Gate Drive Circuitry for Cascode GaN Switches and E-mode Compatibility

Introduction

Gallium Nitride (GaN) power devices enable higher power density, faster switching speeds, and improved efficiency in modern power conversion systems. However, as system voltages and power levels increase, gate drive robustness, noise immunity, and ease of implementation become increasingly critical design considerations. Cascode GaN devices address these challenges by combining the high-speed switching capability of depletion mode (d-mode) GaN with the robust gate characteristics of a low-voltage silicon MOSFET.

Cascode GaN devices are normally-off power switches (see D-mode GaN Remains a Natural Fit for High-Voltage Applications) that can be driven using standard gate driver ICs and conventional gate drive voltages. Unlike enhancement mode (E-mode) GaN devices, cascode GaN does not require a negative gate drive at turn-off, nor additional gate protection or clamping circuitry. This simplifies the gate drive design while providing improved tolerance to high dv/dt and di/dt conditions commonly encountered in high-voltage and high-power applications.

This application note explains practical gate drive implementations for cascode GaN devices and provides recommended gate drive configurations for both unidirectional and bidirectional devices, as well as guidance for replacing existing E-mode GaN designs with cascode GaN solutions. Emphasis is placed on simple, proven gate drive circuits that enable reliable operation while minimizing component count and design complexity.

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1. Cascode GaN Gate Drive Configuration

Renesas High-Voltage GaN devices are high-performance, normally-off devices that do not need a negative gate drive voltage. This streamlines the implementation of simple and conventional gate drive circuits using just a gate resistor and a diode.

1.1 Unidirectional Gate Drive Configuration

This section describes commonly used gate drive circuit implementations for unidirectional cascode GaN products. The configurations shown focus on practical methods to control the switching behavior while maintaining simplicity and robustness.

- **Gate resistors (R_G)** – A gate resistor (R_G) is essential for all switching devices to control the switching speed of a device. The value of R_G should be optimized based on the desired slew rate, voltage overshoot, and electromagnetic interference (EMI) considerations to ensure reliable operation and minimize switching noise. Common practice is to adopt a dual resistor configuration, decoupling turn-on speed from turn-off speed and preventing parasitic turn-on during hard-switched commutations.

Figure 1 shows three common drive circuit configurations:

- Figure 1(a) shows a single resistor controlling both the turn-on and turn-off slew rates.
- Figure 1(b) shows a configuration where separate resistors are used to tune the turn-on and turn-off transients. A separation in turn-on and turn-off gate loop is achieved by using a diode to control the direction of the gate current. The recommended gate resistance values depend on product $R_{DS(on)}$ and are reported in each product datasheet.

  The turn-off resistor is usually smaller than the turn-on resistor to ensure low turn-off delay time in high-frequency soft-switching topologies (LLC, PSFB, matrix, etc.) and ensures a low impedance path to ground during hard-switched transitions, preventing the gate voltage to rise above threshold and avoiding shoot-through.
- Figure 1(c) shows a configuration that can be implemented with a gate driver which provides separate source and sink outputs. This allows the use of dedicated $R_{G(ON)}$ and $R_{G(OFF)}$ to independently control rise and fall transients without an additional diode.

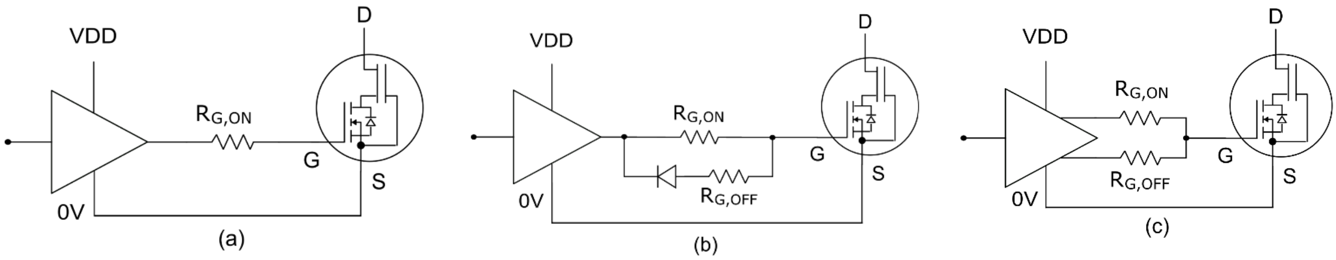

Figure 1. Standard Cascode GaN Drive

1.2 Bidirectional Gate Drive Configuration

Bidirectional switch (BDS) GaN devices are typically driven with separate turn-on and turn-off gate resistors ($R_{G(ON)}$ and $R_{G(OFF)}$) to independently tune the switching transitions in each direction. The turn-off resistor is usually smaller than a turn-on resistor to ensure low turn-off delay time in high-frequency soft-switching topologies (LLC, PSFB, matrix, etc.) and ensure a low-impedance path to ground during hard switching transitions.

