

## 650V Cascode GaN FET in TO-220 (source tab)

### Description

The TPH3212PS 650V, 72mΩ gallium nitride (GaN) FET is a normally-off device. Transphorm GaN FETs offer better efficiency through lower gate charge, faster switching speeds, and smaller reverse recovery charge, delivering significant advantages over traditional silicon (Si) devices.

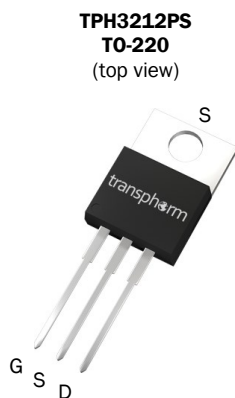
Transphorm is a leading-edge wide band gap supplier with world-class innovation and a portfolio of fully-qualified GaN transistors that enables increased performance and reduced overall system size and cost.

### Related Literature

- [AN0009](#): Recommended External Circuitry for GaN FETs
- [AN0003](#): Printed Circuit Board Layout and Probing

### Ordering Information

Part Number	Package	Package Configuration
TPH3212PS	3 Lead TO-220	Common Source



### Features

- Easy to drive—compatible with standard gate drivers
- Low conduction and switching losses
- Low  $Q_{rr}$  of 90nC—no free-wheeling diode required
- GSD pin layout improves high speed design
- JEDEC-qualified GaN technology
- RoHS compliant and Halogen-free

### Benefits

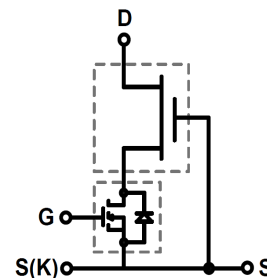
- Increased efficiency through fast switching
- Increased power density
- Reduced system size and weight
- Enables more efficient topologies—easy to implement bridgeless totem-pole designs
- Lower BOM cost

### Applications

- Renewable energy
- Industrial
- Automotive
- Telecom and datacom
- Servo motors

Key Specifications	
$V_{DS}$ (V) min	650
$V_{TDS}$ (V) max	800
$R_{DS(on)}$ (mΩ) max*	85
$Q_{rr}$ (nC) typ	90
$Q_g$ (nC) typ	14

\* Dynamic  $R_{(on)}$



Cascode Device Structure

# TPH3212PS

## Absolute Maximum Ratings ( $T_C=25^\circ\text{C}$ unless otherwise stated)

Symbol	Parameter	Limit Value	Unit	
$I_{D25^\circ\text{C}}$	Continuous drain current @ $T_C=25^\circ\text{C}$ <sup>a</sup>	26.5	A	
$I_{D100^\circ\text{C}}$	Continuous drain current @ $T_C=100^\circ\text{C}$ <sup>a</sup>	16.5	A	
$I_{DM}$	Pulsed drain current (pulse width: 10 $\mu\text{s}$ )	120	A	
$V_{DSS}$	Drain to source voltage	650	V	
$V_{TDS}$	Transient drain to source voltage <sup>b</sup>	800	V	
$V_{GSS}$	Gate to source voltage	$\pm 18$	V	
$P_{D25^\circ\text{C}}$	Maximum power dissipation	104	W	
$T_C$	Operating temperature	Case	-55 to +150	$^\circ\text{C}$
$T_J$		Junction	-55 to +150	$^\circ\text{C}$
$T_S$	Storage temperature	-55 to +150	$^\circ\text{C}$	
$T_{CSOLD}$	Soldering peak temperature <sup>c</sup>	260	$^\circ\text{C}$	

## Thermal Resistance

Symbol	Parameter	Typical	Unit
$R_{\theta JC}$	Junction-to-case	1.2	$^\circ\text{C}/\text{W}$
$R_{\theta JA}$	Junction-to-ambient	62	$^\circ\text{C}/\text{W}$

### Notes:

- For high current operation, see application note AN0009
- In off-state, spike duty cycle  $D < 0.01$ , spike duration  $< 1\mu\text{s}$
- For 10 sec., 1.6mm from the case

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## Electrical Parameter (T<sub>C</sub>=25 °C unless otherwise stated)

