



## GaNFast™ Power IC with GaNSense™ Technology

### 1. Features

#### GaNFast™ Power IC

- Monolithically-integrated gate drive
- Wide  $V_{CC}$  range (9 to 30 V)
- Programmable turn-on  $dV/dt$
- 200 V/ns  $dV/dt$  immunity
- 800 V Transient Voltage Rating
- 650 V Continuous Voltage Rating
- Low 45 mΩ resistance
- Zero reverse recovery charge
- 2 MHz operation

#### GaNSense™ Technology

- Integrated loss-less current sensing
- Short-circuit protection
- Over-temperature protection
- Autonomous low-current standby mode
- Auto-standby mode enable input
- Fault output

#### Small, low-profile SMT QFN

- 8 x 8 mm footprint, 0.85 mm profile
- Minimized package inductance
- Large cooling pad, low thermal resistance

#### Sustainability

- RoHS, Pb-free, REACH-compliant
- Up to 40% energy savings vs Si solutions
- System level 4kg CO<sub>2</sub> Carbon Footprint reduction

#### Product Reliability

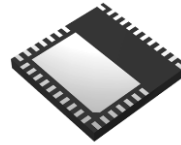
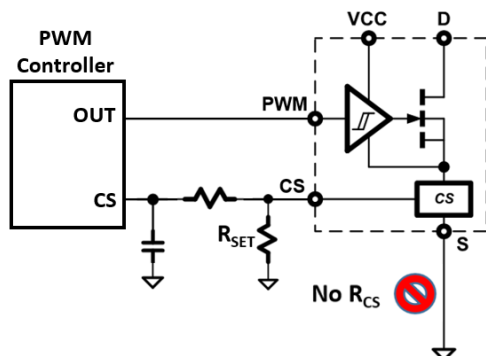
- 20-year limited product warranty  
(see Section 13 for details)

### 2. Topologies / Applications

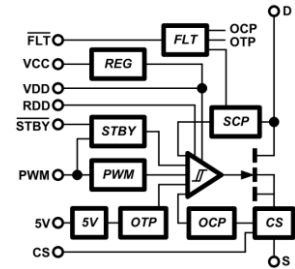
- AC-DC, DC-DC
- ACF, Buck, Boost, Half Bridge, Full Bridge, LLC resonant, Class D, PFC, Motor Drive
- TV SMPS
- Server, Telecom

### 4. Typical Application Circuits

#### Loss-less Current Sensing



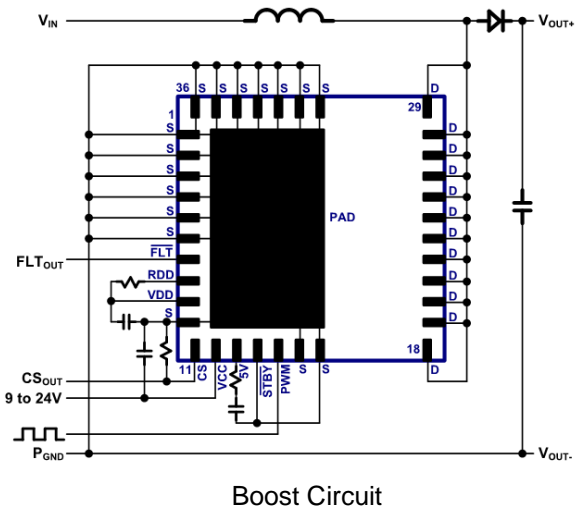
QFN 8 x 8 mm



Simplified schematic

### 3. Description

This GaNFast™ power IC integrates a high performance eMode GaN FET with integrated gate drive to achieve unprecedented high-frequency and high efficiency operation. GaNSense™ technology is also integrated which enables real-time, accurate sensing of voltage, current and temperature to further improve performance and robustness not achieved by any discrete GaN or discrete silicon device. GaNSense™ enables integrated loss-less current sensing which eliminates external current sensing resistors and increases system efficiency. GaNSense™ also enables short circuit and over-temperature protection to increase system robustness, while auto-standby mode increases light, tiny & no-load efficiency. These GaN ICs combine the highest  $dV/dt$  immunity, high-speed integrated drive and industry-standard low-profile, low-inductance, SMT QFN packaging to enable designers to achieve simple, quick and reliable solutions. Navitas' GaN IC technology extends the capabilities of traditional topologies such as boost, half-bridge, buck, LLC and other resonant converters to reach MHz+ frequencies with very high efficiencies and low EMI to achieve unprecedented power densities at a very attractive cost structure.



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## 6. Specifications

### 6.1. Absolute Maximum Ratings<sup>(1)</sup>

(with respect to Source (pad) unless noted)

SYMBOL	PARAMETER	MAX	UNITS
$V_{DS (CONT)}$	Drain-to-Source Voltage	-7 to +650	V
$V_{DS (TRAN)}$	Transient Drain-to-Source Voltage <sup>(2)</sup>	800	V
$V_{CC}$	Supply Voltage	30	V
$V_{DD}$	Drive Supply Voltage	7.2	V
$R_{DD}$	Input Voltage	7.2	V
$V_{STBY}$	Auto-Standby Mode Pin Voltage	-0.6 to +20 or $V_{CC}$	V
$V_{5V}$	5V Pin Voltage	5.6	V
$V_{PWM}$	PWM Input Pin Voltage	-0.6 to +20 or $V_{CC}$	V
$V_{CS}$	CS Pin Voltage	5.6	V
$V_{FLT}$	FLT Pin Voltage	5.6	V
$I_D$	Continuous Drain Current (@ $T_C = 100^\circ\text{C}$ )	24	A
$I_D \text{ PULSE}$	Pulsed Drain Current (10 $\mu\text{s}$ @ $T_J = 25^\circ\text{C}$ )	66	A
$dV/dt$	Slew Rate	200	V/ns
$T_J$	Junction Temperature	-55 to 150	$^\circ\text{C}$
$T_{STOR}$	Storage Temperature	-55 to 150	$^\circ\text{C}$

(1) Absolute maximum ratings are stress ratings; devices subjected to stresses beyond these ratings may cause permanent damage.

(2)  $V_{DS (TRAN)}$  rating allows for surge ratings during non-repetitive events that are <100 $\mu\text{s}$  (for example start-up, line interruption).  $V_{DS (TRAN)}$  rating allows for repetitive events that are <300ns, with 80% derating required (for example repetitive leakage inductance spikes). Refer to Section 8.10 for detailed recommended design guidelines.

## 6.2. Recommended Operating Conditions<sup>(3)</sup>

SYMBOL	PARAMETER	MIN	TYP	MAX	UNITS
$V_{CC}$	Supply Voltage	9		24	V
$V_{PWM}$	PWM Input Pin Voltage	0	5	15 or $V_{CC}$	V
$V_{STBY}$	Auto-Standby Mode Pin Voltage	0	5	15 or $V_{CC}$	V
$R_{DD}$	Gate drive turn-on current set resistor	10	50		$\Omega$
$T_J$	Operating Junction Temperature	-40		125	°C

(3) Exposure to conditions beyond maximum recommended operating conditions for extended periods of time may affect device reliability.

## 6.3. ESD Ratings

SYMBOL	PARAMETER	MAX	UNITS
HBM	Human Body Model (per JESD22-A114)	2,000	V
CDM	Charged Device Model (per JESD22-C101F)	1,000	V

## 6.4. Thermal Resistance

SYMBOL	PARAMETER	TYP	UNITS
$R_{\theta JC}$	Junction-to-Case	0.62	°C/W
$R_{\theta JA}^{(4)}$	Junction-to-Ambient	37.89	°C/W

(4)  $R_{\theta JA}$  measured on DUT mounted on 40mm x 40mm epoxy FR4 PCB with 6.4mm<sup>2</sup> Cu area (1 layer 2 oz Cu)

## 6.5. Electrical Characteristics

Typical conditions:  $V_{DS}=400V$ ,  $V_{CC}=15V$ ,  $F_{SW}=1MHz$ ,  $T_{AMB}=25^{\circ}C$ ,  $I_D=17A$  (unless otherwise specified)

SYMBOL	PARAMETER	MIN	TYP	MAX	UNITS	CONDITIONS
<b>V<sub>CC</sub> &amp; V<sub>DD</sub> Supply Characteristics</b>						
$V_{CCUV+}$	V <sub>CC</sub> UVLO Rising Turn-On Threshold	8.15	8.5	8.9	V	
$V_{CCUV-}$	V <sub>CC</sub> UVLO falling Turn-OFF threshold		7.3		V	
$I_{QCC-STBY}$	V <sub>CC</sub> Standby Current		225		μA	$\overline{STBY} = 0V$ , $V_{PWM} = 0V$
$I_{QCC}$	V <sub>CC</sub> Quiescent Current		430	580	μA	$V_{PWM} = 0V$ , $\overline{STBY} = 5V$
$I_{QCC}$	V <sub>CC</sub> Operating Current		745		μA	$V_{PWM} = 5V$ , $V_{DS} = \text{Open}$
$I_{QCC-SW}$	V <sub>CC</sub> Operating Current		5.7		mA	$F_{SW} = 1MHz$ , $V_{DS} = \text{Open}$
$V_{DD}$	V <sub>DD</sub> Supply Voltage	6	6.4	6.6	V	$V_{CC} = 15V$ , $\overline{STBY} = 5V$
<b>5V Output (5V pin)</b>						
$V_{5V}$	5V Output Voltage	4.9	5.1	5.3	V	$V_{CC} = 15V$ , $\overline{STBY} = 5V$
<b>Input Logic Characteristics (PWM, <math>\overline{STBY}</math>)</b>						
$V_{LOGIC-H}$	Input Logic High Threshold (rising edge)		2.5	2.7	V	
$V_{LOGIC-L}$	Input Logic Low Threshold (falling edge)	1.1	1.2		V	
$V_{LOGIC-HYS}$	Input Logic Hysteresis		1.3		V	
<b>Switching Characteristics</b>						
$F_{SW}$	Switching Frequency			2	MHz	$R_{DD} = 10\Omega$
$t_{PW}$	Pulse width	20			ns	
$T_{ON}$	Turn-on Propagation Delay		22		ns	Fig 1
$T_{OFF}$	Turn-off Propagation Delay		13		ns	Fig 1
$T_R$	Drain rise time		6		ns	Fig 1
$T_F$	Drain fall time		14		ns	Fig 1

