer the majority of their measurement functions in portable packages—which can run on battery power—to simplify on-site measurements, with little or no compromise in performance. de

JACK BROWNE | Technical Contributor

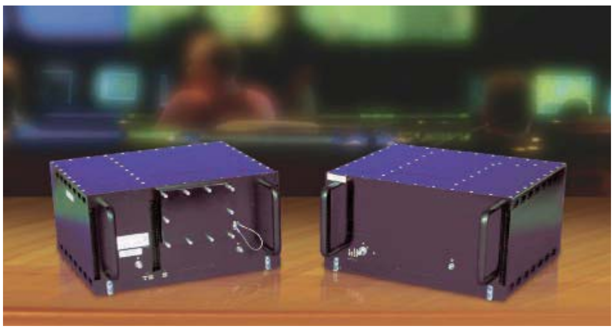
Satellites Serve Wide Communications Reach

Military users are seeking simpler and secure access to satellite systems, aided by portable antennas and readily transportable communications terminals.

SATELLITES HAVE long been key components in military communications networks, and satellite-communications (satcom) equipment suppliers continue to seek ways to make the technology more secure and practical. Although satcom antennas, receivers, transmitters, and other equipment are considered quite mature in terms of many military communications solutions, advances and improvements continue to ease the use of the technology by military customers.

Perhaps one of the more visible current satcom projects is the one spearheaded by Boeing Co. (www.boeing.com) for the United States Air Force's Family of Advanced Beyond Line-of-Sight Terminals (FAB-T) program. The FAB-T satellites and equipment are being designed to work with the Air Force's Advanced Extremely High Frequency (AEHF) constellation of secure, jam-proof communications satellites—most notably, for the command and control of US military forces in the event of a nuclear attack. Boeing won the FAB-T development contract in 2002; it calls for the development of a system with software-programmable communications terminals that could survive a nuclear offensive. These FAB-T terminals *(Fig. 1)* are being designed to uplink to AEHF satellites at rates to 8 Mb/s and to support downlink rates as high as 24 Mb/s.

In an attempt to control the long-term costs of the FAB-T program, the Air Force last year renegotiated its cost-plus contract with Boeing to a fixed-price contract. In addition, the Air Force issued a request for proposal (RFP)—both for alternate FAB-T technology developers and a possible alternate production source—with Raytheon Co. (www.raytheon.com), one of the major players competing for a stake in this sizable satcom program. Raytheon already produces AEHF terminals for the US Army, Navy, and Air Force. These AEHF satellites and terminals provide considerably faster speeds and more enhanced capabilities than the aging Milstar satellites they are meant to replace, although they are also designed to be compatible with the Milstar satellites.



1. These FAB-T terminals are designed to operate with the AEHF satellite constellation for secure military communications. [Photo courtesy of Boeing Co. (www.boeing.com)]

Of course, FAB-T is a program under development, and secure AEHF satcom terminals are not readily available for warfighters. Practical near-term satcom solutions are still required, especially for satcom-on-the-move (SOTM) applications. One of these is the Low-Cost-Terminal (LCT) solution developed by TeleCommunications Systems, Inc. (www.telecomsys.com), Northrop Grumman (www.northropgrumman.com), and Lockheed Martin (www.lockheedmartin.com), designed to protect communications on the move and in contested electronic-warfare (EW) environments. The LCTs, which were developed completely with internal company funds, include two classes of equipment: Protected Communications On The Move (P-COTM) terminals and Protected SIPR/NIPR Access Point (P-SNAP) terminals.

Baseline P-COTM terminals are interoperable with Milstar and AEHF satellites. They work with low-profile, vehicle-mounted satcom antennas only 30 in. in diameter and 12 in. in height. These terminals save cost by leveraging existing satcom technologies and investments. They work with software that can be extended to smaller, fixed satcom terminals that can be packed in transit cases for portable use or onboard unmanned aerial vehicles or piloted aircraft. The terminals can handle transmit rates to 256 kb/s and receive rates to 1.5 Mb/s even in hostile environments (meeting MIL SPEC 810 requirements).