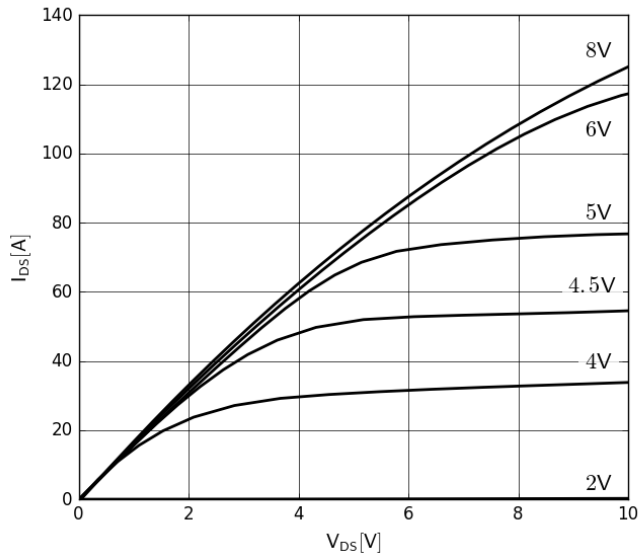
Symbol	Parameter	Min	Typ	Max	Unit	Test Conditions
<b>Forward Device Characteristics</b>						
V <sub>DSS-MAX</sub>	Maximum drain-source voltage	650	—	—	V	V <sub>GS</sub> =0V
V <sub>GS(th)</sub>	Gate threshold voltage	1.6	2.1	2.6	V	V <sub>DS</sub> =V <sub>GS</sub> , I <sub>D</sub> =0.7mA
R <sub>DS(on)</sub>	Drain-source on-resistance (T <sub>J</sub> =25 °C) <sup>a</sup>	—	72	85	mΩ	V <sub>GS</sub> =8V, I <sub>D</sub> =17A, T <sub>J</sub> =25 °C
	Drain-source on-resistance (T <sub>J</sub> =150 °C) <sup>a</sup>	—	148	—		V <sub>GS</sub> =8V, I <sub>D</sub> =17A, T <sub>J</sub> =150 °C
I <sub>DSS</sub>	Drain-to-source leakage current (T <sub>J</sub> =25 °C)	—	3	30	μA	V <sub>DS</sub> =650V, V <sub>GS</sub> =0V, T <sub>J</sub> =25 °C
	Drain-to-source leakage current (T <sub>J</sub> =150 °C)	—	12	—		V <sub>DS</sub> =650V, V <sub>GS</sub> =0V, T <sub>J</sub> =150 °C
I <sub>GSS</sub>	Gate-to-source forward leakage current	—	—	100	nA	V <sub>GS</sub> =18V
	Gate-to-source reverse leakage current	—	—	-100		V <sub>GS</sub> =-18V
C <sub>ISS</sub>	Input capacitance	—	1130	—	pF	V <sub>GS</sub> =0V, V <sub>DS</sub> =400V, f=1MHz
C <sub>OSS</sub>	Output capacitance	—	102	—		
C <sub>RSS</sub>	Reverse transfer capacitance	—	13	—		
C <sub>O(er)</sub>	Output capacitance, energy related <sup>b</sup>	—	142	—	pF	V <sub>GS</sub> =0V, V <sub>DS</sub> =0V to 400V
C <sub>O(tr)</sub>	Output capacitance, time related <sup>c</sup>	—	225	—		
Q <sub>g</sub>	Total gate charge	—	14.6	—	nC	V <sub>DS</sub> =400V, V <sub>GS</sub> =0V to 8V, I <sub>D</sub> =17A
Q <sub>gs</sub>	Gate-source charge	—	3.1	—		
Q <sub>gd</sub>	Gate-drain charge	—	3.4	—		
t <sub>d(on)</sub>	Turn-on delay	—	24	—	ns	V <sub>DS</sub> =400V, V <sub>GS</sub> =0V to 10V, I <sub>D</sub> =18A, R <sub>G</sub> =15Ω (driver internal series resistance), Z <sub>FB</sub> =300Ω @100MHz (see Fig. 13)
t <sub>r</sub>	Rise time	—	7.5	—		
T <sub>d(off)</sub>	Turn-off delay	—	55.5	—		
t <sub>f</sub>	Fall time	—	5	—		
<b>Reverse Device Characteristics</b>						
I <sub>S</sub>	Reverse current	—	—	16.5	A	V <sub>GS</sub> =0V, T <sub>C</sub> =100 °C ≤50% Duty Cycle
V <sub>SD</sub>	Reverse voltage <sup>a</sup>	—	2.0	—	V	V <sub>GS</sub> =0V, I <sub>S</sub> =17A, T <sub>J</sub> =25 °C
		—	1.5	—		V <sub>GS</sub> =0V, I <sub>S</sub> =8.5A, T <sub>J</sub> =25 °C
t <sub>rr</sub>	Reverse recovery time	—	35	—	ns	I <sub>S</sub> =18A, V <sub>DD</sub> =400V, di/dt=1000A/ms, T <sub>J</sub> =25 °C
Q <sub>rr</sub>	Reverse recovery charge	—	90	—	nC	

