

## 650V SuperGaN® FET in TO-263 (source tab)

### Description

The TP65H050G4BS 650V, 50 mΩ gallium nitride (GaN) FET is a normally-off device using Transphorm's Gen IV platform. It combines a state-of-the-art high voltage GaN HEMT with a low voltage silicon MOSFET to offer superior reliability and performance.

The Gen IV SuperGaN® platform uses advanced epi and patented design technologies to simplify manufacturability while improving efficiency over silicon via lower gate charge, output capacitance, crossover loss, and reverse recovery charge.

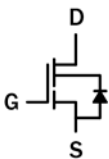
### Related Literature

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

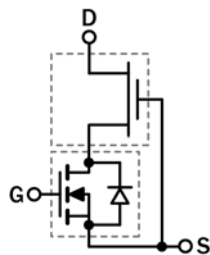
### Ordering Information

| Part Number  | Package | Package Configuration |
|--------------|---------|-----------------------|
| TP65H050G4BS | TO-263  | Source Tab            |

TP65H050G4BS  
TO-263  
(top view)



Cascode Schematic Symbol



Cascode Device Structure

### Features

- JEDEC qualified GaN technology
- Dynamic  $R_{DS(on)eff}$  production tested
- Robust design, defined by
  - Wide gate safety margin
  - Transient over-voltage capability
- Enhanced inrush current capability
- Very low  $Q_{RR}$
- Reduced crossover loss

### Benefits

- Enables AC-DC bridgeless totem-pole PFC designs
  - Increased power density
  - Reduced system size and weight
  - Overall lower system cost
- Achieves increased efficiency in both hard- and soft-switched circuits
- Easy to drive with commonly-used gate drivers
- GSD pin layout improves high speed design

### Applications

- Datacom
- Broad industrial
- PV inverter
- Servo motor



### Key Specifications

|                           |     |
|---------------------------|-----|
| $V_{DSS}$ (V)             | 650 |
| $V_{DSS(TR)}$ (V)         | 800 |
| $R_{DS(on)eff}$ (mΩ) max* | 60  |
| $Q_{RR}$ (nC) typ         | 120 |
| $Q_G$ (nC) typ            | 16  |

\* Dynamic on-resistance; see Figures 18 and 19

# TP65H050G4BS

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

| Symbol        | Parameter  | Limit Value     | Unit             |                  |
|---------------|--|-----------------|------------------|------------------|
| $V_{DSS}$     | Drain to source voltage ( $T_J = -55^\circ\text{C}$ to $150^\circ\text{C}$ ) | 650             | V                |                  |
| $V_{DSS(TR)}$ | Transient drain to source voltage <sup>a</sup>                               | 800             |                  |                  |
| $V_{GSS}$     | Gate to source voltage   | $\pm 20$        |                  |                  |
| $P_D$         | Maximum power dissipation @ $T_c=25^\circ\text{C}$                           | 119             | W                |                  |
| $I_D$         | Continuous drain current @ $T_c=25^\circ\text{C}$ <sup>b</sup>               | 34              | A                |                  |
|               | Continuous drain current @ $T_c=100^\circ\text{C}$ <sup>b</sup>              | 22              | A                |                  |
| $I_{DM}$      | Pulsed drain current (pulse width: 10 $\mu\text{s}$ )                        | 150             | A                |                  |
| $T_C$         | Operating temperature  | Case            | $-55$ to $+150$  | $^\circ\text{C}$ |
| $T_J$         |  | Junction        | $-55$ to $+150$  | $^\circ\text{C}$ |
| $T_S$         | Storage temperature  | $-55$ to $+150$ | $^\circ\text{C}$ |                  |
| $T_{SOLD}$    | Soldering peak temperature <sup>c</sup>                                      | 260             | $^\circ\text{C}$ |                  |

Notes:

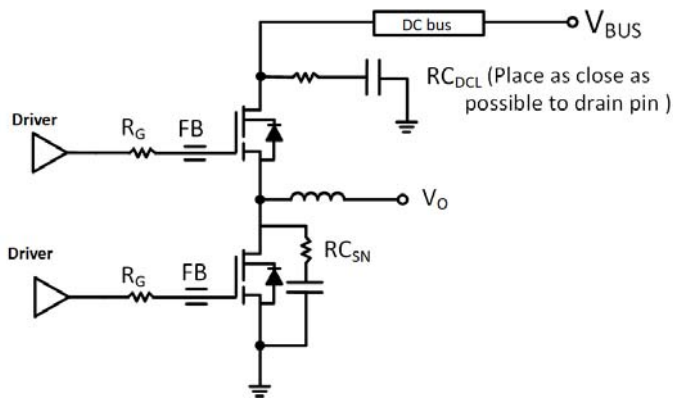
- In off-state, spike duty cycle  $D < 0.01$ , spike duration  $< 30\mu\text{s}$ , non repetitive
- For increased stability at high current operation, see Circuit Implementation on page 3
- Reflow MSL3

## Thermal Resistance

| Symbol          | Parameter           | Maximum | Unit                      |
|-----------------|---------------------|---------|---------------------------|
| $R_{\theta JC}$ | Junction-to-case    | 1.05    | $^\circ\text{C}/\text{W}$ |
| $R_{\theta JA}$ | Junction-to-ambient | 40      | $^\circ\text{C}/\text{W}$ |