The P-SNAP terminals are designed for protected communications at troop halt points, supporting standard 1 Mb/s transmit and 1.5 Mb/s receive rates. These terminals can also be upgraded for full AEHF rates to 8 Mb/s. These terminals are supplied in three transit cases, requiring only about 30 minutes for two personnel to assemble in the field. The P-SNAP terminals are also designed for use in hostile environments (again, meeting MIL SPEC 810 requirements)

ViaSat (www.viasat.com) has worked closely with the US Army to improve its part of the Wideband Global Satcom

2. Inflatable satcom antennas simplify the use of communications terminals in remote locations. [Photo courtesy of GATR Technologies (www.gatr.com)]

(WGS) constellation using the WGS-1 satellite and ViaSat's LinkWay® very-small-aperture-terminal (VSAT) broadband earth terminals. The terminals were used in a recent demonstration with single and multiple time-division-multiple-access (TDMA) carriers to provide reliable, secure satcom networking.

The latest version of the firm's Internet Protocol (IP) modems, the LinkWay$_{S2}$ unit, provides multiple-frequency-band TDMA operation using independent, fast-hopping transmit and receive signal paths. The LinkWay$_{S2}$ modem features a transmit modulator and receive demodulator, each of which can tune on a signal burst-to-burst basis across an 800-MHz range that covers multiple transponders, carrier rates, carrier modulation types, and carrier coding rates. This tuning capability enables efficient allocation of available bandwidth—for military as well as commercial applications—at C-, X-, Ku-, and Ka-band satcom frequencies. The LinkWay$_{S2}$ system, which is available with optional spread-spectrum capability, handles a wide range of modulation types, including binary-phase-shift-keying (BPSK), quadrature-phase-shift-keying (QPSK), and eight-state, phase-shift-keying (8PSK) modulation types.

Recently, ViaSat and Harris Corp. (www.harris.com) demonstrated an upgraded Small Tactical Terminal (STT) KOR-24A system working with one of Harris' high-power amplifiers (HPAs) to enhance air-to-ground operation using both the Soldier Radio Waveform (SRW) and Adaptive Networking Wideband Waveform C signals.

As part of a software-defined radio (SDR), a two-channel SST unit provides simultaneous 63-W Link 16 and 50-W SRW signals. This use of the STT results in a two-channel SDR capable of VHF, UHF, and Link 16 communications. It comes in a tactical data-link terminal weighing about 16 lbs., providing air-to-ground (and satellite-to-ground) communications for various vehicles and mobile units.

One of the keys in making satcom technology more accessible to the armed forces is the development of portable ground-station antennas, and GATR Technologies (www.gatr.com) has created innovative solutions in the form of its inflatable satellite antennas (ISAs). In fact, the US Army recently awarded GATR Technologies a $440-million indefinite-delivery, indefinite-quantity (IDIQ) contract to develop and deliver ISAs. The contract—issued by the US Army's Project Manager, Warfighter Information Network-Tactical, Product Manager Satellite Communications, Commercial SATCOM Terminal Program Office—will provide WGS-certified inflatable antennas and required hardware to the Army, US Marines, and other service branches.

Each ISA features a flexible parabolic disk mounted within an inflatable sphere, which greatly reduces the weight of these antennas and enhances their portability while cutting the costs of transporting a satcom antenna. It uses a large antenna design that supports excellent satcom modem operation and efficient use of available bandwidth. Ideal for remote applications, the firm's antennas *(Fig. 2)* have been used by military, intelligence, and Homeland Security customers at Ku-, C-, X-, and Ka-band frequencies for data and voice transmissions. GATR Technologies notes that the United States and its allied military forces have fielded more than 300 of the ISA terminals since 2008.