Notes:

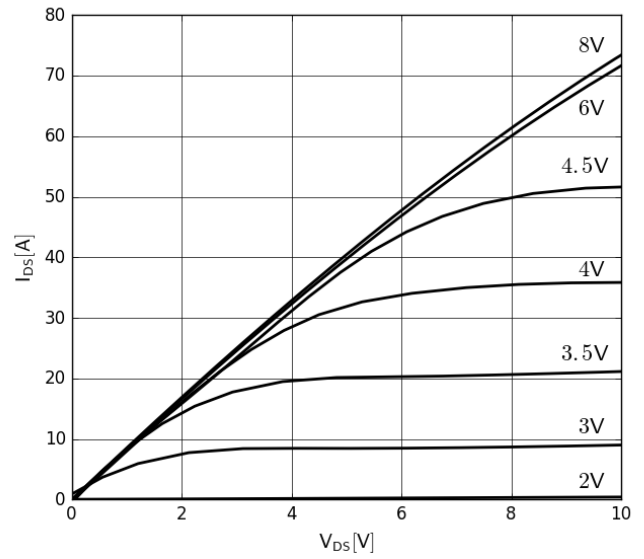
- Dynamic value
- Equivalent capacitance to give same stored energy from 0V to 400V
- Equivalent capacitance to give same charging time from 0V to 400V

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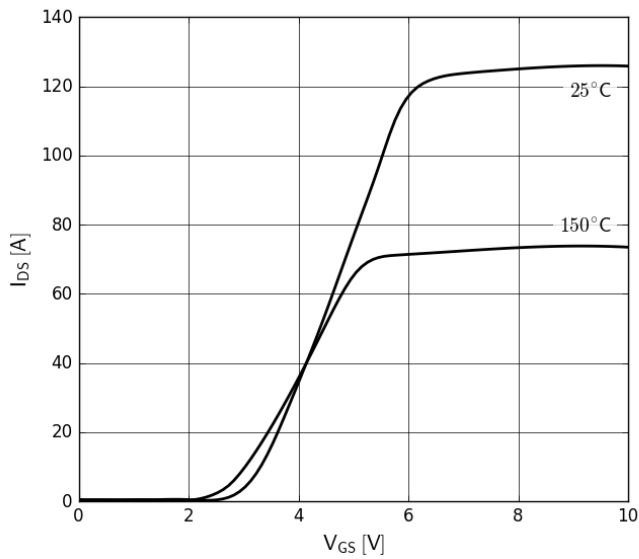
## Typical Characteristics (25 °C unless otherwise stated)



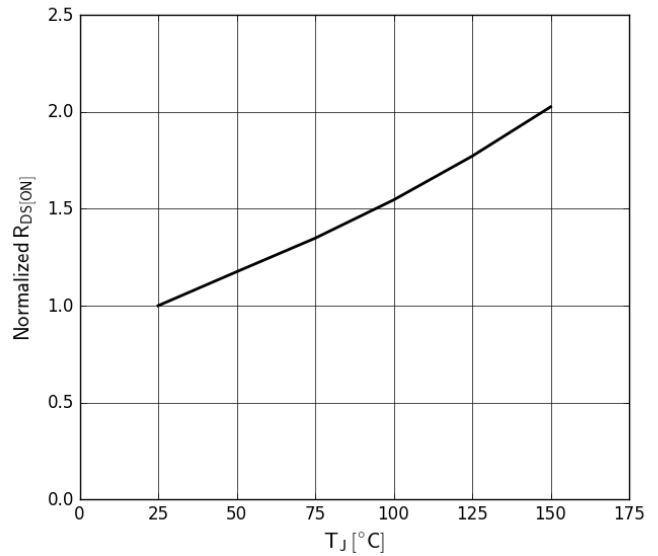
**Figure 1. Typical Output Characteristics  $T_J=25^\circ\text{C}$**   
Parameter:  $V_{GS}$



