HOW2POWER TODAY
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Industry Events

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Power Highlights From CMSE 2023: A New Twist On Voltage Regulator ICs And Radiation Effects In GaN Devices

by David G. Morrison, Editor, How2Power.com

As its name suggests, the annual Components for Military and Space Electronics (CMSE) Conference & Exhibition offers presentations and discussion of high-reliability electronic component developments. As in past years, the focus at the most recent CMSE 2023, which ran April 25-27 in Los Angeles, was primarily on passives, especially capacitors, but also addressed developments in magnetics and packaging and interconnects. While reliability issues figured prominently in many of the presentations, this year's program devoted special attention to supply chain issues, with keynotes and other talks discussing the relevance of the CHIPS Act to defense-related applications and challenges with the act in areas such as packaging and test. There were also presentations on making supply chains more resilient, addressing supply chain quality issues, and related topics.

Despite the emphasis on passives, packaging and supply chains, CMSE 2023 also featured several talks on power semiconductors. These included one discussing a novel voltage regulator IC that leverages optocoupler technology to improve the efficiency of linear regulators under large voltage steps (plus other benefits), and another presentation discussing radiation effects in GaN power devices. Highlights from these two talks are shared here.

Enhancing Voltage Regulator Capabilities With An Optocoupler

At CMSE 2023, Matthew Lumb, the founder of start-up Polaris Semiconductor, gave a presentation on "Efficient DC Voltage Conversion Without Switching—A Path To Extremely Compact & Low Noise DC Voltage Regulators." In his talk, Lumb described his company's development of a new type of voltage regulator that combines the low-EMI, small size and low component count of a linear regulator with the higher efficiency of a switching regulator under large voltage steps. Plus, like a switching regulator, the new regulator has the ability to perform buck or boost operation.

Polaris' new regulator, which is still in the development stage, co-packages an LDO with a high-efficiency photovoltaic-output optocoupler that essentially recycles some of the energy that would normally be lost in the LDO's pass transistor. In a buck application, the optocoupler is in series with the LDO, so that its LEDs reduce the voltage drop across the LDO. But rather than using all the energy it consumes to generate heat, the LEDs convert that energy to light, which the PV cells of the optocoupler then convert back to electrical energy at the desired regulator output voltage (see the diagrams in Fig. 1).

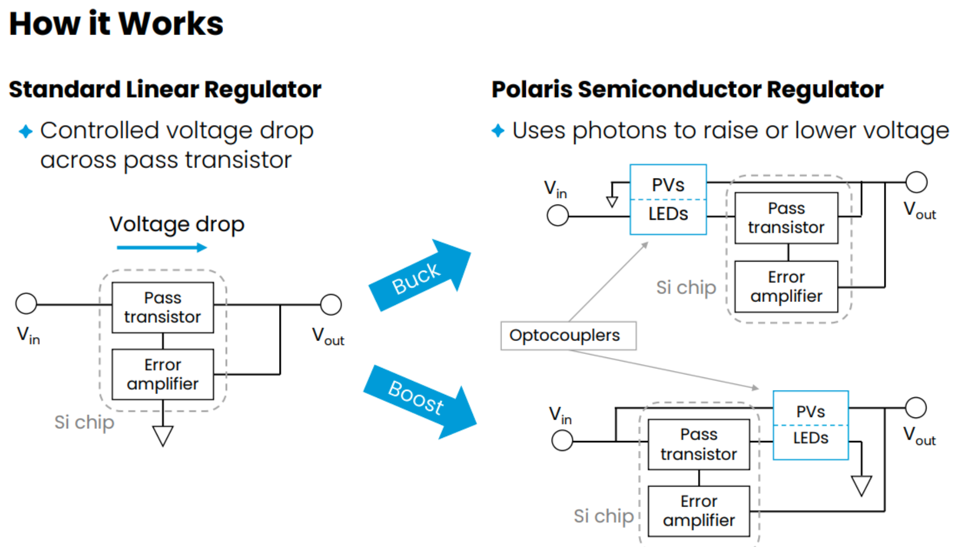

Fig. 1. By inserting a high-efficiency optocoupler in series with a linear regulator's pass transistor, the regulator efficiency is increased for large voltage steps, while also allowing the regulator to work in buck or boost mode.