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## Circuit Implementation



Layout Recommendations: (See also [AN0009](#))

Gate Loop:

- Gate Driver: SiLab Si823x/Si827x
- Keep gate loop compact
- Minimize coupling with power loop

Power loop:

- Minimize power loop path inductance
- Minimize switching node coupling with high and low power plane
- Add DC bus snubber to reduce to voltage ringing
- Add Switching node snubber for high current operation

**Simplified Half-bridge Schematic ( See also on Figure 13)**

Recommended gate drive: (0V, 12V) with  $R_G = 45\Omega$

| Gate Ferrite Bead (FB1)      | Required DC Link RC Snubber ( $RC_{DCL}$ ) <sup>a</sup> | Recommended Switching Node RC Snubber ( $RC_{SN}$ ) |
|------------------------------|---|---|
| 240 – 300 $\Omega$ at 100MHz | [4.7nF + 5 $\Omega$ ] x 2                               | See note b and c below                              |

Notes:

- $RC_{DCL}$  should be placed as close as possible to the drain pin
- $RC_{SN}$  is needed only if  $R_G$  is smaller than recommendations
- If required, please use 15 $\Omega$ +47pF

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

| Symbol                                | Parameter                                       | Min | Typ  | Max  | Unit  | Test Conditions  |
|---------------------------------------|---|-----|------|------|-------|--|
| <b>Forward Device Characteristics</b> |   |     |      |      |       |  |
| V <sub>DSS(BL)</sub>                  | Drain-source voltage                            | 650 | —    | —    | V     | V <sub>GS</sub> =0V  |
| V <sub>GS(th)</sub>                   | Gate threshold voltage                          | 3.3 | 4    | 4.8  | V     | V <sub>DS</sub> =V <sub>GS</sub> , I <sub>D</sub> =0.7mA   |
| ΔV <sub>GS(th)/T<sub>J</sub></sub>    | Gate threshold voltage temperature coefficient  | —   | -6.2 | —    | mV/°C |  |
| R <sub>DS(on)eff</sub>                | Drain-source on-resistance <sup>a</sup>         | —   | 50   | 60   | mΩ    | V <sub>GS</sub> =10V, I <sub>D</sub> =22A  |
|                                       |   | —   | 105  | —    |       | V <sub>GS</sub> =10V, I <sub>D</sub> =22A, T <sub>J</sub> =150 °C  |
| I <sub>DSS</sub>                      | Drain-to-source leakage current                 | —   | 4    | 40   | μA    | V <sub>DS</sub> =650V, V <sub>GS</sub> =0V   |
|                                       |   | —   | 15   | —    |       | 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> =20V   |
|                                       |   | —   | —    | -100 |       | V <sub>GS</sub> =-20V  |
| C <sub>ISS</sub>                      | Input capacitance                               | —   | 1000 | —    | pF    | V <sub>GS</sub> =0V, V <sub>DS</sub> =400V, f=1MHz   |
| C <sub>OSS</sub>                      | Output capacitance                              | —   | 110  | —    |       |  |
| C <sub>RSS</sub>                      | Reverse transfer capacitance                    | —   | 6    | —    |       |  |
| C <sub>O(er)</sub>                    | Output capacitance, energy related <sup>b</sup> | —   | 164  | —    | 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>   | —   | 280  | —    |       |  |
| Q <sub>G</sub>                        | Total gate charge                               | —   | 16   | 24   | nC    | V <sub>DS</sub> =400V, V <sub>GS</sub> =0V to 10V, I <sub>D</sub> =22A   |
| Q <sub>GS</sub>                       | Gate-source charge                              | —   | 6    | —    |       |  |
| Q <sub>GD</sub>                       | Gate-drain charge                               | —   | 5    | —    |       |  |
| Q <sub>OSS</sub>                      | Output charge                                   | —   | 120  | —    | nC    | V <sub>GS</sub> =0V, V <sub>DS</sub> =0V to 400V   |
| t <sub>D(on)</sub>                    | Turn-on delay                                   | —   | 49.2 | —    | ns    | V <sub>DS</sub> =400V, V <sub>GS</sub> =0V to 10V, I <sub>D</sub> =22A, R <sub>g</sub> =45Ω, Z <sub>FB</sub> =240Ω at 100MHz (See Figure 14) |
| t <sub>R</sub>                        | Rise time                                       | —   | 11.3 | —    |       |  |
| t <sub>D(off)</sub>                   | Turn-off delay                                  | —   | 88.3 | —    |       |  |
| t <sub>F</sub>                        | Fall time                                       | —   | 10.9 | —    |       |  |

Notes:

- Dynamic on-resistance; see Figures 17 and 18 for test circuit and conditions
- Equivalent capacitance to give same stored energy as V<sub>DS</sub> rises from 0V to 400V
- Equivalent capacitance to give same charging time as V<sub>DS</sub> rises from 0V to 400V

