

# Field Stop Trench IGBT

## 650 V, 40 A

### FGAF40S65AQ

#### Description

Using novel field stop IGBT technology, ON Semiconductor's new series of field stop 4th generation of RC IGBTs offer the optimum performance for PFC applications and welder where low conduction and switching losses are essential.

#### Features

- Maximum Junction Temperature:  $T_J = 175^{\circ}\text{C}$
- Positive Temperature Co-efficient for Easy Parallel Operating
- High Current Capability
- Low Saturation Voltage:  $V_{CE(sat)} = 1.6\text{ V (Typ.) @ } I_C = 40\text{ A}$
- 100% of the Parts Tested for  $I_{LM}$  (Note 1)
- High Input Impedance
- Fast Switching
- Tighten Parameter Distribution
- IGBT with Monolithic Reverse Conducting Diode
- This Device is Pb-Free and is RoHS Compliant

#### Applications

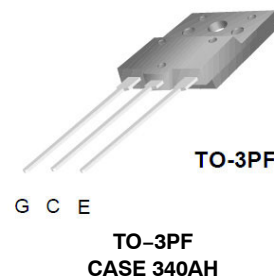
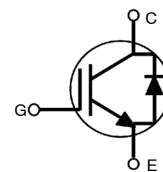
- PFC, Welder



**ON Semiconductor®**

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| $V_{CES}$ | $I_C$ |
|-----------|-------|
| 650 V     | 40 A  |



#### ORDERING INFORMATION

See detailed ordering and shipping information on page 2 of this data sheet.

# FGAF40S65AQ

## PACKAGE MARKING AND ORDERING INFORMATION

| Part Number | Device Marking | Package | Reel Size | Tape Width | Quantity per Tube |
|-------------|----------------|---------|-----------|------------|-------------------|
| FGAF40S65AQ | FGAF40S65AQ    | TO-3PF  | –         | –          | 30                |

**Table 1. ABSOLUTE MAXIMUM RATINGS**

| Symbol            | Description                                                         | FGAF40S65AQ                 | Unit             |
|-------------------|---------------------------------------------------------------------|-----------------------------|------------------|
| $V_{CES}$         | Collector to Emitter Voltage                                        | 650                         | V                |
| $V_{GES}$         | Gate to Emitter Voltage                                             | $\pm 20$                    | V                |
|                   | Transient Gate to Emitter Voltage                                   | $\pm 30$                    | V                |
| $I_C$             | Collector Current                                                   | @ $T_C = 25^\circ\text{C}$  | A                |
|                   |                                                                     | @ $T_C = 100^\circ\text{C}$ |                  |
| $I_{LM}$ (Note 1) | Pulsed Collector Current                                            | @ $T_C = 25^\circ\text{C}$  | A                |
| $I_{CM}$ (Note 2) | Pulsed Collector Current                                            |                             | A                |
| $I_F$             | Diode Forward Current                                               | @ $T_C = 25^\circ\text{C}$  | A                |
|                   |                                                                     | @ $T_C = 100^\circ\text{C}$ | A                |
| $I_{FM}$ (Note 2) | Pulsed Diode Maximum Forward Current                                |                             | A                |
| $P_D$             | Maximum Power Dissipation                                           | @ $T_C = 25^\circ\text{C}$  | W                |
|                   |                                                                     | @ $T_C = 100^\circ\text{C}$ | W                |
| $T_J$             | Operating Junction Temperature Range                                | –55 to +175                 | $^\circ\text{C}$ |
| $T_{STG}$         | Storage Temperature Range                                           | –55 to +175                 | $^\circ\text{C}$ |
| $T_L$             | Maximum Lead Temp. for Soldering Purposes, 1/8" from case for 5 sec | 300                         | $^\circ\text{C}$ |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1.  $V_{CC} = 400\text{ V}$ ,  $V_{GE} = 15\text{ V}$ ,  $I_C = 160\text{ A}$ ,  $R_G = 7\ \Omega$ , Inductive Load.