Figure 2 shows two common implementations:

- Figure 2(a) shows a configuration with a gate driver which provides single-ended output.
- Figure 2(b) shows a configuration with a gate driver which provides separate source and sink outputs.

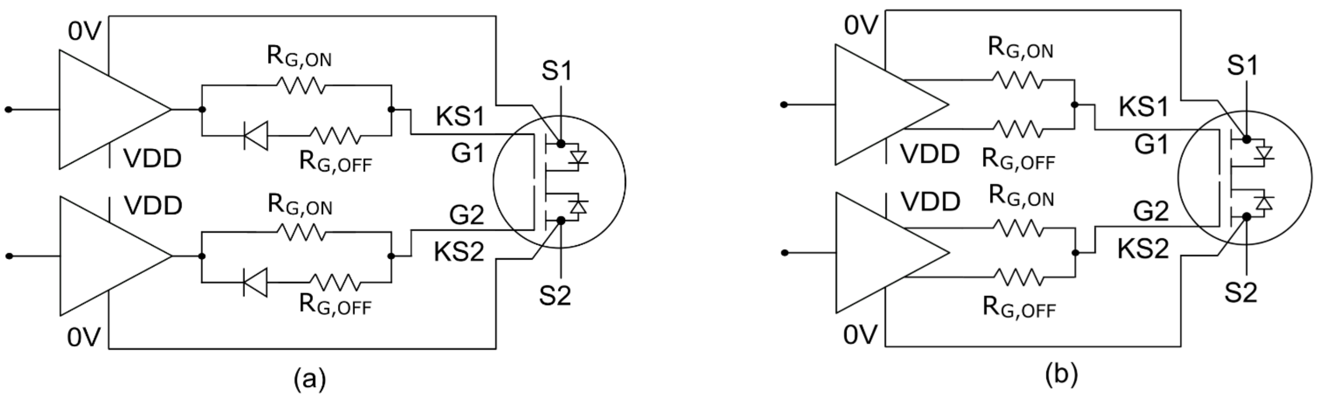

Figure 2. Standard Gate Drive for Cascode BDS GaN

2. Recommended Gate Drive Level for Cascode GaN Products

The voltage used to drive the gate of cascode GaN devices should be selected to fully enhance the internal silicon MOSFET. Renesas offers multiple product families with different threshold voltages, including 2V, 3V and 4V to offer compatibility with the widest range of applications and gate supply voltages, ensuring compatibility with E-mode GaN devices, silicon MOSFETs and SiC MOSFETs.

Typical recommended gate drive ranges are reported in the following for GaN products with 2V, 3V and 4V threshold.

2.1 Cascode GaN Products with 2V Threshold

Table 1. Recommended V_{GS} for Renesas GaN Products with 2V Threshold

Symbol	Parameter [1]	Minimum	Recommended	Maximum	Unit
$V_{GS,off}$	Off-State Gate Voltage	-20	0	0	V
$V_{GS,on}$	On-State Gate Voltage	5	6	20	

