RIC70115 Gate Driver Features for Reliable and Efficient GaN HEMT Operation in Space

RIC70115

About this document

Scope and purpose

This application note introduces the key features of the RIC70115, a radiation hardened (RH) low-side and high-side single channel gate driver optimized for GaN HEMT and logic-level (LL) Si MOSFETs for space applications. RIC70115 features Truly Differential Input (TDI), a tightly regulated 4.8V driver voltage and a Miller clamp (MC) function. These three features make RIC70115 outstanding among typical low-side gate drivers in the market.

Intended audience

The intended audience for this document is applications, field applications, design, systems, or any engineer working in the field of power electronics.

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1 Introduction

Space and defense industries face the critical challenge of delivering enhanced in-orbit compute power in small and efficient semiconductors without compromising reliability or radiation performance. This increase in power demand has led to an increase in the bus distribution voltage from 28V to 80V/120V to maintain the current within reasonable magnitudes so that the thermal performance is not affected. Another trend is the introduction of wide bandgap (WBG) semiconductor materials so that power systems can switch faster and reduce the size of the magnetics components. Finally, launch mass and volume are at premium with Size, Weight , Power and Cost (SWaP-C) pressure increasing the demand for higher power density.

Gallium Nitride, High Electron Mobility Transistors (GaN HEMT) are types of WBG semiconductors finding new uses in space systems. Its two-dimensional electron gas (2DEG) enables high electron mobility in the channel allowing higher switching frequencies and lower R_{DSon} values compared to Si MOSFETs. Also, its bandgap energy of 3.4eV enables higher breakdown voltages compared to Si MOSFETs. Moreover, the 2DEG channel does not have an oxide layer which makes GaN HEMT inherently Total Ionizing Dose (TID) free.

The features of RIC70115 maximize the electrical performance of GaN HEMT based power architectures. This application note will explain how these features allow GaN HEMT to be utilized in any single-ended or double-ended power topology, handle the high bus voltage demands, optimize efficiency without compromising gate reliability and avoid cross conduction.

2 Truly Differential Input (TDI)

RIC70115 features TDI at IN+/IN- pins. This feature allows the device to be controlled by the voltage difference between IN+ and IN- pins rejecting any common mode voltage present on those pins. This allows the gate driver to be used in a high-side operation aside from low-side operation. Another benefit of this feature is the noise immunity from ground bounce during the switching transitions allowing the device to have a robust switching performance. This is especially true for GaN HEMT which switches at higher switching frequencies compared to Si MOSFET.

2.1 High-side operation

The TDI feature allows the driver to operate in a high-side configuration using TDI resistors that are connected in series between the input logic signal and IN+/IN- pins. These resistors block the common-mode voltage V_{CMR} from the VSS pin which is connected to the SW node, as shown in Figure 1. This allows the input logic signal V_{IN} to be referenced to the control ground reference of the system and not to VSS.

A typical power topology that needs a high-side driver is the buck converter where the switching device is connected between the input voltage and the switching node.

To bias the device in high-side configuration, a floating bias supply referenced to the source of the GaN HEMT is needed. This floating bias could come from an auxiliary winding of a transformer.

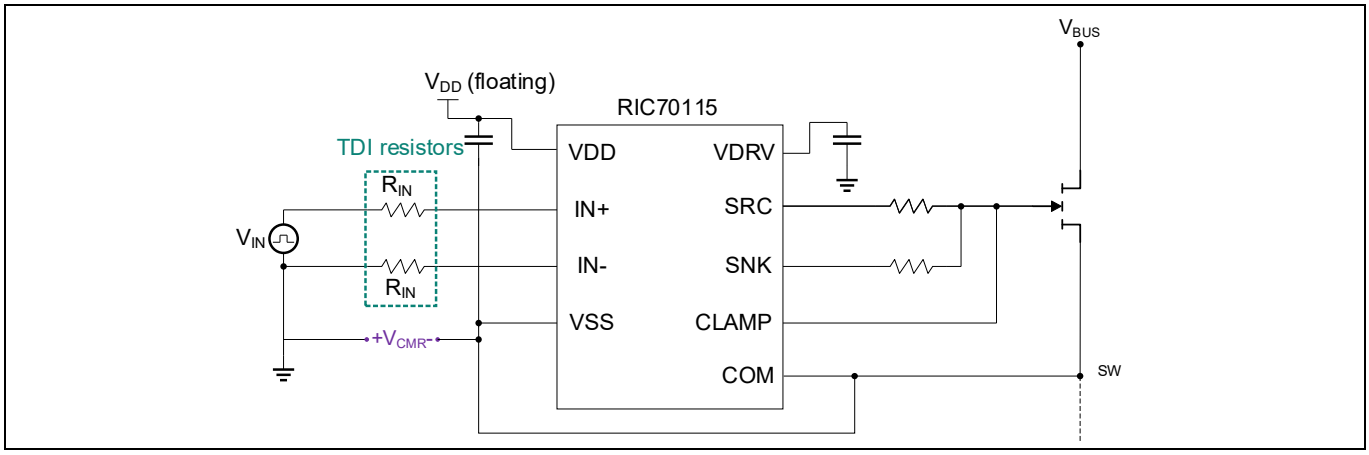


Figure 1 RIC70115 in high-side configuration

2.1.1 TDI resistor selection

RIC70115 requires precise input resistors on the IN+ and IN- pins. These resistors are not optional, even if the application does not require the TDI function (e.g. low-side operation). The input logic thresholds at the IN+ and IN- pins are designed to be paired with the specified input resistor values. These input resistors should be selected with a 0.1% tolerance, especially in high-side applications, where the common-mode voltage rating is contingent upon tight matching of input resistors. Extra care should be taken to ensure that these resistors are symmetrical, so that stray capacitance across them is also tightly matched. Table 1 shows the recommended TDI resistors for three typical input voltages.

Table 1 Recommended TDI resistors

Input type	Amplitude (V)	R_{in} (kΩ)
Digital/Analog	3.3	47

Input type	Amplitude (V)	R_{in} (kΩ)
Digital/Analog	5.0	75
Analog	12	180

Common input logic voltage levels coming from a microcontroller or FPGA are 3.3V and 5V. However, an analog controller whose bias voltage is 12V could also be used to control RIC70115.

The main factor influencing the selection of these values is the logic thresholds. TDI resistors are selected so that the rising threshold is around 2/3 of the logic voltage amplitude and the falling threshold around 1/3 of the logic voltage amplitude. These threshold levels allow the driver to be immune to ground-bounce noise, especially in the high-side configuration. Something to note is that these thresholds are measured before the TDI resistors, not at the IN+/IN- pins. Table 2 shows the typical values of the logic threshold voltages for an input logic voltage of 3.3V.

Table 2 Typical values of input logic thresholds for $V_{IN\text{-}logic}$=3.3V

Parameter	Value typ. (V)	R_{in} (kΩ)
V_{IHD} Differential input logic threshold for turn on	2.0	47
V_{ILD} Differential input logic threshold for turn off	1.3	47

Once the values of the TDI resistors are established, the user needs to verify that the TDI resistors are rated for the correct amount of power as they will dissipate power during high-side operation. The power rating can be calculated with Equation 1

$$P = \frac{V_{bus,max}^2}{R_{in}} \cdot D$$

Equation 1 Power rating of TDI resistors

Where,

- R_{in} is the TDI resistor
- $V_{CMR,max}$ is the maximum common-mode voltage
- I_{SNK} is the sinking current at IN+/IN- pins when the driver is sourcing current in high-side operation
- $V_{bus,max}$is the maximum bus voltage of the half-bridge

For power dissipation, it is important to consider the duty cycle D at the maximum bus voltage $V_{bus,max}$. Table 3 lists some examples for selecting the input resistors, based on logic voltage level, maximum DC bus voltage and duty cycle. For most applications, the power requirement is quite low, thereby allowing the designer to select very small resistor packages such as 0402 or 0603.