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In other words, the opto improves the efficiency of buck conversion using the LDO by reducing the voltage drop across the LDO. And by providing a photovoltaic current source in parallel with the LDO output powered by the LED section, additional current is supplied to the load. This breaks the efficiency limit for an LDO, where the output current is less than or equal to the input current.

This is a very clever concept and perhaps others have considered applying it before. However, this approach is impractical with a standard commercial optocoupler, which according to Lumb, has a conversion efficiency of only 1-2% due to undirected emissions, reflection and escape cone losses, and spectral mismatch of the LED and PV. Higher efficiencies have been achieved at research scale, but those efficiencies are still relatively low.

However, Polaris has developed a novel GaAs-based monolithic optocoupler device that achieves a peak efficiency of 52% (power out of the photovoltaic versus power into the LED), which Lumb expects to reach 60% with additional improvements. The technology used to manufacture this optocoupler is the same as for GaAs LEDs, VCSELs and other optoelectronic devices.

The company has built a range of prototypes that achieve significant improvement in efficiency versus a standard LDO. For example, the Polaris regulator can step down a 5-V bus to 1.8 V with 66% efficiency versus 36% efficiency for a linear regulator (see the table in Fig. 2). As noted, the regulator can achieve galvanic isolation and has the potential to operate like a conventional LDO in a bypass mode.

Non-rad-hard prototypes

- Built a range of proof-of-concept chips, some packaged, some at breadboard level
- Possibility for bypass operation
- Can also achieve galvanic isolation

Voltage in / Voltage out	Polaris regulator efficiency	Linear regulator efficiency	Relative improvement
3.3V/5V (boost)	67%	N/A	N/A
4V/2.5V	77%	66%	17%
3.3V/1.8V	74%	53%	40%
5V/1.8V	66%	36%	80%

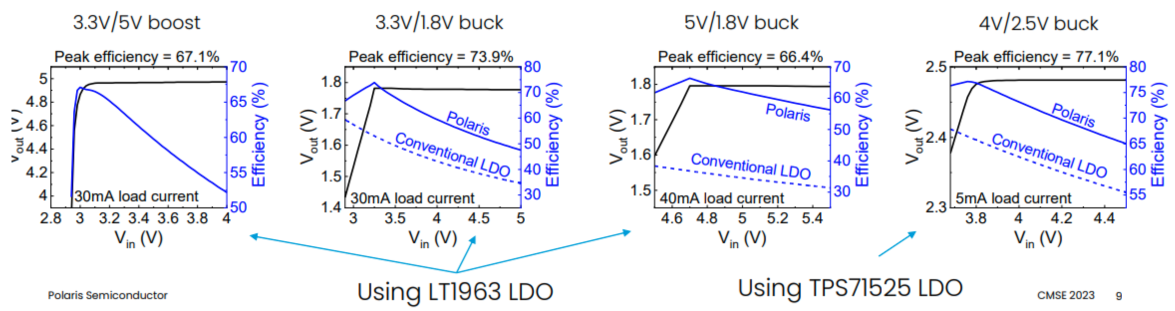

Fig. 2. Polaris' voltage regulator prototypes, which employ standard LDO chips in combination with the company's specialized optocouplers, achieve higher efficiency stepdown than the LDO would on its own, while also demonstrating the boost capability.

As previously mentioned, Polaris' regulator can be configured to operate in boost mode. In this case, the optocoupler follows the pass transistor, such that the voltage generated by the optocoupler's PVs determines the output voltage by adding their generated voltage to Vin of the regulator.