1. Specifications intended for applications using single-ended topologies (ex-Flyback).

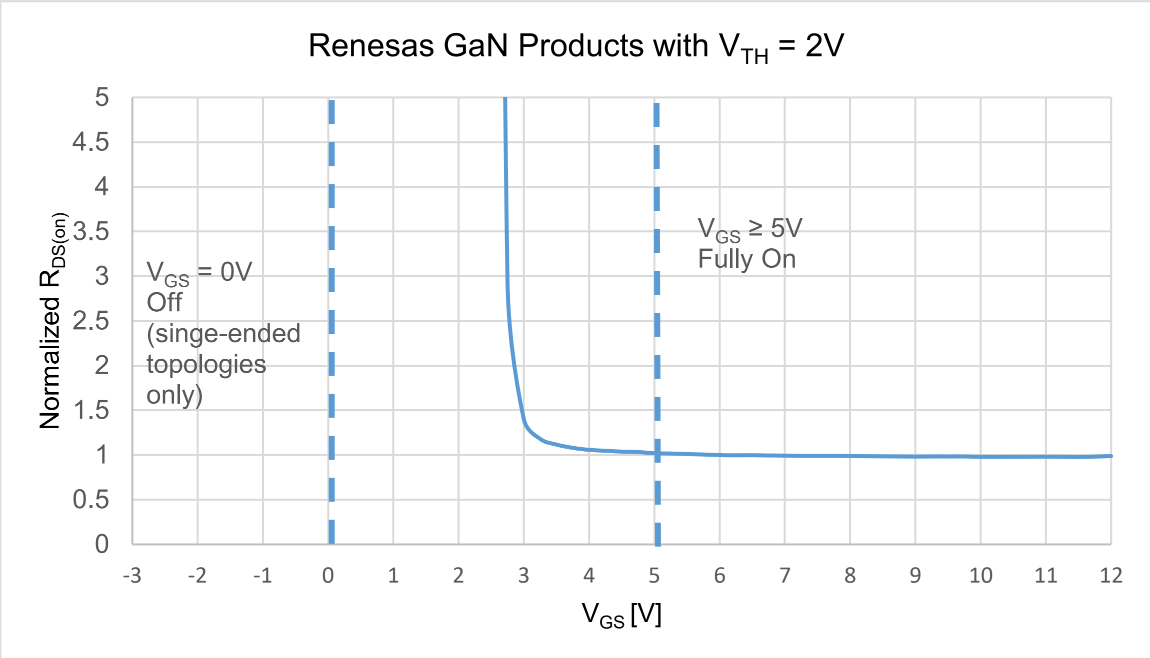

Figure 3. V_{GS} vs $R_{DS(on)}$ for 2V Threshold Renesas Cascode Products

2.2 Cascode GaN Products with 3V Threshold

Table 2. Recommended V_{GS} for Renesas GaN Products with 3V Threshold

Symbol	Parameter [1]	Minimum	Recommended	Maximum	Unit
$V_{GS,off}$	Off-State Gate Voltage	-20	0	0	V
$V_{GS,on}$	On-State Gate Voltage	7	9	20	

1. Specifications intended for applications using single-ended and Half-Bridge Topologies (ex-PFC, LLC, Microinverter, Inverters).

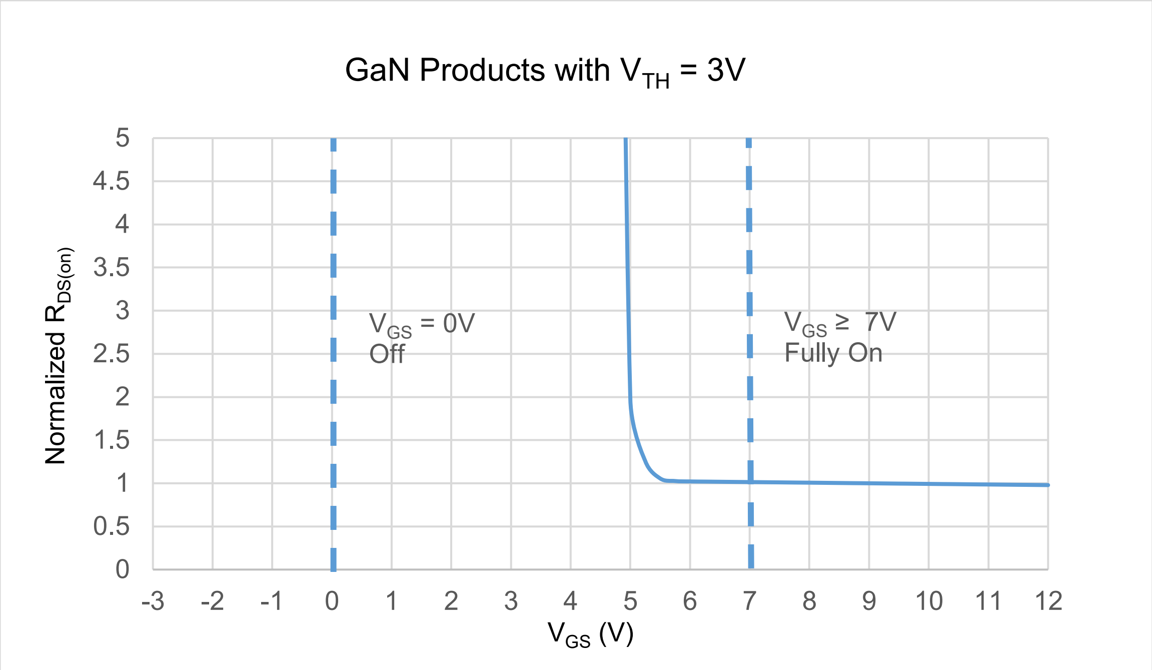

Figure 4. V_{GS} vs $R_{DS(on)}$ for 3V Threshold Renesas Cascode Products

2.3 Cascode GaN Products with 4V Threshold

Table 3. Recommended V_{GS} for Renesas GaN Products with 2V Threshold

Symbol	Parameter [1]	Minimum	Recommended	Maximum	Unit
$V_{GS,off}$	Off-State Gate Voltage	-20	0	0	V
$V_{GS,on}$	On-State Gate Voltage	8	9–12	20	

1. Specifications intended for applications using single-ended and Half-Bridge Topologies (ex-PFC, LLC, Microinverter, Inverters).