Table 3 Power dissipation for selected input resistors

Maximum DC bus voltage (V)	Logic voltage (V)	Duty ratio	TDI input resistance (kΩ)	Resistor tolerance (%)	Power dissipation (mW)
60	3.3	0.25	47	0.1	20
	5	0.25	75	0.1	10
80	3.3	0.25	47	0.1	100
	5	0.25	75	0.1	60

2.1.2 IN+/IN- negative voltage

During high-side operation, V_{CMR} generates a negative voltage at IN+/IN- with respect to VSS. The TDI resistor in series with an internal resistor at IN+/IN- pins form a resistor divider with V_{CMR} in series with the input logic voltage as shown in Figure 2.

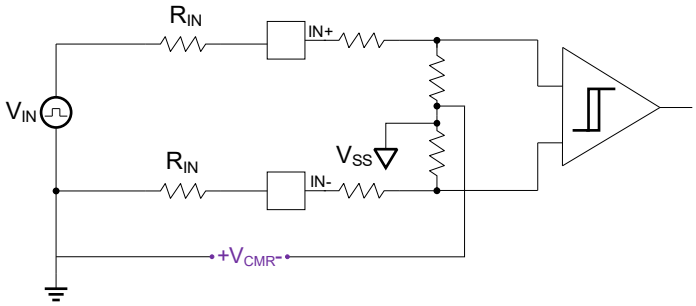


Figure 2 Common-mode voltage across IN+/IN- pins during high side operation

For this reason, the absolute max ratings in the RIC70115 Datasheet show a negative voltage as shown in Table 4. The negative voltage was calculated considering a minimum V_{CMR} of -150 V DC and a maximum value of 10 V DC.

Table 4 Min and Max values at IN+/IN- pins

Parameter	Min	Max	Note
V_{IN} IN+/IN- pins voltage	-6.5 V	0.3 V	Referenced to VSS

2.2 Low-side operation

TDI resistors are also needed in low-side operation. For low-side operation, TDI resistors provide enhanced noise immunity from ground-bounce during switching transitions. This is especially true for GaN HEMTs, as they switch at potentially higher switching frequencies, generating higher dV/dt at the switching node.

Due to the parasitic inductance coming from the PCB layout, the connection between the return of the controller and the return of the gate driver could experience ground-bounce. This ground bounce could generate an unwanted voltage potential between the input of the controller and the ground reference, which could potentially induce false turn on. Compared to traditional low-side drivers, RIC70115 is not connected directly to

IN+/IN- pins but instead are connected through the TDI resistors which block any unwanted voltage potential coming from ground bounce.

Figure 3 shows a comparison between a traditional gate driver and RIC70115.

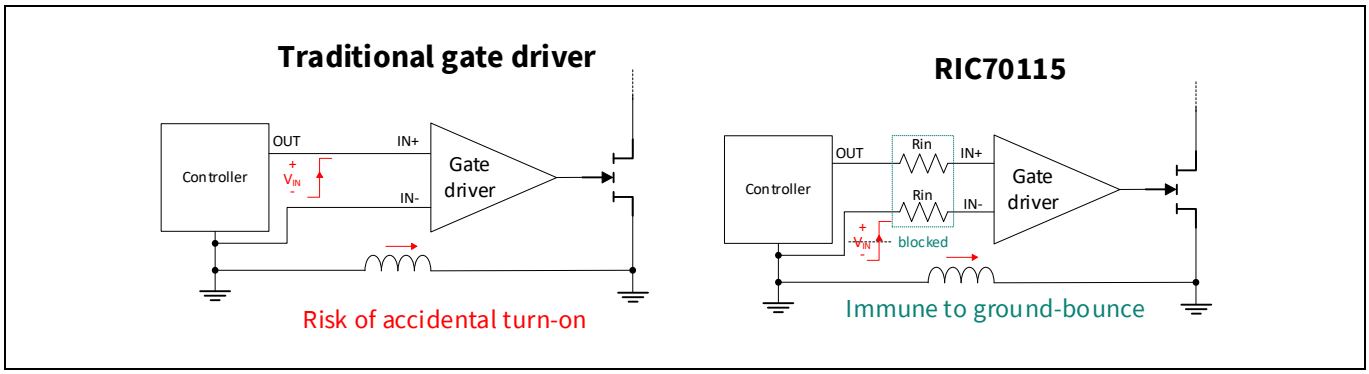


Figure 3 Enhanced noise immunity using TDI resistors in low-side configuration

2.3 Typical application - Half-bridge

Bridge converters are commonly used as Intermediate Bus Converters (IBC) within a satellite power system in applications such as motor-drives and DC-AC inverters. Common bridge power topologies include the synchronous buck, half-bridge, LLC and full bridge converters. RIC70115 can be used to drive the low-side and high-side of a half-bridge using GaN HEMT or LL Si MOSFET. Its immunity to common mode voltage up to 150V DC makes it well suited for typical bus voltages of 28V or 100V. Figure 4 shows the schematic of a half-bridge using RIC70115

A bootstrap diode and capacitor is used to bias the high-side driver. When the low-side GaN HEMT is on, the bootstrap diode is forward biased and the VDD supply charges the bootstrap capacitor. When the low-side GaN HEMT is fully turned off, the bootstrap diode is reversed bias and the bootstrap capacitor discharges through VDD pin of the high-side driver delivering the energy needed to turn on the high-side GaN HEMT.