**Figure 2. Typical Output Characteristics  $T_J=150^\circ\text{C}$**   
Parameter:  $V_{GS}$



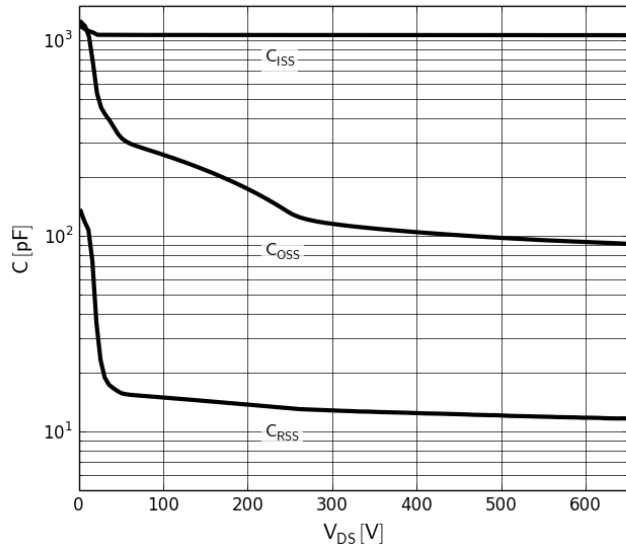
**Figure 3. Typical Transfer Characteristics**  
 $V_{DS}=10\text{V}$ , Parameter:  $T_J$