## 6.6. Electrical Characteristics (2, cont.)

Typical conditions:  $V_{DS}=400V$ ,  $V_{CC}=15V$ ,  $F_{SW}=1MHz$ ,  $T_{AMB}=25^{\circ}C$ ,  $I_D=17A$  (unless otherwise specified)

SYMBOL	PARAMETER	MIN	TYP	MAX	UNITS	CONDITIONS
<b>Current Sense Characteristics (CS pin)</b>						
$I_{CS}$	CS Pin Output Current	1.16	1.25	1.34	mA	$V_{PWM} = 5V$ , $I_{DS} = 17A$
Offset	CS Output Offset		+14		$\mu A$	$V_{PWM} = 5V$ , $I_{DS} = 0A$
$t_{CSDLY}$	CS Pin Delay (from $I_{DS}$ to $V_{CS}$ , at 10% rated current)		55		ns	$di/dt = 40A/\mu s$ , $R_{SET} = 400\Omega$ , $C_{CS} = 25pF$
<b>Over-Current Protection</b>						
$V_{OCP+}$	OCP detection threshold		1.9		V	$di/dt = 0.1A/\mu s$ , $R_{CS} = 800\Omega$ , measured at CS pin
<b>Standby Mode Characteristics</b>						
$t_{TO\_STBY}$	Time Out Delay to Enter Standby Mode		80		$\mu s$	$V_{PWM} = 0V$ , $\overline{STBY} = 0V$
$t_{ON\_FP}$	First Pulse Propagation Delay		20		ns	$V_{PWM} = 5V$ pulse, $\overline{STBY} = 0V$
<b>Over-Temperature Protection</b>						
$T_{OTP+}$	OTP Shutdown Threshold		165		$^{\circ}C$	
$T_{OTP\_HYS}$	OTP Restart Hysteresis		65		$^{\circ}C$	
<b>Short Circuit Protection (SCP)</b>						
$V_{SCP+}$	$V_{DS(ON)}$ short circuit detect threshold		12.5		V	$V_{CC}$ independent   $V_{PWM} = 5V$
$t_{SCP\_SDDL}$	Shut-Down delay (short circuit during operation)		21		ns	$R_{DD}$ independent
<b>General Fault Protection Characteristics</b>						
$t_{FLT\_BLANK}$	Fault blanking time		103		ns	
$t_{FLT\_SIS}$	S/D delay, Start-Up into O/C or S/C		133		ns	$R_{DD} = 1\Omega$
<b>Fault (FLTBAR) Pin Characteristics</b>						
$V_{OH}$	Output voltage high level		$V_{SV}$		V	No Fault detected OR Fault cleared
$V_{OL}$	Output voltage low level		0		V	Fault detected
$t_R$	Output voltage rise time		6		ns	$CL = 100pF$
$t_F$	Output voltage fall time		6		ns	$CL = 100pF$

## 6.7. Electrical Characteristics (3, cont.)

Typical conditions:  $V_{DS}=400V$ ,  $V_{CC}=15V$ ,  $F_{SW}=1MHz$ ,  $T_{AMB}=25^{\circ}C$ ,  $I_D=17A$  (unless otherwise specified)

SYMBOL	PARAMETER	MIN	TYP	MAX	UNITS	CONDITIONS
<b>GaN FET Characteristics</b>						
$I_{DSS}$	Drain-Source Leakage Current		2	45	$\mu A$	$V_{DS} = 650 V$ , $V_{PWM} = 0 V$
$I_{DSS}$	Drain-Source Leakage Current, $T_C = 150^{\circ}C$		36		$\mu A$	$V_{DS} = 650 V$ , $V_{PWM} = 0 V$ , $T_C = 150^{\circ}C$
$R_{DS(ON)}$	Drain-Source Resistance		45	55	$m\Omega$	$V_{PWM} = 5 V$ , $I_{DS} = 17 A$
$V_{SD}$	Source-Drain Reverse Voltage		3		V	$V_{PWM} = 0 V$ , $I_{SD} = 17 A$
$Q_{OSS}$	Output Charge		75		nC	
$Q_{RR}$	Reverse Recovery Charge		0		nC	
$C_{OSS}$	Output Capacitance		96		pF	$V_{DS} = 400 V$ , $V_{PWM} = 0 V$
$E_{OSS}$	Energy Stored in Output Capacitance		10		$\mu J$	$V_{DS} = 400 V$ , $V_{PWM} = 0 V$
$C_{O(er)}^{(Note\ 1)}$	Effective Output Capacitance, Energy Related		124		pF	$V_{DS} = 400 V$ , $V_{PWM} = 0 V$
$C_{O(tr)}^{(Note\ 2)}$	Effective Output Capacitance, Time Related		188		pF	$V_{DS} = 400 V$ , $V_{PWM} = 0 V$

(Note 1):  $C_{O(er)}$  is a fixed capacitance that gives the same stored energy as  $C_{OSS}$  while  $V_{DS}$  is rising from 0 to 400 V

(Note 2):  $C_{O(tr)}$  is a fixed capacitance that gives the same charging time as  $C_{OSS}$  while  $V_{DS}$  is rising from 0 to 400 V

## 6.8. Switching Waveforms

( $T_C = 25\text{ }^{\circ}\text{C}$  unless otherwise specified)

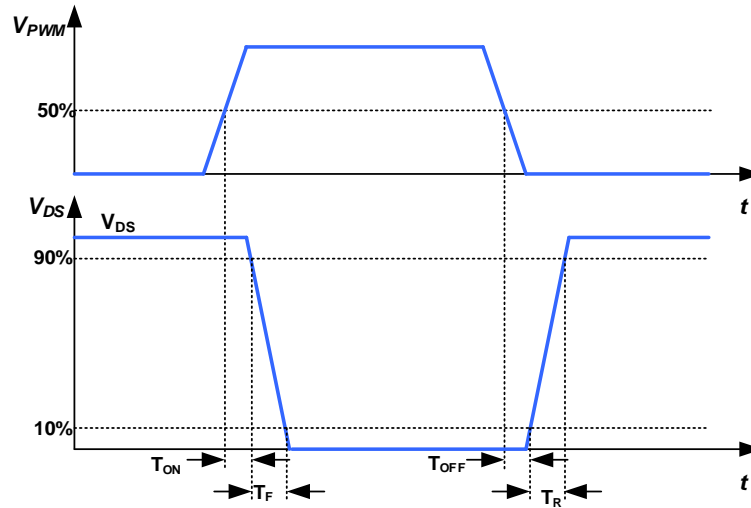


Fig. 1. Propagation Delay and Rise/Fall Time Definition



## 6.9. Characteristic Graphs

(GaN FET,  $T_c = 25^\circ\text{C}$  unless otherwise specified)

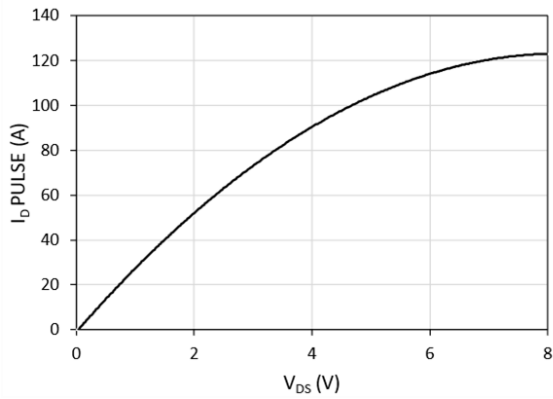


Fig. 2. Pulsed Drain current ( $I_D$  PULSE) vs. drain-to-source voltage ( $V_{DS}$ ) at  $T = 25^\circ\text{C}$

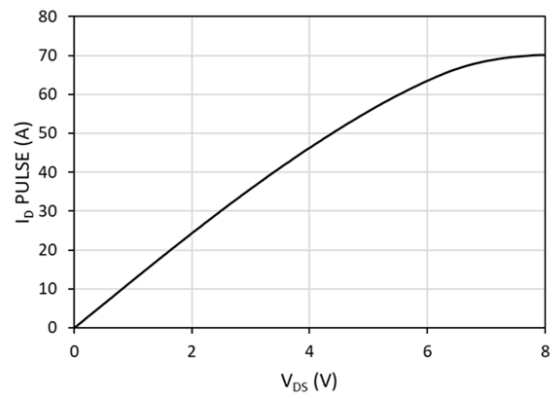


Fig. 3. Pulsed Drain current ( $I_D$  PULSE) vs. drain-to-source voltage ( $V_{DS}$ ) at  $T = 125^\circ\text{C}$

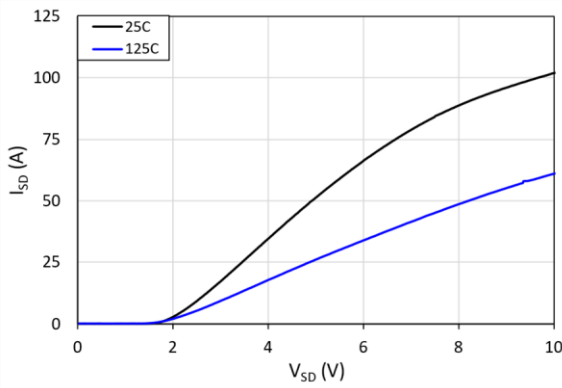


Fig. 4. Source-to-drain reverse conduction voltage

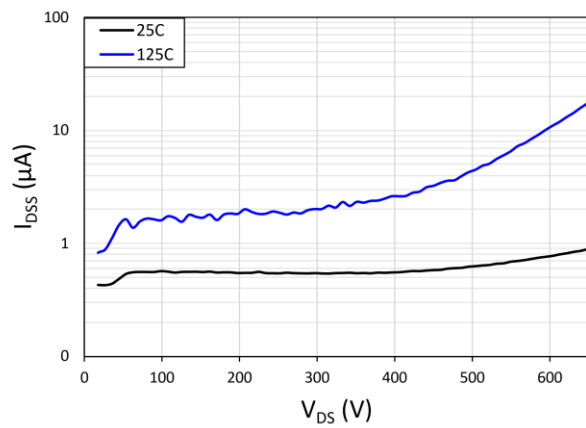


Fig. 5. Drain-to-source leakage current ( $I_{DSS}$ ) vs. drain-to-source voltage ( $V_{DS}$ )