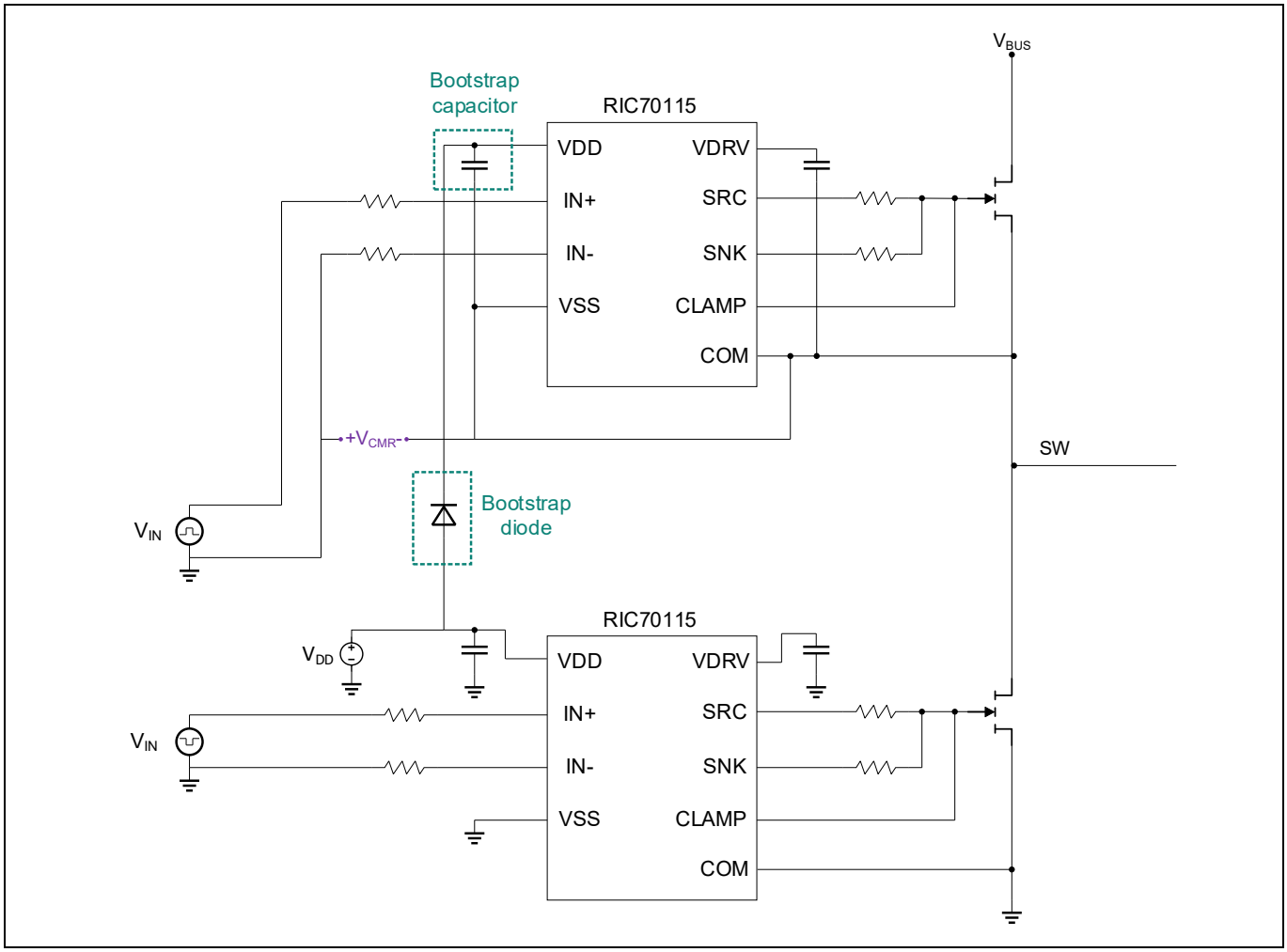


Figure 4 Half-bridge configuration using RIC70115 and GaN HEMT

2.3.1 Simulation analysis

Simulations were performed for a typical half-bridge configuration using RIC70115 gate driver and IG1NT052N10R 100V GaN HEMT Spice models. A typical 28V bus voltage is applied as the input voltage. 47kΩ TDI resistors are used to interface the 3.3V input logic signals and IN+/IN- pins of the driver. Figure 5 shows the schematic of a half-bridge converter in Simetrix. The RIC70115 SPICE model can be found in the RIC70115 product folder SPICE model.

Table 5 Half-bridge parameters

Parameter	Designator	Value
Input voltage	VIN	28V
Switching frequency	f_{sw}	500kHz
Input logic voltage	V_{pulse}	3.3V
TDI resistors	R1, R2, R4, R8	47kΩ
Low side driver bias voltage	V_{DD}	12V
High-side driver bias	D1, C1	Bootstrap diode, 100nF

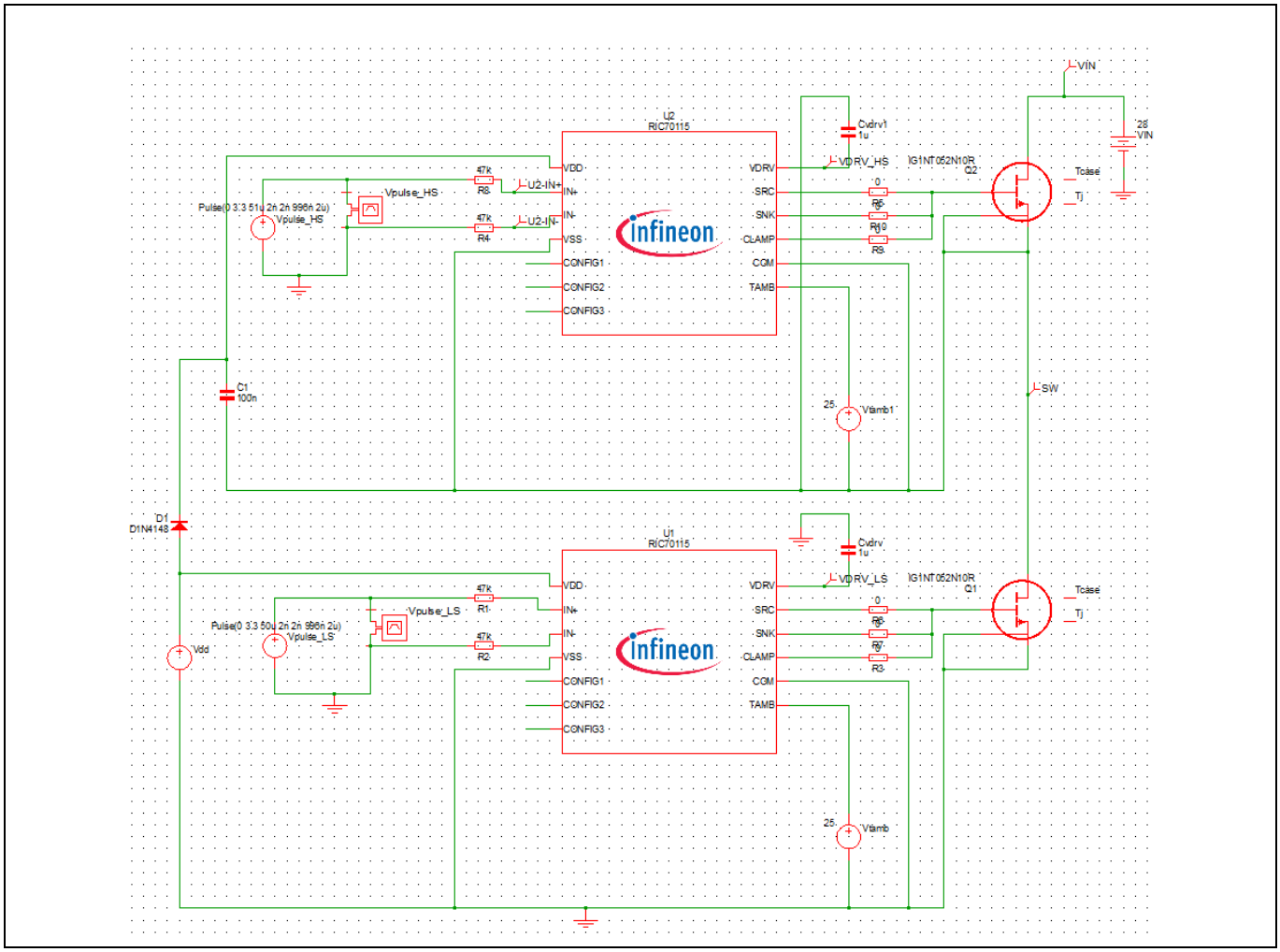


Figure 5 Schematic of a half-bridge in Simetrix

Figure 6 shows the simulations results in steady state. The voltages at IN+ and IN- pins of the high-side driver U2 are shown at the top of the figure. As can be observed, both waveforms are very similar in magnitude, this is because both pins have a common-mode voltage coming from the SW node during high-side operation. This common-mode voltage is blocked by the TDI resistors, allowing the driver to be controlled by the differential

signal provided by the input logic pulses. Therefore, these results show the common-mode voltage rejection performance of the driver during high-side operation.

