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Electronic Design.

In Pursuit of Robust, Higher-Speed Power Designs with GaN

Gallium-nitride power designs have triple the power of silicon with half the weight and size, plus the added bonus of 20X the speed of silicon.

Traditional power transistors have long contributed to power losses (aka lower efficiency) in switching power-supply designs. Lossy power switching and conduction that occur in these power transistors fall into two categories:

Switching losses: Power transistors are typically a main contributor to power losses within a switching power supply.

Conduction losses: These losses are usually caused by a flow of current when the transistor is on, along with switching losses that typically occur in the transition between off and on states

When GaN transistors are turned on, they will look like a resistance that's between the source and drain. This is typically referred to as the on-resistance ($R_{DS(on)}$). Conduction losses are proportional to $R_{DS(on)}$.

Some GaN Applications

GaN usage in a low-voltage isolated DC-DC converter for aircraft provides excellent power density. To achieve a high power density, each stage of the power converter must be optimized to get full benefit of the topology that's chosen.

For example, a MORE Electrical Aircraft (MEA) needs a solid power density coupled with a 270-V DC high-voltage DC (HVDC) bus along with a 28-V DC bus that has a low-voltage DC (LVDC) battery for safety *(Fig. 1)*.

The high-voltage 270 V DC reduces the volume and mass for the aircraft electrical network.

Three topologies were selected:
- DAB (dual active bridge)
- LCC (resonant topology with series and parallel capacitors)
- LLC (resonant topology with series and parallel inductors)

There will be a compromise between component values, resonant current, and voltage across the passive compo-
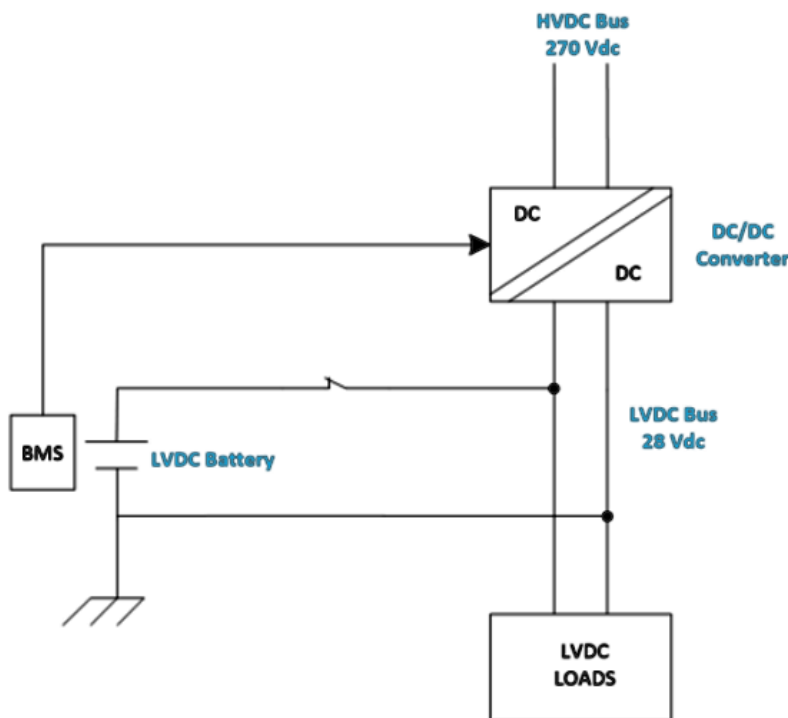
1. Shown is a low-voltage battery system with a DC-DC converter. (S. Carcouet; J. Ecrabey, Image courtesy of Reference 3)

nent, which leads to the 8-kW converter in *Figure 2* being sized as a single converter.

The Winner is LLC

The best choice was the LLC, which is better suited to

2. Depicted from top to bottom are the LLC, LCC, and DAB topologies. (S. Carcouet; J. Ecrabey, Image courtesy of Reference 3)

	LLC	LCC	DAB
Fr	120kHz	100kHz	100kHz
λ	4	0.5	
Q	0.4	2	
Cr	330nF	68nF	
Lr	5.3µH	37µH	13µH
Lm	21µH		
Cp		136nF	

3. These are the characteristics for an 8-kW converter in a single module. (S. Carcouet; J. Ecrabey, Image courtesy of Reference 3)

reach a high mass power density even though an added high-frequency (HF) capacitor was required (this capacitor element ensures that no saturation will occur in the transformer) *(Fig. 3)*.

