GeneSiC SEMICONDUCTOR **2N7635-GA**

Normally – OFF Silicon Carbide Junction Transistor

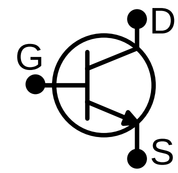
V_{DS}	=	600 V
$R_{DS(ON)}$	=	425 mΩ
$I_{D\ (Tc\ =\ 25°C)}$	=	10 A
$h_{FE\ (Tc\ =\ 25°C)}$	=	110

Features

- 225°C maximum operating temperature
- Electrically Isolated Base Plate
- Gate Oxide Free SiC Switch
- Exceptional Safe Operating Area
- Excellent Gain Linearity
- Temperature Independent Switching Performance
- Low Output Capacitance
- Positive Temperature Coefficient of $R_{DS,ON}$
- Suitable for Connecting an Anti-parallel Diode

Package

- RoHS Compliant



TO – 257 (Isolated Base-plate Hermetic Package)

Advantages

- Compatible with Si MOSFET/IGBT Gate Drive ICs
- > 20 µs Short-Circuit Withstand Capability
- Lowest-in-class Conduction Losses
- High Circuit Efficiency
- Minimal Input Signal Distortion
- High Amplifier Bandwidth

Applications

- Down Hole Oil Drilling
- Geothermal Instrumentation
- Solenoid Actuators
- General Purpose High-Temperature Switching
- Amplifiers
- Solar Inverters
- Switched-Mode Power Supply (SMPS)
- Power Factor Correction (PFC)

Table of Contents

Section I: Absolute Maximum Ratings

Parameter	Symbol	Conditions	Value	Unit	Notes
Drain – Source Voltage	V_{DS}	V_{GS} = 0 V	600	V	
Continuous Drain Current	I_D	T_J = 225°C, T_C = 25 °C	10	A	
Continuous Gate Current	I_G		0.5	A	
Turn-Off Safe Operating Area	RBSOA	T_{VJ} = 225°C, I_G = 0.5 A, Clamped Inductive Load	$I_{D,max}$ = 10 @ $V_{DS} \leq V_{DSmax}$	A	
Short Circuit Safe Operating Area	SCSOA	T_{VJ} = 225°C, I_G = 0.5 A, V_{DS} = 400 V, Non Repetitive	>20	µs	
Reverse Gate – Source Voltage	V_{SG}		30	V	
Reverse Drain – Source Voltage	V_{SD}		25	V	
Power Dissipation	P_{tot}	T_C = 25 °C, t_p > 100 ms	47	W	
Storage Temperature	T_{stg}		-55 to 225	°C	

Section II: Static Electrical Characteristics

Parameter	Symbol	Conditions	Value			Unit	Notes
			Min.	Typical	Max.		
A: On State							
Drain – Source On Resistance	$R_{DS(ON)}$	I_D = 4 A, T_j = 25 °C I_D = 4 A, T_j = 175 °C I_D = 4 A, T_j = 220 °C		425 800 1180		mΩ	Fig. 5
Gate – Source Saturation Voltage	$V_{GS,sat}$	I_D = 5 A, I_D/I_G = 40, T_j = 25 °C I_D = 5 A, I_D/I_G = 30, T_j = 175 °C		3.45 3.22		V	Fig. 7
DC Current Gain	h_{FE}	V_{DS} = 5 V, I_D = 5 A, T_j = 25 °C V_{DS} = 5 V, I_D = 5 A, T_j = 220 °C	90 60	110 80		–	Fig. 5
B: Off State							
Drain Leakage Current	I_{DSS}	V_{DS} = 600 V, V_{GS} = 0 V, T_j = 25 °C V_{DS} = 600 V, V_{GS} = 0 V, T_j = 175 °C V_{DS} = 600 V, V_{GS} = 0 V, T_j = 220 °C		0.1 1 10		μA	Fig. 8
Gate Leakage Current	I_{SG}	V_{SG} = 20 V, T_j = 25 °C		20		nA	
C: Thermal							
Thermal resistance, junction - case	R_{thJC}			4.18		°C/W	