**Figure 4. Normalized On-Resistance**  
 $I_D=17\text{A}$ ,  $V_{GS}=8\text{V}$

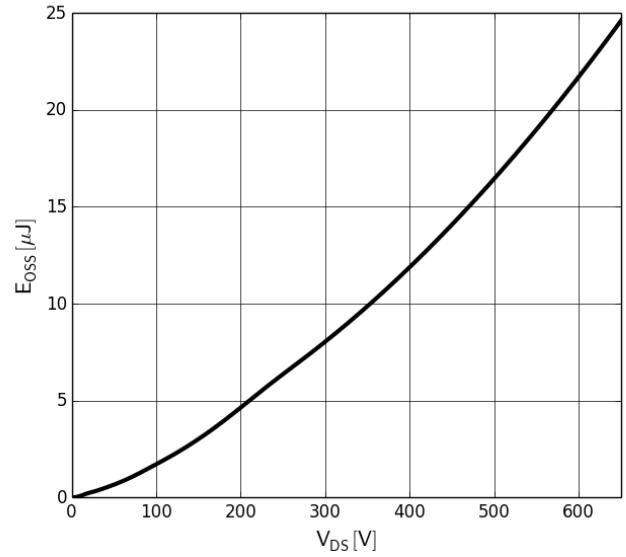
# TPH3212PS

## Typical Characteristics (25 °C unless otherwise stated)

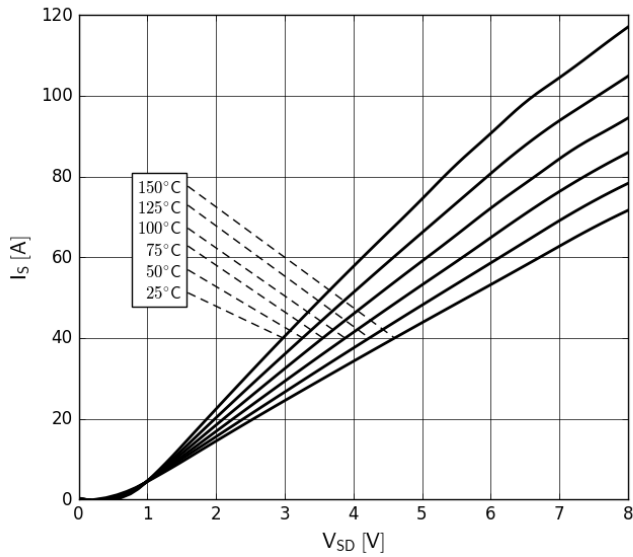


**Figure 5. Typical Capacitance**

$V_{GS}=0V, f=1MHz$

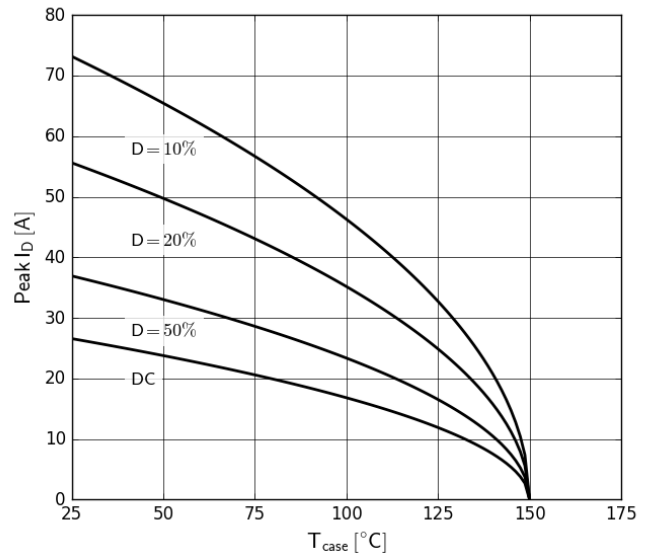


**Figure 6. Typical  $C_{OSS}$  Stored Energy**



**Figure 7. Forward Characteristics of Rev. Diode**

$I_S=f(V_{SD}), \text{Parameter } T_J$

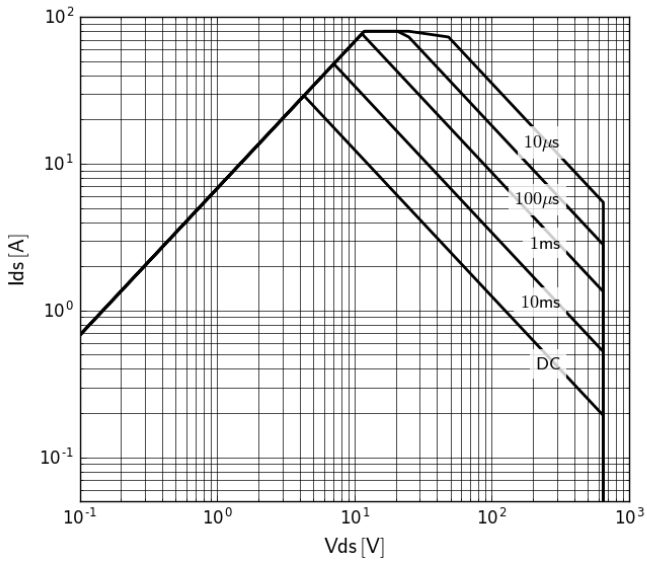


**Figure 8. Current Derating**

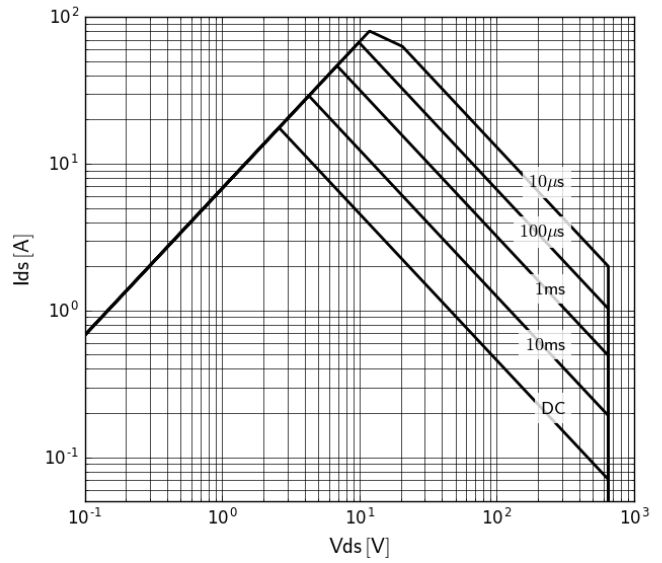
Pulse width  $\leq 10\mu s$

# TPH3212PS

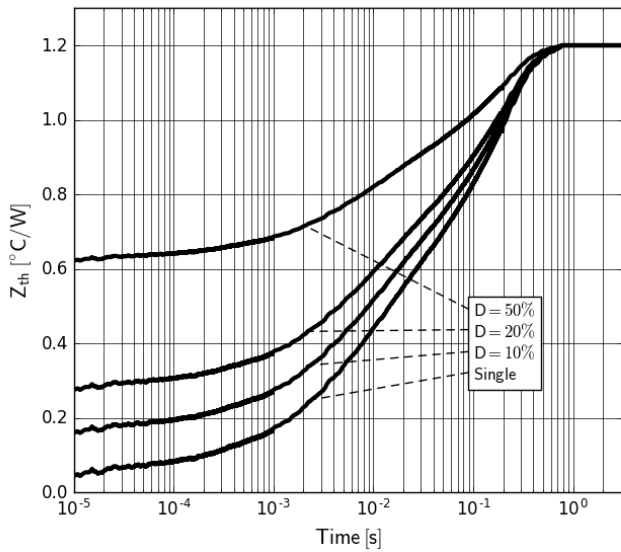
## Typical Characteristics (25 °C unless otherwise stated)