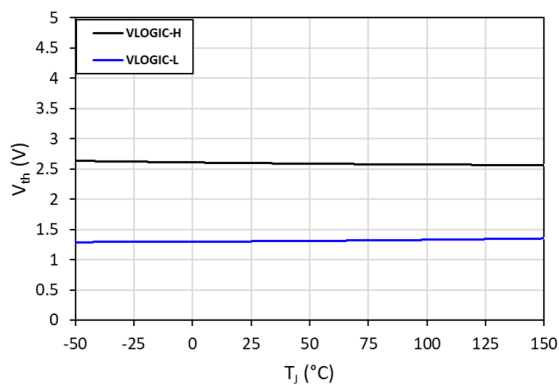


Fig. 6.  $V_{LOGIC-H}$  and  $V_{LOGIC-L}$  vs. junction temperature ( $T_J$ )

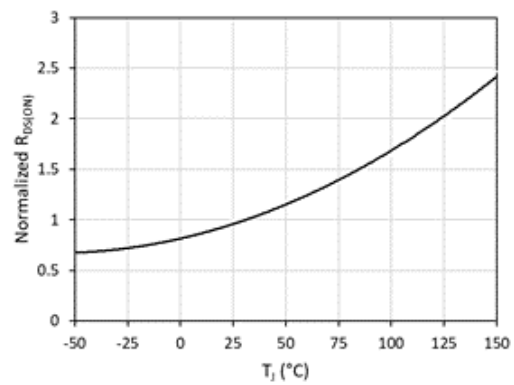


Fig. 7. Normalized on-resistance ( $R_{DS(ON)}$ ) vs. junction temperature ( $T_J$ )

## Characteristic Graphs (Cont.)

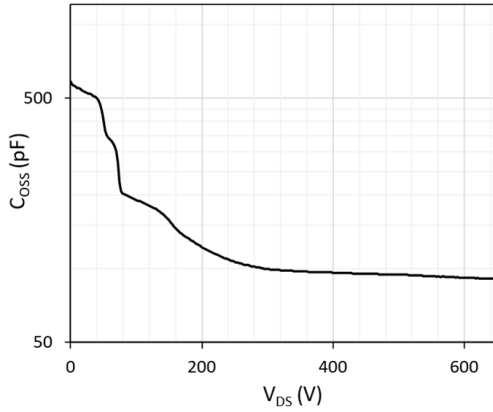


Fig. 8. Output capacitance ( $C_{OSS}$ ) vs. drain-to-source voltage ( $V_{DS}$ )

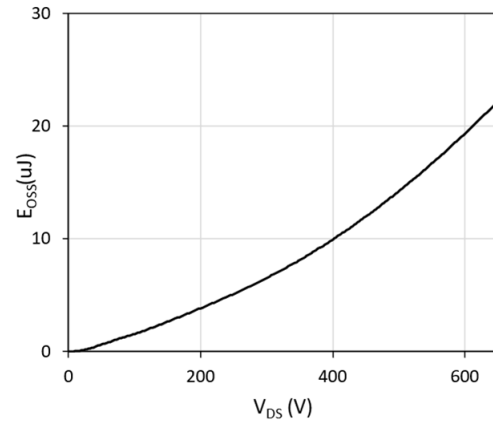


Fig. 9. Energy stored in output capacitance ( $E_{OSS}$ ) vs. drain-to-source voltage ( $V_{DS}$ )

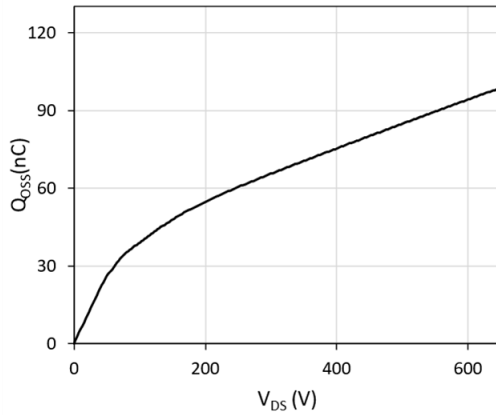


Fig. 10. Charge stored in output capacitance ( $Q_{OSS}$ ) vs. drain-to-source voltage ( $V_{DS}$ )

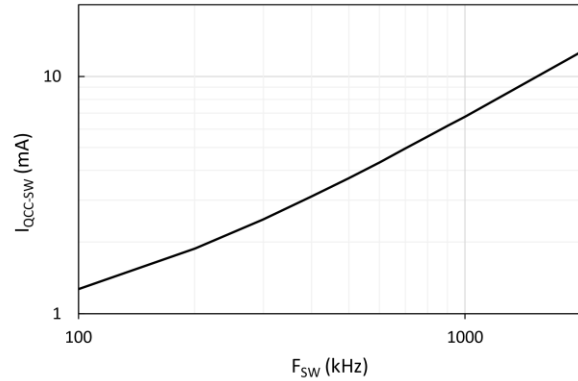


Fig. 11.  $V_{CC}$  operating current ( $I_{QCC-SW}$ ) vs. operating frequency ( $F_{SW}$ )

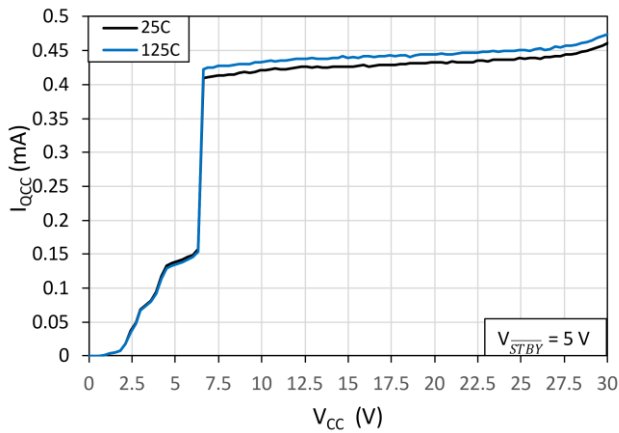


Fig. 12.  $V_{CC}$  quiescent current ( $I_{QCC}$ ) vs. supply voltage ( $V_{CC}$ )

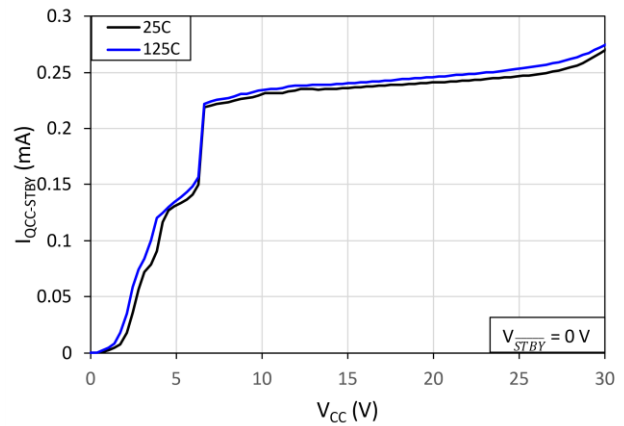


Fig. 13.  $V_{CC}$  stand-by quiescent current ( $I_{QCC}$ ) vs. supply voltage ( $V_{CC}$ )

## Characteristic Graphs (Cont.)

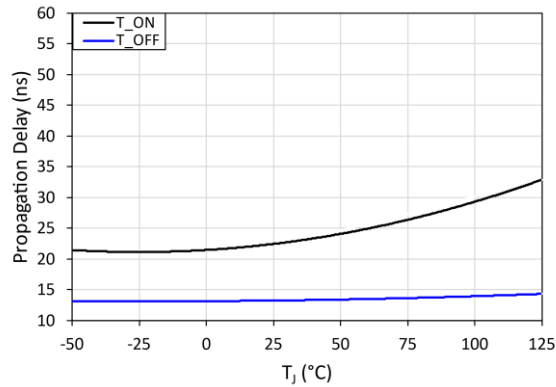


Fig. 14. Propagation delay ( $T_{ON}$  and  $T_{OFF}$ ) vs. junction temperature ( $T_J$ )

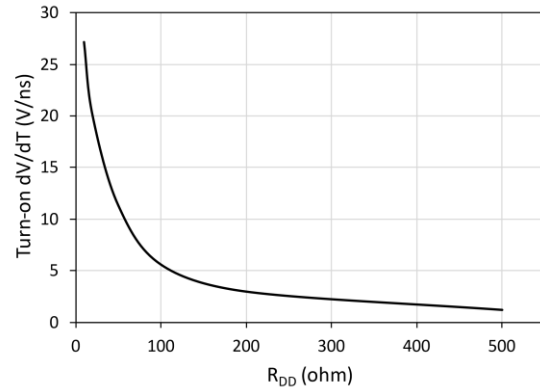


Fig. 15. Slew rate ( $dV/dt$ ) vs. gate drive turn-on current set resistance ( $R_{DD}$ ) at  $T = 25\text{ °C}$

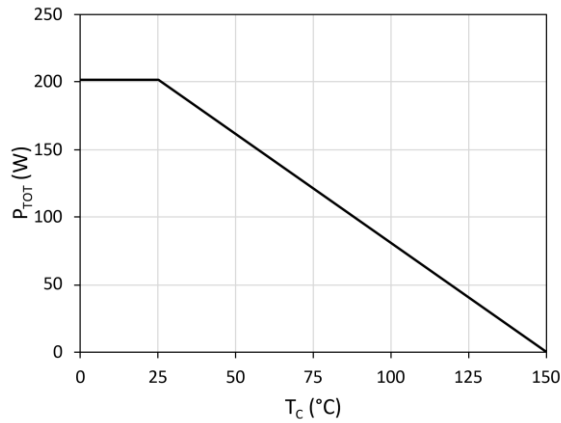


Fig. 16. Power dissipation ( $P_{TOT}$ ) vs. case temperature ( $T_C$ )