Section III: Dynamic Electrical Characteristics

Parameter	Symbol	Conditions	Value			Unit	Notes
			Min.	Typical	Max.		
A: Capacitance and Gate Charge							
Input Capacitance	C_{iss}	V_{GS} = 0 V, V_D = 600 V, f = 1 MHz		310		pF	Fig. 9
Reverse Transfer/Output Capacitance	C_{rss}/C_{oss}	V_{DS} = 600 V, *f* = 1 MHz		17		pF	Fig. 9
Output Capacitance Stored Energy	E_{OSS}	V_{GS} = 0 V, V_{DS} = 600 V, *f* = 1 MHz		2.8		μJ	Fig. 10
Effective Output Capacitance, time related	$C_{oss,tr}$	I_D = constant, V_{GS} = 0 V, V_{DS} = 0…400 V		27		pF	
Effective Output Capacitance, energy related	$C_{oss,er}$	V_{GS} = 0 V, V_{DS} = 0…400 V		21		pF	
Gate-Source Charge	Q_{GS}	V_{GS} = -5…3 V		3		nC	
Gate-Drain Charge	Q_{GD}	V_{GS} = 0 V, V_{DS} = 0…400 V		11		nC	
Gate Charge - Total	Q_G	Q_{GS} + Q_{GD}		14		nC	
B: Switching[1]							
Internal Gate Resistance – zero bias	$R_{G(INT-ZERO)}$	*f* = 1 MHz, V_{AC} = 50 mV, V_{DS} = 0 V, V_{GS} = 0 V, T_j = 175 ºC		14.5		Ω	
Internal Gate Resistance – ON	$R_{G(INT-ON)}$	V_{GS} > 2.5 V, V_{DS} = 0 V, T_j = 175 ºC		0.37		Ω	
Turn On Delay Time	$t_{d(on)}$	T_j = 175 ºC, V_{DS} = 400 V, I_D = 4 A, Resistive Load Refer to Section V for additional driving information.		5		ns	
Fall Time, V_{DS}	t_f			46		ns	Fig. 11
Turn Off Delay Time	$t_{d(off)}$			75		ns	
Rise Time, V_{DS}	t_r			19		ns	Fig. 12
Turn On Delay Time	$t_{d(on)}$	T_j = 225 ºC, V_{DS} = 400 V, I_D = 4 A, Resistive Load		10		ns	
Fall Time, V_{DS}	t_f			46		ns	Fig. 11
Turn Off Delay Time	$t_{d(off)}$			115		ns	
Rise Time, V_{DS}	t_r			18		ns	Fig. 12
Turn-On Energy Per Pulse	E_{on}	T_j = 175 ºC, V_{DS} = 400 V, I_D = 4 A, Inductive Load Refer to Section V.		24		μJ	Fig. 11
Turn-Off Energy Per Pulse	E_{off}			8		μJ	Fig. 12,
Total Switching Energy	E_{tot}			32		μJ	
Turn-On Energy Per Pulse	E_{on}	T_j = 225 ºC, V_{DS} = 400 V, I_D = 4 A, Inductive Load		31		μJ	Fig. 11
Turn-Off Energy Per Pulse	E_{off}			9		μJ	Fig. 12
Total Switching Energy	E_{tot}			40		μJ	