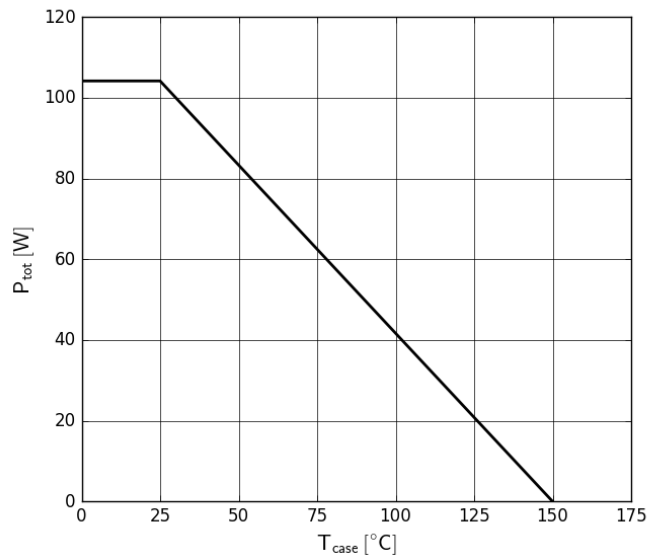
**Figure 9. Safe Operating Area  $T_C=25^\circ\text{C}$   
(calculated based on thermal limit)**



**Figure 10. Safe Operating Area  $T_C=80^\circ\text{C}$   
(calculated based on thermal limit)**



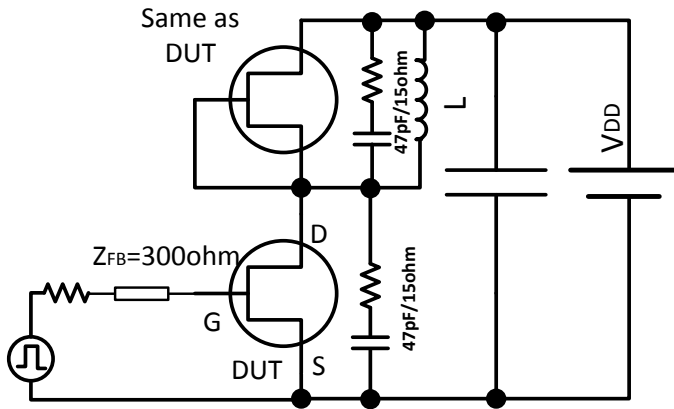
**Figure 11. Transient Thermal Resistance**



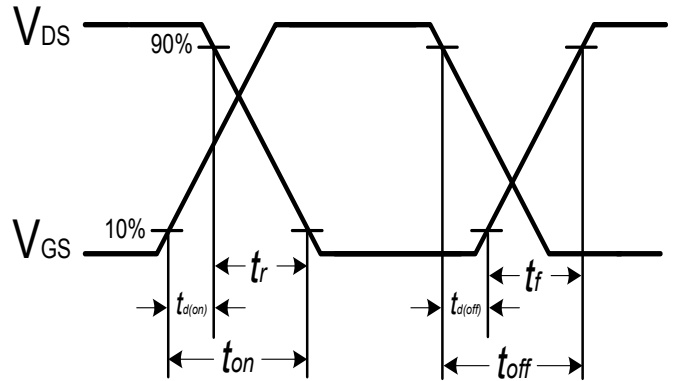
**Figure 12. Power Dissipation**

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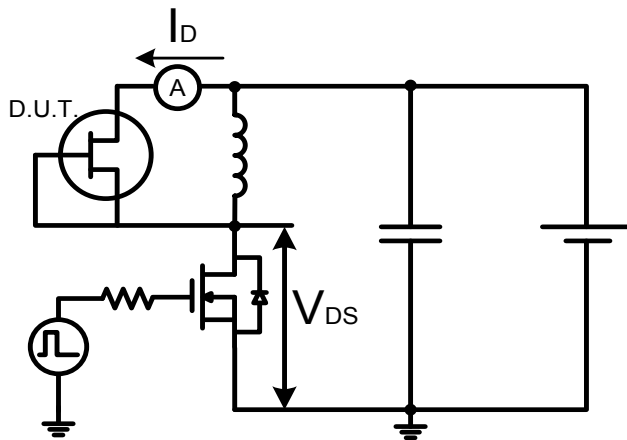
## Test Circuits and Waveforms



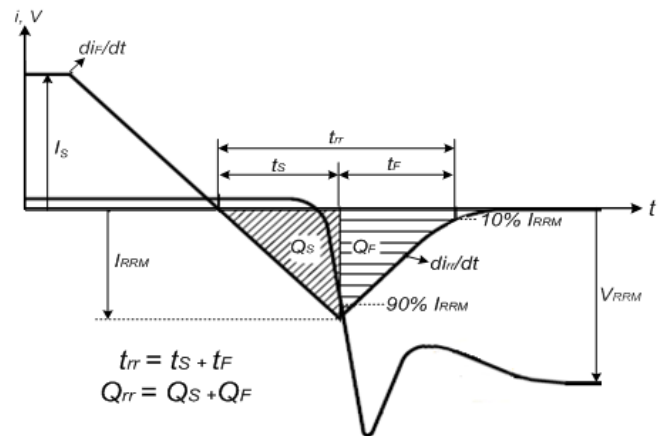
**Figure 13. Switching Time Test Circuit**  
\*See app note AN0009 for methods to ensure clean switching