2. Repetitive rating: Pulse width limited by max. junction temperature.

**Table 2. THERMAL CHARACTERISTICS**

| Symbol                 | Parameter                                     | FGAF40S65AQ | Unit               |
|------------------------|-----------------------------------------------|-------------|--------------------|
| $R_{\theta JC}$ (IGBT) | Thermal Resistance, Junction to Case, Max.    | 1.6         | $^\circ\text{C/W}$ |
| $R_{\theta JA}$        | Thermal Resistance, Junction to Ambient, Max. | 40          | $^\circ\text{C/W}$ |

# FGAF40S65AQ

**Table 3. ELECTRICAL CHARACTERISTICS OF THE IGBT** ( $T_C = 25^\circ\text{C}$  unless otherwise noted)

| Symbol                               | Parameter                                    | Test Conditions                                                                                                                      | Min | Typ  | Max  | Unit |
|--------------------------------------|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|-----|------|------|------|
| OFF CHARACTERISTICS                  |                                              |                                                                                                                                      |     |      |      |      |
| BV <sub>CES</sub>                    | Collector to Emitter Breakdown Voltage       | V <sub>GE</sub> = 0 V, I <sub>C</sub> = 1 mA                                                                                         | 650 | –    | –    | V    |
| ΔBV <sub>CES</sub> / ΔT <sub>J</sub> | Temperature Coefficient of Breakdown Voltage | V <sub>GE</sub> = 0 V, I <sub>C</sub> = 1 mA                                                                                         | –   | 0.5  | –    | V/°C |
| I <sub>CES</sub>                     | Collector Cut-Off Current                    | V <sub>CE</sub> = V <sub>CES</sub> , V <sub>GE</sub> = 0 V                                                                           | –   | –    | 250  | μA   |
| I <sub>GES</sub>                     | G–E Leakage Current                          | V <sub>GE</sub> = V <sub>GES</sub> , V <sub>CE</sub> = 0 V                                                                           | –   | –    | ±400 | nA   |
| ON CHARACTERISTICS                   |                                              |                                                                                                                                      |     |      |      |      |
| V <sub>GE(th)</sub>                  | G–E Threshold Voltage                        | I <sub>C</sub> = 40 mA, V <sub>CE</sub> = V <sub>GE</sub>                                                                            | 2.6 | 5.3  | 6.6  | V    |
| V <sub>CE(sat)</sub>                 | Collector to Emitter Saturation Voltage      | I <sub>C</sub> = 40 A, V <sub>GE</sub> = 15 V                                                                                        | –   | 1.6  | 2.1  | V    |
|                                      |                                              | I <sub>C</sub> = 40 A, V <sub>GE</sub> = 15 V, T <sub>C</sub> = 175°C                                                                | –   | 1.9  | –    | V    |
| DYNAMIC CHARACTERISTICS              |                                              |                                                                                                                                      |     |      |      |      |
| C <sub>ies</sub>                     | Input Capacitance                            | V <sub>CE</sub> = 30 V, V <sub>GE</sub> = 0 V, f = 1 MHz                                                                             | –   | 2590 | –    | pF   |
| C <sub>oes</sub>                     | Output Capacitance                           |                                                                                                                                      | –   | 35   | –    | pF   |
| C <sub>res</sub>                     | Reverse Transfer Capacitance                 |                                                                                                                                      | –   | 10   | –    | pF   |
| SWITCHING CHARACTERISTICS            |                                              |                                                                                                                                      |     |      |      |      |
| T <sub>d(on)</sub>                   | Turn-On Delay Time                           | V <sub>CC</sub> = 400 V, I <sub>C</sub> = 10 A, R <sub>G</sub> = 6 Ω, V <sub>GE</sub> = 15 V, Inductive Load, T <sub>C</sub> = 25°C  | –   | 17.8 | –    | ns   |
| T <sub>r</sub>                       | Rise Time                                    |                                                                                                                                      | –   | 6.3  | –    | ns   |
| T <sub>d(off)</sub>                  | Turn-Off Delay Time                          |                                                                                                                                      | –   | 81.6 | –    | ns   |
| T <sub>f</sub>                       | Fall Time                                    |                                                                                                                                      | –   | 9.3  | –    | ns   |
| E <sub>on</sub>                      | Turn-On Switching Loss                       |                                                                                                                                      | –   | 132  | –    | μJ   |
| E <sub>off</sub>                     | Turn-Off Switching Loss                      |                                                                                                                                      | –   | 62   | –    | μJ   |
| E <sub>ts</sub>                      | Total Switching Loss                         |                                                                                                                                      | –   | 194  | –    | μJ   |
| T <sub>d(on)</sub>                   | Turn-On Delay Time                           | V <sub>CC</sub> = 400 V, I <sub>C</sub> = 20 A, R <sub>G</sub> = 6 Ω, V <sub>GE</sub> = 15 V, Inductive Load, T <sub>C</sub> = 25°C  | –   | 19.5 | –    | ns   |
| T <sub>r</sub>                       | Rise Time                                    |                                                                                                                                      | –   | 9.6  | –    | ns   |
| T <sub>d(off)</sub>                  | Turn-Off Delay Time                          |                                                                                                                                      | –   | 76.8 | –    | ns   |
| T <sub>f</sub>                       | Fall Time                                    |                                                                                                                                      | –   | 7.4  | –    | ns   |
| E <sub>on</sub>                      | Turn-On Switching Loss                       |                                                                                                                                      | –   | 296  | –    | μJ   |
| E <sub>off</sub>                     | Turn-Off Switching Loss                      |                                                                                                                                      | –   | 111  | –    | μJ   |
| E <sub>ts</sub>                      | Total Switching Loss                         |                                                                                                                                      | –   | 407  | –    | μJ   |
| T <sub>d(on)</sub>                   | Turn-On Delay Time                           | V <sub>CC</sub> = 400 V, I <sub>C</sub> = 10 A, R <sub>G</sub> = 6 Ω, V <sub>GE</sub> = 15 V, Inductive Load, T <sub>C</sub> = 175°C | –   | 17.5 | –    | ns   |
| T <sub>r</sub>                       | Rise Time                                    |                                                                                                                                      | –   | 6.8  | –    | ns   |
| T <sub>d(off)</sub>                  | Turn-Off Delay Time                          |                                                                                                                                      | –   | 88   | –    | ns   |
| T <sub>f</sub>                       | Fall Time                                    |                                                                                                                                      | –   | 9.7  | –    | ns   |
| E <sub>on</sub>                      | Turn-On Switching Loss                       |                                                                                                                                      | –   | 285  | –    | μJ   |
| E <sub>off</sub>                     | Turn-Off Switching Loss                      |                                                                                                                                      | –   | 106  | –    | μJ   |
| E <sub>ts</sub>                      | Total Switching Loss                         |                                                                                                                                      | –   | 391  | –    | μJ   |

