Electronic Design

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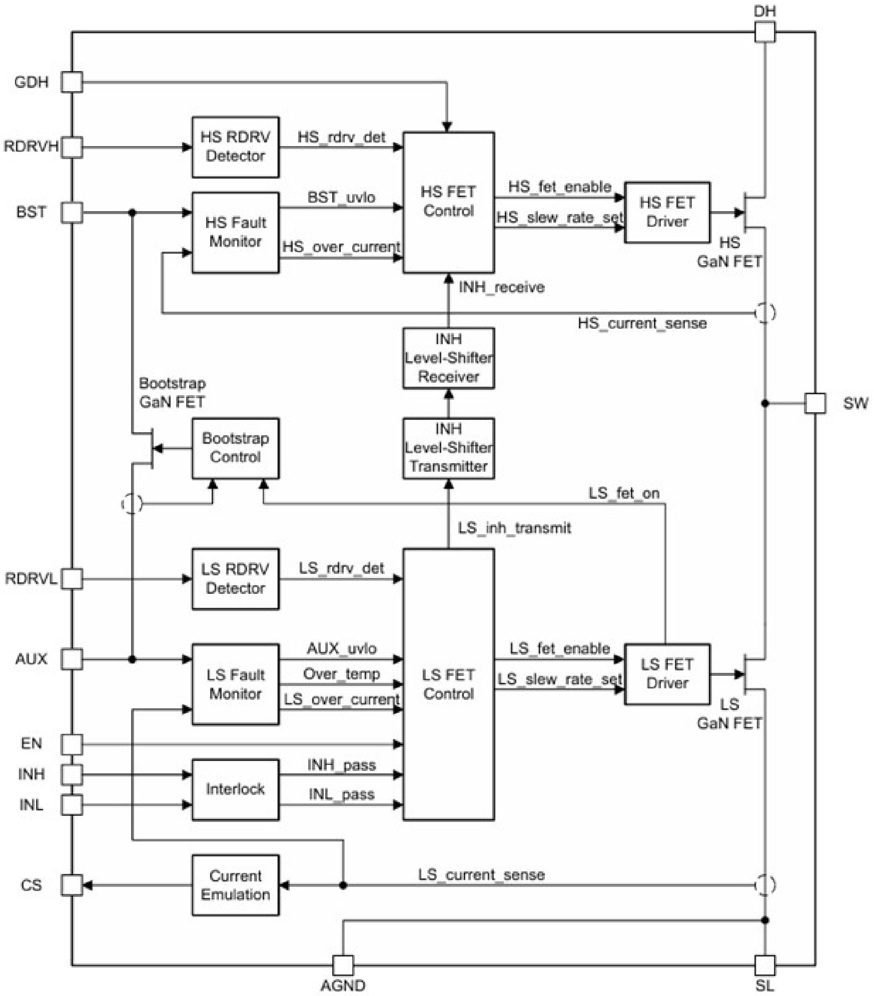
Gravitate to These GaN Apps to Enhance Power Performance

Power-converter density and efficiency can be improved using techniques like GaN HEMTs in a half-bridge configuration.

Savvy power design engineers know how to improve power-converter density and efficiency by incorporating gallium-nitride (GaN) devices into their designs. These devices switch faster than silicon MOSFETs, potentially lowering switching losses.

GaN power stages are used in a wide range of applications, such as telecommunications, motor drives, servers, and laptop adapters, and even onboard electric-vehicle chargers.

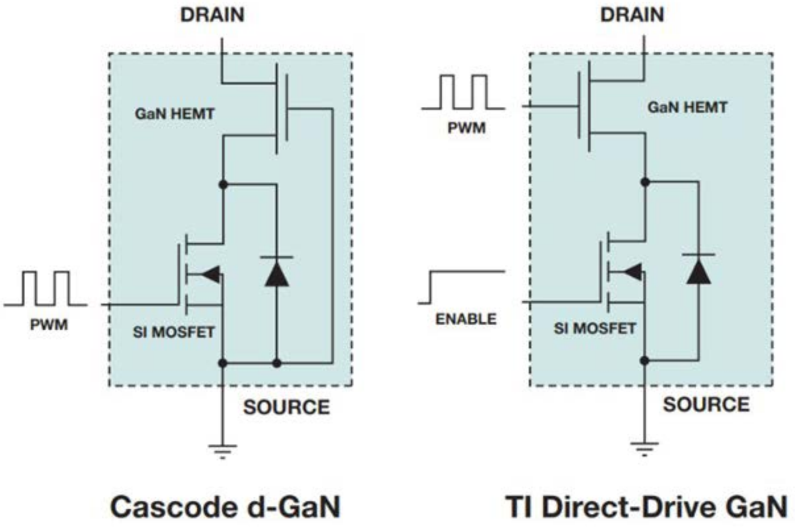
On that front, Texas Instruments offers GaN integrated drivers with protection, such as the LMG2650 GaN half-bridge *(Fig. 1)*, which are targeted at switching power supplies. The 650-V GaN driver FETs in this device can handle the high voltages found in offline power switching applications. The low output capacitive charge reduces both the energy and time necessary for power-converter switching—a critical feature for creating efficient and small power converters.