# TP65H050G4BS

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

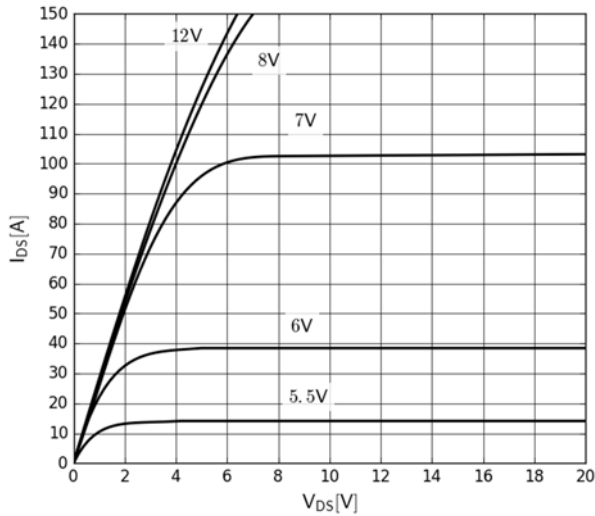
| Symbol                                | Parameter                        | Min | Typ | Max  | Unit | Test Conditions  |
|---------------------------------------|----------------------------------|-----|-----|------|------|--|
| <b>Reverse Device Characteristics</b> |                                  |     |     |      |      |  |
| I <sub>S</sub>                        | Reverse current                  | —   | —   | 22   | A    | V <sub>GS</sub> =0V, T <sub>C</sub> =100 °C, ≤25% duty cycle |
| V <sub>SD</sub>                       | Reverse voltage <sup>a</sup>     | —   | 2.2 | 2.6  | V    | V <sub>GS</sub> =0V, I <sub>S</sub> =22A                     |
|                                       |                                  | —   | 1.6 | 1.9  |      | V <sub>GS</sub> =0V, I <sub>S</sub> =11A                     |
| t <sub>RR</sub>                       | Reverse recovery time            | —   | 50  | —    | ns   | I <sub>S</sub> =22A, V <sub>DD</sub> =400V                   |
| Q <sub>RR</sub>                       | Reverse recovery charge          | —   | 120 | —    | nC   |  |
| (di/dt) <sub>RM</sub>                 | Reverse diode di/dt <sup>b</sup> | —   | —   | 2500 | A/μs | Circuit implementation and parameters on page 3              |

Notes:

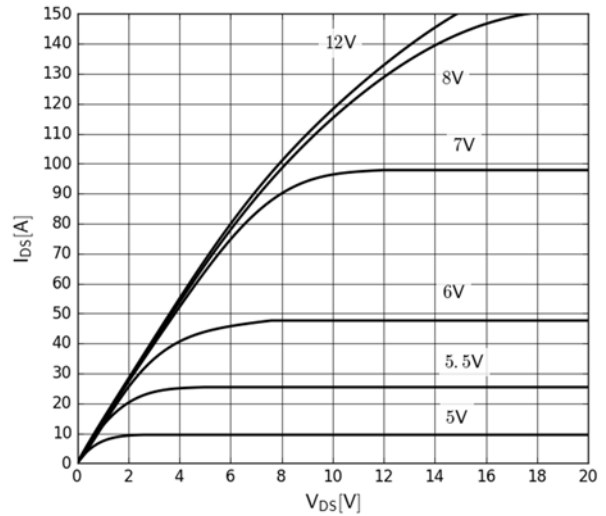
- a. Includes dynamic R<sub>DS(on)</sub> effect
- b. Reverse conduction di/dt will not exceed this max value with recommended R<sub>G</sub>.

# TP65H050G4BS

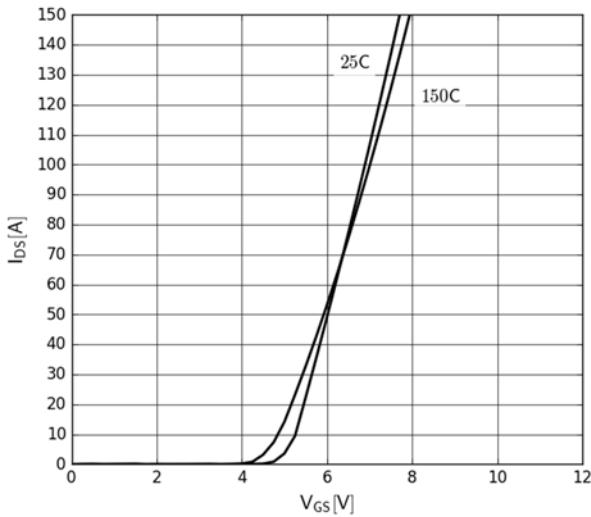
Typical Characteristics ( $T_C=25^\circ\text{C}$  unless otherwise stated)



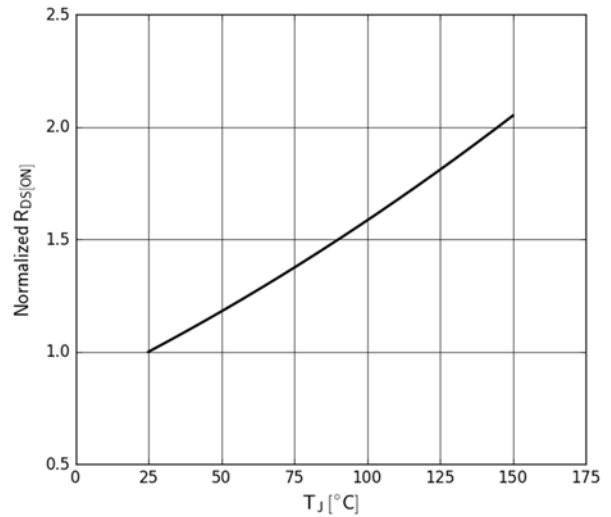
**Figure 1. Typical Output Characteristics  $T_J=25^\circ\text{C}$**   
Parameter:  $V_{GS}$