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**Table 3. ELECTRICAL CHARACTERISTICS OF THE IGBT** ( $T_C = 25^\circ\text{C}$  unless otherwise noted)

| Symbol                           | Parameter                | Test Conditions                                                                                                                              | Min | Typ  | Max | Unit          |
|----------------------------------|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|-----|------|-----|---------------|
| <b>SWITCHING CHARACTERISTICS</b> |                          |                                                                                                                                              |     |      |     |               |
| $T_{d(on)}$                      | Turn-On Delay Time       | $V_{CC} = 400\text{ V}$ , $I_C = 20\text{ A}$ ,<br>$R_G = 6\ \Omega$ , $V_{GE} = 15\text{ V}$ ,<br>Inductive Load, $T_C = 175^\circ\text{C}$ | –   | 19.1 | –   | ns            |
| $T_r$                            | Rise Time                |                                                                                                                                              | –   | 11.2 | –   | ns            |
| $T_{d(off)}$                     | Turn-Off Delay Time      |                                                                                                                                              | –   | 81.6 | –   | ns            |
| $T_f$                            | Fall Time                |                                                                                                                                              | –   | 9.2  | –   | ns            |
| $E_{on}$                         | Turn-On Switching Loss   |                                                                                                                                              | –   | 552  | –   | $\mu\text{J}$ |
| $E_{off}$                        | Turn-Off Switching Loss  |                                                                                                                                              | –   | 186  | –   | $\mu\text{J}$ |
| $E_{ts}$                         | Total Switching Loss     |                                                                                                                                              | –   | 738  | –   | $\mu\text{J}$ |
| $Q_g$                            | Total Gate Charge        | $V_{CE} = 400\text{ V}$ , $I_C = 40\text{ A}$ ,<br>$V_{GE} = 15\text{ V}$                                                                    | –   | 75   | –   | nC            |
| $Q_{ge}$                         | Gate to Emitter Charge   |                                                                                                                                              | –   | 15   | –   | nC            |
| $Q_{gc}$                         | Gate to Collector Charge |                                                                                                                                              | –   | 18   | –   | nC            |

