Can You Drive GaNFETs with a DC-to-DC Controller Originally Designed for Silicon MOSFETs?

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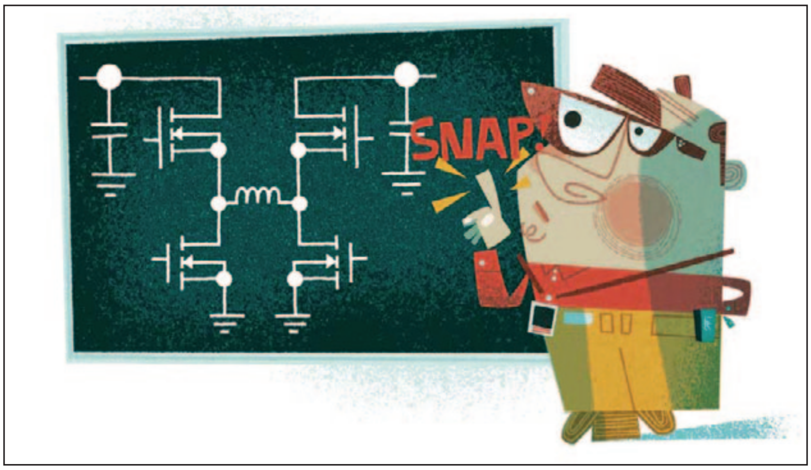
Question

How can I design a 4-switch buck-boost DC-to-DC converter using GaNFETs when there are no controllers specifically made to drive GaNFETs available?



Answer

GaNFETs are notoriously more difficult to drive and may require extra protection components if using a driver meant for silicon (Si) MOSFETs. Proper care in choosing the correct drive voltage and some small protection circuitry can provide a safe, all-in-one, high frequency GaN drive for a 4-switch buck-boost controller.

Introduction

In the never-ending quest to reduce board size and increase efficiency, gallium nitride field effect transistor (GaNFET) power devices have become an ideal candidate to push these boundaries. GaN is an emerging technology that promises higher power with ultrafast switching and reduced switching losses. These advantages allow for more power dense solutions. The current market is saturated with a myriad of different Si MOSFET drivers, and new GaN drivers and controllers with built-in GaN drivers are some years away from becoming accessible. Along with simple, dedicated GaNFET drivers (such as the LT8418), complex buck and boost controllers targeted for GaN exist on the market (LTC7890, LTC7891). There is still no straightforward 4-switch buck-boost solution. However, driving GaNFETs is not as difficult as it may seem. With some simple background knowledge, Si MOSFET targeted controllers can be adapted to drive GaNFETs. The LT8390A is a great candidate as it is a unique 2MHz buck-boost controller with very low dead time (25ns) (see Figure 1). The buck-boost scheme has the sense resistor in line with the inductor and outside of both hot loops - a novel feature for buck-boosts. This allows the controller to operate in peak