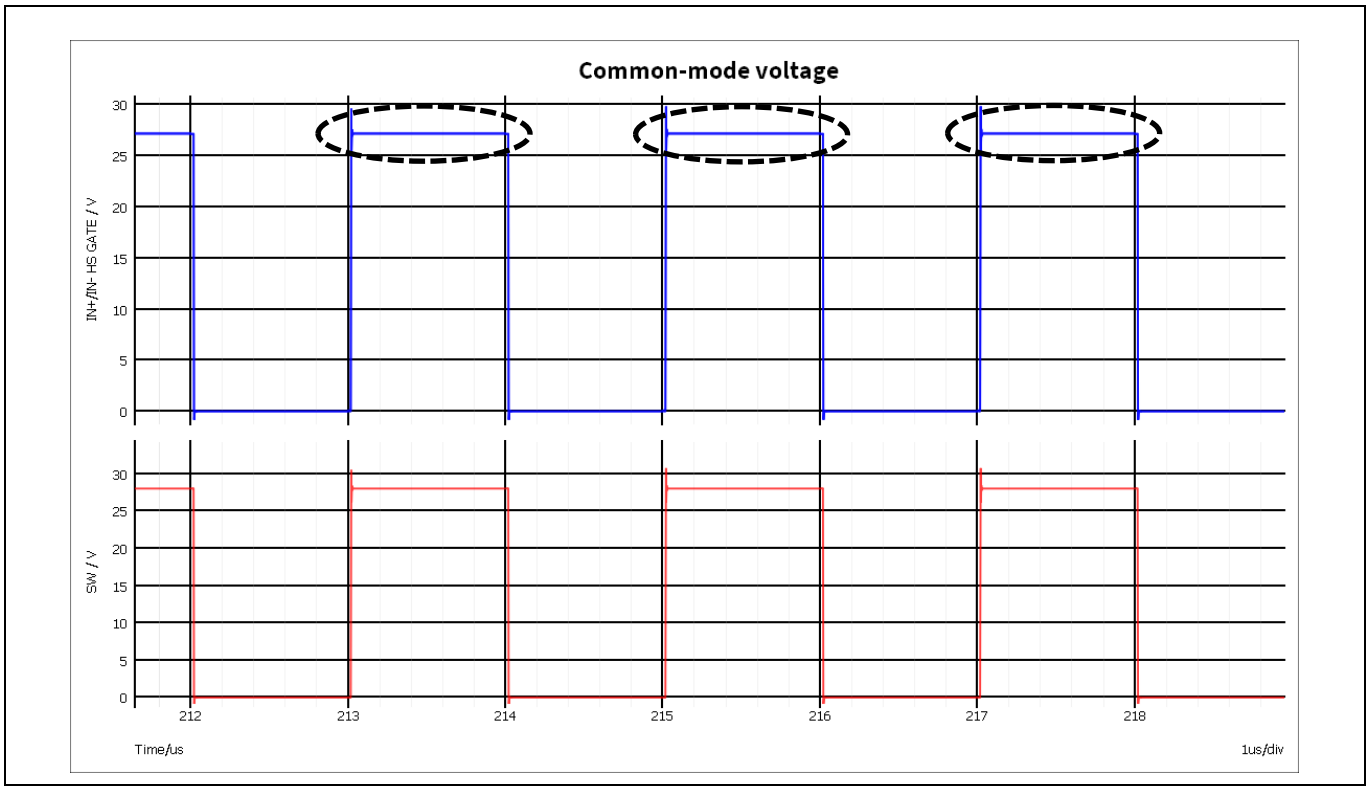


Figure 6 Simulation results of a Half-bridge in Simetrix

2.4 Typical application – Synchronous rectifier

Another interesting application for GaN drivers used in space applications is driving secondary-side, synchronous rectifiers. Figure 7 shows the schematic of a synchronous rectifier at the output of a forward converter.

As both GaN HEMT sources are connected to the ground reference of the secondary side, this simplifies the bias for both drivers as the VDD supply can be referenced to the same ground.

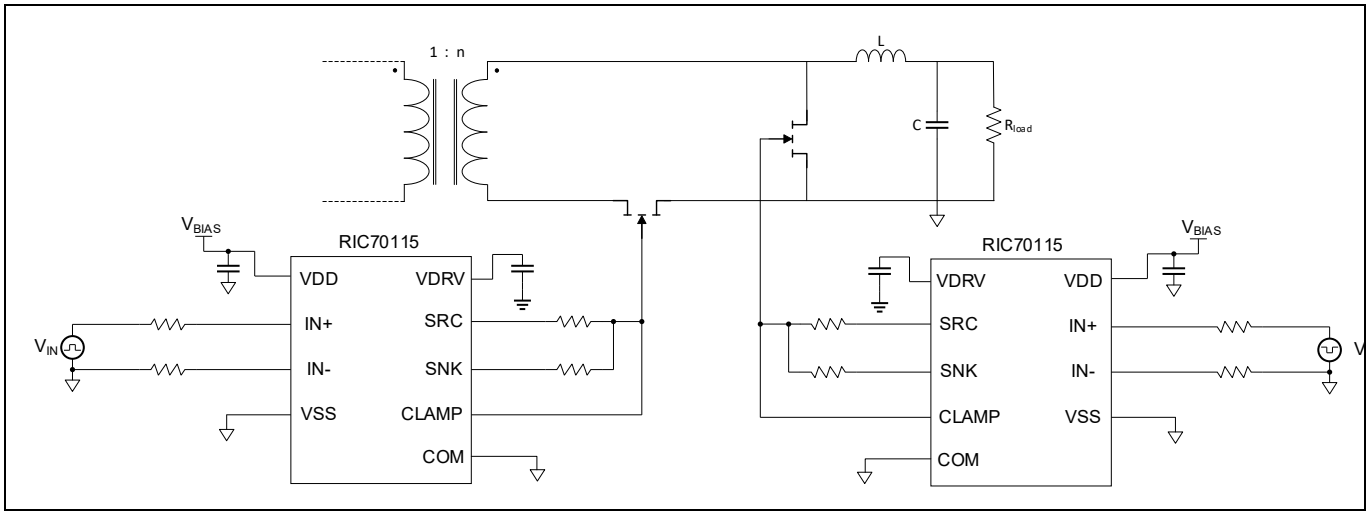


Figure 7 Synchronous rectifier at the output of a forward converter

3 Driver voltage

RIC70115 features a 4.8V driver voltage (VDRV). This voltage is tightly regulated by an integrated LDO whose input is the VDD supply. 4.8V selection was based on a tradeoff between low conduction losses and gate reliability of a typical GaN HEMT such as IG1NT052N10R. This tradeoff is explained in detail in the two subsections below.

3.1 Conduction losses

VDRV pin has an under-voltage lockout (UVLO) rising and falling of 4.6V and 4.5V (typical values) respectively. VDRV UVLO rising prevents the driver from operating at any outputs lower than 4.6V to avoid high $R_{DS(on)}$ value that might lead to higher conduction losses. Furthermore, VDRV UVLO falling prevents the driver from operating in the case of an overload condition.

It is well known that GaN HEMT have a typical driver voltage of 5V. However, a slightly lower value of 4.8V was selected to improve gate reliability performance. Figure 8 shows the $R_{DS(on)}$ of IG1NT052N10R GaN HEMT. At V_{GS}=4.8V, it is seen that $R_{DS(on)}$ does not change for different temperatures and have very similar values compared to V_{GS}=5V. This allows RIC70115 to drive at 4.8V without compromising conduction losses.