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

**Table 4. ELECTRICAL CHARACTERISTICS OF THE DIODE** ( $T_C = 25^\circ\text{C}$  unless otherwise noted)

| Symbol           | Parameter                     | Test Conditions                                          |                        | Min | Typ  | Max | Unit |
|------------------|-------------------------------|----------------------------------------------------------|------------------------|-----|------|-----|------|
| V <sub>FM</sub>  | Diode Forward Voltage         | I <sub>F</sub> = 20 A                                    | T <sub>C</sub> = 25°C  | –   | 1.2  | 1.6 | V    |
|                  |                               |                                                          | T <sub>C</sub> = 175°C | –   | 1.16 | –   |      |
| E <sub>rec</sub> | Reverse Recovery Energy       | I <sub>F</sub> = 20 A,<br>dI <sub>F</sub> /dt = 200 A/μs | T <sub>C</sub> = 175°C | –   | 325  | –   | μJ   |
| T <sub>rr</sub>  | Diode Reverse Recovery Time   |                                                          | T <sub>C</sub> = 25°C  | –   | 274  | –   | ns   |
|                  |                               |                                                          | T <sub>C</sub> = 175°C | –   | 362  | –   |      |
| Q <sub>rr</sub>  | Diode Reverse Recovery Charge |                                                          | T <sub>C</sub> = 25°C  | –   | 1596 | –   | nC   |
|                  |                               |                                                          | T <sub>C</sub> = 175°C | –   | 2651 | –   |      |