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



**Figure 3. Typical Transfer Characteristics**  
 $V_{DS}=20\text{V}$ , parameter:  $T_J$



**Figure 4. Normalized On-resistance**  
 $I_D=30\text{A}$ ,  $V_{GS}=8\text{V}$

# TP65H050G4BS

Typical Characteristics ( $T_C=25^\circ\text{C}$  unless otherwise stated)

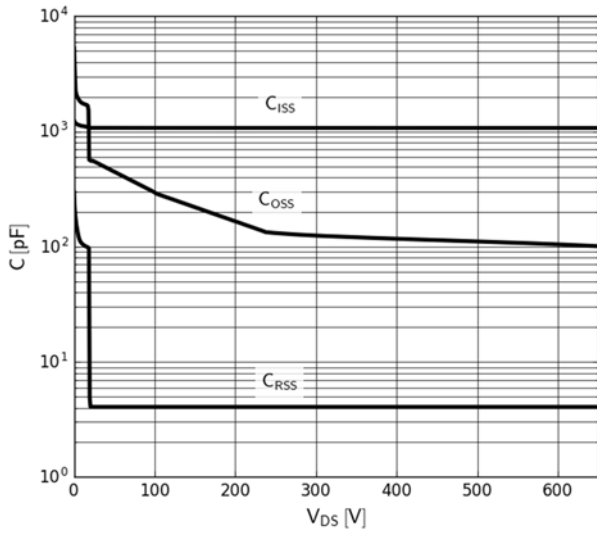


Figure 5. Typical Capacitance

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

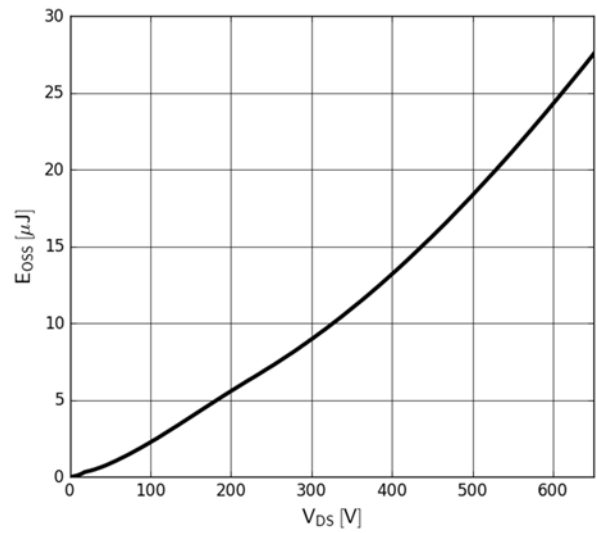


Figure 6. Typical  $C_{oss}$  Stored Energy

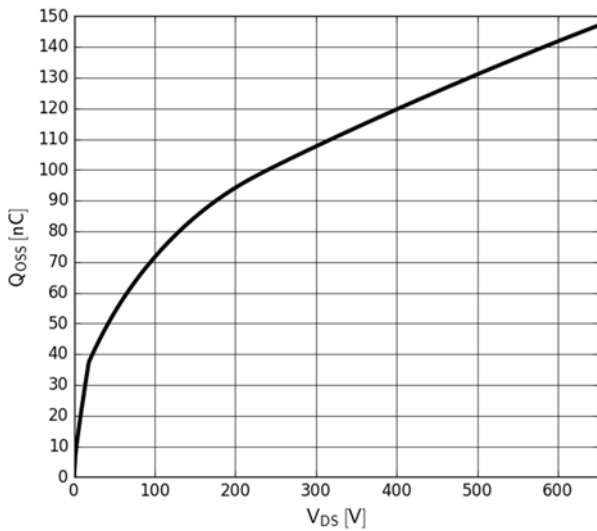


Figure 7. Typical  $Q_{oss}$

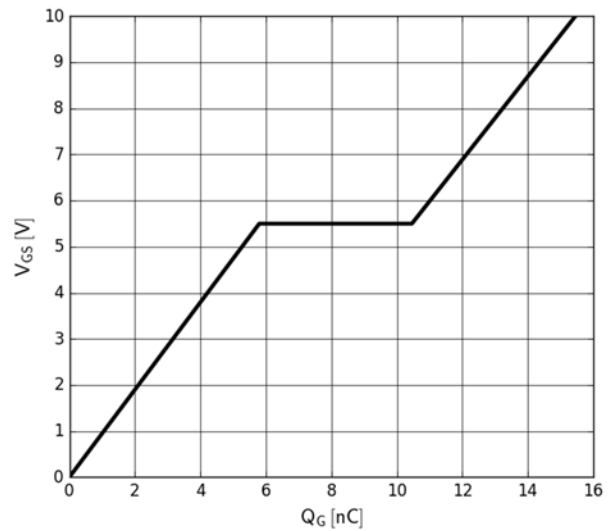


Figure 8. Typical Gate Charge

$I_{DS}=32A$ ,  $V_{DS}=400V$

# TP65H050G4BS

Typical Characteristics ( $T_C=25^\circ\text{C}$  unless otherwise stated)