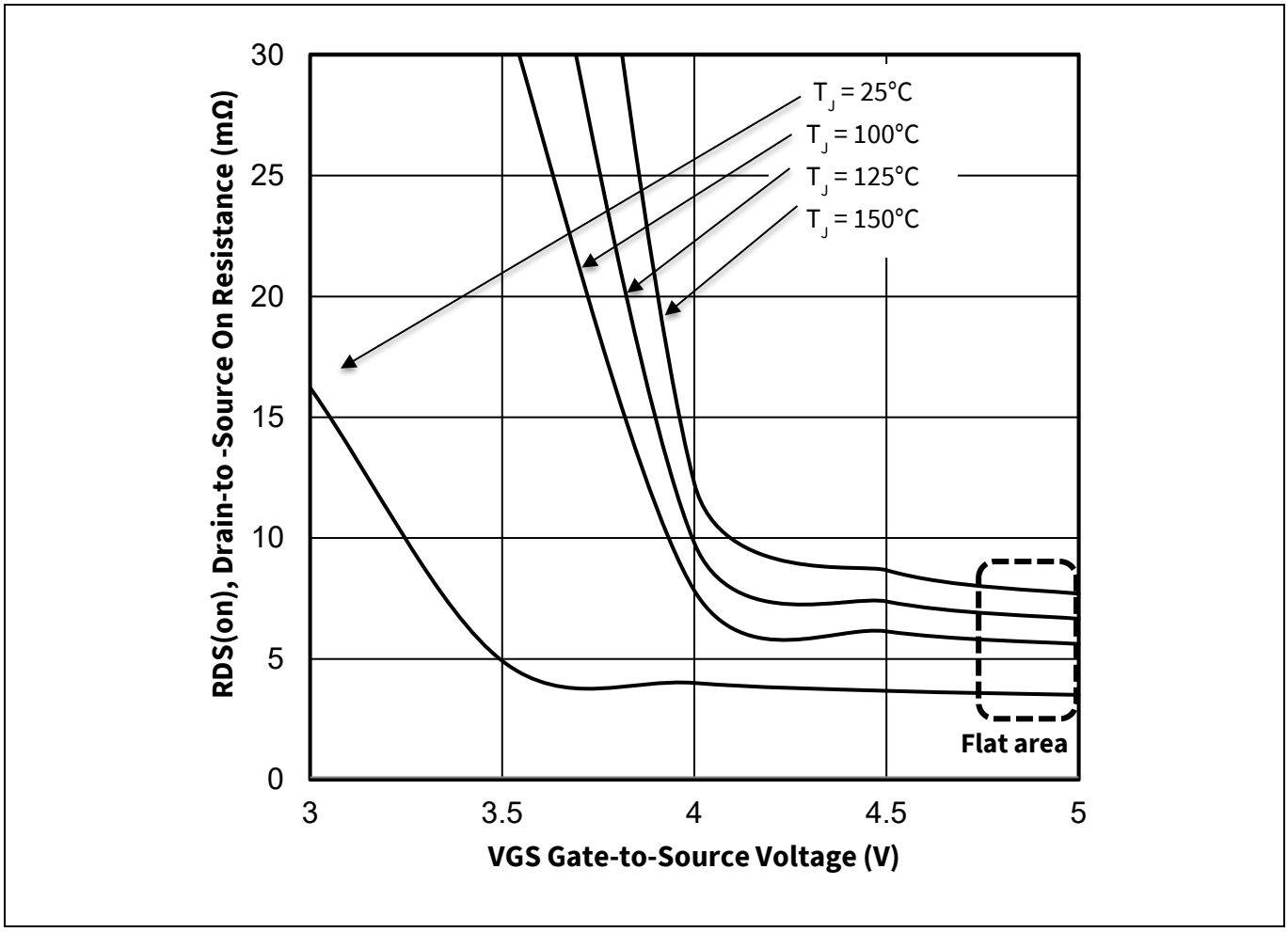


Figure 8 $R_{DS(on)}$ vs. V_{GS} for IG1NT052N10R GaN HEMT

3.2 Reliability

GaN HEMT used in space applications must meet stringent reliability requirements for typical GEO satellite orbit or any mission profiles. To meet these requirements, a good understanding of the failure mechanisms and failure rates is needed. Currently, most of the commercially available GaN HEMT devices are manufactured on a Si substrate. This type of GaN HEMT has inherent material lifetime degradation that causes intrinsic failures. Another failure type are extrinsic failures, which are caused by factors such as manufacturing process, contamination, packaging defects and electrostatic discharge (ESD), among others.

Figure 9 shows the Weibull distribution of IG1NT052N10R GaN HEMT for intrinsic and extrinsic distributions at V_{GS}=5V. On the other hand, Figure 10 shows the Weibull distribution of the same device but at V_{GS}=4.8V. The test conditions are shown in Table 6. Both cases have both branches below the target area but for V_{GS}=4.8V case, the extrinsic branch has lower ppm than V_{GS}=5V. These results are summarized in Table 7.

Table 6 Test conditions for Gate Reliability of IG1NT052N10R

Test conditions	Value
Transient peak V_{GS}	5.5V
Effective temperature	25°C
Sample size (intrinsic branch)	Few hundred devices from 3 qualification wafer lots
Sample size (extrinsic branch)	~65,000 devices

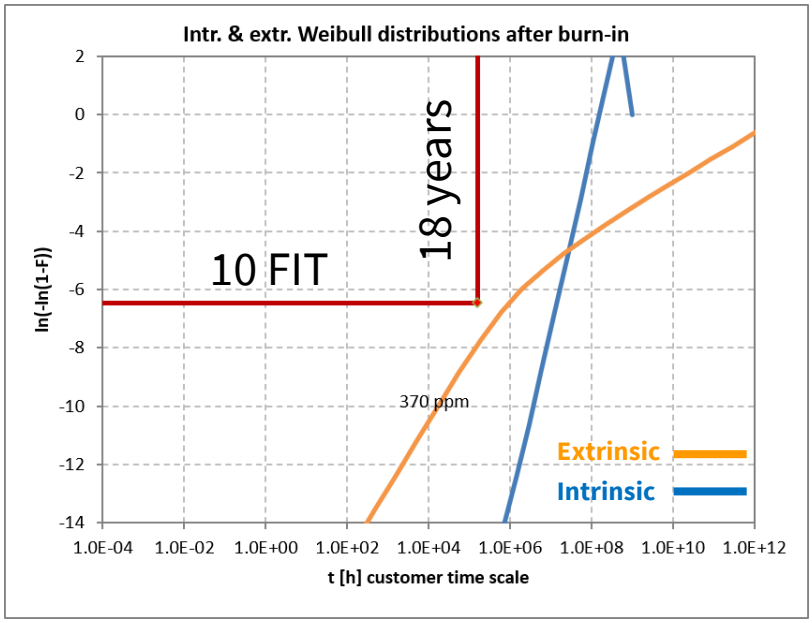


Figure 9 Gate reliability results at V_{GS}=5V for IG1NT052N10R GaN HEMT for GEO profile mission

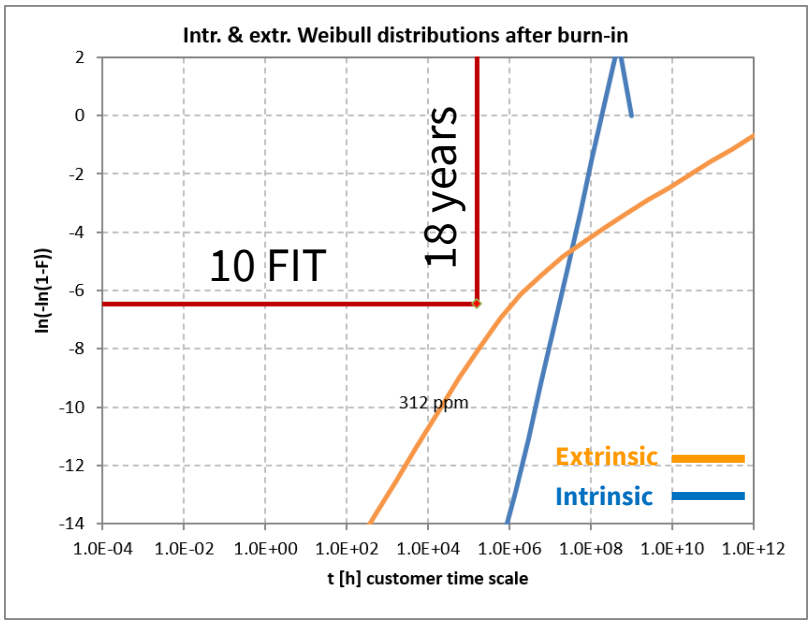


Figure 10 Gate reliability at V_{GS}=4.8V results for IG1NT052N10R GaN HEMT for GEO profile mission