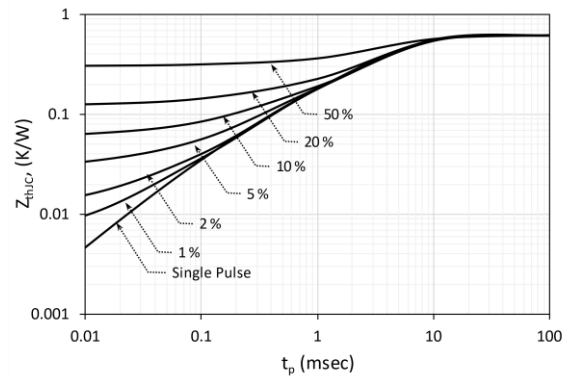


Fig. 17. Max. thermal transient impedance ( $Z_{thJC}$ ) vs. pulse width ( $t_p$ )

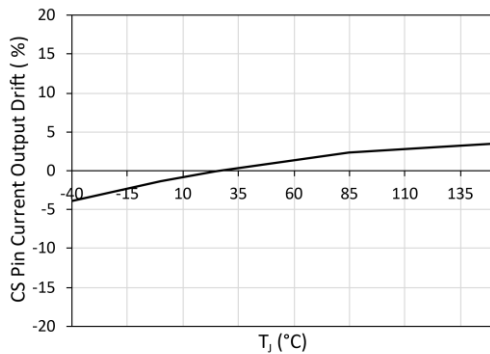


Fig. 18. CS Pin Current Output Drift vs. case temperature ( $T_C$ )

## 7. Pin Configurations and Functions

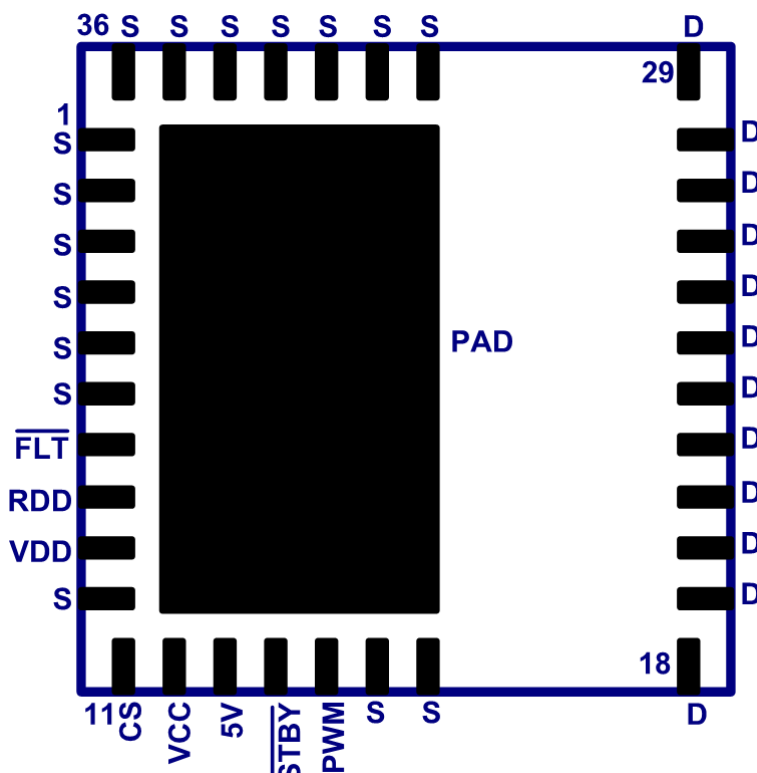


Fig. 19. Package Top View

Pin		I/O <sup>(1)</sup>	Description
Number	Symbol		
10, 17	S	G	Connect directly to Source PAD
9	V <sub>DD</sub>	O	Gate drive supply voltage
8	R <sub>DD</sub>	O	Gate drive turn-on current set pin (using R <sub>DD</sub> for dV/dt control)
11	CS	O	GaN FET I <sub>DS</sub> current sensing set pin. Internal current source and external resistor sets current measurement level. External resistor reference is Source..
13	5V	O	5V internal supply voltage. Connect 10 nF capacitor between 5V pin and Source.
18 - 29	D	P	Drain of power FET
12	V <sub>CC</sub>	P	IC supply voltage. Provided externally.
15	PWM	I	PWM input (wrt Source)
14	STBY	I	Auto-standby mode input. Connect to Source to enable auto-standby.
1 - 6, 16, 30 - 36, PAD	S	G	Source of power FET & IC supply ground. Metal PAD on bottom of package.
7	FLT	O	Fault output, will go from 5V to 0V during OCP, OTP, or ISAT fault conditions.

(5) I = Input, O = Output, P = Power, G = Ground

## 8. Functional Description

The following functional description contains additional information regarding the IC operating modes and pin functionality.

### 8.1. GaN Power IC Connections and Component Values

The typical connection diagram for this GaN Power IC is shown in Fig. 20. The IC pins include drain of the GaN power FET (D), source of the GaN power FET (S), IC supply ( $V_{CC}$ ), gate drive supply ( $V_{DD}$ ), gate drive turn-on control SET input ( $R_{DD}$ ), PWM input (PWM), Fault output (FLT), current sensing output (CS), auto-standby mode input ( $\overline{STBY}$ ), and a 5V supply (5V). The Source pad and Source pins (S) should all be connected to the system PGND. The Source pins (S) should each be connected externally to the Source pad directly underneath the IC. The Drain Pins (D) should all be shorted together in the PCB layout (see Section 9). The external components around the IC include  $V_{CC}$  filter capacitor ( $C_{VCC}$ ) connected between  $V_{CC}$  pin and S,  $V_{DD}$  filter capacitor ( $C_{VDD}$ ) connected between  $V_{DD}$  pin and S, turn-on dV/dt set resistor ( $R_{DD}$ ) connected in between  $V_{DD}$  pin and  $R_{DD}$  pin, a current sense amplitude set resistor ( $R_{SET}$ ) connected between CS pin and S, and auto-standby mode pin ( $\overline{STBY}$ ) connected to S. A series resistor ( $R_{5V}$ , 20 ohm) capacitor ( $C_{5V}$ , 0.01uF max) is required between pin 5V and S. This 5V pin is for internal purposes only and must not be used for biasing external circuitry.

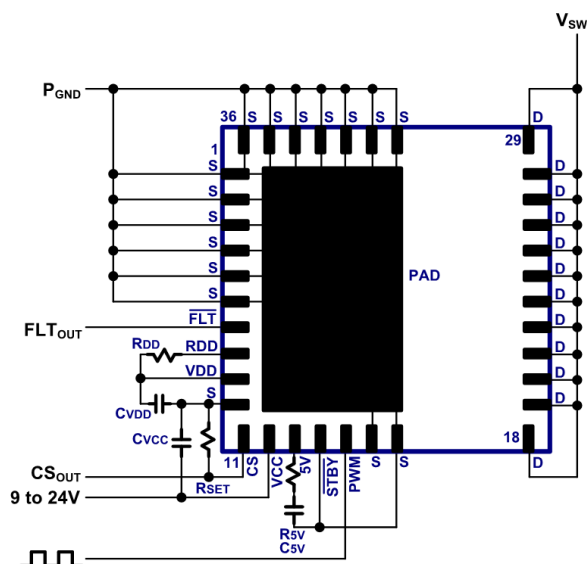


Fig. 20. IC connection diagram

The following table (Table I) shows the recommended component values (typical only) for the external components connected to the pins of this GaN power IC. These components should be placed as close as possible to the IC. Please see PCB Layout Guidelines for more information.

SYM	DESCRIPTION	TYP	UNITS
$C_{VCC}$	$V_{CC}$ supply capacitor	0.1	$\mu F$
$C_{VDD}$	$V_{DD}$ supply capacitor	0.010	$\mu F$
$R_{DD}$	Gate drive turn-on current set resistor	50	$\Omega$
$R_{SET}$	Current sense amplitude set resistor	Depends on system design (See Section 8.6 , Equation 1)	$\Omega$
$C_{5V}$	5V supply capacitor	10 (Max)	nF
$R_{5V}$	5V supply resistor	20	$\Omega$

Table I. Recommended component values (typical only).

## 8.2. UVLO Mode

This GaN Power IC includes under-voltage lockout (UVLO) circuits for properly disabling all of the internal circuitry when  $V_{CC}$  is below the  $V_{CCUV+}$  threshold (8.9V, typical) and  $V_{DD}$  is below the  $V_{DDUV+}$  threshold (5V, typical). During UVLO Mode, the internal gate drive and power FET are disabled and  $V_{CC}$  consumes a low quiescent current (240 $\mu$ A, typical). As the  $V_{CC}$  supply voltage increases (Fig. 21), the voltage at the  $V_{DD}$  pin also increases and exceeds  $V_{DDUV+}$ . The  $V_{DD}$  voltage continues to increase with  $V_{CC}$  until it gets limited to a constant voltage level (6.4V, typical) by the internal regulator. The  $V_{CC}$  voltage continues to increase until it exceeds  $V_{CCUV+}$  and the IC enters Normal Operating Mode. The gate drive is enabled and the control signal at the PWM input turns the internal GaN power FET on and off normally. During system power off, when  $V_{CC}$  decreases below the  $V_{CCUV-}$  threshold (7.6V, typical), the gate drive is disabled and the IC enters UVLO Mode.