[1] – All times are relative to the Drain-Source Voltage V_{DS}

Section IV: Figures

A: Static Characteristic

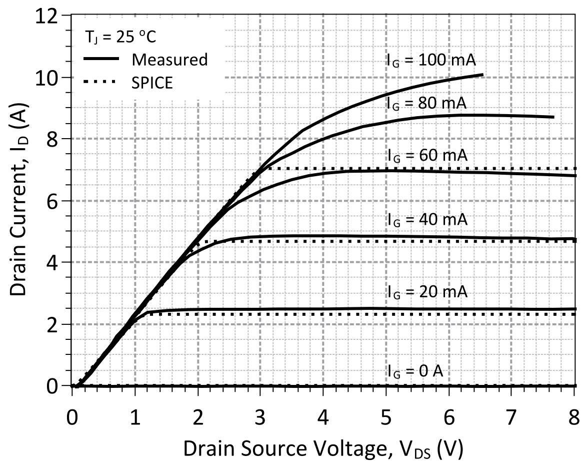


Figure 1: Typical Output Characteristics at 25 °C

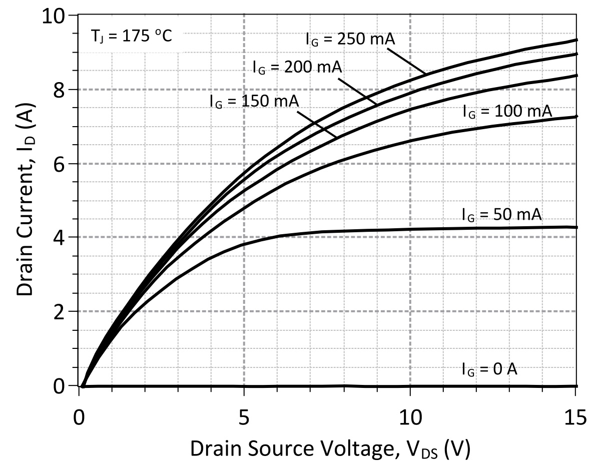


Figure 2: Typical Output Characteristics at 175 °C

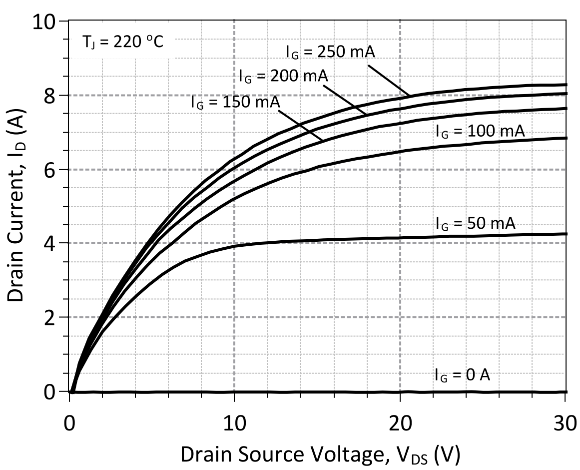


Figure 3: Typical Output Characteristics at 220 °C

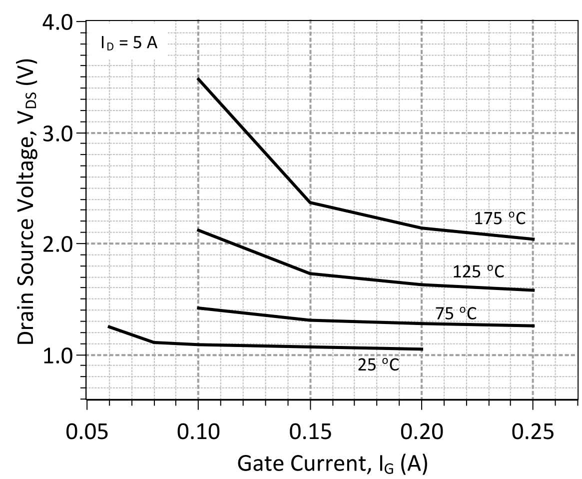


Figure 4: Drain-Source Voltage vs. Gate Current

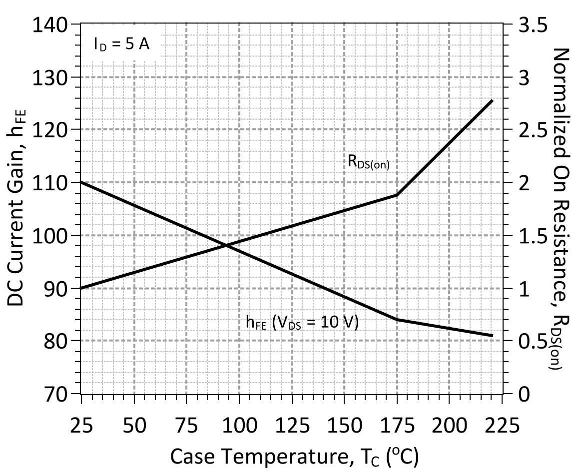


Figure 5: DC Current Gain and Normalized On-Resistance vs. Temperature

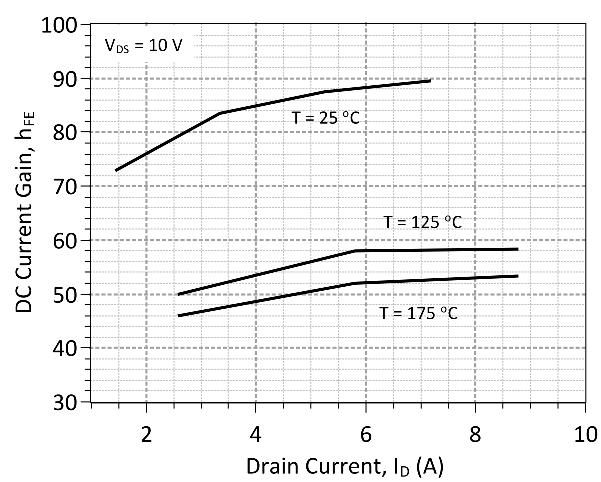


Figure 6: DC Current Gain vs. Drain Current

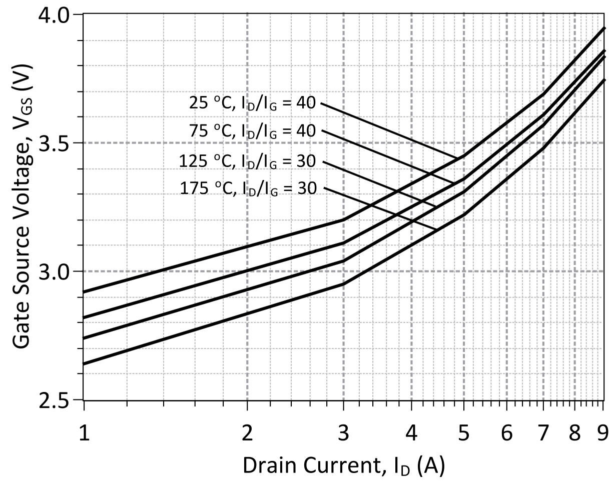


Figure 7: Typical Gate – Source Saturation Voltage

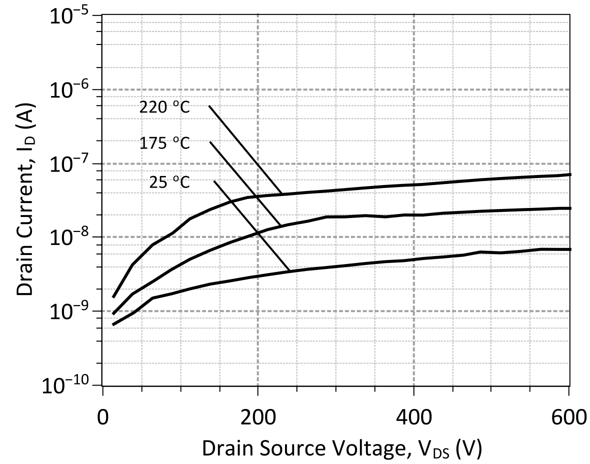


Figure 8: Typical Blocking Characteristics

B: Dynamic Characteristic Figures

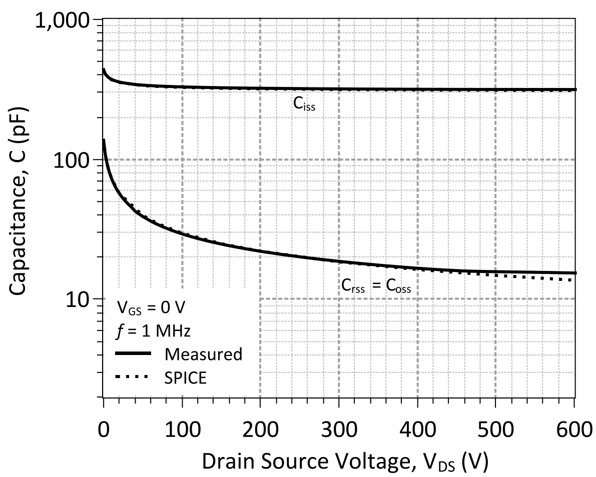