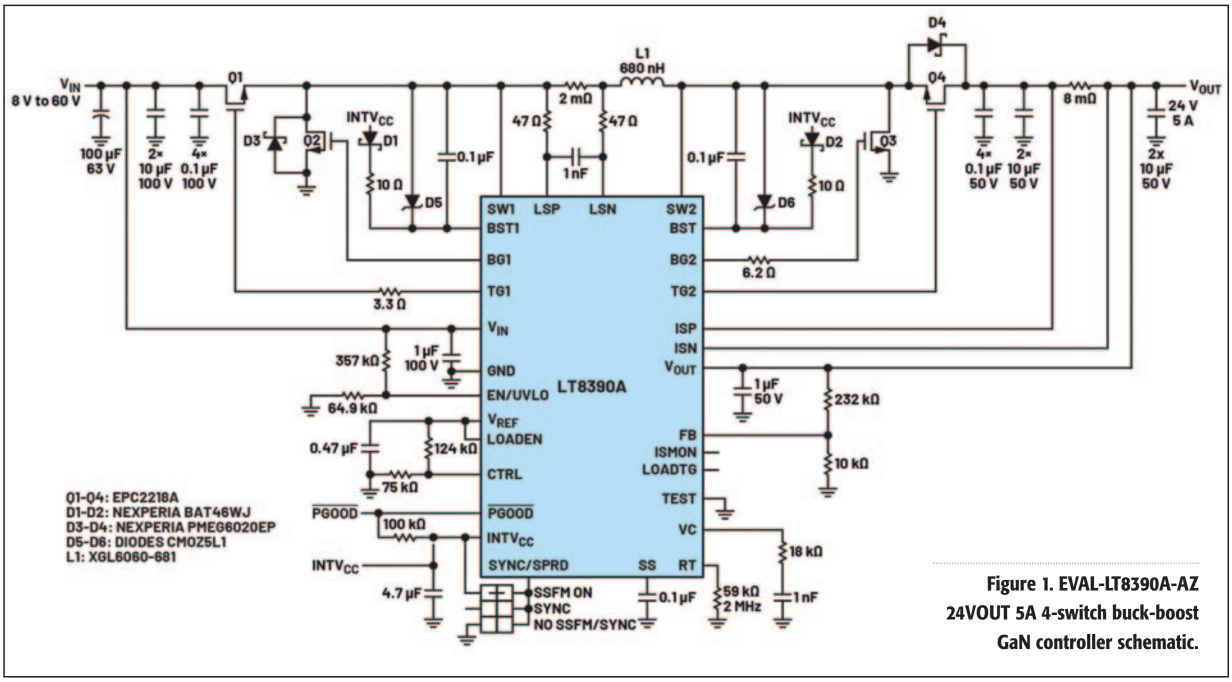


Figure 1. EVAL-LT8390A-AZ 24VOUT 5A 4-switch buck-boost GaN controller schematic.

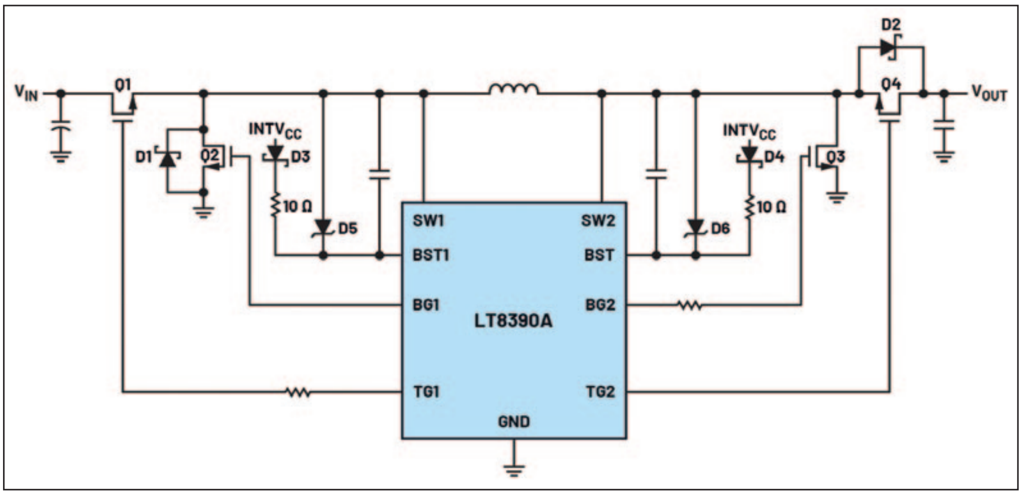


Figure 2. Simplified 4-switch buck-boost GaN controller schematic with GaN control protection components.

current mode control in both boost and buck regions of operation (as well as 4-switch buck-boost). While the article delves into 4-switch buck-boost GaNFET control, the information can be extended to simple buck or boost controllers.

5V Gate Driver Is a Must

For high power conversion, silicon drivers typically operate above 5V, with typical silicon MOSFET gate drivers ranging from 7V to 10V or even higher. This poses a challenge to GaNFETs, as they commonly have an absolute maximum gate voltage rating of 6V. Even the ringing caused by stray PCB inductances on the gate and source return lines that exceed the maximum gate voltage can lead to catastrophic failures. Careful layout considerations are necessary to safely and effectively drive a GaNFET by minimising inductances in the gate and source return signals. In addition to layout, implementing component-level protection is crucial in preventing catastrophic overvoltage of the gates.