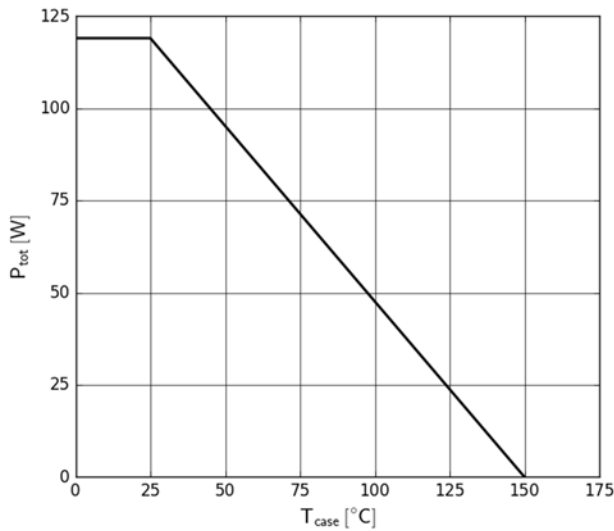


Figure 9. Power Dissipation

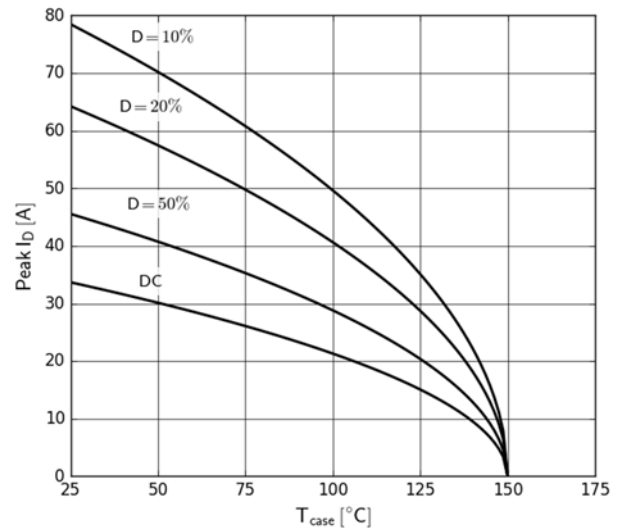


Figure 10. Current Derating  
Pulse width  $\leq 10\mu\text{s}$ ,  $V_{GS} \geq 10\text{V}$

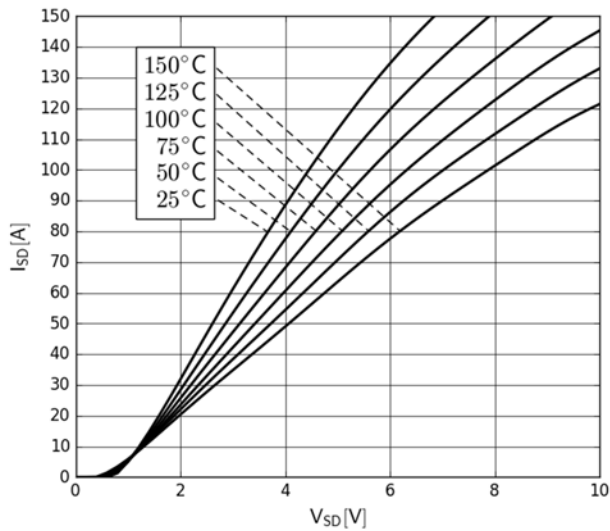


Figure 11. Forward Characteristics of Rev. Diode  
 $I_S=f(V_{SD})$ , parameter:  $T_J$

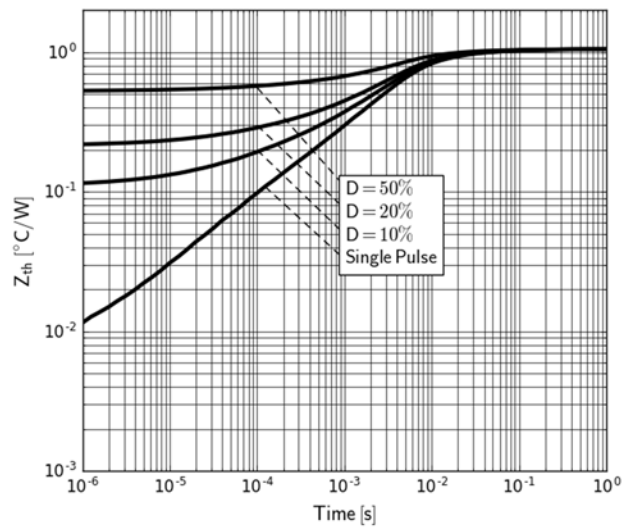


Figure 12. Transient Thermal Resistance



# TP65H050G4BS

Typical Characteristics ( $T_C=25^\circ\text{C}$  unless otherwise stated)

