Electronic Design

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The GaN Advantage in DC-DC Power Converters

Gallium nitride has proven to be an exceptional alternative to silicon, especially in devices bound for outer space.

When designers need high-voltage to low-voltage DC-DC converter designs, both the input and output voltage will usually fall within a wide range *(Fig. 1)*.

Figure 1 demonstrates the relationship between input voltage and output voltage. We observe that the maximum output voltage is 14 V, while the input voltage drops to 200 V. When the output voltage falls between 14 and 16 V, the converter will be able to output full power with the current derated. Therefore, when the output voltage falls between 9 and 14 V, the converter is able to output the maximum current with power derated *(Fig. 2)*.

The DC-DC converter in the example is capable of operating at 90% efficiency while being able to meet all periodic and random deviation (PARD) performance for space applications.[1]

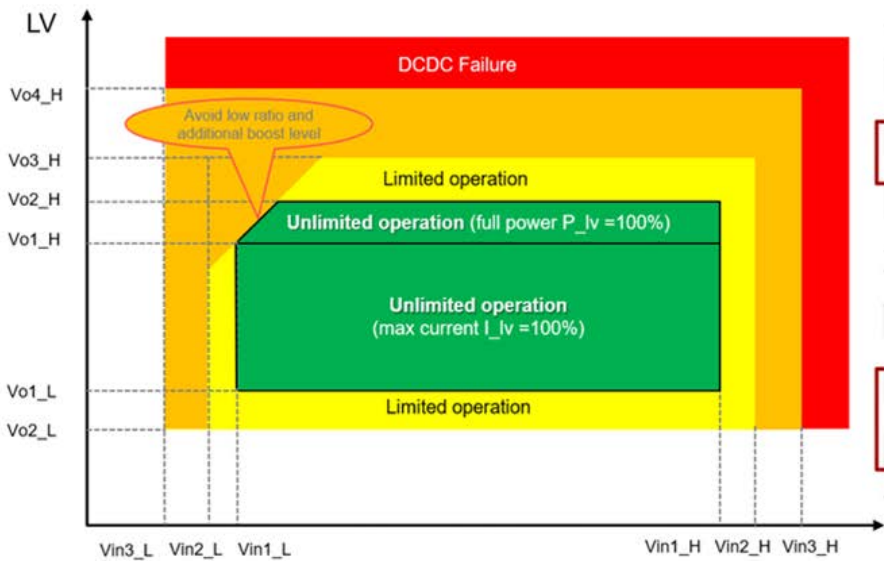
Power losses can be reduced by employing advanced power-converter zero-voltage-switching (ZVS) and zero-current-switching (ZCS) topologies. Unfortunately, while the frequency of operation increases, switching losses will reduce efficiency.

The latest benchmark is at 100 V via Infineon's BSC060N10NS3-G, which has a figure of merit (FOM) of 0.072 Ohm-mm^2. Compared to International Rectifier's IRF100 FOM of 4 Ohm-mm^2, it's close to the theoretical limit for silicon (Si) devices.

Why GaN is Superior Over Si/SiC for Space Applications

GaN transistors hold a number of advantages over silicon and silicon carbide (SiC):

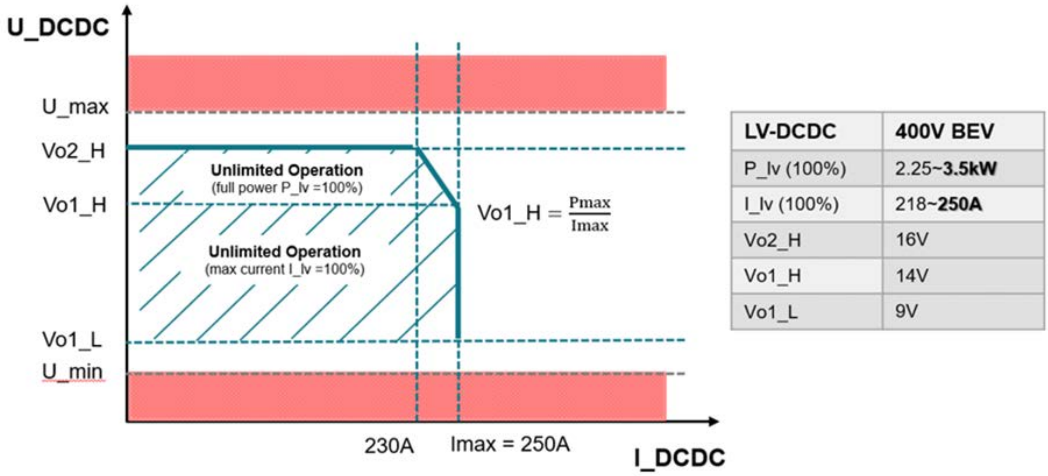
- Lower on-resistance
- Higher switching speed



High Voltage	
Vin3_H (Overvoltage limit)	650V
Vin2_H (Overvoltage protection)	500V
Vin1_H (Upper nominal voltage limit)	**450V**
Vin1_L (Lower nominal voltage limit)	**200V**
Vin2_L (Lower transitory voltage limit)	170V
Vin3_L (Undervoltage protection)	130V

Low Voltage	
Vo4_H (Overvoltage limit)	36V
Vo3_H (Overvoltage protection)	19V
Vo2_H (Upper nominal voltage limit)	**16V**
Vo1_H (Lower nominal voltage limit)	**14V**
Vo1_L (Lower **transitory** voltage limit)	**9V**
Vo2_L (Undervoltage protection)	6V

1. For high-voltage to low-voltage DC-DC converter designs, both the input and output voltage typically fall within a wide range. (Texas Instruments)



2. Shown is the maximum output power and maximum output current for a converter. (Texas Instruments)

- Better thermal conductivity
- Smaller physical size
- Lower cost

Advances in GaN HEMT devices have led to a high FOM versus their silicon counterparts. However, they're both still far from their theoretical limit.[6]

SiC devices can withstand higher voltages, as high as 1,200 V, while GaN devices withstand lower voltages and power densities. Due to the close to zero switch-off times of GaN devices (high electron mobility along with a dV/dt greater than 100 V/s as compared to the 50 V/s of silicon MOSFETs), they will find homes in very high-frequency applications, bringing high efficiency and performance.

This ideally positive characteristic could prove to be inconvenient, though. If the parasitic capacitances of the component aren't close to zero, current spikes on the order of tens of amperes can be generated, which may cause problems in the electromagnetic-compatibility test phase.

SiC devices maintain further advantages in the packages used, specifically when adopting TO-247 and TO-220 options, which allows forthe rapid replacement of IGBTs and MOSFETs with the SiC devices. On the other hand, GaN has better results with SMD packages, which are lighter, smaller, and typically relegated to new projects.

Overall, radiation hardening is one of the most crucial requirements of active devices used in space applications. Such devices, like Texas Instruments' ADC12QJ1600-SP 12-bit, quad-channel, 1.6-Gsample/s analog-to-digital converter, are available at a 300-krad space-grade quality level.

Summary

Because of the wide bandgap, GaN HEMT devices are far less susceptible to space radiation. That's because GaN-based crystal structure is said to be radiation hardened by design due to its unique material property. As a result, for the first time in history, power-converter topologies can be designed and operated at megahertz frequency ranges without compromise in power efficiency.

References

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