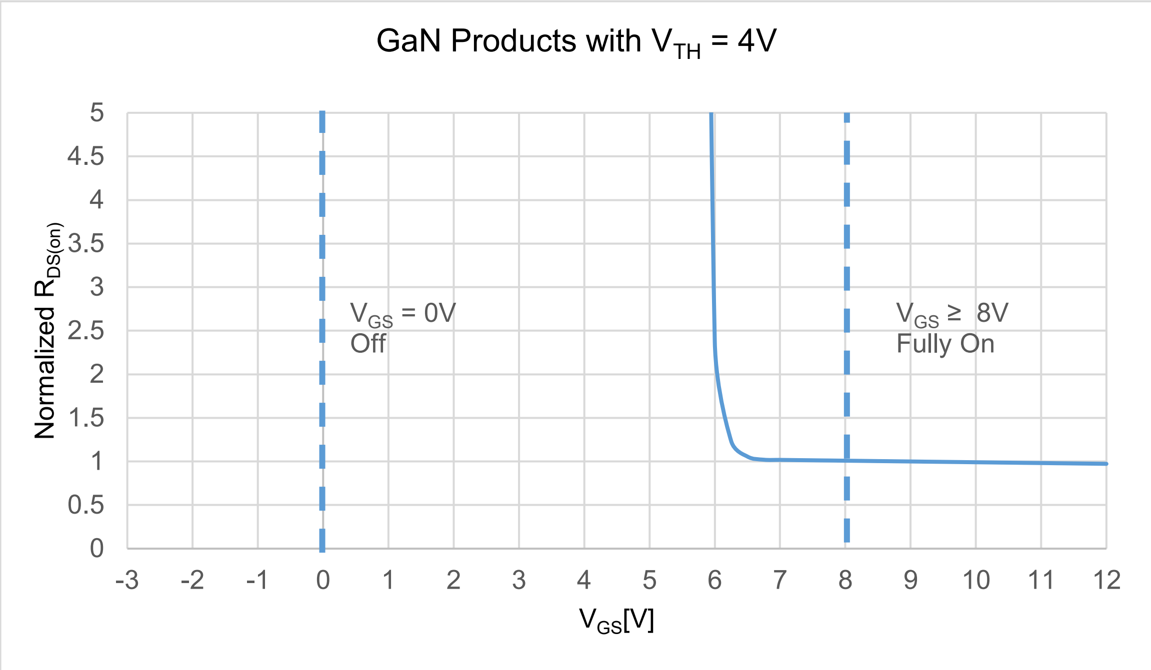

Figure 5. V_{GS} vs $R_{DS(on)}$ for 4V Threshold Renesas Cascode Products

3. Replacing E-mode GaN with Cascode GaN

A key advantage of cascode GaN is that it can be used as a practical replacement for E-mode GaN in many existing designs with minimal changes to the gate-drive circuitry. Because cascode GaN does not require negative gate bias at turn-off and provides a robust gate interface compatible with conventional driver voltages, many of the auxiliary components typically added for E-mode gate protection or biasing can be removed or simplified. In most cases, migrating from E-mode GaN to cascode GaN is straightforward: the same driver and PCB layout can be retained, while ancillary components can be eliminated as illustrated in the gate-drive examples shown in Figure 6.

When migrating from E-mode GaN to cascode GaN, it is important to verify that the applied gate voltage is appropriate for the threshold voltage of the selected cascode device. E-mode GaN devices typically operate with a gate voltage swing that may include a negative turn-off voltage (for example, -5V to -2V) and a positive turn-on voltage (for example, 3.5V to 6V).

In contrast, cascode GaN devices are designed to operate with conventional positive gate-drive voltages. Therefore, designers should ensure that the applied gate-drive voltage is consistent with the requirements of the selected cascode GaN device. Refer to section 2 for the recommended gate-drive levels based on V_{TH}.

3.1 Replacing GIT E-mode GaN with Cascode GaN

The standard gate-drive circuitry typically used with GIT E-mode GaN devices is shown in Figure 6. This implementation commonly includes an added R_{SS} network and a coupling capacitor C_C, which are used to shape the effective gate behavior and improve robustness during fast switching transients.