The LT8390A provides a 5V gate driver specifically designed for lower gate drive FETs, making it an ideal choice for GaNFETs. The issue is silicon FET drivers often lack protection against accidental overvoltage. In particular, the bootstrap supply for the top FETs on silicon gate drivers is unregulated, which means that the top gate driver can easily drift up above the absolute maximum voltage of the GaNFET. Figure 2 shows how to address this: a 5.1V Zener diode (D5 and D6) is placed in parallel with the bootstrap capacitor to clamp that voltage at the recommended drive level of the GaNFET. This ensures that the gate voltage remains within the safe operating range.

Additionally, for even more protection, a 10Ω resistor is added in series with the bootstrap diodes (D3 and D4) to reduce any ringing that might be caused by the very fast and high power switch node.

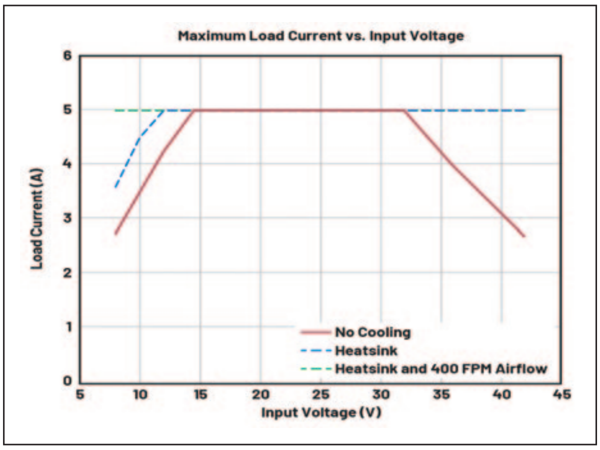


Figure 3. EVAL-LT8390A-AZ maximum output current vs. input voltage. The board can produce 120W through a wide input range at high frequency.

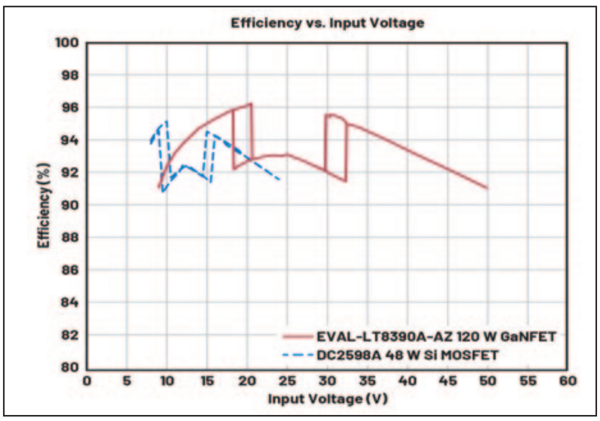


Figure 4. EVAL-LT8390A-AZ GaN controller efficiency vs. DC2598A Si MOSFET controller efficiency. GaNFETs provide higher efficiency at higher voltage.

Dead Time and Body Diode Challenges

In traditional converters, a catch diode is present to conduct during the off-time. Synchronous converters replace the catch diode with another switch to reduce the forward conduction loss of a diode. However, a problem arises if the top and bottom switches turn on simultaneously, resulting in shoot-through. In the event of a shoot-through, both FETS can be essentially short to ground, which can lead to component failures and other disastrous consequences. To prevent this, controllers implement dead time, a period where neither the top nor bottom switch is turned on. Typical synchronous DC-to-DC controllers implement dead times of up to 60ns. This dead time is not a significant concern with silicon MOSFETs since the body diode conducts during this period.

GaNFETs do not have body diodes and switch on/off significantly faster than silicon MOSFETs. Instead of body diodes conducting during the dead time, GaNFETs can conduct with 2V to 4V compared to the typical 0.7V of a diode. This conduction voltage, multiplied by the conduction current, can result in nearly 6? more power loss during the dead time. This increased power loss, combined with a long dead time, can lead to overheating and damage to the FETs. The best solution is to minimise the dead time. However, controllers meant for silicon FETs design the dead time around the fact that silicon

FETs have slow turn-on/off characteristics (in the tens of ns). Therefore, the dead time is set longer to prevent shoot through.