# FGAF40S65AQ

## TYPICAL CHARACTERISTICS

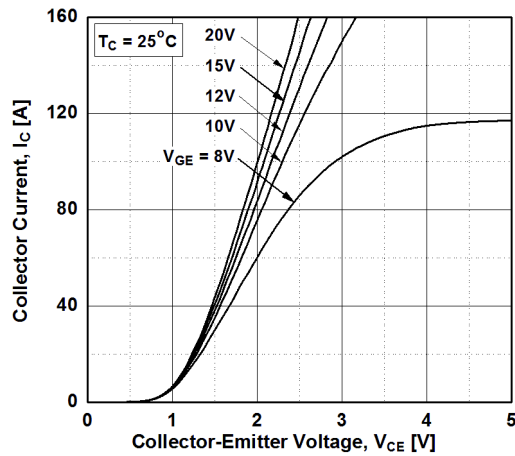


Figure 1. Typical Output Characteristics

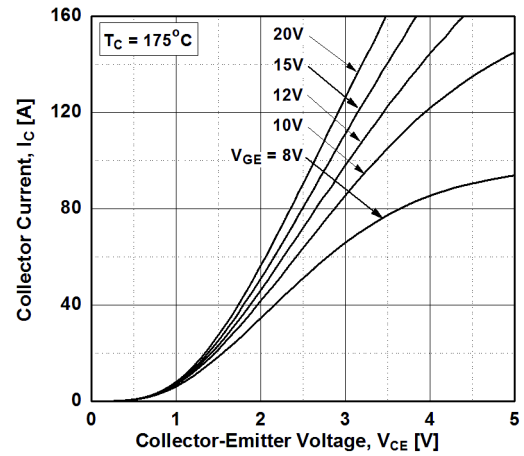


Figure 2. Typical Output Characteristics

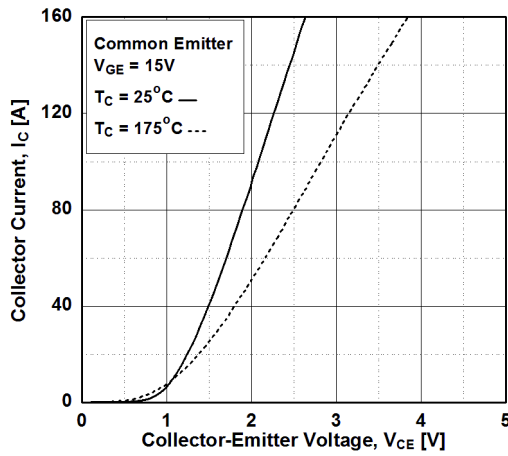


Figure 3. Typical Saturation Voltage Characteristics

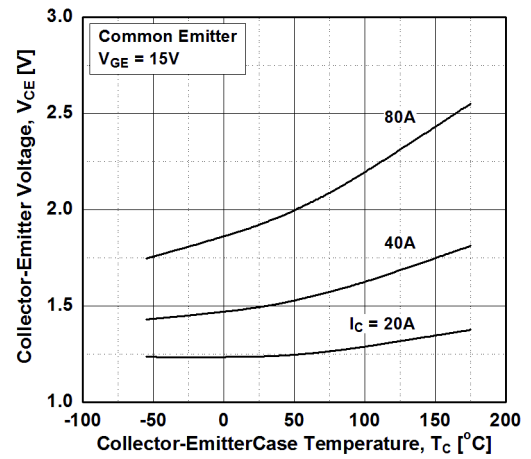


Figure 4. Saturation Voltage vs. Case Temperature at Variant Current Level

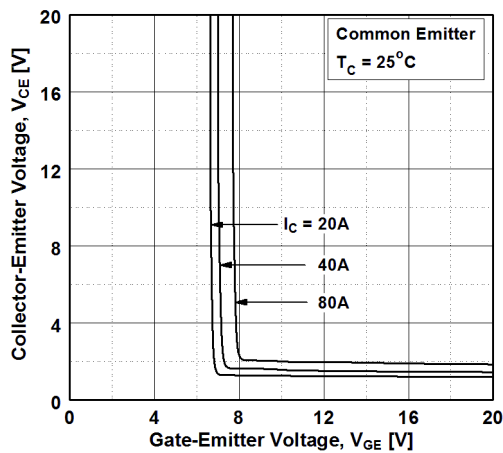


Figure 5. Saturation Voltage vs.  $V_{GE}$

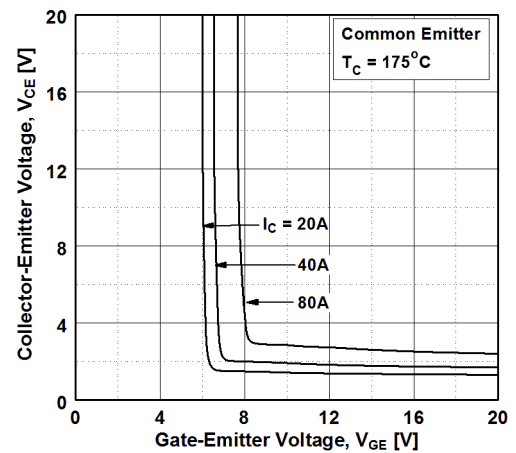


Figure 6. Saturation Voltage vs.  $V_{GE}$

TYPICAL CHARACTERISTICS (Continued)