KVH Industries (www.kvh.com) provides a number of compact satcom solutions, especially for maritime applications, such as its Ku-band TracPhone V7 VSAT system. With voice and Internet communications capability, the system is suitable for military and government users requiring reliable communications. The system's three-axis stabilized antenna is designed to lock onto Ku-band satellite signals while operating in land vehicles and within maritime systems. The firm claims that its TracPhone V7-IP is about 85% smaller than standard VSAT systems, and is fully enclosed for protection from contamination. The Ku-band TracPhone V7 systems support download rates to 2 Mb/s and upload rates to 1 Mb/s.

In some cases, secure satcom systems such as the Skynet 5 system are available for a mix of users, including military and government customers. This commercially controlled Skynet 5 satellite constellation, which was designed and constructed by Astrium Services (www.astriumservices.com) for the UK Ministry of Defence, consists of seven X-band and UHF satellites with 160-W transponders based on high-power traveling-wave-tube-amplifier transmitters. Astrium—one of the largest suppliers of satcom services to NATO—developed each Skynet satellite with global, zone, and spot downlink beams that can be cross connected to meet changing operating conditions, optimizing satcom link budgets for different users. de

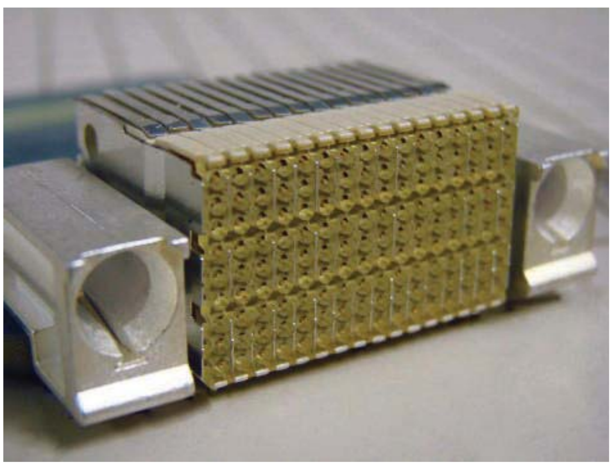
"With the complex mix of signals in modern military electronic systems, the cables and connectors found in those systems range from basic signal and power cables to multiple-conductor collections."

(continued from p. 1)

performance can impose a limit on the rest of the system.

The variety of cables and connectors used in military and aerospace systems is as large as the types of signals carried through those systems. The quality of the dielectric material wrapping a cable, for example, can impact the electrical performance of the cable, especially when required to minimize signal losses at higher frequencies. Connector dimensions must be tightly controlled at higher frequencies to minimize losses and signal reflections, and also to provide smooth transitions. The size, weight, and power (SWaP) requirements of modern systems impact interconnections for most aerospace and defense applications and, with the growing use of unmanned ground vehicles (UGVs) and unmanned aerial vehicles (UAVs) in these applications, the interconnections are being subjected to increasingly hostile operating environments.

Interconnections in military and aerospace systems are formed by many different types of cables and connectors, depending upon the mechanical and electrical requirements. Parameters guiding a choice of cable assembly in an airborne application include data rate, frequency, signal power, tolerable loss, and even the weight of the assembly. Whether for analog, digital, or a mix of signals, cables and connectors for military electronic systems must weather (pun intended) different types of storms, maintaining consistent performance under the best and worst operating conditions. New interconnect solutions are constantly emerging for military applications due to the broad uses and environments for those applications.



1. The KVPX family of connectors are compatible with OpenVPX™ interconnections but are built with the ruggedness and reliability needed for military and aerospace applications. [Photo courtesy of Smiths Connectors (www.smithsinterconnect.com).]

Amphenol (www.amphenol.com), for example, offers a wide range of interconnects for aerospace/military applications, including connectors qualified to MIL-DTL-38999 requirements and MIL-C-26500 connectors (with bayonet or threaded coupling and aluminum or stainless-steel shells). The firm also manufactures the MIL-STD-1760 Stores Management Connector System for use on aircraft that carry rail-launched missiles or are designed for MIL-STD-1760 Weapons Release type quick-disconnect connectors.