When replacing a GIT E-mode GaN device with a cascode GaN device, these additional components are no longer required. The same gate driver and general gate-drive approach can be retained, with only the following changes:

- Remove R_{SS} (not populated)
- Replace C_C with a 0Ω resistor (short)

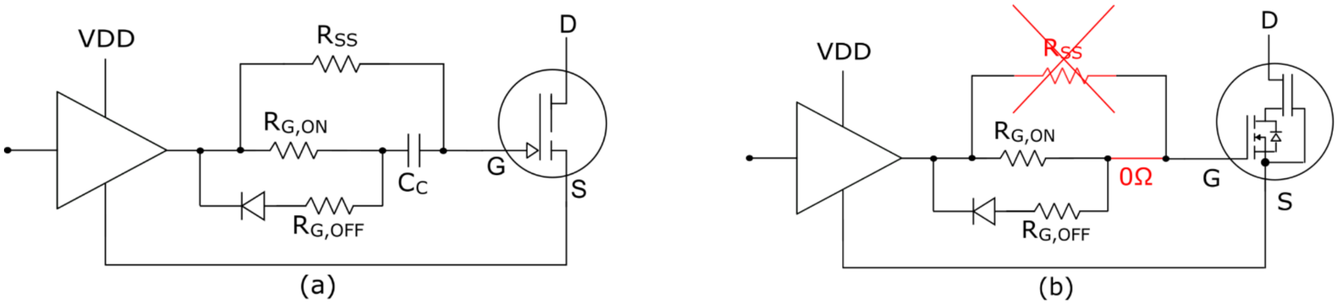

Figure 6. Standard GIT Gate Drive (a); Replacing with Cascode GaN (b)

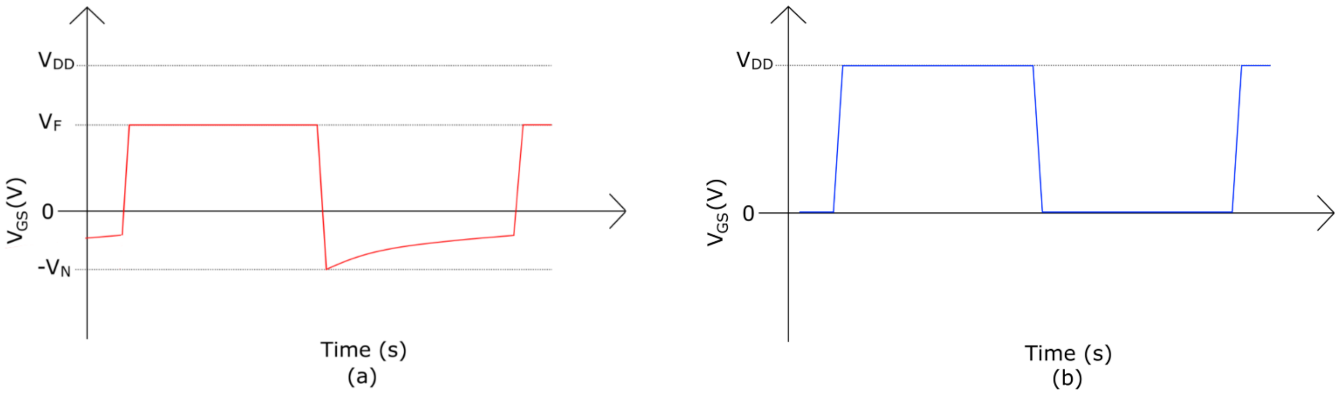

Figure 7. Standard GIT V_{GS} Waveform (a); Standard Cascode GaN V_{GS} Waveform (b)

Figure 8 demonstrates GIT E-mode GaN with a bipolar gate driver supply which can also be replaced with cascode GaN by changing the following:

- Replace V_2 and C_C with a 0Ω resistor (short)
- Remove C_2, R_{SS}

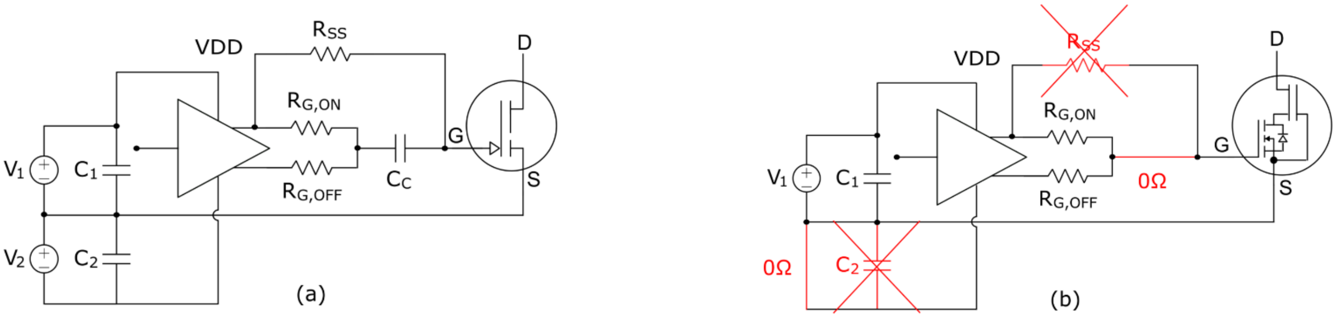

Figure 8. GIT Gate Drive with Bipolar Drive Supply (a); Replacing with Cascode GaN (b)