The LT8390A has a set 25ns dead time, which is a shorter dead time compared to many synchronous controllers on the market. While this is suitable for high frequency, high power MOSFET control, it is still too long for GaNFETs. GaNFETs can turn on extremely quickly (in the ones of ns). Therefore, to mitigate additional conduction losses during the dead time, it is recommended to add a catch Schottky diode in antiparallel with the synchronous GaNFET to divert the conduction to a less lossy pathway. D1 and D2 in Figure 2 show which FET to place the Schottky diodes across. D1 is placed across the synchronous buck side FET, and D2 is across the synchronous boost side FET. For a simple buck converter, only D1 is required. For a simple boost, use D2.

Higher Power with Higher Frequency

The LT8390A has a switching frequency up to 2MHz. GaNFETs have significantly lower switching losses compared to Si MOSFETs, enabling similar power losses at higher switching frequencies and voltages. The EVAL-LT8390A-AZ GaNFET board demonstrates the efficiency and compact size advantages of using GaNFETs by setting the switching frequency to 2MHz.

With an output of 24V, the GaNFETs can produce 120W of power at room temperature. The board size is comparable to the previous LT8390A evaluation board: the DC2598A, which uses silicon MOSFETs and provides a 12VOUT with 48W power.

Figure 3 shows the maximum power capability of a 2MHz GaN buck-boost, while Figure 4 compares the efficiency of both boards. Even at higher voltages, and 2.5? output power, the GaNFET board produces better efficiency than the Si MOSFET board. The utilisation of GaNFETs allows operation at higher voltages and power with a similar board area.

Table 1. DC-to-DC Controllers Compatible with GaNFETs

Recommended GaN Controllers	Topology	Max Input/ Output Voltage	Switching Frequency	GaN Safe features
LTC7890	Dual buck GaN controller	100V	100kHz to 3MHz	▸ Smart bootstrap ▸ Split gate drive ▸ Smart near-zero dead time ▸ Adjustable 7ns to 60ns dead time
LTC7891	Buck GaN controller	100V	100kHz to 3MHz	▸ Smart bootstrap ▸ Split gate drive ▸ Smart near-zero dead time ▸ Adjustable 7ns to 60ns dead time
LT8418	Half-bridge GaN gate driver	100V	Up to 10MHz	▸ Low propagation delay ▸ Fast and powerful gate drive ▸ Split gate drive ▸ Smart bootstrap ▸ Gate drive over-voltage lockout
LT8390/ LT8390A/ LT8392	4-switch buck-boost controller	60V	LT8390/LT8392: 150kHz to 650kHz LT8390A: 600kHz to 2MHz	▸ Si MOSFET controller with 5V gate driver
LT8391/ LT8391A/ LT8391D	4-switch buck-boost LED driver controller	60V	LT8391/LT8391D: 150kHz to 650kHz LT8391A: 600kHz to 2MHz	▸ Si MOSFET controller with 5V gate driver

Conclusion

If there are no DC-to-DC controllers that specifically have GaNFET driving capabilities, it is still possible to drive them effectively. Even using a controller originally meant to drive Si MOSFETs, the EVAL-LT8390A-AZ can easily outpower and achieve higher efficiency in a similar board area. Table 1 shows a wide selection of recommended controllers for driving GaNFETs. For even higher power requirements, such as paralleled buck-boost GaNFET control, please contact the factory. By researching a controller that offers a 5V gate driver and incorporating additional external protection circuit components, it is possible to drive GaNFETs safely and explore more options in power conversion design.

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About the Author

Kevin Thai is an applications manager with Analog Devices in San Jose, California. He works in the IPS Power Products Group and oversees the isolated flyback and protection product lines along with other boost, buck-boost, and GaN controller products. He received his B.S. degree in electrical engineering from Cal Poly, San Luis Obispo, in 2017, and M.S. degree in electrical engineering from University of California, Los Angeles, in 2018.