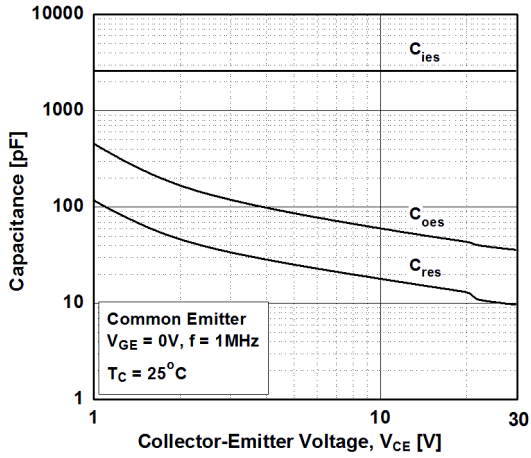


Figure 7. Capacitance Characteristics

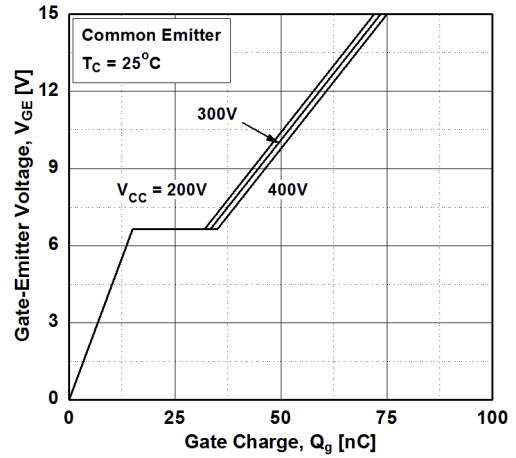


Figure 8. Gate Charge Characteristics

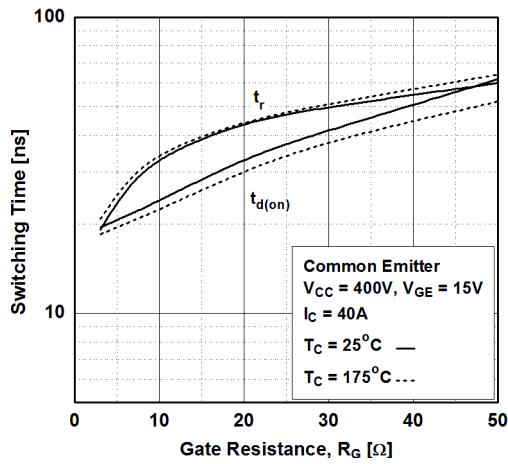


Figure 9. Turn-on Characteristics vs. Gate Resistance

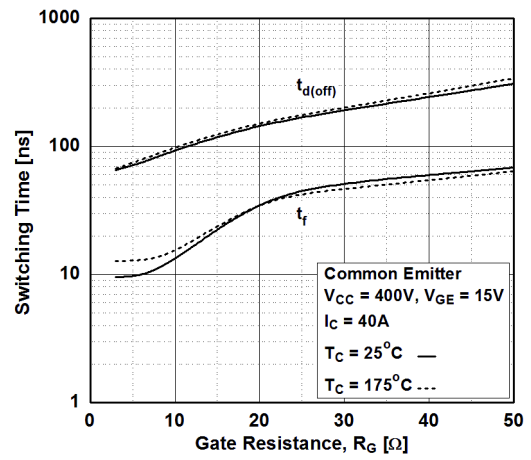


Figure 10. Turn-off Characteristics vs. Gate Resistance

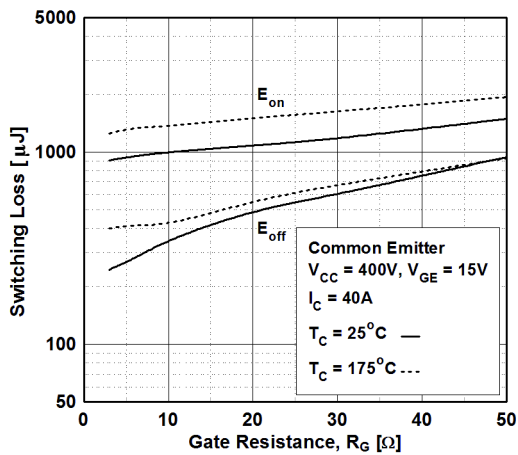


Figure 11. Switching Loss vs. Gate Resistance

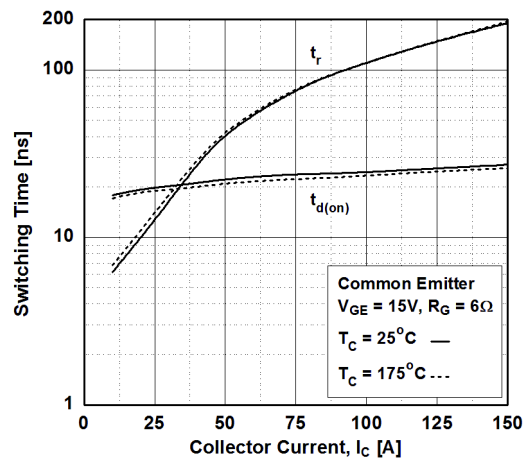


Figure 12. Turn-on Characteristics vs. Collector Current

TYPICAL CHARACTERISTICS (Continued)