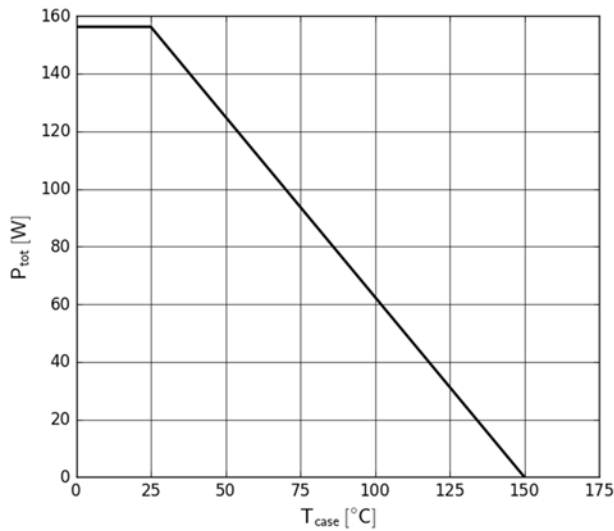


Figure 9. Power Dissipation

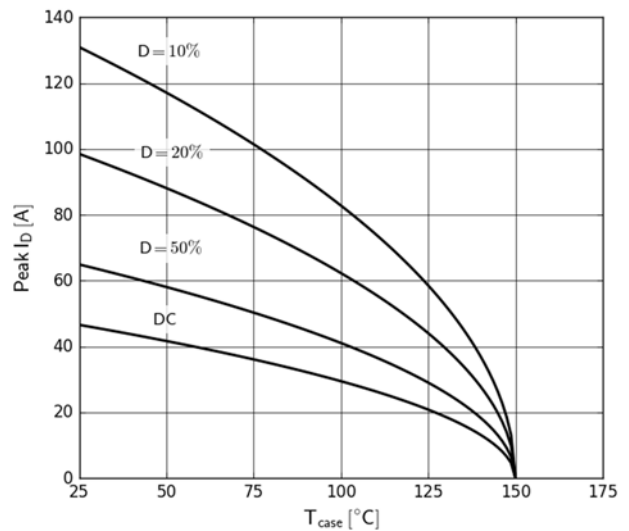


Figure 10. Current Derating  
Pulse width  $\leq 10\mu\text{s}$ ,  $V_{GS} \geq 10\text{V}$

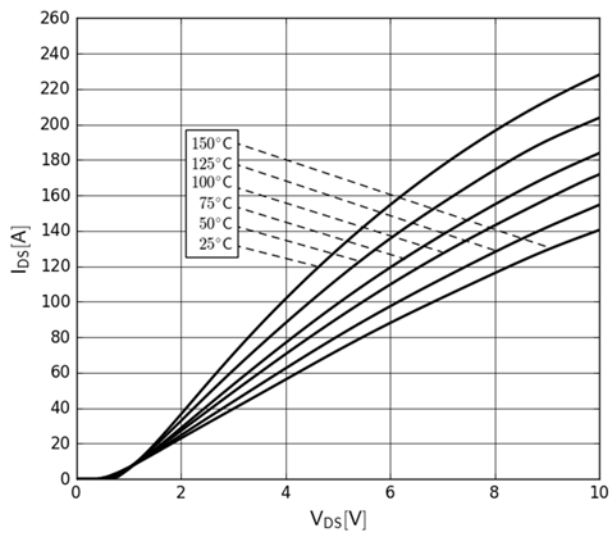


Figure 11. Forward Characteristics of Rev. Diode  
 $I_S=f(V_{SD})$ , parameter:  $T_J$

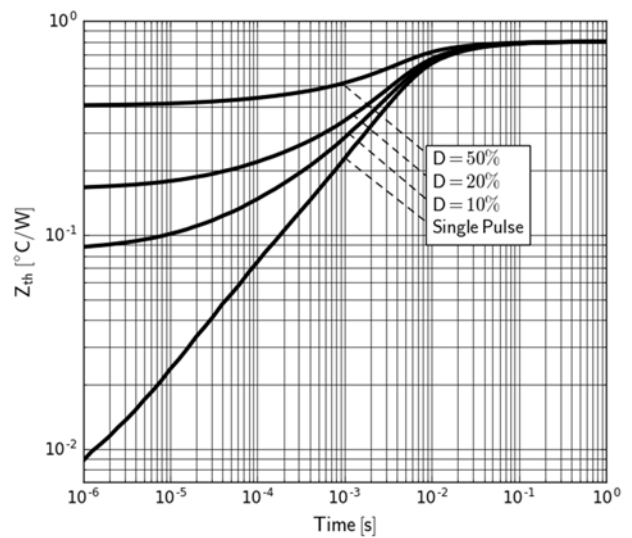


Figure 12. Transient Thermal Resistance

# TP65H050G4BS

Typical Characteristics ( $T_c=25^\circ\text{C}$  unless otherwise stated)