1. The LMG2650 is a 650-V GaN FET half-bridge with an integrated driver and current sense. (Image courtesy of Texas Instruments)

GaN HEMTs

The GaN device in the depletion mode (D-mode GaN) offers both performance and manufacturing advantages. The normally "on" nature while in this mode during power-up may lead to some abnormal operating conditions.



2. This image shows the difference between Direct-Drive GaN and cascoded D-mode GaN. (Image courtesy of Texas Instruments)

Also, it will require the use of a negative power supply at the gate to turn off.

This can be overcome by connecting the D-mode GaN high electron mobility transistor (HEMT) in series with a low-voltage silicon MOSFET in the cascoded D-mode GaN structure. The gate of the HEMT is shorted to the source of the MOSFET, while the HEMT source connects to the drain of the silicon MOSFET *(Fig. 2)*.

Texas Instruments' solution—TI Direct-Drive—directly drives the GaN HEMT FET, whereby the silicon switch is employed as an enable switch at startup. In this way, the silicon switch doesn't switch at every cycle, but the GaN switch will do so.

Low-Damage AlGaN/GaN MIS-HEMTs

A low-damage atomic layer etching (ALE) process can enhance the performance of recessed-gate metal-insulator-semiconductor HEMTs (MIS-HEMTs).[4] An enhancement-mode (E-mode) AlGaN/GaN recessed-gate MIS-HEMT, with an optimal remaining 5 nm thickness, had state-of-the-art features that included an $I_{D,MAX}$ of 400 mA/mm, a competitive V_{TH} of +2.0 V, an on/off current ratio of 10^9, and a high breakdown voltage (BV) of 830 V.

The high performance of the recessed-gate MIS-HEMT was achieved not only due to the low-damage ALE process, but also precise etching AlGaN thickness control.

Dielectric Failure Detection and More for GaN Power Transistors

It may surprise readers that GaN power devices face significant challenges with reliability *(Fig. 3)*.[5,7]

A high-temperature gate bias (HTGB) stress test evaluates the reliability of FET gate structures. In HTGB testing, the source and drain terminals are connected to 0 V, a voltage is applied to the gate, and the ambient temperature is set to the maximum-rated junction T_j. Both voltage and temperature are used to accelerate the operating stress conditions.

There are three key failure modes caused by HTGB stress:

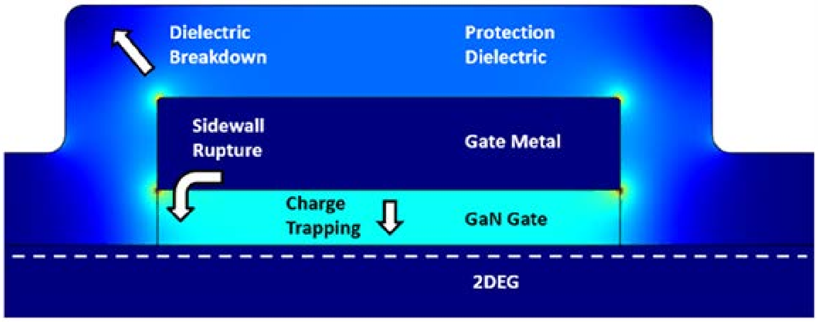
1. Dielectric failure/breakdown resulting from a high electric field in the protection dielectric surrounding the gate. This failure mode is analogous to oxide breakdown mechanisms that occur in MOSFETs.
2. Rupture in the gate side wall is an avalanche breakdown mechanism that occurs due to field crowding at the vertical edge of the gate near the gate metal. This failure mode may be controlled via proper surface passivation and electrostatic design.
3. Gate bias induced drain leakage current.

GaN, Nuclear Reactors, and Harsh Environments

It's quite amazing that GaN semiconductors can successfully withstand the harsh environment close to a nuclear reactor core. Why is this important?

This discovery might make it possible to locate GaN electronic components closer to sensors within an operating nuclear reactor. It will ultimately lead to more accurate and precise measurements in more compact designs.

This means that not too far in the future, wireless sensors



3. The electric-field magnitude inside an E-mode GaN gate is V_{GS} = 5 V. Shown are the failure modes that are exacerbated by high electric fields. (Image cour-tesy of Efficient Power Conversion)

will be able to operate within nuclear reactors. This includes small advanced modular and microreactor designs that are currently under development.

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