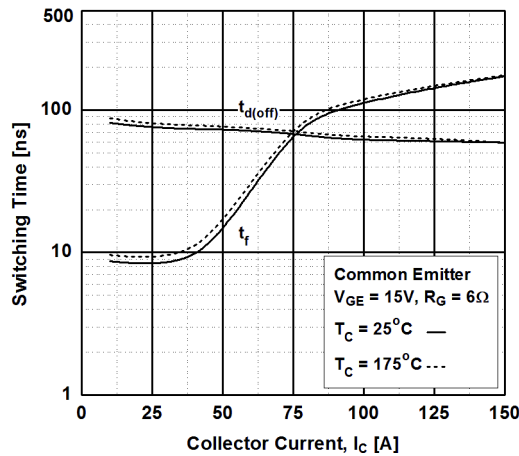


Figure 13. Turn-off Characteristics vs. Collector Current

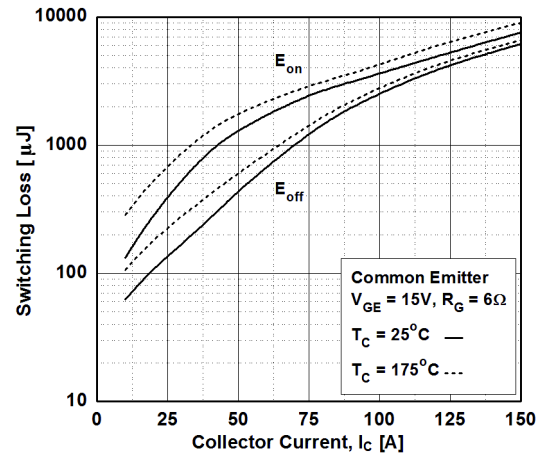


Figure 14. Switching Loss vs. Collector Current

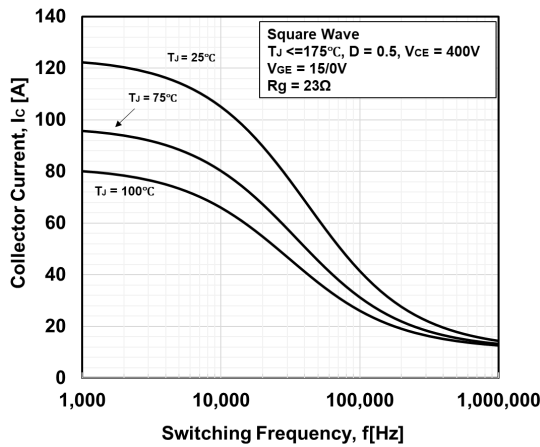


Figure 15. Load Current vs. Frequency

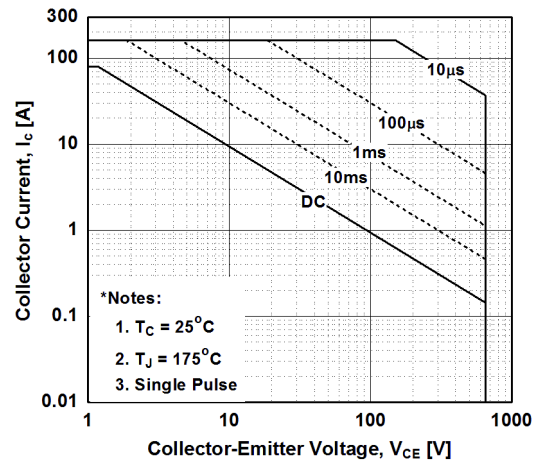


Figure 16. SOA Characteristics

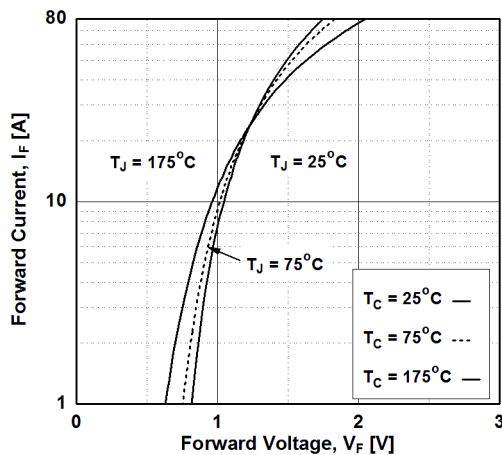


Figure 17. Forward Characteristics

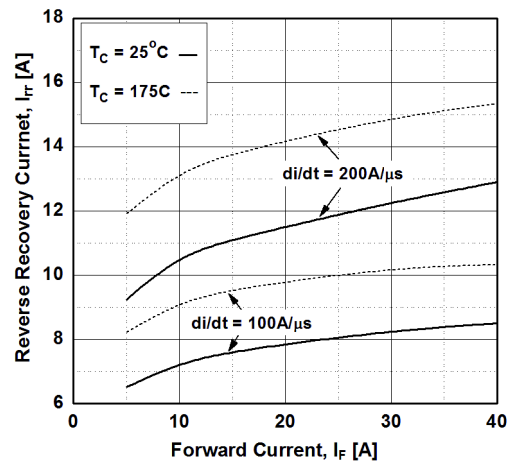


Figure 18. Reverse Recovery Current

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## TYPICAL CHARACTERISTICS (Continued)