Table 7 Gate Reliability results for IG1NT052N10R GaN HEMT

V_{GS} voltage	Extrinsic branch
4.8V	370 ppm
5V	312 ppm

4 Miller clamp

RIC70115 features a Miller Clamp (MC) function that improves the gate driver robustness from experiencing an induced false turn-on. Higher power demand in a satellite system leads to higher bus voltages and higher switching frequencies. These two factors increase significantly the dV/dt at the switching node, which generates a transient current through the capacitive divider formed by the internal C_{gd} and C_{gs} capacitors in the low-side FET and can generate a potential at the gate voltage which if not accounted for, can induce a false turn-on. This is especially true for GaN HEMT which compared to Si MOSFET can switch at higher frequencies.

The MC prevents this by providing low impedance at the gate once the gate reaches a threshold voltage of 0.8V (typ.) when the FET is turning off. Figure 11 shows the current sink path during the turn-off time of the FET.

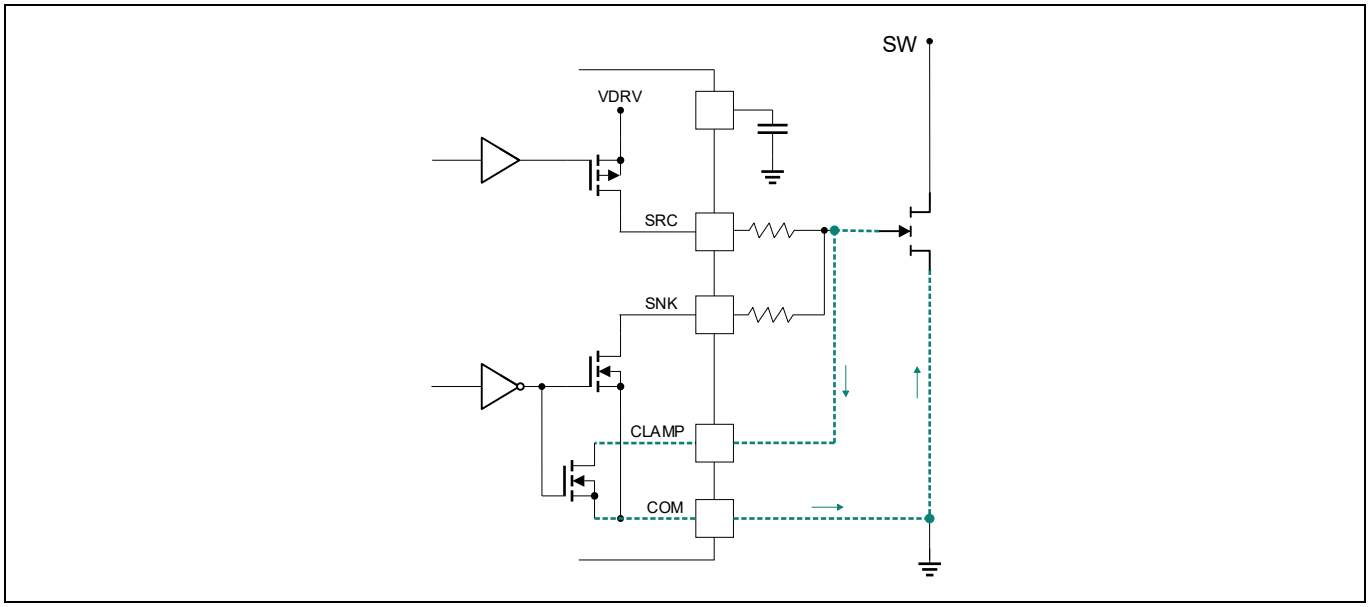


Figure 11 Miller Clamp loop using RIC70115

4.1 Implementation results

The evaluation board of RIC70115 was utilized to test the MC. RIC70849EVAL1 is a half-bridge that uses two RIC70115 gate drivers and two IG1NT052N10R GaN HEMT in an open loop configuration. A dead time generator circuit was utilized to generate complementary PWM control signals. The system parameters of the simulation are shown in Table 8 and the schematic is shown in Figure 12.

Table 8 System parameters of a Half-bridge

Parameter	Value
V_{BUS}	80V
f_{sw}	500kHz
Low and high side switches	IG1NT052N10R
Low and high side drivers	RIC70115
V_{DD} supply for drivers	5V
V_{BUS}	80V

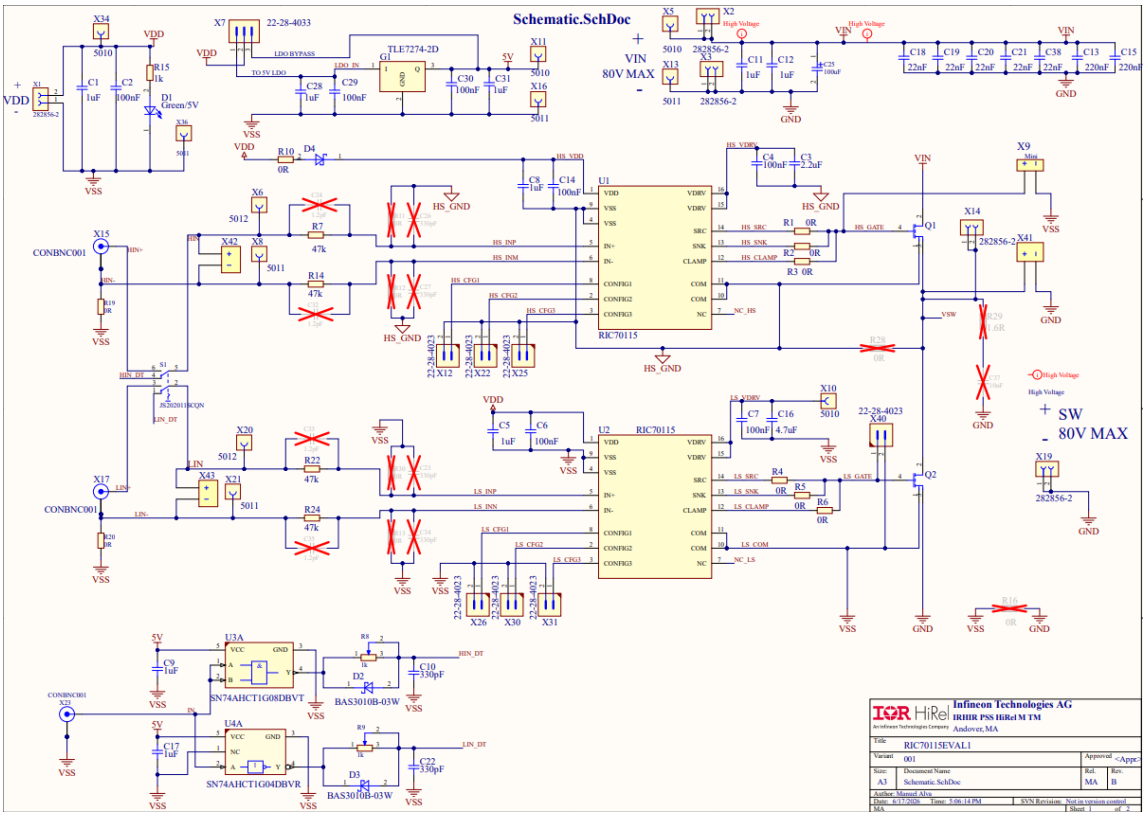


Figure 12 Schematic of RIC70115EVAL1

Two cases were analyzed. The first case is presented in Figure 13 where the MC pin of the low-side driver is not connected and a second case is presented in Figure 14 where it is connected. Both cases were tested with the same system parameters shown in Table 8. As shown, the gate-to-source voltage is below the threshold of IG1NT052N10R (1.5V typ.) when the MC pin is connected to the gate. On the other hand, the gate-to-source voltage is above the threshold when the MC pin is not connected. Table 9 shows the values for both cases.