The KVPX family of ruggedized connectors from Smiths Connectors (www.smithsinterconnect.com), for instance, are VITA 63 type connectors that are compatible with popular OpenVPX interconnection systems but constructed with the high reliability needed for military and aerospace use. This shielded, high-density, modular interconnect system *(Fig. 1)*, available from the firm's Hypertronics company (www.hypertronics.com), has been optimized for differential pair architectures in extremely tight connector/cable grids.

The connectors can handle data rates from 80 Mb/s to 6.25 Gb/s. They are scalable to work at data rates of more than 10 Gb/s and fit into backplane grids as tight as 1.8 × 1.8 mm for creating compact circuit-card solutions for military systems. They are footprint compatible with VITA 46 and VITA 48 connector standards and feature integrated electrostatic-discharge (ESD) protection.

These connectors typify the needs of military and aerospace applications, with low required insertion and extraction forces and rated for a high number of insertions without degradation in performance. In addition, they are constructed with insulators that exceed NASA's requirements for deep-space outgassing, and they feature a contact system with low contact resistance for repeatable electrical performance.

Another novel connector design, the Dualok Interconnect System from Amphenol Aerospace (www.amphenol-aerospace.com), was designed for use in harsh environments across multiple markets, including in commercial and military aircraft. The compact interconnect *(Fig. 2)* employs an anti-decoupling mechanism that can be used on almost any cylindrical plug connector and backshell. It is designed to improve electrical performance in harsh environments, additionally providing a savings in size and weight compared to standard electrical connectors.

> **"Parameters guiding a choice of cable assembly in an airborne application include data rate, frequency, and even weight."**

In addition to electrical interconnect systems, optical-fiber interconnect systems have growing appeal for designers of military and aerospace systems, owing both to their wide bandwidths and their enhanced immunity to jamming and interference. Interconnect systems such as the VITA 66 fiber-optic backplane connector have helped simplify the integration of fiber-optic signals and subsystems into military and aerospace system designs. As technologies like full-motion video expand onto the electronic battlefield, the need increases for the bandwidths and data rates supported by optical fibers. Suppliers such as L-Com Global Connectivity (www.l-com.com) offer fiber-optic cable assemblies in single-mode and multimode configurations for use in harsh environments, along with extensive supporting fiber-optic components (such as couplers and attenuators).

In addressing growing concerns for maintaining the signal integrity (SI) of high-speed data transmissions, WL Gore & Associates (www.gore.com) has developed GORE Shielded Twisted Pair Cables. They are capable of providing consistent performance across temperature ranges as wide as −55 to +200°C, to account for the rapid changes in temperatures during aircraft takeoffs and landings. These cables also meet Federal Aviation Administration (FAA; www.faa.gov) requirements for flammability, smoke, and toxicity in a variety of different formats, including ribbonized cable assemblies and hybrid round-cable assemblies. These cables feature small diameters for increased flexibility and tight bend radii, accommodating tight spacing requirements on board modern aircraft designs.

2. The Dualok Interconnect System provides excellent electrical performance in harsh environments using a compact interconnect approach that can be used in commercial and military applications. [Photo courtesy of Amphenol Aerospace (www.amphenol-aerospace.com).]

Suppliers of interconnect solutions for military/aerospace systems have long been challenged in keeping pace with such a different variety of products, especially as analog frequencies and data rates increase. Higher operating frequencies translate into smaller connector and cable dimensions and the need for greater precision in machining those interconnections, although those smaller weights and sizes from the interconnections are what military designers are seeking for their systems.