Figure 9: Input, Output, and Reverse Transfer Capacitance

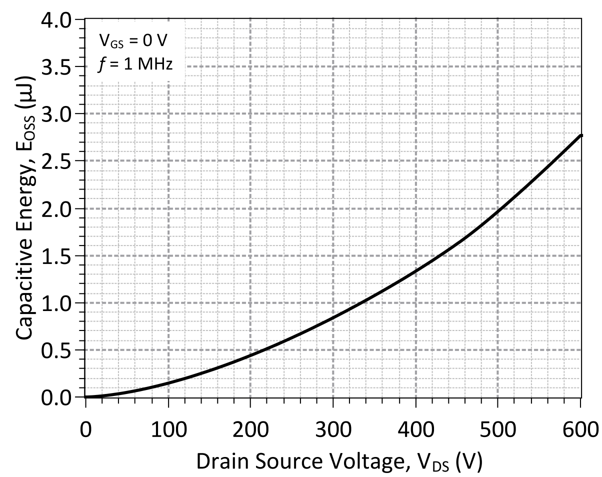


Figure 10: Output Capacitance Stored Energy

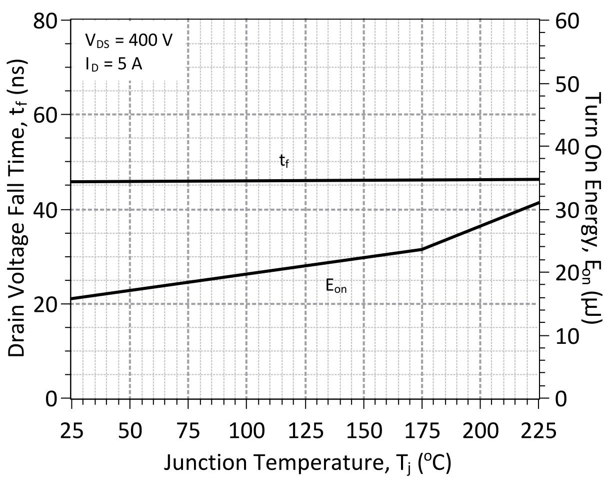


Figure 11: Typical Switching Times and Turn On Energy Losses vs. Temperature

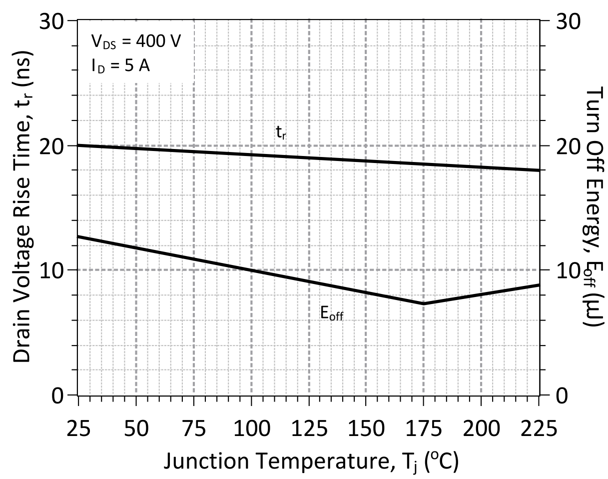


Figure 12: Typical Switching Times and Turn Off Energy Losses vs. Temperature

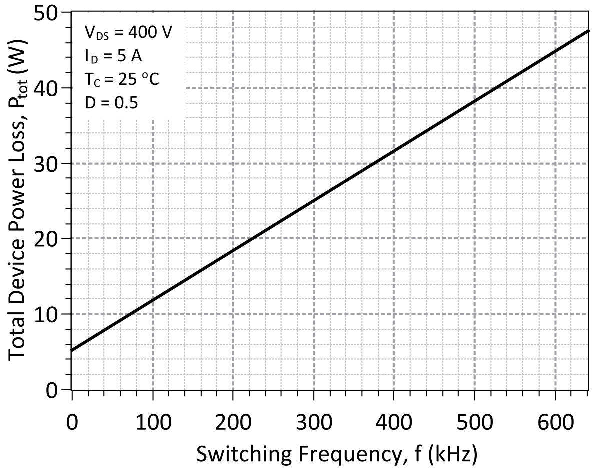


Figure 13: Typical Hard Switched Device Power Loss vs. Switching Frequency [2]

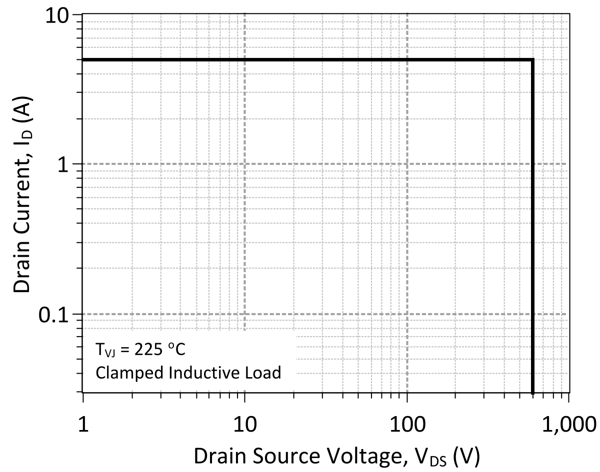


Figure 14: Turn-Off Safe Operating Area

Section V: Driving the 2N7635-GA

The 2N7635-GA is a current controlled SiC transistor which requires a positive gate current for turn-on and to remain in on-state. It may be driven by different drive topologies depending on the intended application.

Table 1: Estimated Power Consumption and switching frequencies for various Gate Drive topologies.

Drive Topology	Gate Drive Power Consumption	Switching Frequency
Simple TTL	High	Low
Constant Current	Medium	Medium
High Speed – Boost Capacitor	Medium	High
High Speed – Boost Inductor	Low	High
Proportional	Lowest	Medium
Pulsed Power	Medium	N/A

A: Simple TTL Drive

The 2N7635-GA may be driven by 5 V TTL logic using a simple current amplification stage. The current amplifier output current must meet or exceed the steady state gate current, $I_{G,steady,}$ required to operate the 2N7635-GA. An external gate resistor R_G, shown in the Figure 15 topology, sets $I_{G,steady}$ to the required level which is dependent on the SJT drain current I_D and DC current gain h_{FE}, R_G may be calculated from the equation below. The value of $V_{EC,sat}$ can be taken from the PNP datasheet, a partial list of high-temperature PNP and NPN transistors options is given below. High-temperature MOSFETs may also be used in the topology.