As noted in Fig. 2 above, one of the regulators used was TI's TPS71525 LDO, a 50-mA, 2.5-V fixed output regulator. This chip was co-packaged with a Polaris optocoupler in a prototype that offers proof of concept but is not optimized for size. Nevertheless, it occupies a 7-mm QFN which is still reasonably small given that no external inductor is needed.

The load regulation of the Polaris regulator compared to the TPS71525 LDO by itself is similar, but the Polaris device has 20% higher efficiency. Polaris also found that the load step response of its regulator was identical to that of the LDO by itself. However, a SPICE simulation of PSRR revealed slightly lower PSSR at high frequency with optocouplers, which the company plans to check with bench measurements.

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Polaris is also working with rad hard LDOs from TI as part of their efforts to develop space-grade versions of its regulators. According to Lumb, his company is perhaps a year away from having a more mature device that could be deemed a "commercial product." However, in terms of having a space-qualified product, that's still "a ways off".

Offering a small footprint and low EMI, Polaris' regulator will be particularly valuable for space. However, Lumb says they should also find uses in automotive and IoT applications. "They serve as drop-in replacements for linears and if you have to use a linear over a large [voltage] step, you'll use this," says Lumb. For more information, contact Matthew Lumb.

Assessing Radiation Performance Of GaN Power Devices

Roger Roisen of Teledyne e2v HiRel Defense Systems gave a talk on "AlGaN/GaN Radiation Effects," which reviewed the company's investigations into GaN power semiconductors, and their performance with respect to radiation effects. He also discussed his company's efforts in developing their own GaN power devices, using their own foundries.

Roisen explained that his company began researching GaN power devices about five years ago and decided that "GaN was the way to go with power conversion". He went on to say that while he is a "big advocate of GaN for power conversion," there are several factors that system designers must be aware of with respect to GaN devices (Fig. 5).

First of all, "ESD performance is terrible—like the early days of CMOS," said Roisen. This sensitivity to overvoltage is attributed to the very low gate capacitance of the devices. "Also, these [devices] are not meant to operate in the linear region. The quicker you can turn them on, the lower the switching losses," observed Roisen.

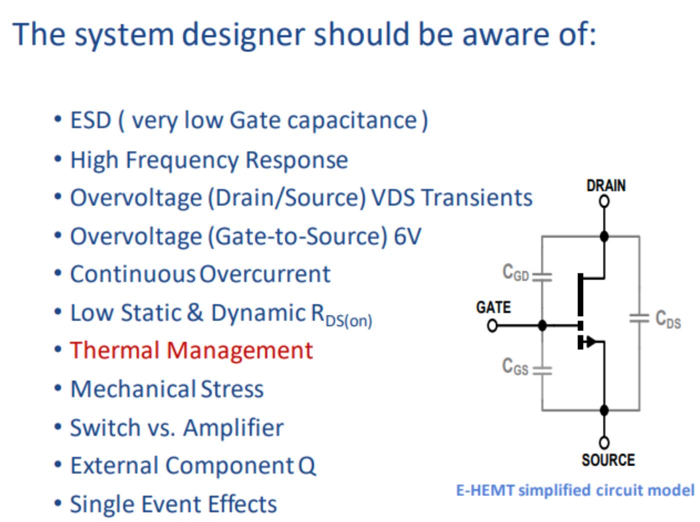

Fig. 5. GaN power semiconductors offer benefits such as higher efficiency and higher frequency switching, but designers looking to apply them in space applications must consider their specific characteristics.

As the discussion moved on to radiation effects, Roisen presented information on the performance of Teledyne's GaN power semiconductors as well as those from other vendors. As noted in his presentation, "TDY GaN transistors are fabricated using a standard island cell. TID response follows data sheet delta parametrics, as the technology is cell based."

His presentation also noted that "TID response is a function of technology in smaller power devices and scales according to current capability." For TDY's GaN power devices a standard island cell has a current capability of 7.5 A, and based on that they have developed four 650-V devices, which range in current capability from a single cell rated at 7.5 A up to 8 cells at 60 A.