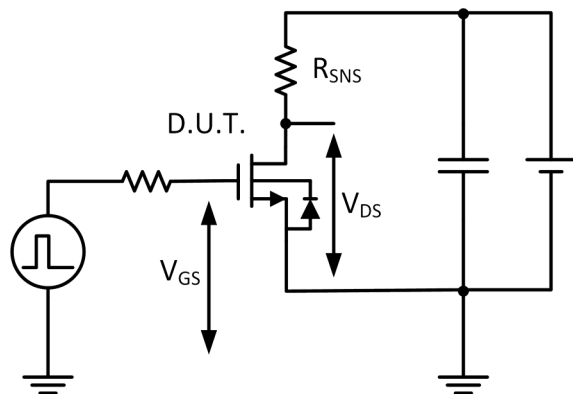
**Figure 14. Switching Time Waveform**



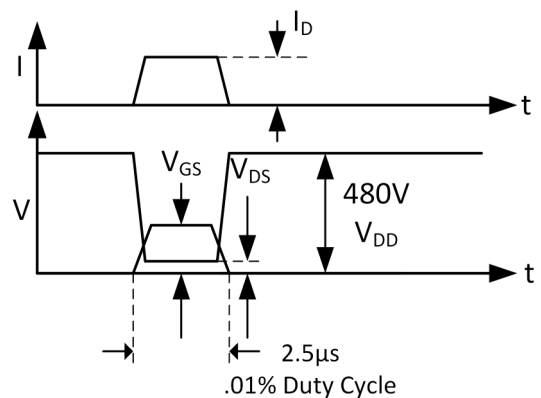
**Figure 15. Test Circuit for Diode Characteristics**



**Figure 16. Diode Recovery Waveform**



**Figure 17. Test Circuit for Dynamic  $R_{DS(on)}$**



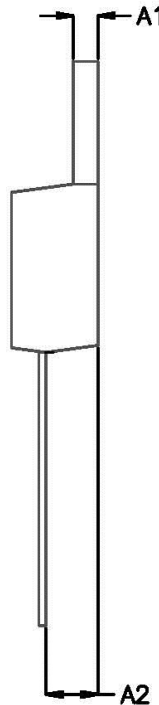
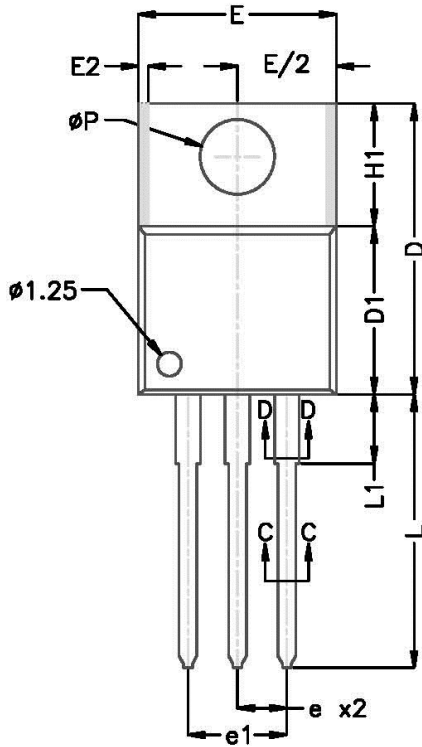
**Figure 18. Dynamic  $R_{DS(on)}$  Waveform**