Table 9 V_{GS} voltage of low-side driver with and without MC

Low-side driver MC pin	V_{GS} voltage during switching transition
Not connected	2.24V
Connected to gate	1.32V

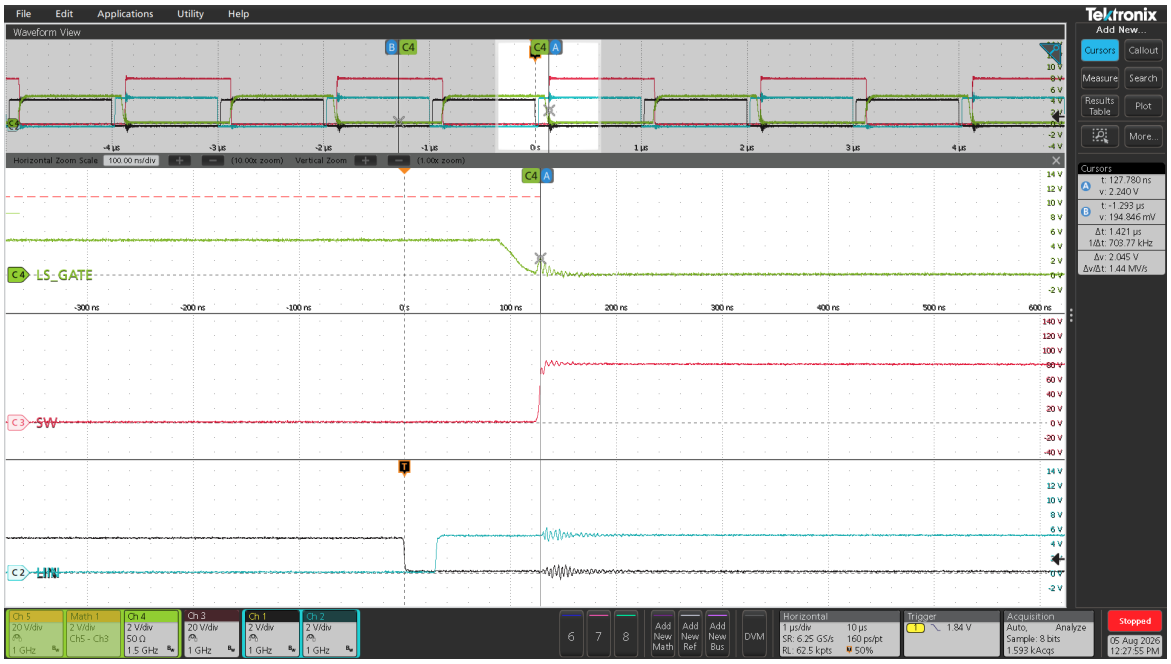


Figure 13 V_{GS} voltage for low-side driver with MC disconnected

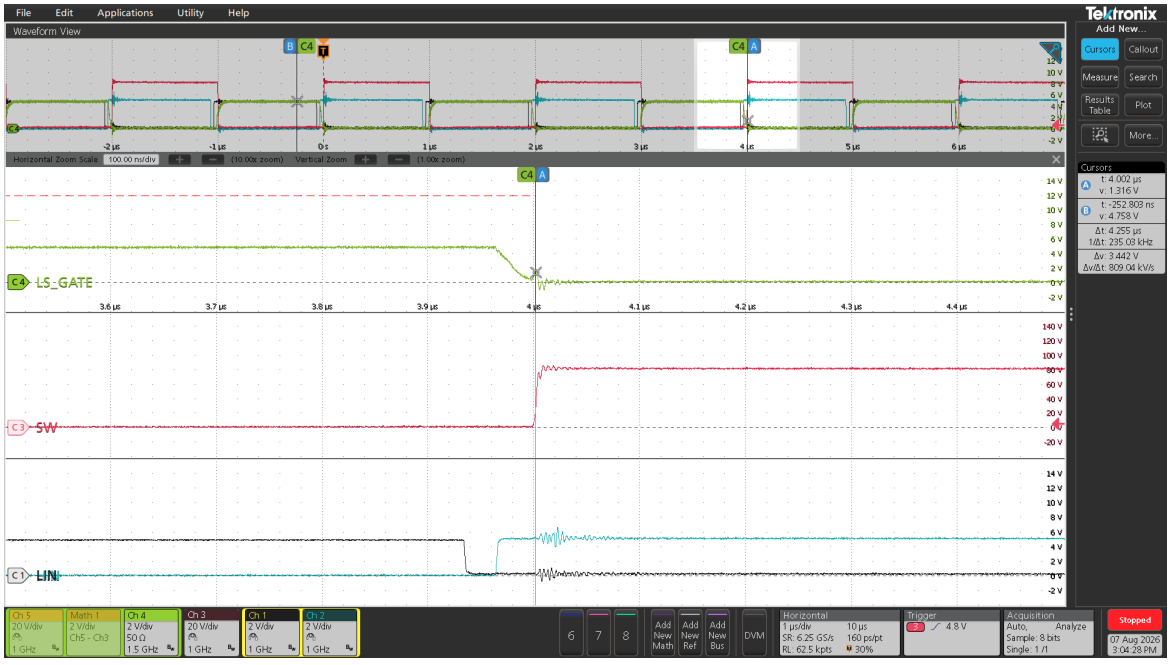


Figure 14 V_{GS} voltage for low-side driver with MC pin connected

5 Split outputs

RIC70115 features split outputs at SRC and SNK pins which allow the user to tune the turn-on and turn-off speeds of the power switches independently. This is especially beneficial for high-frequency and high-voltage applications where the dV/dt at the switching node is very high, causing possible EMI challenges. To prevent this, the turn-on speed should be slowed down increasing the gate driver resistor at SRC pin while the turn-off speed can be maximized to prevent a shoot-through.

For an optimal selection of the gate driver resistor, a good tradeoff between EMI and switching losses must be considered. At higher values, the switching speed is decreased but the switching losses will increase as the miller plateau time increases. On the other hand, at lower values, the switching losses are minimized but the switching speed could cause excessive ringing at the switching node.

Figure 15 shows the turn-on and turn-off paths in RIC70115 in a low-side configuration.