Roisen presented several measurement results for testing of his company's and another vendor's GaN devices for susceptibility under total ionizing dose (TID). His slides showed measurements of "Displacement Damage (DD) total-ionizing-dose (TID) GaN Effects (see Fig. 6)" "Total-ionizing-dose (TID) Effects for MOS-HEMT vs E-

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HEMT," and "Total-ionizing-dose (TID) Charge Trapping E-HEMT". According to Roisen, the key takeaway from these tests on the GaN power transistor was "we discovered that it's total dose impervious."

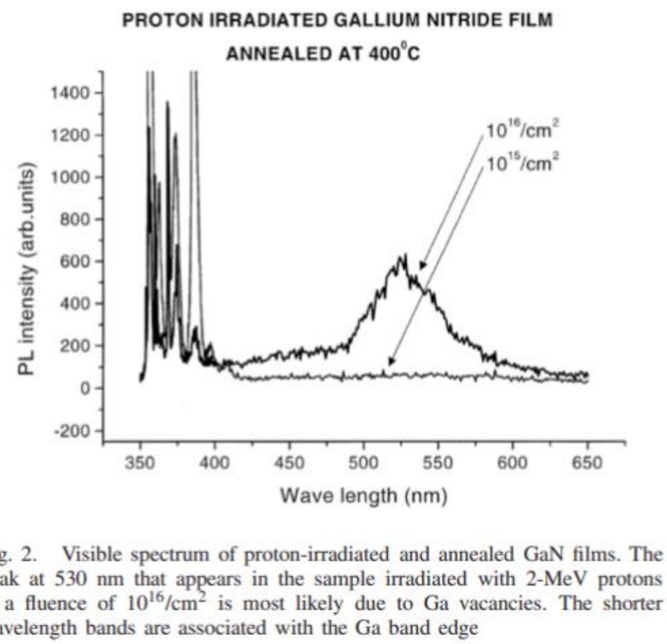

Fig. 6. Per Roisen's presentation, "AlGaN/GaNmaterials and devices were typically found to be highly resistant to radiation exposure under exposure conditions that approximate even the most challenging space radiation environments [2], as illustrated in Fig. 2."

However, in testing devices for single event effects, they found that some devices suffered displacement damage, though this varied from lot to lot in device testing. Testing two lots of 650-V 15-A devices at the Radiation Effects Laboratory at Texas A&M, the company found that susceptibility to single event burnout (SEB) varied with V_{DS} and LET values (Fig. 7).