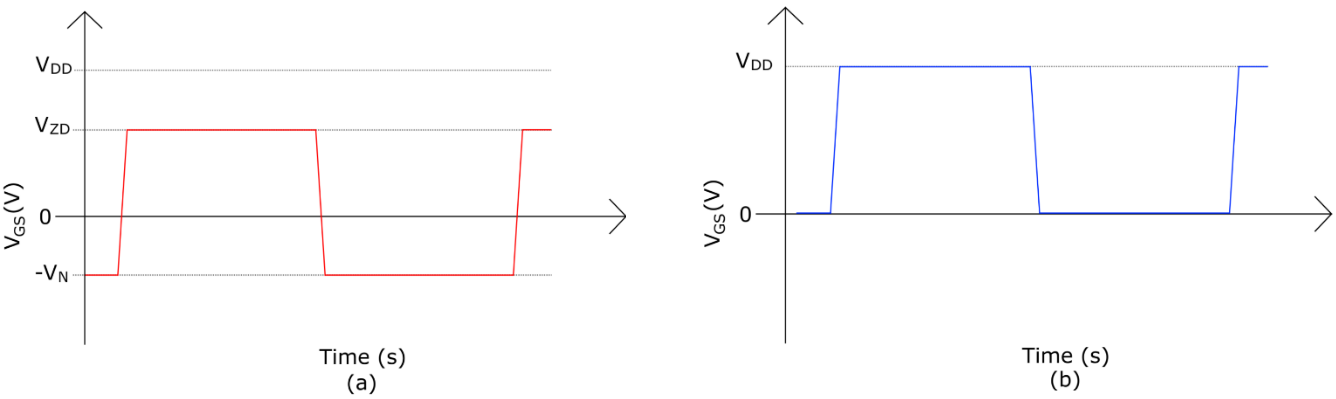

Figure 9. GIT Gate Drive with Bipolar Drive Supply V_{GS} Waveform (a) Standard GaN V_{GS} Waveform (b)

Figure 10 demonstrates GIT E-mode GaN with a Zener diode to generate the second voltage source. In this case, to replace GIT E-mode with cascode, do the following:

- Remove D_1 and C_2
- Replace R_Z with 0Ω resistor (short)

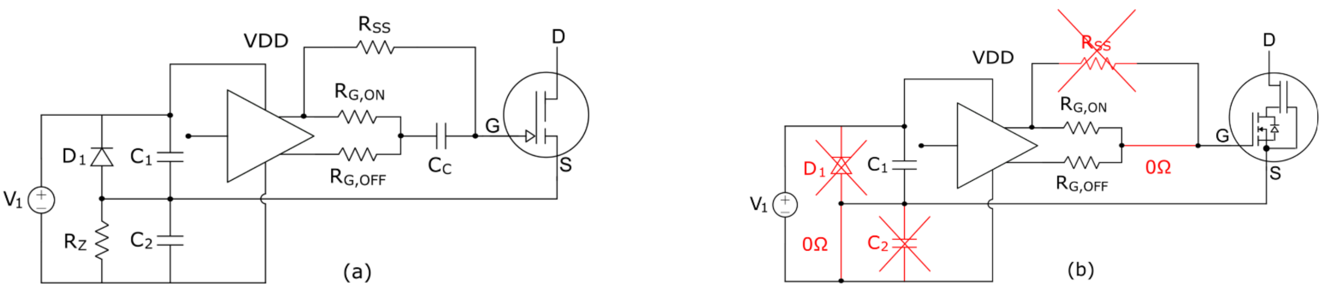

Figure 10. GIT Gate Drive with Zener Diode (a); Replacing with Cascode GaN (b)

3.2 Replacing SGT E-mode GaN with Cascode GaN

The standard gate-drive circuitry typically used with SGT E-mode GaN devices is shown in Figure 11. Compared to GIT implementations, SGT-based gate drives often include additional gate protection components (for example, clamp diodes or Zener devices) to limit gate overvoltage during fast dv/dt events and layout-induced ringing.