Some firms, such as High Speed Interconnects (www.highspeedint.com), have built reputations by creating custom cable assemblies based on the wide range of connectors and cables preferred by military/aerospace users. Such companies form standard, semi-custom, and custom cable assemblies for analog and digital applications using wire gauges from 16 AWG to 52 AWG. High Speed Interconnects—which works with the latest design software, test systems, and manufacturing equipment—can supply cables and cable assemblies to MIL-SPEC requirements, as well as commercial-off-the-shelf products, with certifications that include MIL-SPEC, AS9100 revision C, ISO9001, ITAR Registered, and IPC 610/620 Certified qualifications. The firm has refined its use of expanded polytetrafluoroethylene (ePTFE) dielectric materials in its multiple-conductor cable assemblies to achieve isolation between many different signal types.

Modern military cable specifiers can even design systems with an alternative to semirigid cables, using Conformable Coax cables from SRC Cables (www.src-cables.com). These are low-loss, rigid coaxial cables in 0.047-, 0.085-, 0.141-, and 0.250-in. diameters that can be shaped by hand or bent to precise form with computer numerically controlled equipment. The cables consist of a silver-covered copper-clad steel center conductor with polytetrafluouroethylene dielectric material and a copper-tin shield that aids both formability and durability. The firm temperature-cycles the dielectric material to improve upon phase stability with temperature. It promotes the cables as a viable option for applications through 20 GHz that require small bend radii and the capability to rebend the shape of the cable as a prototype or design progresses. de

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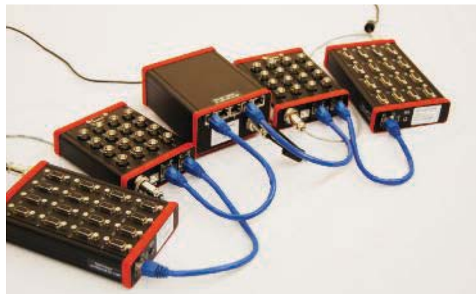

mechanical responses of aircraft structures to different stresses, design integrity can be verified. The modular Titan DAQ system is available in both standard and custom models. It can be used for durability and fatigue, noise and vibration, shock, compression and acoustics measurements. It is designed for integration with a wide range of sensing types, including accelerometers, microphones, and transducers. Each Titan central processing unit (CPU) supports as many as eight Titan Mini-Recorders (each with 16 channels), with as many as 128 analog channels and digital channels. The Titan CPU Expander connects multiple Titan CPUs to create DAQ systems with as many as 1024 analog channels plus digital channels, with data recorded directly to an internal 16-GB SD card (and support for 32 GB) or to a host personal computer. The system operates at sampling rates to 2500 samples/s.

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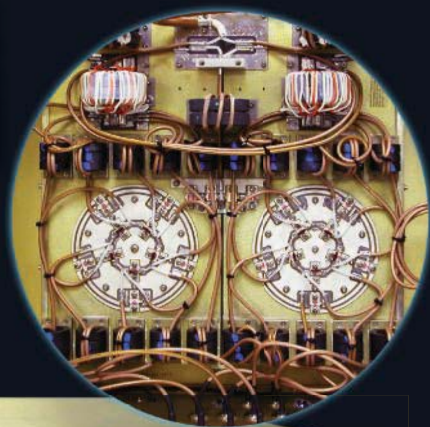

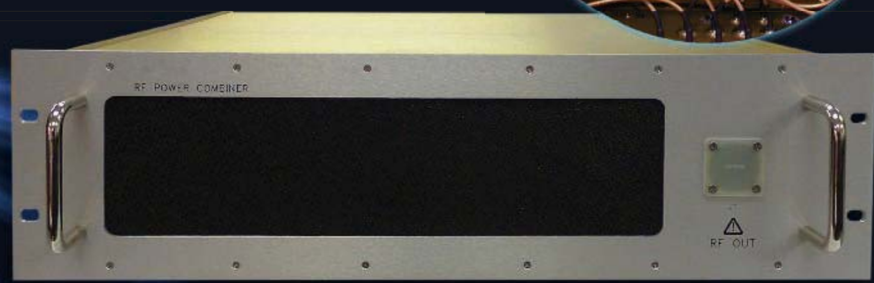

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