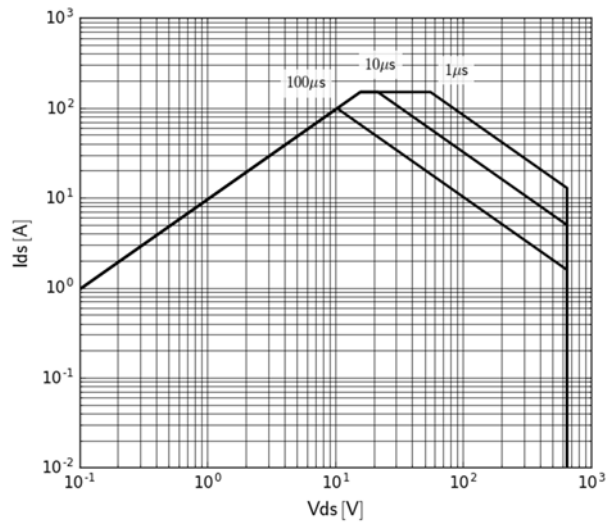
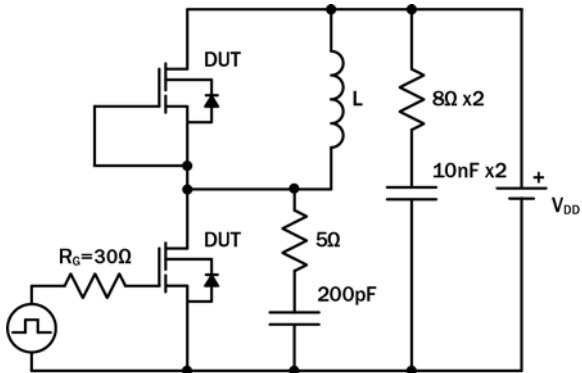


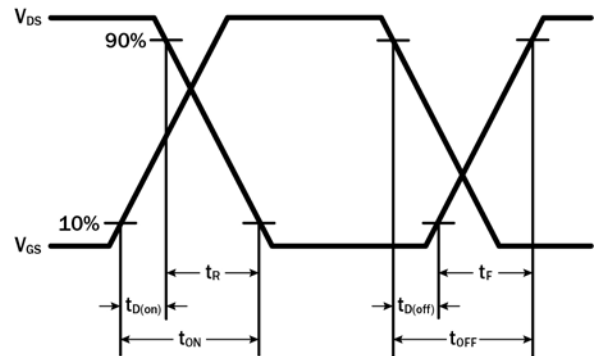
Figure 13. Safe Operating Area  $T_c=25^\circ\text{C}$

# TP65H050G4BS

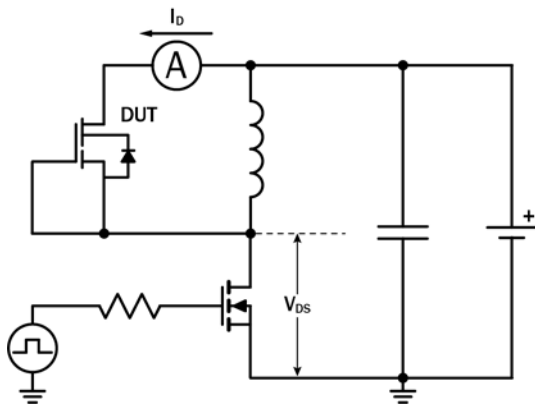
## Test Circuits and Waveforms



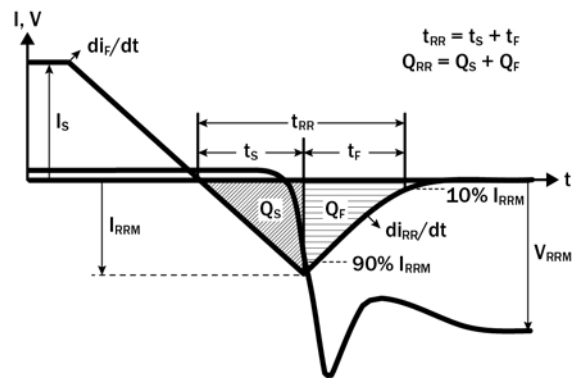
**Figure 13. Switching Time Test Circuit**  
(see circuit implementation on page 3 for methods to ensure clean switching)



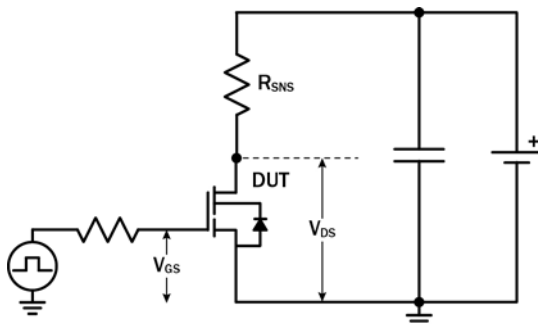
**Figure 14. Switching Time Waveform**



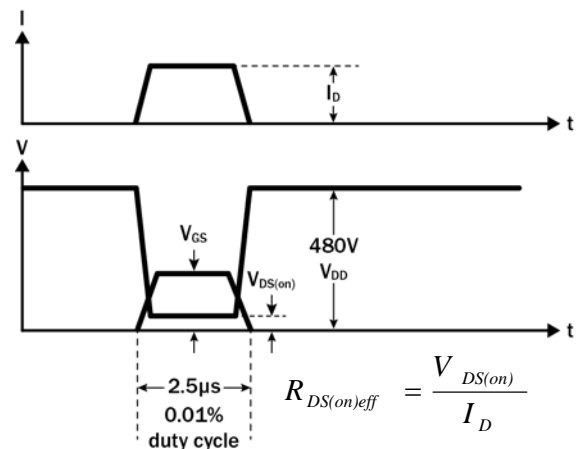
**Figure 15. Diode Characteristics Test Circuit**