Because the output current is critical, the converter design is split into four modules, each with 2 kW in parallel. This was done because:

- Avoidance of paralleling GaN devices, since they will not be easily addressed for good current sharing.
- HF capacitors will have better availability, using 100 nF instead of 330 nF.
- Use a PCB design instead of a bus-bar output on the secondary side.
- MOSFET performance and lower losses that will enable the reduction of the heatsink.

GaN high electron mobility transistors (HEMTs) are used in the primary bridge, leading to low losses with high switching commutation. Custom passive transformer and capacitor components facilitate integration with good power density.

The power-density performance in this converter is 1.3 kW/kg. Extrapolation at the ambient temperature of 40°C, along with a powerful optimization of the converter, will lead to a power density of almost 2kW/kg. This is a successful objective for a power converter in an aircraft application *(Fig. 4)*.
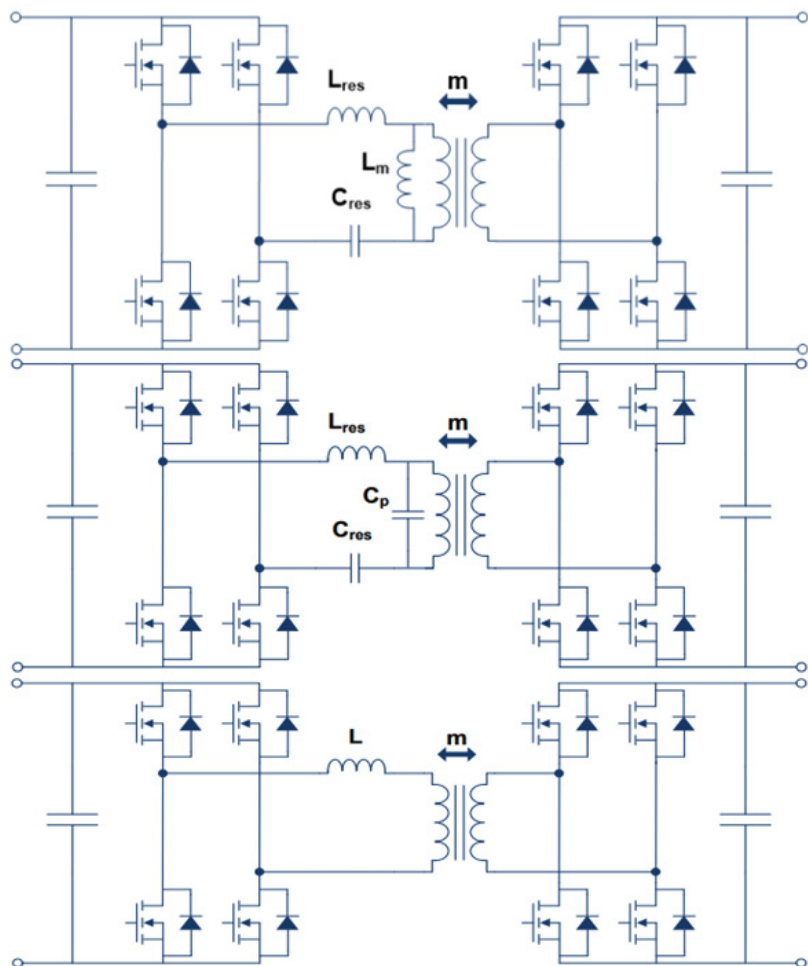
GaN for LiDAR

Light detection and ranging (LiDAR) has a plethora of applications, such as drones, automotive, robotics, retinal imagers, speed measurement devices, range finders, surveying equipment, and many more. [4]

LiDAR has a transmission system that sends out a brief high-current light pulse. This pulse bounces off objects and subsequently returns to a receiver. The time between the signal leaving the transmitter and returning is used to calculate the total distance that the pulse has traveled.