When replacing an SGT E-mode GaN product with a cascode GaN product, the gate-drive network can be simplified because the cascode structure provides a more robust gate interface compatible with conventional driver voltages. As shown in the transition from Figure 11(a) to Figure 11(b), the same gate driver can typically be retained, with the following changes:

- Remove R_{SS}
- Remove ZD_1 and ZD_2
- Replace C_C with a 0Ω resistor (short)

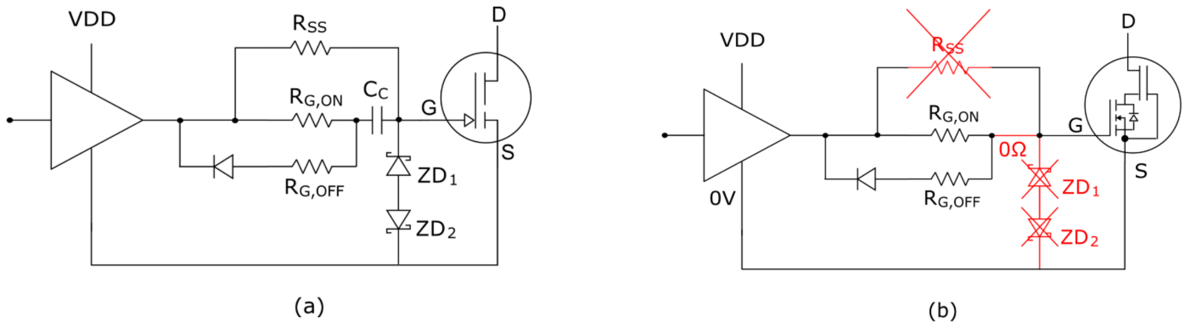

Figure 11. Standard SGT Gate Drive (a); Replacing with Cascode GaN (b)

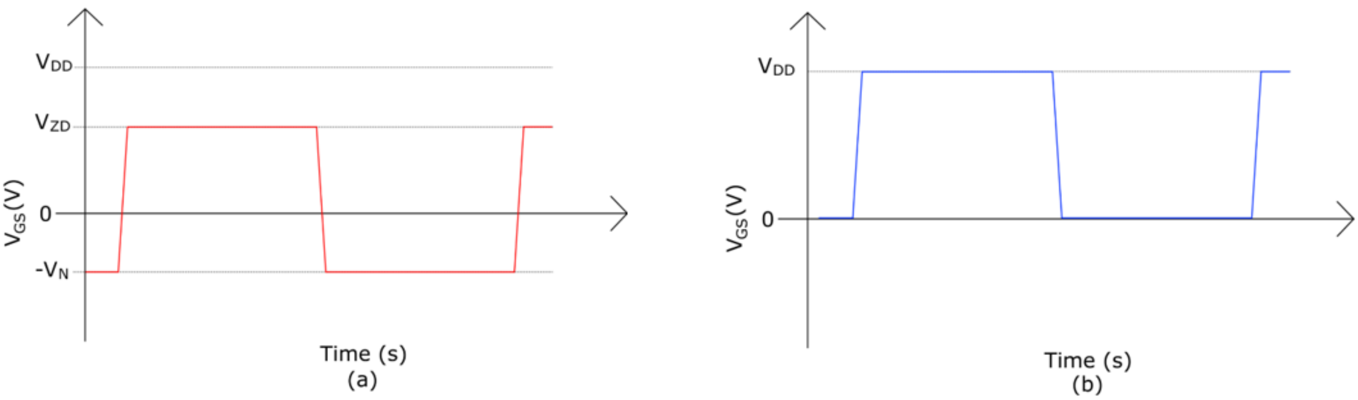

Figure 12. Standard SGT V_{GS} Waveform (a); Standard Cascode GaN V_{GS} Waveform (b)

3.3 Replacing E-mode BDS GaN with Cascode BDS GaN

Bidirectional E-mode GaN implementations (either GIT or SGT) often include additional gate-drive components to improve noise immunity and protect the gate during high dv/dt switching events. When migrating to a cascode bidirectional switch (BDS), the gate-drive network can typically be simplified while preserving the same overall driver interface and layout approach.

Figure 13 illustrates a single gate-drive circuit that can be populated to support GIT BDS E-mode and its replacement with cascode BDS GaN. Figure 14 illustrates a single gate-drive circuit that can be populated to support SGT BDS E-mode and its replacement with cascode BDS GaN. In both cases, just like the unidirectional devices, cascode BDS GaN can replace E-mode BDS GaN with the simple removal or shorting of components just as with the unidirectional devices. Similar to UDS devices, with BDS devices it is important to verify that the proper V_{GS} is applied when swapping devices.