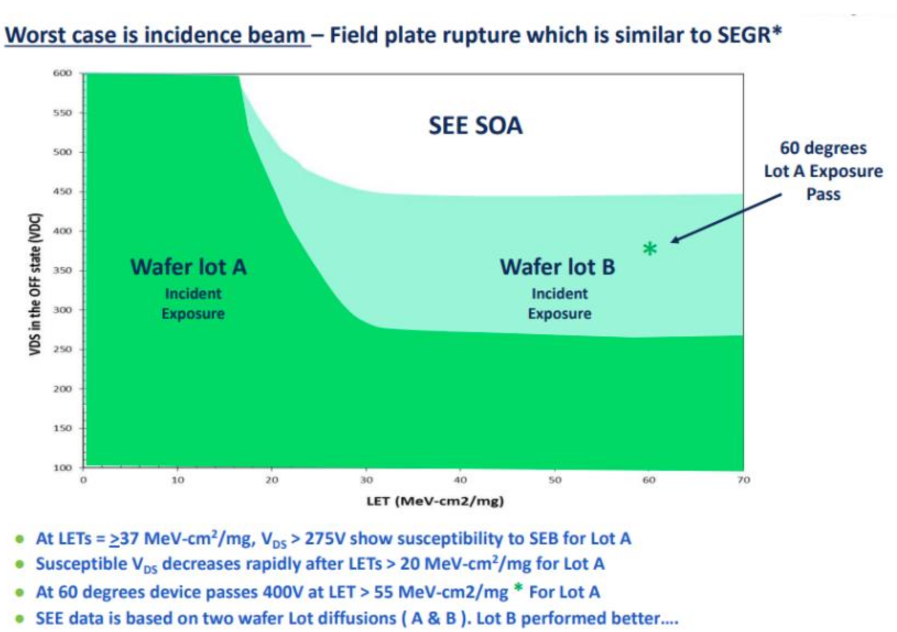

Fig. 7. Testing two lots of Teledyne's 650-V, 15-A GaN power transistors revealed their sensitivity to SEEs, particularly single-event burn out, as a function of V_{DS} and LET, and the lot-to-lot variations. Areas in green indicate the V_{DS} levels at which the devices passed over the range of LET levels, revealing the SEE safe operating areas for the two test lots.

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At V_{DS} values above 275 V and LETs ≥ 37 MeV*cm^2/mg, one lot showed susceptibility to SEB. Below LET = 20 MeV*cm^2/mg, neither lot was susceptible to SEB all the way up to V_{DS} values of 600 V. But then as LET values rose above 20 MeV*cm^2/mg, the V_{DS} value at which devices (in lot A) failed, decreased. When the test was performed at the worst-case incidence angle of 60 degrees, one device from lot A passed at V_{DS} = 400 V and LET > 55 MeV*cm^2/mg. These results suggest the need for voltage derating in the application.

Roisen concluded his talk by saying that there's a place for both depletion-mode and enhancement-mode GaN devices in space, while also cautioning that lot traceability, characterization of devices, and SEE testing are all critical to ensuring the reliability of GaN power transistors in space. For more information, contact Roger Roisen.

Additional power semiconductor-related talks given at CMSE 2023 can be found in the presentation schedule shown below.

CMSE 2023 Presentation Schedule

Wednesday, April 26

0800-0815	Welcome Intro CMSE General Chair	Thomas J Green TJ Green Associates
	Session #1A : Passive Components for Military and H Rel Space Systems **Session Chair: Daniel West (*Kyocera/AVX*)**	
0815-0840	Derating and Technology in Polymer Tantalum Capacitors	Yuri Freeman & P. Lessner Yageo Group
0840-0905	Derating Tantalum Capacitors Depends on the Cathode System	Jon Rhan & Jerard Jose Vishay
0905-0930	The Next Decade Capacitor Requirements from Automotive to Space Environments	Tomas Zednicek Ph.D. EPCI
0930-0955	ESA Recent Challenges in Space Missions: Cracked Capacitors' Time Bomb and Forbidden Solderless Connectors	Léo Farhat ESA
0955-1020	**COFFEE BREAK**	
1020-1045	A Simplified Approach to Choosing a DC Blocking Capacitor	Brian Ward Vishay
1045-1110	Effect of Defect Dynamics on Reliability of X7R Multilayer Ceramic Capacitors	Pedram Yousefian Penn State
1110-1200	**KEYNOTE (LIVE STREAM): DOD AND THE CHIPS ACT – ENSURING NATIONAL SECURITY REQUIREMENTS ARE PART OF THE IMPLEMENTATION** **Dr. Christine (Chris) Michienzi** **Senior Technology Advisor to the Undersecretary of Defense for Acquisition & Sustainment**	
1200-1355	**LUNCH in the Exhibits Area** **SPONSORED BY RESILINC**	
1355-1420	Building Resilience Into Your Supply Chain	Peter Guinto Resilinc
1420-1445	Challenges with the CHIPS Act	Sultan Lilani Integra Technologies
	Session #1B : Design Alternatives for Military and Space Electronics **Sesion Chair: Tomas Zednicek (*EPCI*)**	
1445-1510	Designing and Application Considerations for Space Grade Ferrite Beads	Scott Harris Vanguard
1510-1535	Ultracapacitors- Operate in Environments Beyond Battery Capabilities	Mitch Koffel Nanoramics