$$R_{G,max} = \frac{\left(5.0\,V - V_{EC,sat}(PNP) - V_{GS,sat}(SJT)\right) * h_{FE}(T, I_D)}{I_D * 1.5}$$

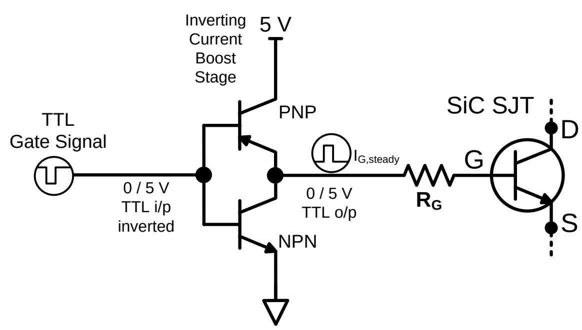


Figure 15: Simple TTL Gate Drive Topology

Table 2: Partial List of High-Temperature BJTs for TTL Gate Driving

BJT Part Number	Type	$T_{j,max}$ (°C)
PHPT60603PY	PNP	175
PHPT60603NY	NPN	175
2N2222	NPN	200
2N6730	PNP	200
2N2905	PNP	200
2N5883	PNP	200
2N5885	NPN	200

B: High Speed Driving

For ultra high speed 2N7635-GA switching (t_r, t_f < 20 ns) while maintaining low gate drive losses the supplied gate current should include a positive current peak during turn-on, a negative voltage peak during turn-off, and continuous gate current I_G to remain on.

An SJT is rapidly switched from its blocking state to on-state, when the necessary gate charge for turn-on, Q_G, is supplied by a burst of high gate current until the gate-source capacitance, C_{GS}, and gate-drain capacitance, C_{GD}, are fully charged. Ideally, the burst should terminate when the drain voltage has fallen to its on-state value in order to avoid unnecessary drive losses. A negative voltage peak is recommended for the turn-off transition in order to ensure that the gate current is not being supplied under high dV/dt due to the Miller effect. While satisfactory turn off can be achieved with V_{GS} = 0 V, a negative V_{GS} value may be used in order to speed up the turn-off transition.

B:1: High Speed, Low Loss Drive with Boost Capacitor

The 2N7635-GA may be driven using a High Speed, Low Loss Drive with Boost Capacitor topology in which multiple voltage levels, a gate resistor, and a gate capacitor are used to provide current peaks at turn-on and turn-off for fast switching and a continuous gate current while in on-state. As shown in Figure 16, in this topology two gate driver ICs are utilized. An external gate resistor R_G is driven by a low voltage driver to supply the continuous gate current throughout on-state.and a gate capacitor C_G is driven at a higher voltage level to supply a high current peak at turn-on and turn-off. A 3 kV isolated evaluation gate drive board (GA03IDDJT30-FR4) from GeneSiC Semiconductor utilizing this topology is commercially available for high and low-side driving, its datasheet provides additional details about this drive topology.

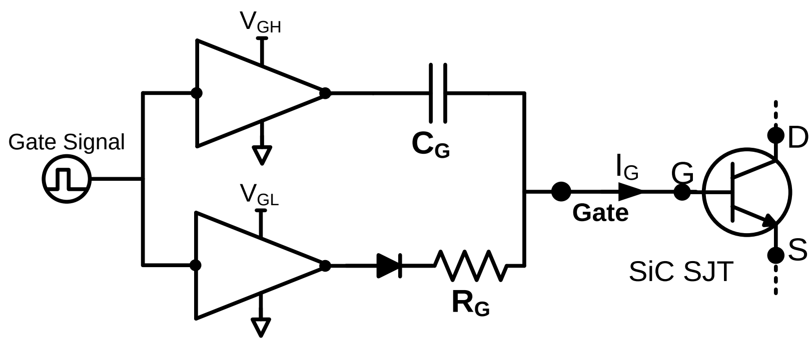


Figure 16: High Speed, Low Loss Drive with Boost Capacitor Topology

B:2: High Speed, Low Loss Drive with Boost Inductor

A High Speed, Low-Loss Driver with Boost Inductor is also capable of driving the 2N7635-GA at high-speed. It utilizes a gate drive inductor instead of a capacitor to provide the high-current gate current pulses $I_{G,on}$ and $I_{G,off}$. During operation, inductor L is charged to a specified $I_{G,on}$ current value then made to discharge I_L into the SJT gate pin using logic control of S_1, S_2, S_3, and S_4, as shown in Figure 17. After turn on, while the device remains on the necessary steady state gate current $I_{G,steady}$ is supplied from source V_{CC} through R_G. Please refer to the article "A current-source concept for fast and efficient driving of silicon carbide transistors" by Dr. Jacek Rąbkowski for additional information on this driving topology.[3]