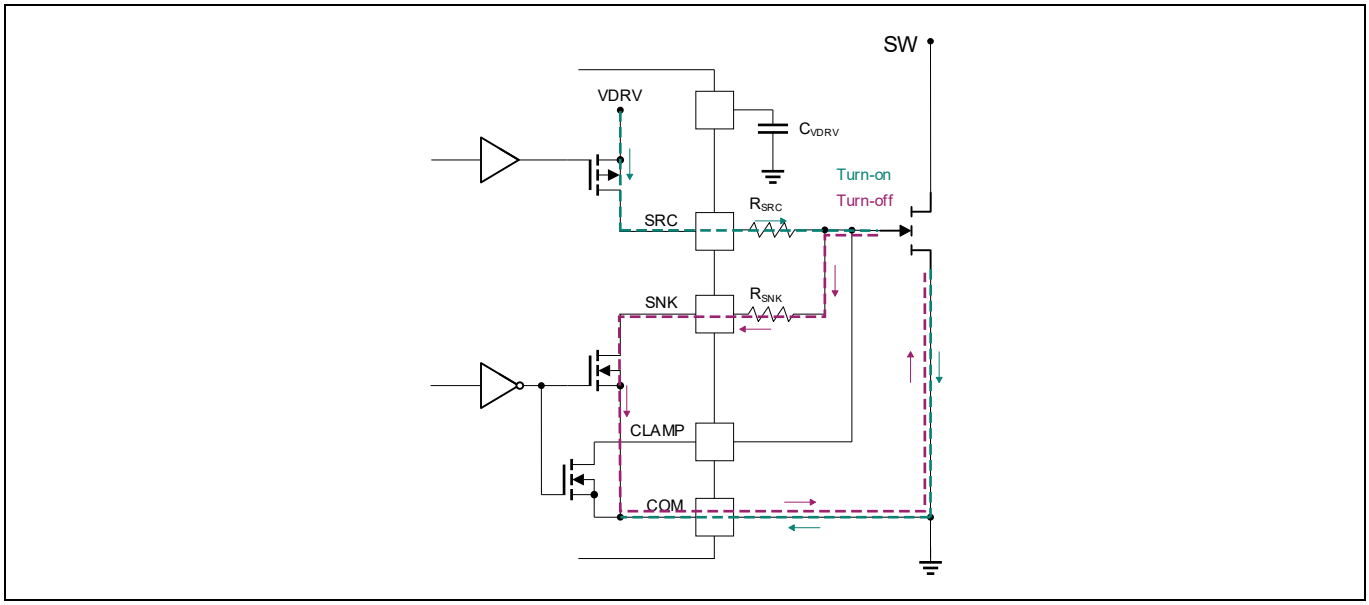


Figure 15 Turn-on and turn-off paths during switching transitions

6 Programmable blanking time

RIC70115 features programmable blanking time that can be configured using the CONFIG pins. Blanking time is an internal delay during which the driver ignores any input differential signal that could occur during the switching transitions. During these switching transitions, noise coming from the high dv/dt of the switching node could couple into the controller signal causing a false turn-on. This is prevented by delaying the output during the blanking time interval. Therefore, any noise whose time length is shorter than the configured blanking time will be ignored by the driver.

Figure 16 shows the propagation delay during the turn-on and turn-off transitions. The propagation delay will be always higher than the blanking time as it captures the natural delay of the internal circuits aside from the blanking time.

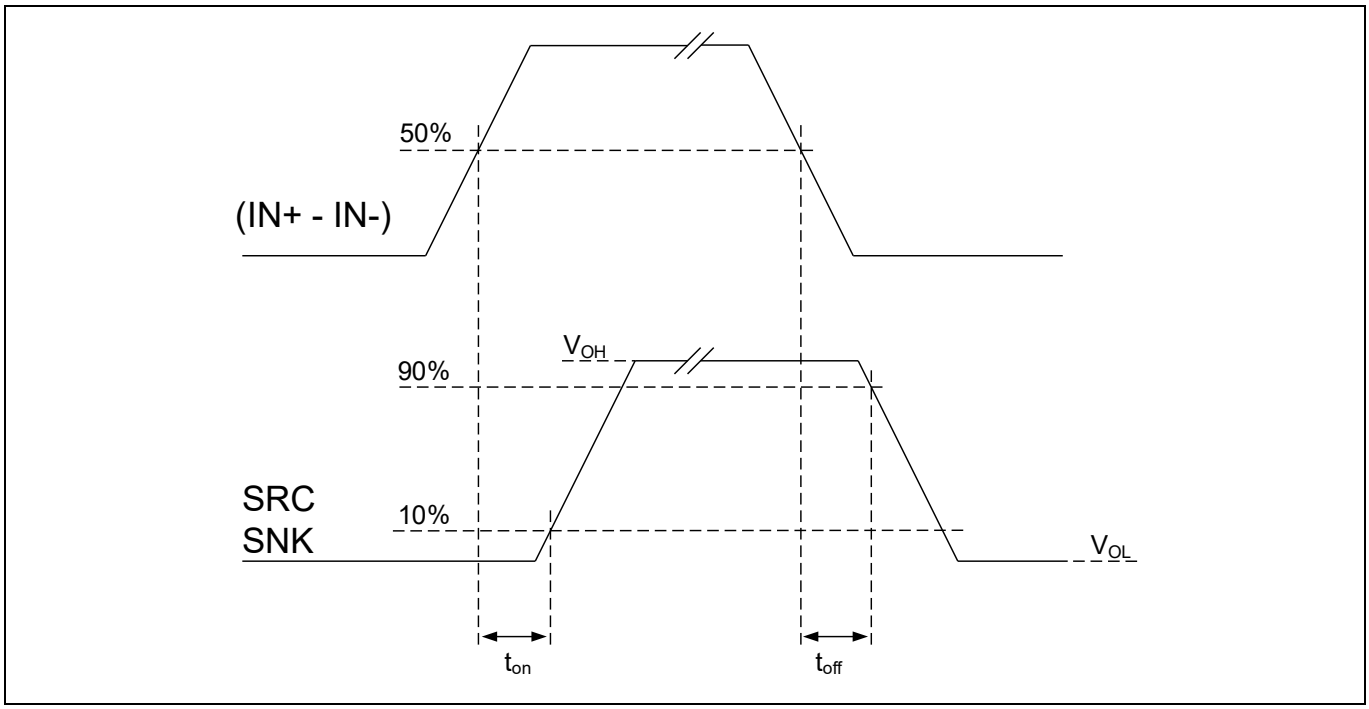


Figure 16 Turn-on and turn-off propagation delay

Table 10 shows the different blanking time values that the driver can be configured.

Table 10 Blanking time based on CONFIG pins settings

CONFIG 3	CONFIG 2	CONFIG 1	Blanking time
Open	Open	Open	0 ns
Open	Open	VSS	20 ns
Open	VSS	Open	37 ns
Open	VSS	VSS	58 ns
VSS	Open	Open	77 ns
VSS	Open	VSS	97 ns
VSS	VSS	Open	116 ns
VSS	VSS	VSS	135 ns

7 Conclusion

As a summary, the following features of RIC70115 have been discussed.

- **Truly Differential Input:** enables high-side operation by blocking common mode voltage present at IN+/IN- pins and provides noise-immunity during low-side operation blocking ground bounce voltage during switching transitions.
- **Driver voltage:** tightly regulated 4.8V driver voltage provides low $R_{DS(on)}$ on GaN HEMT to lower conduction closes without compromising gate reliability.
- **Miller clamp:** provides low impedance at the gate of the power switch to prevent any induced turn-on coming from the charging of the miller plateau capacitor from the high dv/dt of the switching node.
- **Split outputs:** allows the user to control the turn-on and turn-off witching speeds independently so that the turn on can be slowed down while keeping a fast turn-off to prevent cross conduction.
- **Programmable blanking time:** prevents the driver from responding to any noisy input signals that could occur during switching transitions.

All these features optimize the electrical performance of GaN HEMTs while assuring high reliability for any mission profile. This makes RIC70115 ideal for space applications that require higher bus voltages, robust switching performance and high-power density that can meet market challenges that are coming from initiatives like SWaP-C.

References

[1] RIC70115G

[2] RIC70115EVAL1

Revision history

Document revision	Date	Description of changes
1.0	08/10/2026	Initial revision

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Edition 2026-08-10

Published by

Infineon Technologies AG

Am Campeon 1-15

85579 Neubiberg

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