Transmitting signals faster will lead to higher-accuracy results because more data can then be interpreted by the receiver. Gate drivers are important here since they're able to send multiple pulses at very high speeds, leading to high-frequency operation.

Low-side drivers tend are quite common for LIDAR ap-

plications. Texas Instruments has two recommended GaN gate drivers for LIDAR: the LMG1020 and LMG1025-Q1.

These two gate drivers enable high-frequency applications, nanosecond pulse widths, and a short propagation delay. They will drive a FET to produce an optical laser pulse of less than 1.5 ns at a power higher than 100 W.

Some of the key components of the LiDAR reference design in *Figure 5* include a pulse-shortening buffer that creates nanosecond pulse widths, an LMG1020 GaN FET gate driver that drives a GaN FET to produce 60-A 1-ns laser optical pulses exceeding 100 W, and a laser di-
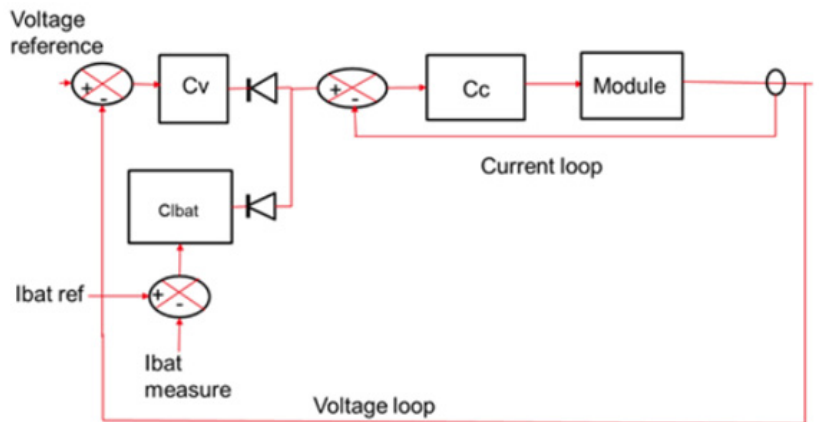
4. Shown is an LLC module with regulation. (Image courtesy of Reference 3)
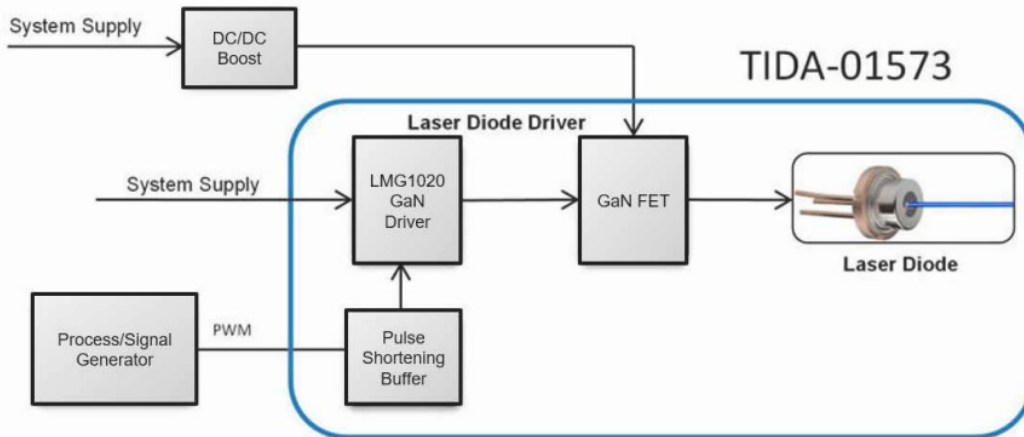
5. The block diagram of a general LIDAR application, taken from the [TIDA-01573](#) reference design. (Texas Instruments, Image courtesy of Reference 4)
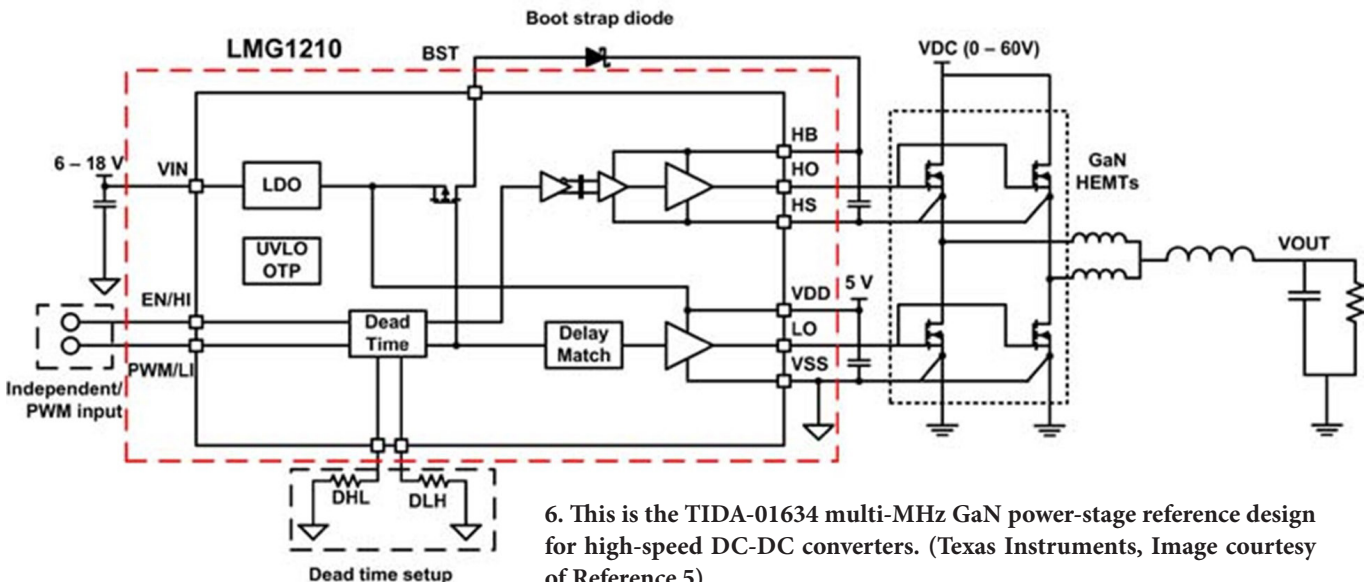
6. This is the TIDA-01634 multi-MHz GaN power-stage reference design for high-speed DC-DC converters. (Texas Instruments, Image courtesy of Reference 5)