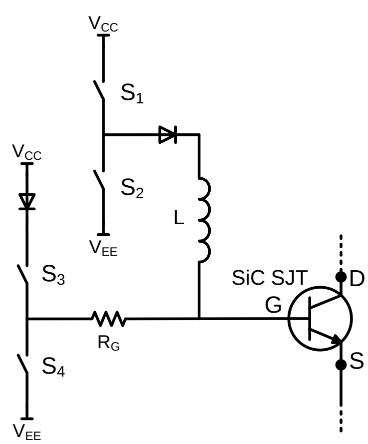


Figure 17: High Speed, Low-Loss Driver with Boost Inductor Topology

[3] – Archives of Electrical Engineering. Volume 62, Issue 2, Pages 333–343, ISSN (Print) 0004-0746, DOI: 10.2478/aee-2013-0026, June 2013

C: Proportional Gate Current Driving

A proportional gate drive topology may be beneficial for applications in which the 2N7635-GA will operate over a wide range of drain current conditions to lower the gate drive power consumption. A proportional gate driver relies on instantaneous drain current I_D feedback to vary the steady state gate current $I_{G,steady}$ supplied to the 2N7635-GA.

C:1: Voltage Controlled Proportional Driver

A voltage controlled proportional driver relies on a gate drive integrated circuit to detect the 2N7635-GA drain-source voltage V_{DS} during on-state to sense I_D. The integrated circuit will then increase or decrease I_G in response to I_D. This allows I_G and gate drive power consumption to reduce while I_D is low or for I_G to increase when I_D increases. A high voltage diode connected between the drain and sense protects the integrated circuit from high-voltage when blocking. A simplified version of this topology is shown in Figure 18. Additional information will be available in the future at http://www.genesicsemi.com/references/product-notes/.

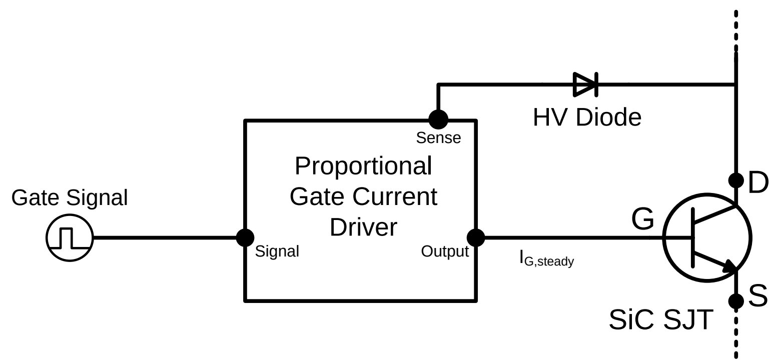


Figure 18: Simplified Voltage Controlled Proportional Driver

C:2: Current Controlled Proportional Driver

The current controlled proportional driver relies on a low-loss transformer in the drain or source path to provide feedback of the 2N7635-GA drain current during on-state to supply $I_{G,steady}$ into the gate. $I_{G,steady}$ will increase or decrease in response to I_D at a fixed forced current gain which is set be the turns ratio of the transformer, $h_{force} = I_D / I_G = N_2 / N_1$. 2N7635-GA is initially tuned-on using a gate current pulse supplied into an RC drive circuit to allow I_D current to begin flowing. This topology allows $I_{G,steady}$ and the gate drive power consumption to reduce while I_D is relatively low or for $I_{G,steady}$ to increase when I_D increases. A simplified version of this topology is shown in Figure 19. Additional information will be available in the future at http://www.genesicsemi.com/references/product-notes/.