# TPH3212PS

## Mechanical

## 3 Lead T0-220 (PS) Package

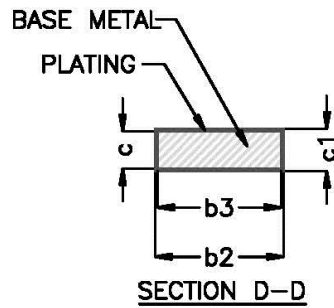
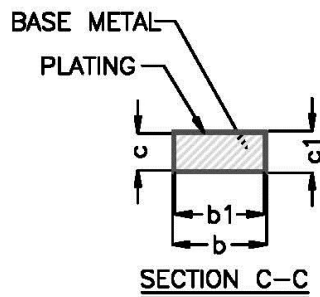
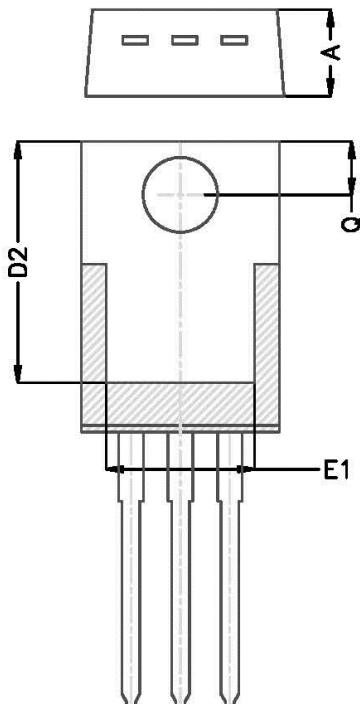
Pin 1: Gate; Pin 2: Source; Pin 3: Drain, Tab: Source



SYMBOL	MILLIMETERS			INCHES		
	MINIMUM	NOMINAL	MAXIMUM	MINIMUM	NOMINAL	MAXIMUM
A	3.56	4.45	4.83	0.140	0.175	0.190
A1	0.51	1.27	1.40	0.020	0.050	0.055
A2	2.03	-	2.92	0.080	-	0.115
b	0.38	-	1.01	0.015	-	0.040
b1	0.38	-	0.97	0.015	-	0.038
b2	1.14	-	1.78	0.045	-	0.070
b3	1.14	1.27	1.73	0.045	0.050	0.068
c	0.38	-	0.61	0.014	-	0.024
c1	0.38	0.38	0.56	0.014	0.015	0.022
D	14.22	-	16.51	0.560	-	0.650
D1	8.38	8.64	9.02	0.330	0.340	0.355
D2	11.68	-	12.88	0.460	-	0.507
E	9.65	10.19	10.87	0.380	0.401	0.420
E1	6.86	-	8.89	0.270	-	0.350
E2	-	-	0.76	-	-	0.030
e	2.54 BSC			0.100 BSC		
e1	5.08 BSC			0.200 BSC		
H1	5.84	6.30	6.86	0.230	0.248	0.270
L	12.70	14.05	14.73	0.500	0.553	0.580
L1	-	-	6.35	-	-	0.250
øP	3.54	3.84	4.08	0.139	0.151	0.161
Q	2.54	-	3.42	0.100	-	0.135

### NOTES:

1. DIMENSIONS D & E DO NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.127 MM (0.005") PER SIDE. THESE DIMENSIONS ARE MEASURED AT THE OUTERMOST EXTREME OF THE PLASTIC BODY.
2. DIMENSIONS E2 & H1 DEFINE A ZONE WHERE STAMPING AND SINGULATION IRREGULARITIES ARE ALLOWED.
3. OUTLINE CONFORMS TO JEDEC TO-220AB.





# TPH3212PS

## Design Considerations

The fast switching of GaN devices reduces current-voltage cross-over losses and enables high frequency operation while simultaneously achieving high efficiency. However, taking full advantage of the fast switching characteristics of GaN switches requires adherence to specific PCB layout guidelines and probing techniques.

Before evaluating Transphorm GaN devices, see application note [Printed Circuit Board Layout and Probing for GaN Power Switches](#). The table below provides some practical rules that should be followed during the evaluation.

### When Evaluating Transphorm GaN Devices:

DO	DO NOT
Minimize circuit inductance by keeping traces short, both in the drive and power loop	Twist the pins of TO-220 or TO-247 to accommodate GDS board layout
Minimize lead length of TO-220 and TO-247 package when mounting to the PCB	Use long traces in drive circuit, long lead length of the devices
Use shortest sense loop for probing; attach the probe and its ground connection directly to the test points	Use differential mode probe or probe ground clip with long wire
See <a href="#">AN0003</a> : Printed Circuit Board Layout and Probing	

## Application Notes

- [AN0002](#): Characteristics of Transphorm GaN Power Switches
- [AN0003](#): Printed Circuit Board Layout and Probing
- [AN0004](#): Designing Hard-switched Bridges with GaN
- [AN0008](#): Drain Voltage and Avalanche Ratings for GaN FETs
- [AN0009](#): Recommended External Circuitry for GaN FETs

## Evaluation Boards

- TDHBG2500P100-KIT: 2.5KW hard-switched half-bridge, buck or boost evaluation platform

# TPH3212PS

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## Revision History

Version	Date	Change(s)
10	11/14/2016	Add application note AN0009
11	12/12/2016	Formatting Changes to p. 3, revision of dynamic measurement verbiage