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1535-1550	**COFFEE BREAK**	
1550-1615	New Products Offerings for Military and Spacecraft Electronics with various screening and QCI options	Richard Duong Q-tech
1615-1640	Compact and Reliable Transformer with Integrated Inductor	Victor W. Quinn Exxelia
1640-1705	Copper Braided Solder Columns – Extending Life in Space Applications	Marty Hart Topline Corporation
1705-1730	Legacy Program Engineering Stock Validation and Counterfeit Inspection	Aaron Dermarderosian Raytheon Technologies
1730-2000	**WELCOME RECEPTION in the Exhibits Area**	

Thursday, April 27

0800-0835	**KEYNOTE: STRIKING A BALANCE BETWEEN COMPLIANCE AND RISK** **James W. Wade, Ph.D.** **Engineering and Mission Assurance Executive**	
Session # 2A: Advanced Packaging for Microwave and High Densitly Intereconnects **Session Chair: Sultan Lilani (*Integra Technologies*)**		
0835-0900	Advanced Packaging: Critical Ecosystem and Reliability Considerations	Kaysar Rahim Northrop Grumman Corporation
0900-0925	Thermal Analysis of Die Attach Materials for a High Power GaN Device	Casey Krawiec StratEdge
0925-0950	The Evolution of Moore's Law Through Chipletized Architectures	Tony Trinh, Thomas Smelker, Trevor Ashby, Jennifer Keenan Mercury Systems
0950-1015	Effective Advanced Heat Spreading Thermal Solutions For GaN Devices	Bill Ishii Sumitomo Electric
1015-1040	**COFFEE BREAK**	
1040-1105	An Integrated Workflow for Semiconductor Package Design	Andras Vass-Varnai, Albert Prosuk, Jimmy He Siemens
1105-1130	New GaN Power Products for Avionics, Defense & Space	Roger Roisen Teledyne
1130-1155	TGV Cu Metallisation on Glass Technology for Avionics Application	Tetsuya Onishi, Masatoshi Takayama Koto Electric Co., Ltd.
1155-1220	Advanced Packaging for Government Needs	Julian Warchall, Ph.D., Saverio Fazzari Booz Allen Hamilton
1220-1345	**LUNCH in the Exhibits Area**	
Session #2B : Quality and Reliability Considerations for Microcircuits Used in Harsh Environments **Sesion Chair: Larry Harztark (*Aerospace Corp*)**		
1345-1410	PWB Delamination Defects on Overhaul & Repair (O/R) Assemblies. Analysis and Variances to J-STD-001H & IPC-A-610	Aaron Dermarderosian Raytheon Technologies
1410-1435	Supply Chain Quality Challenges	Zac Elliott, Asaf Jivilik Siemens, Cybord
1435-1500	Non-Hermetic Inherently Robust Film Capacitor Designs for Embedded Power Applications in Military and Space Electronics	Zach Kilsmith Quantic Paktron

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1500-1525	Ceramic and Metal Repackaging of Plastic Encapsulated Microcircuits for Hermetic Solutions	Erick M. Spory, Ph.D. Global Circuit Innovations
1525-1550	Recent Advances in Microcircuit Standards	Shri Agarwal NASA JPL
1550-1555	COFFEE BREAK	
1555-1620	Connector Upscreening for Space Applications	Ted Bartlett Integra Technologies
1620-1645	Efficient DC Voltage Conversion Without Switching – A Path to Extremely Compact and Low-Noise DC Voltage Regulators	Matthew Lumb Polaris Semiconductor LLC
1645-1710	Enhancing Microelectronic Package Reliability Through Getter Material Integration & Inner Gas Atmosphere Characterization	Luca Mauri, Giovanni Zafarana, Enea Rizzi, Alessio Corazza SAES
1710-1730	Novel Waffle Pack Lid Clip System Shows Promise in Mitigating Costly Thin Die Migration	Darby Davis, Gel-Pak Craig Blanchette, BAE Systems

For more information, see the full CMSE 2023 conference program or visit the conference website.

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