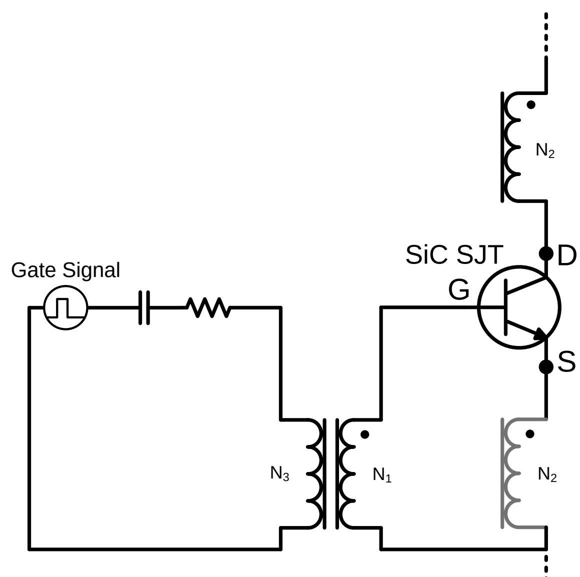
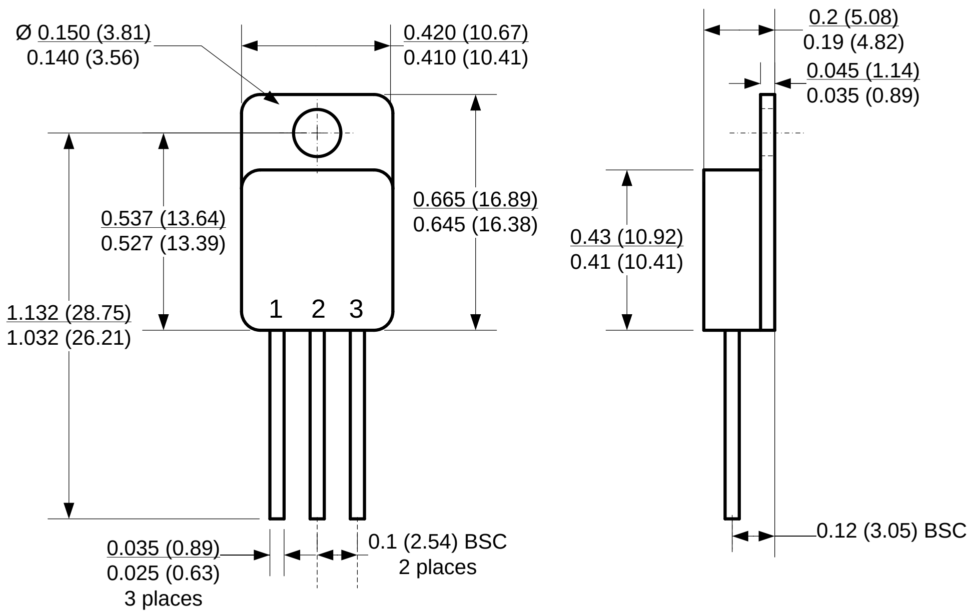


Figure 19: Simplified Current Controlled Proportional Driver

Section VI: Package Dimensions

TO-257 **PACKAGE OUTLINE**



NOTE
1. CONTROLLED DIMENSION IS INCH. DIMENSION IN BRACKET IS MILLIMETER.
2. DIMENSIONS DO NOT INCLUDE END FLASH, MOLD FLASH, MATERIAL PROTRUSIONS

Revision History			
Date	Revision	Comments	Supersedes
2014/12/12	6	Updated Electrical Characteristics	
2014/08/23	5	Updated Electrical Characteristics	
2014/03/20	4	Updated Gate Drive Section	
2014/02/11	3	Updated Electrical Characteristics	
2013/12/19	2	Updated Gate Drive Section	
2013/11/18	1	Updated Electrical Characteristics	
2012/08/24	0	Initial release	

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Dulles, VA 20166

Section VII: SPICE Model Parameters

This is a secure document. Please copy this code from the SPICE model PDF file on our website (http://www.genesicsemi.com/images/hit_sic/sjt/2N7635-GA_SPICE.pdf) into LTSPICE (version 4) software for simulation of the 2N7635-GA.

```
*     MODEL OF GeneSiC Semiconductor Inc.
*
*     $Revision:   1.3           $
*     $Date:   12-DEC-2014       $
*
*     GeneSiC Semiconductor Inc.
*     43670 Trade Center Place Ste. 155
*     Dulles, VA 20166
*
*     COPYRIGHT (C) 2014 GeneSiC Semiconductor Inc.
*     ALL RIGHTS RESERVED
*
* These models are provided "AS IS, WHERE IS, AND WITH NO WARRANTY
* OF ANY KIND EITHER EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED
* TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A
* PARTICULAR PURPOSE."
* Models accurate up to 2 times rated drain current.
*
.model 2N7635 NPN
+ IS       9.8338E-48
+ ISE      1.0733E-26
+ EG       3.23
+ BF       130
+ BR       0.55
+ IKF      200
+ NF       1
+ NE       2.
+ RB       14.5
+ IRB      0.002
+ RBM      0.37
+ RE       0.231
+ RC       0.16
+ CJC      1.37E-10
+ VJC      3.150960833
+ MJC      0.43821105
+ CJE      2.97E-10
+ VJE      2.901930244
+ MJE      0.475141754
+ XTI      3
+ XTB      -0.45
+ TRC1     1.50E-02
+ VCEO     600
+ ICRATING 10
+ MFG      GeneSiC_Semiconductor
*
* End of 2N7635-GA SPICE Model
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