**Figure 16. Diode Recovery Waveform**



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



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

# TP65H050G4BS

## Design Considerations

The fast switching of GaN devices reduces current-voltage crossover 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                                       |  |

## GaN Design Resources

The complete technical library of GaN design tools can be found at [transphormusa.com/design](https://transphormusa.com/design):

- Evaluation kits
- Application notes
- Design guides
- Simulation models
- Technical papers and presentations

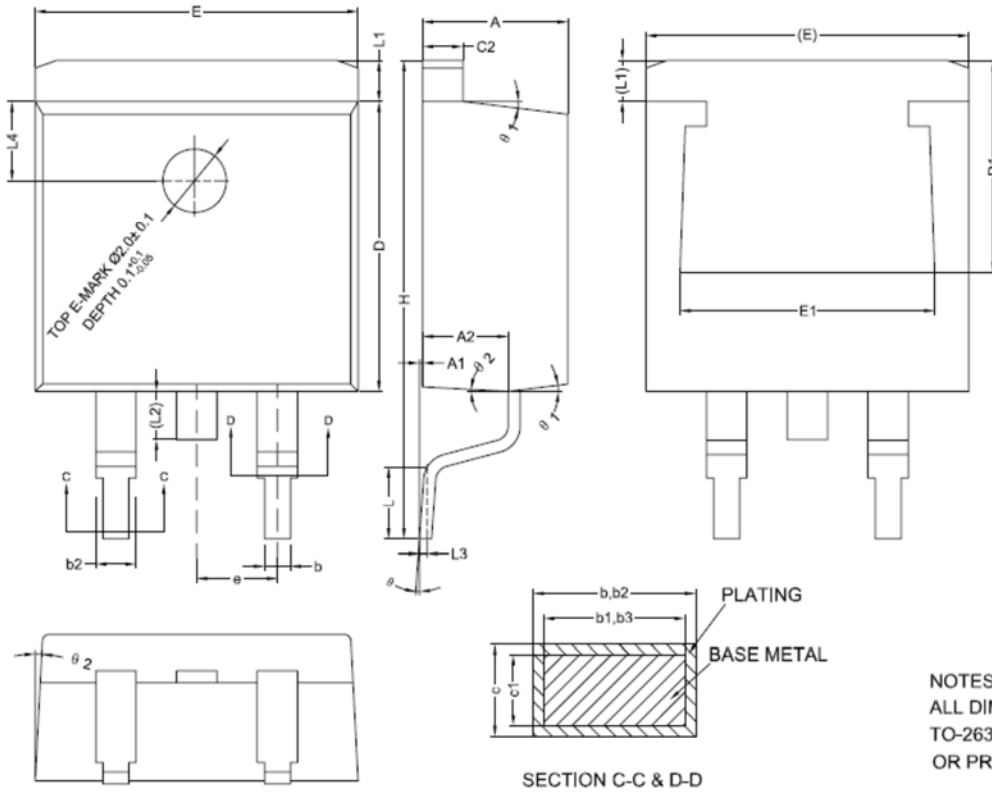
# TP65H050G4BS

## Mechanical

## 3 Lead T0-247 Package

COMMON DIMENSIONS  
(UNITS OF MEASURE=MILLIMETER)

| SYMBOL     | MIN     | NOM   | MAX   |
|------------|---------|-------|-------|
| A          | 4.40    | 4.57  | 4.70  |
| A1         | 0       | 0.10  | 0.25  |
| A2         | 2.59    | 2.69  | 2.79  |
| b          | 0.77    | -     | 0.90  |
| b1         | 0.76    | 0.81  | 0.86  |
| b2         | 1.23    | -     | 1.36  |
| b3         | 1.22    | 1.27  | 1.32  |
| c          | 0.34    | -     | 0.47  |
| c1         | 0.33    | 0.38  | 0.43  |
| c2         | 1.22    | -     | 1.32  |
| D          | 9.05    | 9.15  | 9.25  |
| D1         | 6.60    | -     | -     |
| E          | 10.06   | 10.16 | 10.26 |
| E1         | 7.80    | -     | 8.20  |
| e          | 2.54BSC |       |       |
| H          | 14.70   | 15.10 | 15.50 |
| L          | 2.00    | 2.30  | 2.60  |
| L1         | 1.17    | 1.27  | 1.40  |
| L2         | -       | -     | 1.75  |
| L3         | 0.25BSC |       |       |
| L4         | 2.00REF |       |       |
| $\theta$   | 0°      | -     | 8°    |
| $\theta_1$ | 5°      | 7°    | 9°    |
| $\theta_2$ | 1°      | 3°    | 5°    |



NOTES:  
ALL DIMENSIONS REFER TO JEDEC STANDARD TO-263 AB DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.

# TP65H050G4BS

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## Revision History

| Version | Date       | Change(s)                    |
|---------|------------|------------------------------|
| 0       | 10/16/2020 | Create preliminary datasheet |
| 0.1     | 01/06/2021 | Update $V_{DSS(TR)}$         |
| 0.2     | 05/06/2021 | preliminary datasheet update |
| 1.0     | 10/13/2021 | Released datasheet           |