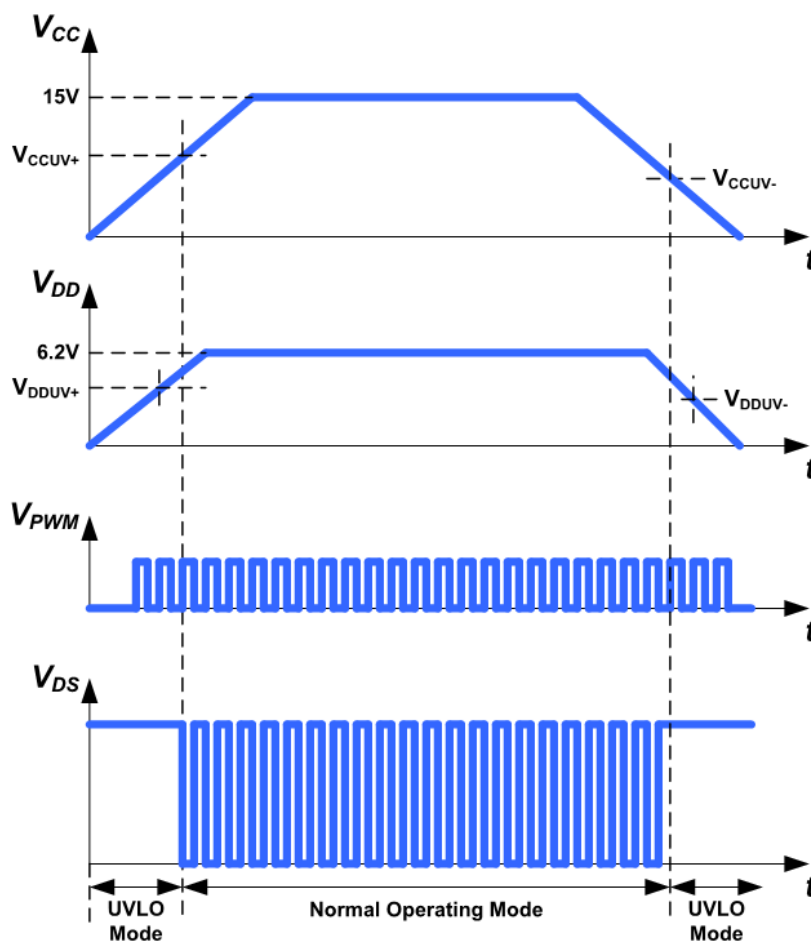


Fig. 21. UVLO Mode timing diagram

### 8.3. Normal Operating Mode

During Normal Operating Mode, all of the internal circuit blocks are active.  $V_{CC}$  is above 9V,  $V_{DD}$  is maintained at 6.4V by the internal voltage regulator, and the internal gate drive and power FET are both enabled. The external PWM signal at the PWM pin determines the frequency and duty-cycle of the internal gate of the power FET. As the PWM voltage toggles above and below the rising and falling input thresholds (2.6V and 1.1V), the internal power FET toggles on and off (Fig. 22). The drain of the power FET then toggles between the source voltage (power ground) and a higher voltage level (650V, max), depending on the external power conversion circuit topology. During each on-time, the CS pin outputs a voltage signal from the internal loss-less current sensing circuit. This circuit measures the current flowing in the GaN power FET without the need for an external current sensing resistor (see section 8.6 GaNSense Technology Loss-Less Current Sensing).

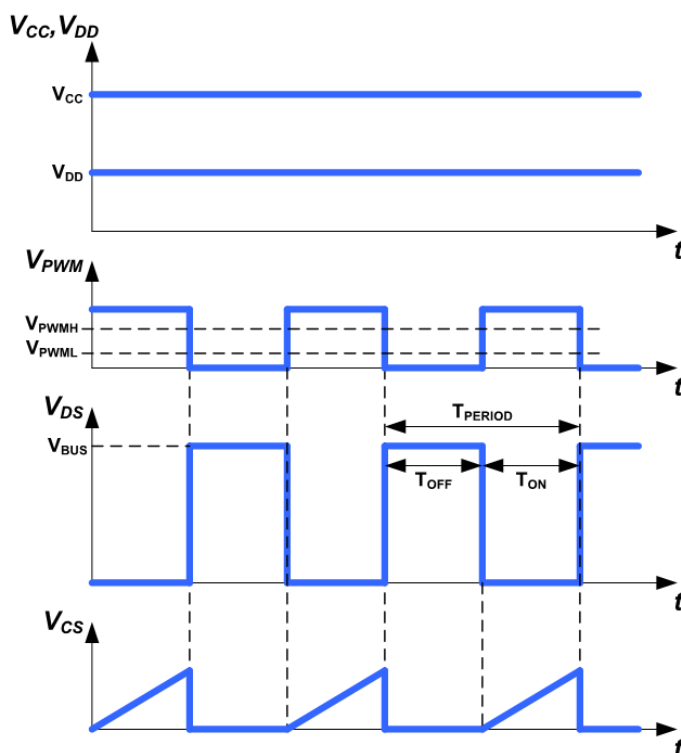


Fig. 22. Normal operating mode timing diagram

## 8.4. Low Power Standby Mode

This GaN Power IC includes an autonomous Low Power Standby Mode for disabling the IC and reducing the  $V_{CC}$  current consumption. During Normal Operating Mode, the PWM pin toggles high and low to turn the GaN power FET on and off. If the input pulses at the PWM pin stop and stay below the lower  $V_{PWML}$  turn-off threshold (1.1V, typical) for the duration of the internal timeout standby delay ( $t_{TO\_STBY}$ , 85 $\mu$ sec, typical), then the IC will automatically enter Low Power Standby Mode (Fig. 23). This will disable the gate drive and other internal circuitry and reduce the  $V_{CC}$  supply current to a low level (240 $\mu$ A, typical). When the PWM pulses restart, the IC will wake up instantly at the first rising edge of the PWM input and enter Normal Operating Mode again. To enable auto Standby Mode, the auto-standby mode pin ( $\overline{STBY}$ ) should always be connected to S (set low). To disable auto Standby Mode,  $\overline{STBY}$  pin should be connected to the 5V pin (set high).

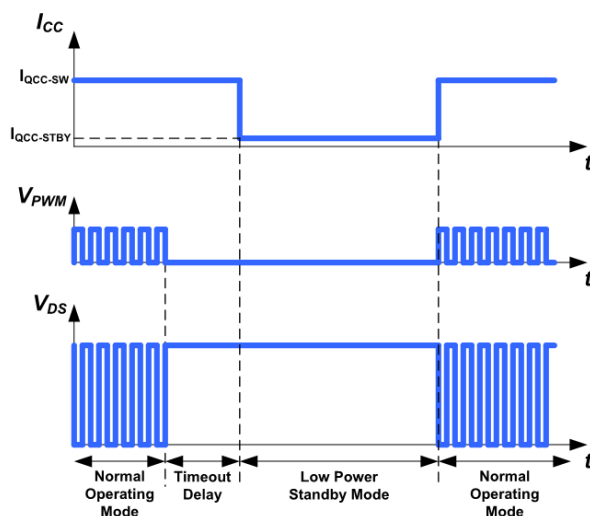


Fig. 23. Autonomous Low Power Standby Mode timing diagram

## 8.5. Programmable Turn-on dV/dt Control

During first start-up pulses or during hard-switching conditions, it is desirable to limit the slew rate ( $dV/dt$ ) of the drain of the power FET during turn-on. This is necessary to reduce EMI or reduce circuit switching noise. To program the turn-on  $dV/dt$  rate of the internal power FET, a resistor ( $R_{DD}$ ) is placed in between the  $V_{DD}$  pin and the  $R_{DD}$  pin. This resistor ( $R_{DD}$ ) sets the turn-on current of the internal gate driver and therefore sets the turn-on falling edge  $dV/dt$  rate of the drain of the power FET (Fig. 24).

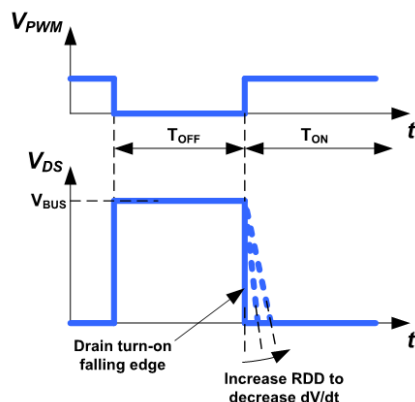


Fig. 24. Turn-on  $dV/dt$  slew rate control



## 8.6. GaNSense™ Technology Loss-Less Current Sensing

For many applications it is necessary to sense the cycle-by-cycle current flowing through the power FET. Existing current sensing solutions include placing a current sensing resistor in between the source of the power FET and P<sub>GND</sub>. This resistor method increases system conduction power losses, creates a hotspot on the PCB, and lowers overall system efficiency. To eliminate this external resistor and hotspot, and increase system efficiency, this IC includes GaNSense™ Technology for integrated and accurate loss-less current sensing. The current flowing through the internal GaN power FET is sensed internally and then converted to a current at the current sensing output pin (CS). An external resistor ( $R_{SET}$ ) is connected from the CS pin to the S pin and is used to set the amplitude of the CS pin voltage signal (Fig. 25). This allows for the CS pin signal to be programmed to work with different controllers with different current sensing input thresholds.

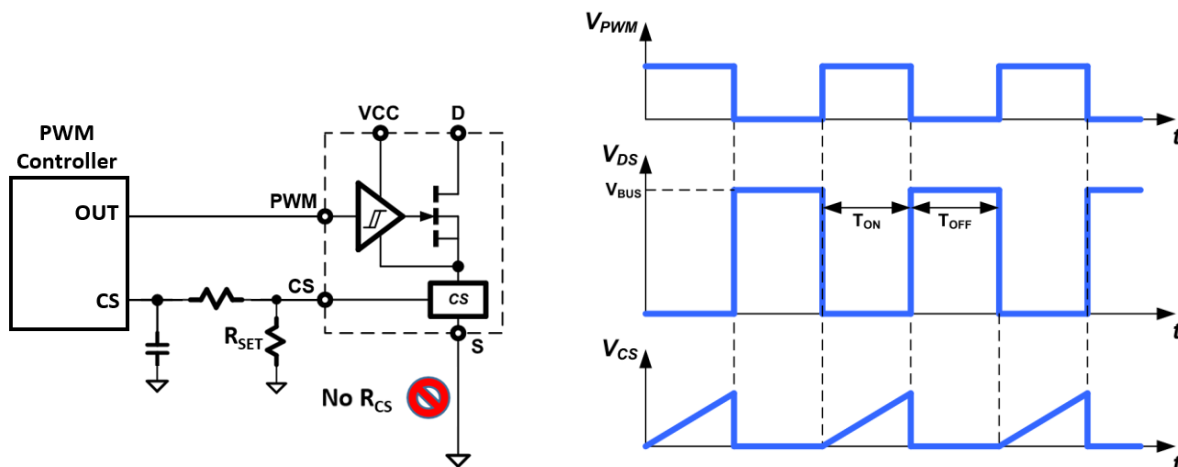


Fig. 25. Current sensing circuit and timing diagram

When comparing GaNSense™ Technology versus existing external resistor sensing method (Fig. 26), the total ON resistance,  $R_{ON(TOT)}$ , can be substantially reduced. For a 300W high-frequency boost PFC circuit, for example,  $R_{ON(TOT)}$  is reduced from 95m to 45m. The power loss savings by eliminating the external resistor results in a +0.2% efficiency benefit for the overall system and elimination of the  $R_{CS}$  PCB hotspot.