ode.[4] The driver pulses the GaN FET on and off so that the laser diode can send multiple pulses that will map objects and their distances.

GaN in a High-Speed Synchronous Buck DC-DC Power Converter

GaN HEMTs are featured in a multi-MHz power design tailored for high-speed DC-C converters.[5] Texas Instruments' LMG1210 is a half-bridge GaN driver that uses GaN power HEMTs. Applications include 5G telecom power, industrial power supplies, and telecom servers *(Fig. 6)*.

The Benefits of GaN in Power Design

The power of GaN enables robust power designs, and GaN devices also help achieve smaller size with higher efficiency in such designs. The technology improves conduction losses and reduces switching losses.

Furthermore, GaN doesn't have a body diode to lower losses obtained during dead-time. The current that would flow through the body diode of a silicon transistor will now flow through the $R_{DS(on)}$ with GaN. This substantially reduced the losses incurred during dead-time.

References

1. "GaN: Pushing the limits of power density & efficiency," TI.com.

2. "How Gallium Nitride (GaN) Enables Smaller, More Efficient Power Supplies," CUI Inc.

3. "High efficiency, low voltage, isolated DC-DC converter based on GaN devices for aircraft application," S. Carcouet, J. Ecrabey, EPE'23 ECCE Europe.

4 "GaN Applications," Application Brief, Donaldo Sanchez, Hagar Mohamed, Texas Instruments, SLUAAM2, August 2022.

5. "Multi-MHz GaN Power Stage Reference Design for High-Speed DC/DC Converter," TIDA-01634, Texas Instruments.