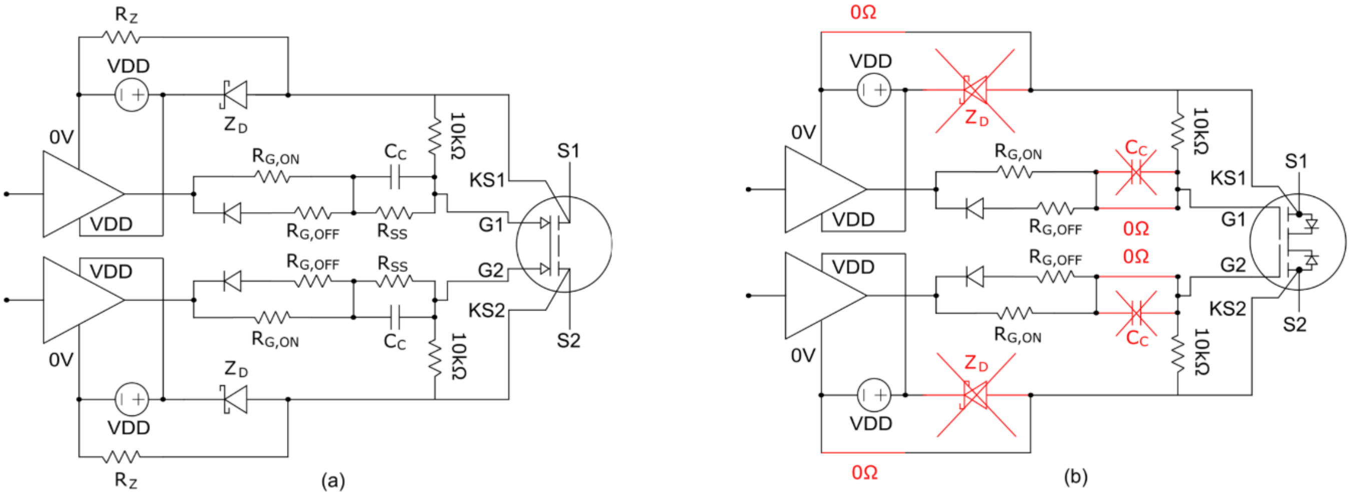

Figure 13. GIT Gate Drive for BDS GaN (a); Replacing with Cascode BDS GaN (b)

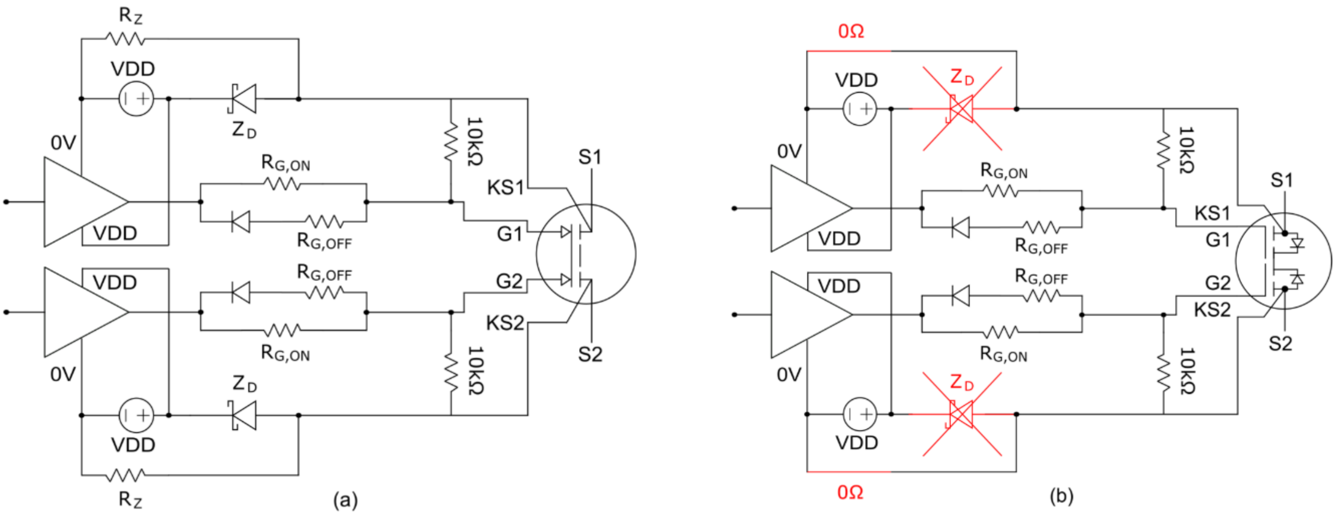

Figure 14. SGT Gate Drive for BDS GaN (a); Replacing with Cascode BDS GaN (b)

4. Revision History

Revision	Date	Description
1.00	Jun 30, 2026	Initial release.