### External Resistor Sensing Method

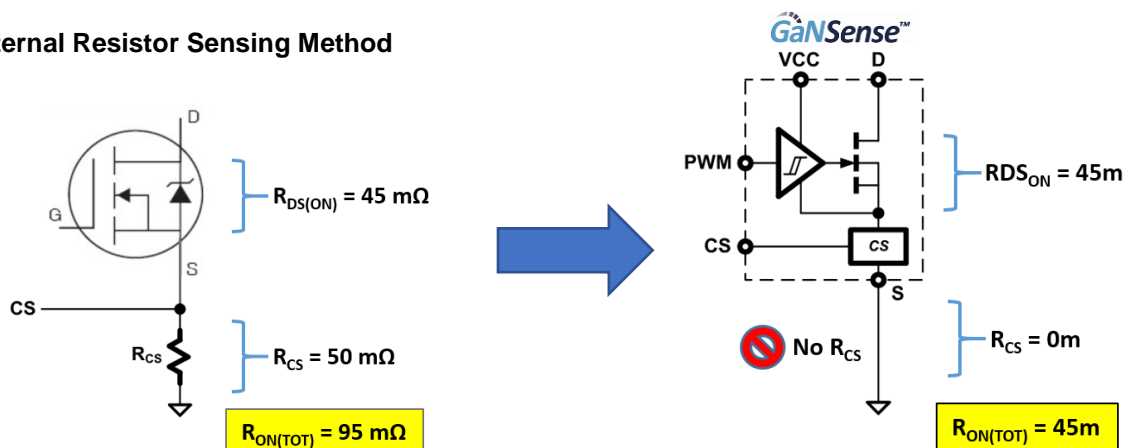


Fig. 26. External resistor sensing vs. GaNSense™ Technology

## GaNSense™ Technology Loss-Less Current Sensing (cont.)

To select the correct  $R_{SET}$  resistor value, the following equation (Equation 1) can be used. This equation uses the equivalent desired external current sensing resistor value ( $R_{CS}$ ), together with the gain of the internal sensing circuitry, to generate the equivalent  $R_{SET}$  resistor value. This  $R_{SET}$  value will then give the correct voltage level at the CS pin to be compatible with the internal current sensing threshold of the system controller.

$$I_{OUT} \text{ Ratio} = \frac{I_{DS}}{I_{CS}} = \frac{17A}{0.00125A} = 13600$$

$$R_{SET} = 13600 * R_{CS}$$

$$13600 * 50m\Omega = 680 \Omega$$

Equation 1.  $R_{SET}$  resistor value equation

## 8.7. Over Current Protection (OCP)

This GaN Power IC includes cycle-by-cycle over-current detection and protection (OCP) circuitry to protect the GaN power FET against high current levels. During the on-time of each switching cycle, should the peak current exceed the internal OCP threshold (2V, typical), then the internal gate drive will turn the GaN power FET off quickly and truncate the on-time period to prevent damage from occurring to the IC. The IC will then turn on again at the next PWM rising edge at the start of the next on-time period (Fig.27). This OCP protection feature will self-protect the IC each switching cycle against fast peak over current events and greatly increase the robustness and reliability of the system. The actual peak current threshold can be calculated using Equation 2 and is a function of the internal current-sensing ratio and the external  $R_{SET}$  resistor. The internal OCP threshold (2V, typical) is much higher than the OCP thresholds of many popular PWM controllers. This ensures good compatibility of this IC with existing controllers without OCP threshold conflicts. Once an OCP fault is detected, the FLT(BAR) output will be pulled low. The FLT(BAR) pin will remain low until the fault condition is cleared by PWM falling low.

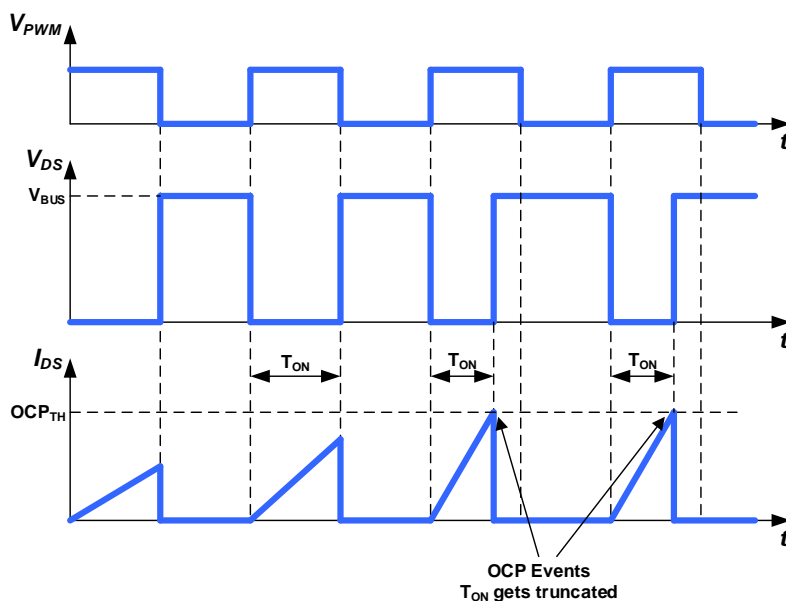


Fig. 27. OCP threshold timing diagram

$$I_{OCP} = \frac{[1.9V \times 13600]}{R_{SET}}$$

Equation 2. OCP current threshold equation

## 8.8. Short-Circuit Protection (SCP)

This GaN Power IC integrates SCP protection, protecting the GaN power FET from catastrophic destruction during a short circuit event. The  $V_{DS(ON)}$  of the GaN power FET is monitored during each on-time period and compared with a fixed voltage. During a short circuit event, the power FET will saturate and the  $V_{DS(ON)}$  level will not decrease to the  $R_{DS(ON)}$  range. After the power FET gate turns on, for the duration of the fault blanking interval, all Fault signals are blanked, but afterwards, if  $V_{DS}$  is still above  $V_{SCP+}$ , the GaN power FET will be turned off to prevent catastrophic destruction. Subsequent turn on behavior of the GaN power FET is governed by the specific SCP protection mode selected (below).

**Default Mode set in Factory:** The power FET remains OFF until the next Turn-ON pulse at the PWM pin, at which point, the power FET will Turn-ON again. Once a Short Circuit is detected, the FLT(BAR) output will be pulled low. The FLT(BAR) pin will remain low until the fault condition is cleared by PWM falling low.

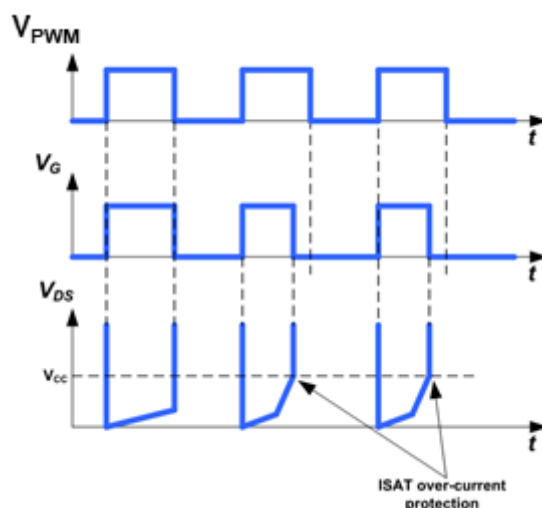


Figure 28. SCP Cycle-by-Cycle Timing Diagram

**Optional Mode, contact Navitas for Samples:** The power FET will remain Latched-OFF and the FLT(BAR) output will remain pulled low until the fault condition is cleared by PWM remaining low for 30us. If PWM goes high before 30us has elapsed, the latch timer will reset.

## 8.9. Over Temperature Protection (OTP)

This GaN Power IC includes over-temperature detection and protection (OTP) circuitry to protect the IC against excessively high junction temperatures ( $T_J$ ). High junction temperatures can occur due to overload, high ambient temperatures, and/or poor thermal management. Should  $T_J$  exceed the internal  $T_{OTP+}$  threshold (160C, typical) then the IC will latch off safely. When  $T_J$  decreases again and falls below the internal  $T_{OTP-}$  threshold (100C, typical), then the OTP latch will be reset. Until then, internal OTP latch guaranteed to remain in the correct state while  $V_{CC}$  is greater than 5V. During an OTP event, this GaN IC will latch off and the system  $V_{CC}$  supply voltage will decrease due to the loss of the aux winding supply. The system  $V_{CC}$  will fall below the lower UV- threshold of the controller and the high-voltage start-up circuit will turn-on and  $V_{CC}$  will increase again (Fig. 29).  $V_{CC}$  will increase above the rising UV+ threshold and the controller turn on again and deliver PWM pulses again. Once an OTP fault is detected, the FLT(BAR) output will be pulled low. The FLT(BAR) pin will remain low until the fault condition is cleared by  $T_{JUNC}$  decreasing below  $T_{OTP-}$ .

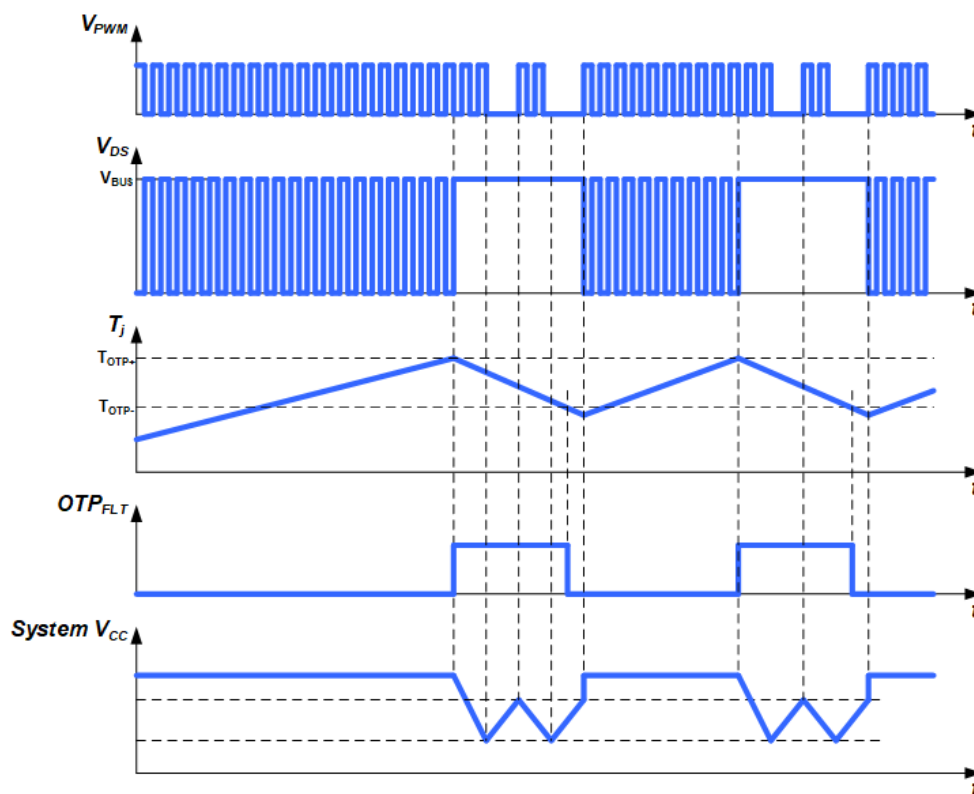


Fig. 29. OTP threshold timing diagram

## 8.10. Drain-to-Source Voltage Considerations

GaN Power ICs have been designed and tested to provide significant design margin to handle transient and continuous voltage conditions that are commonly seen in single-ended topologies, such as quasi-resonant (QR) flyback applications. The different voltage levels and recommended margins in a typical QR flyback can be analyzed using Fig. 30. When the device is switched off, the energy stored in the transformer leakage inductance will cause  $V_{DS}$  to overshoot to the level of  $V_{SPIKE}$ . The clamp circuit should be designed to control the magnitude of  $V_{SPIKE}$ . After dissipation of the leakage energy, the device  $V_{DS}$  will settle to the level of the bus voltage plus the reflected output voltage which is defined in Fig. 30 as  $V_{DS-OFF}$ .

- For repetitive events, 80% derating should be applied from  $V_{DS(TRAN)}$  rating (800V) to 640V max under the worst case operating conditions.
- It is recommended to design the system such that  $V_{DS-OFF}$  is derated 80% from the  $V_{DS(CONT)}$  (650V) max rating to 520V.
- For half-bridge based topologies, such as LLC,  $V_{DS}$  voltage is clamped to the bus voltage.  $V_{DS}$  should be designed such that it meets the  $V_{DS-OFF}$  derating guideline (520V).
- Non-repetitive events are infrequent, one-time conditions such as line surge, ESD, and lightning. No derating from the  $V_{DS(TRAN)}$  rating (800V) is needed for non-repetitive  $V_{SPIKE}$  durations  $< 100 \mu s$ . The  $V_{DS(TRAN)}$  rating (800V) allows for repetitive events that are  $< 100 ns$ , with 80% derating required (for example repetitive leakage inductance spikes).

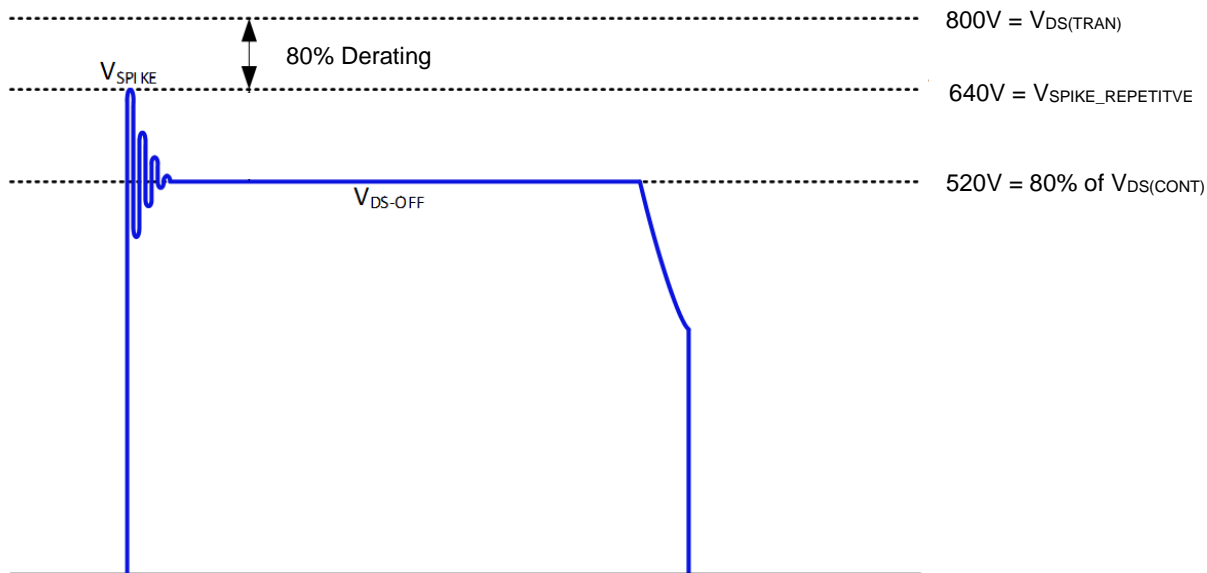
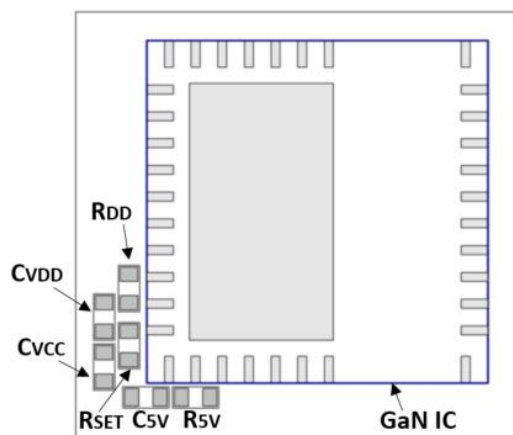


Fig. 30. QR flyback drain-to-source voltage stress diagram

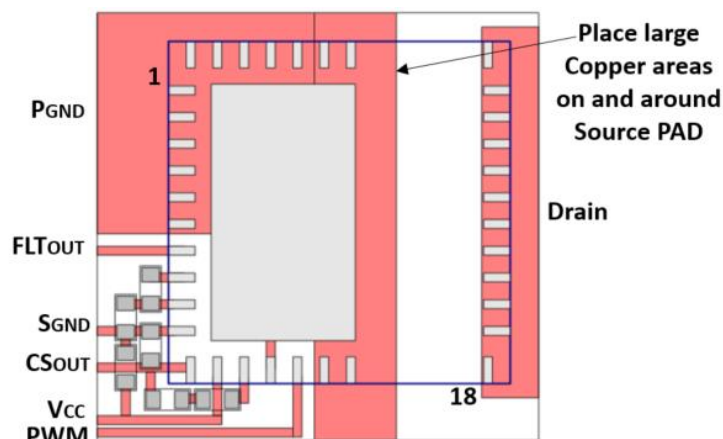
## 9. PCB Layout Guidelines

For best electrical and thermal results, these PCB layout guidelines (and 4 steps below) must be followed:

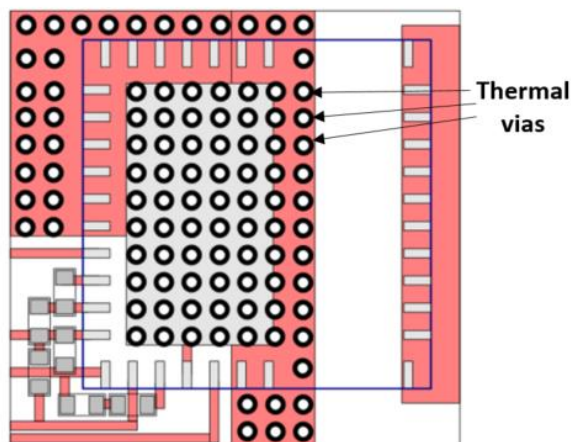
- 1) Place IC components as close as possible to the GaN IC. Place  $R_{SET}$  resistor directly next to CS pin to minimize high frequency switching noise.
- 2) Connect the ground of IC components to Source pin 10 to minimize high frequency switching noise.
- 3) Route all connections on single layer. This allows for large thermal copper areas on other layers.
- 4) Place large copper areas on and around Source pad.
- 5) Place many thermal vias inside Source pad and inside source copper areas.
- 6) Place large as possible copper areas on all other layers (bottom, top, mid1, mid2).



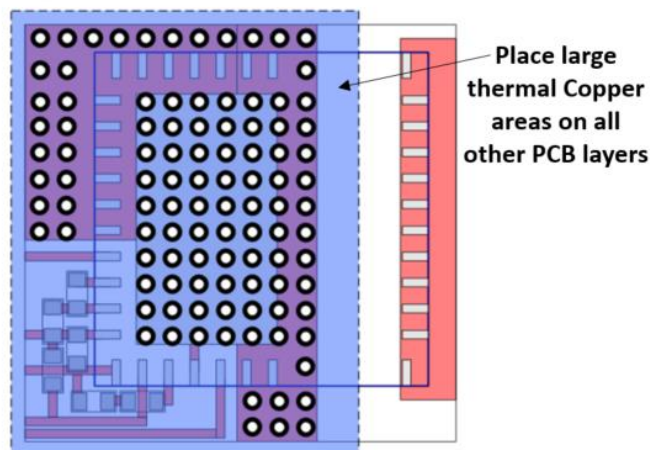
**Step 1.** Place GaN IC and components on PCB.  
Place components as close as possible to IC!



**Step 2.** Route all connections on single layer.  
Make large copper areas on and around Source pad!



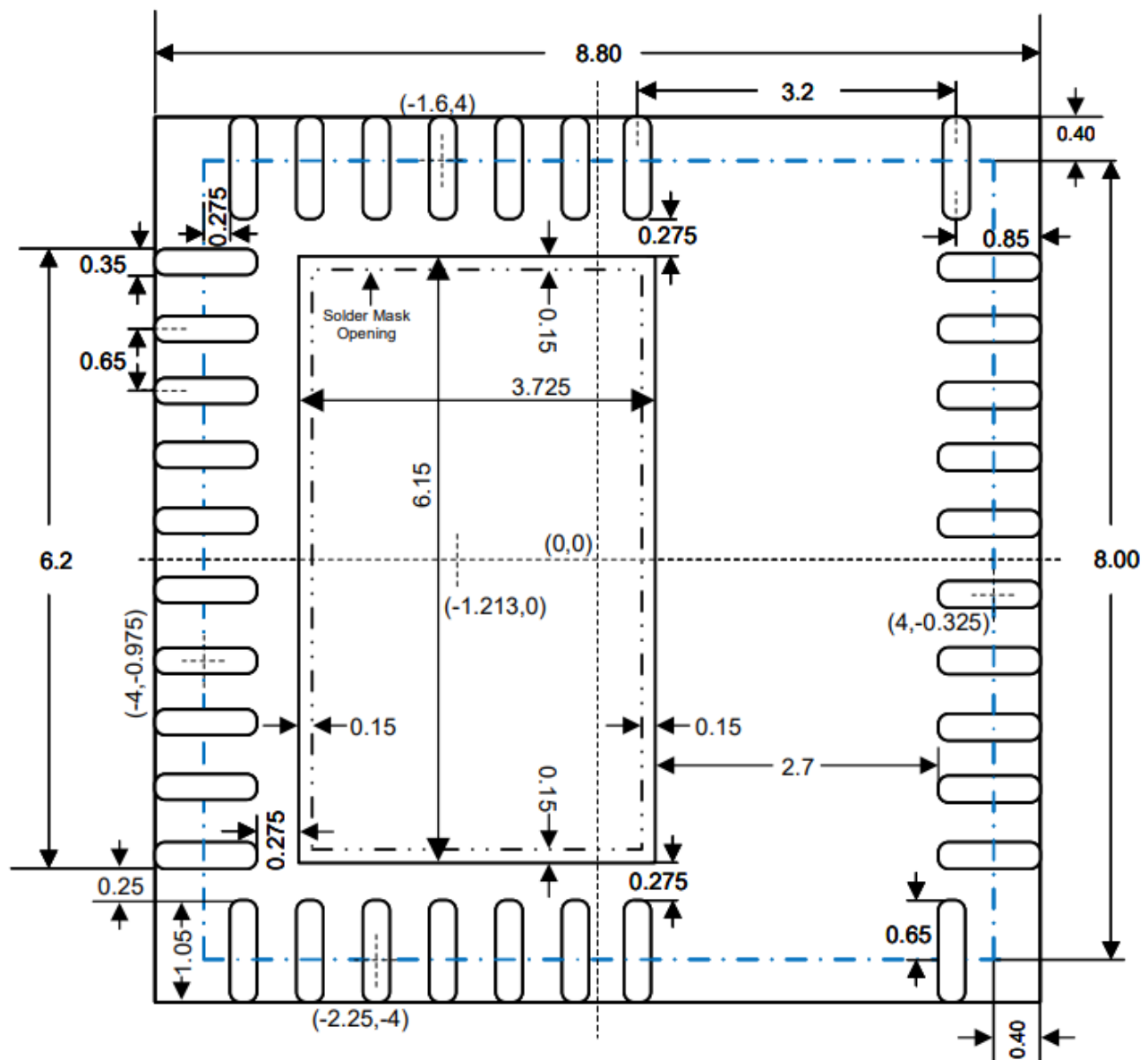
**Step 3.** Place many thermal vias inside source pad and inside source copper areas.  
(dia=0.65mm, hole=0.33mm, pitch=0.925mm, via wall=1mil)



**Step 4.** Place large copper areas on other layers.  
Make all thermal copper areas as large as possible!

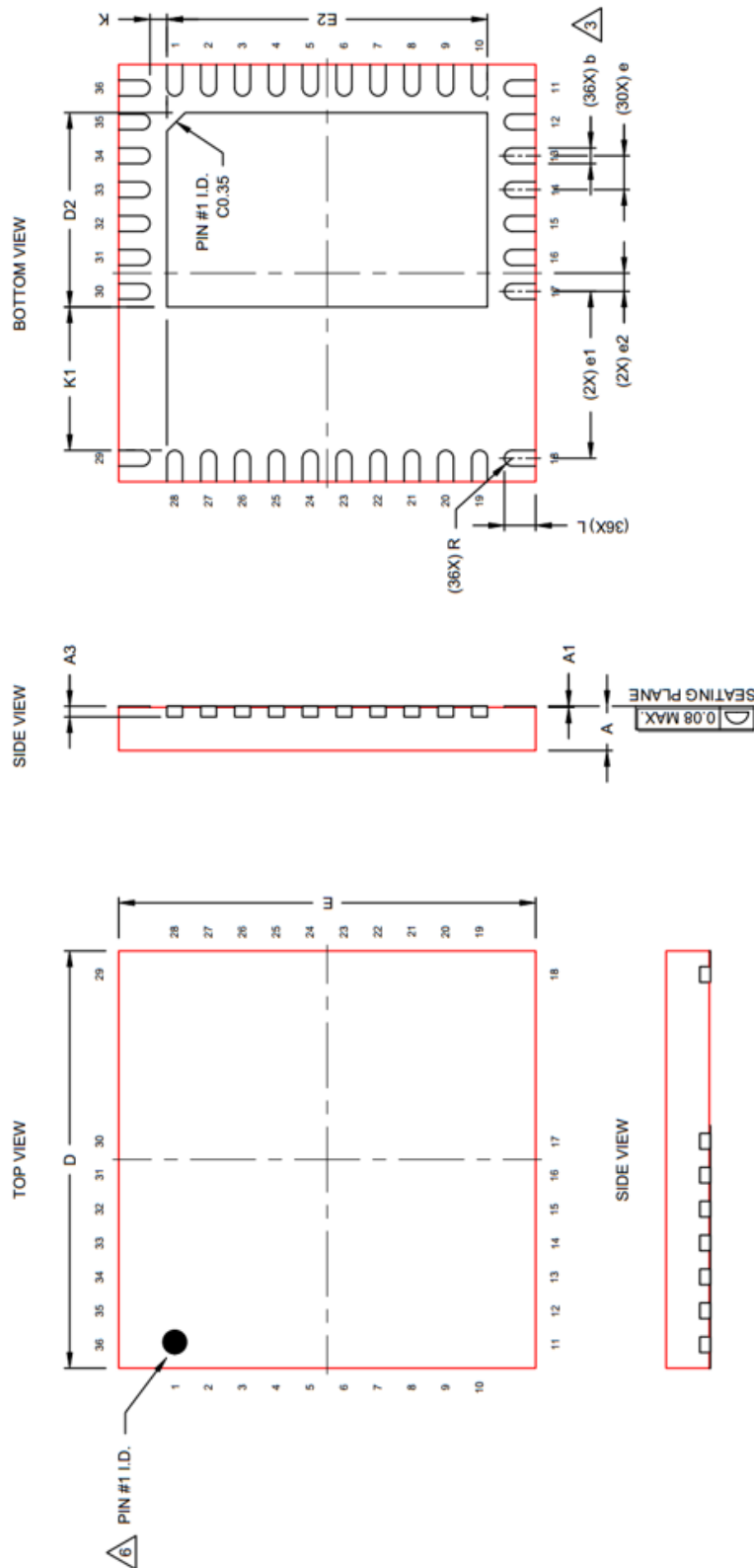


## 10. Recommended PCB Land Pattern



All dimensions are in mm

## 11. Package Outline (Power QFN)



SYM	MIN	NOM	MAX
A	0.80	0.85	0.90
A1	0.00	0.02	0.05
A3		0.203 REF	
D	7.90	8.00	8.10
E	7.90	8.00	8.10
D2	3.625	3.725	3.825
E2	6.05	6.15	6.25
b	0.25	0.30	0.35
e		0.65 BSC	
e1		3.20 BSC	
e2		0.35 BSC	
K		0.325 REF	
K1		2.75 REF	
L	0.50	0.60	0.70
R		0.15 REF	



## 12. Ordering Information

Part Number	Operating Temperature Grade	Storage Temperature Range	Package	MSL Rating	Packing (Tape & Reel)
NV6169-RA	-55°C to +150°C T <sub>CASE</sub>	-55°C to +150°C T <sub>CASE</sub>	8 x 8 mm PQFN	3	1,000: 7" Reel
NV6169	-55°C to +150°C T <sub>CASE</sub>	-55°C to +150°C T <sub>CASE</sub>	8 x 8 mm PQFN	3	3,000: 13" Reel

## 13. 20-Year Limited Product Warranty

The 20-year limited warranty applies to all packaged Navitas GaNFast Power ICs in mass production, subject to the terms and conditions of, Navitas' express limited product warranty, available at <https://navitassemi.com/terms-conditions>. The warranted specifications include only the MIN and MAX values only listed in Absolute Maximum Ratings, ESD Ratings and Electrical Characteristics sections of this datasheet. Typical (TYP) values or other specifications are not warranted.



## 14. Revision History

Date	Status	Notes
Jan. 24, 2022	PRELIMINARY	First publication
May 2, 2022	PRELIMINARY	Added 20-Year Limited Product Warranty
June 5, 2023	FINAL	Updated Rdson_max spec, updated PCB layout
Nov 28, 2023	FINAL	Updated Packing QTY
Apr. 17, 2024	FINAL	VDSmax footnote (2), update Section 8.10 Drain-to-Source Voltage Considerations
Nov. 14, 2024	FINAL	Updated TnR Qty to 3,000: 13" Reel

## Additional Information

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