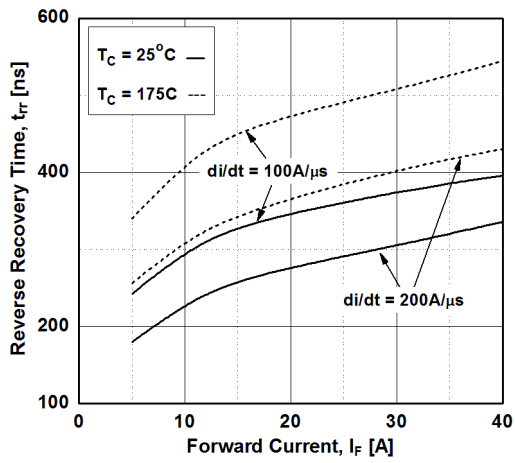


Figure 19. Reverse Recovery Time

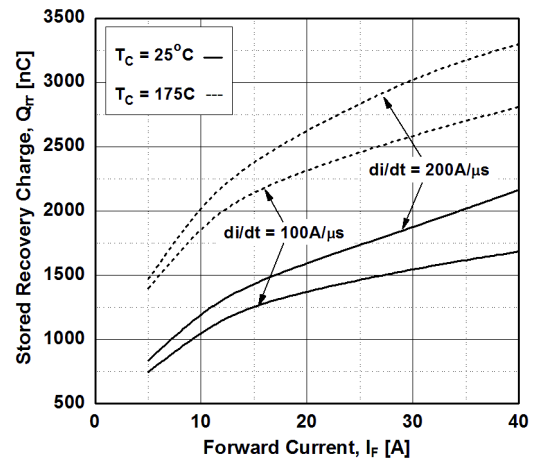


Figure 20. Stored Charge

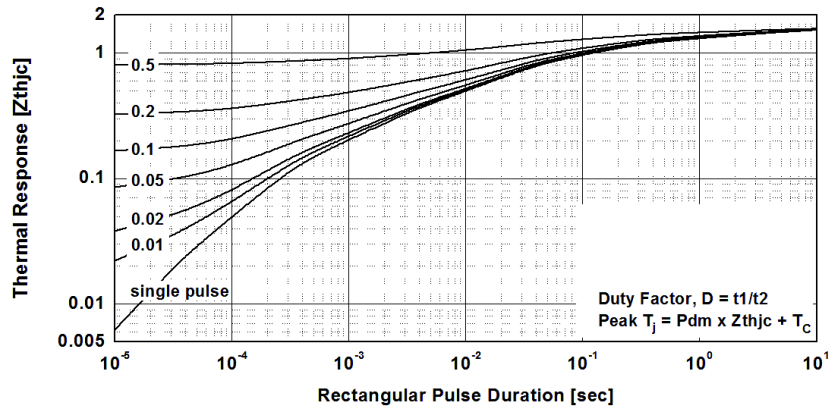


Figure 21. Transient Thermal Impedance of IGBT



# MECHANICAL CASE OUTLINE

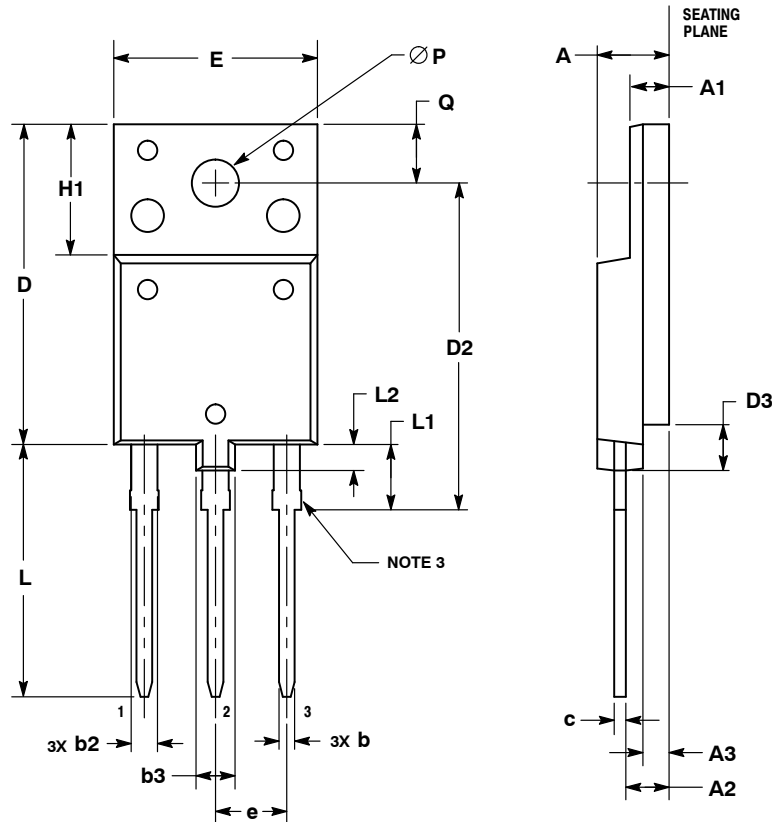
## PACKAGE DIMENSIONS

ON Semiconductor®

ON

### TO-3PF-3L CASE 340AH ISSUE A

DATE 09 JAN 2015



#### NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 2009.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. CONTOUR UNCONTROLLED IN THIS AREA (6 PLACES).
4. DIMENSIONS D AND E DO NOT INCLUDE MOLD FLASH OR GATE PROTRUSIONS. MOLD FLASH AND GATE PROTRUSIONS NOT TO EXCEED 0.13 PER SIDE. THESE DIMENSIONS ARE TO BE MEASURED AT THE OUTERMOST EXTREME OF THE PLASTIC BODY.
5. DIMENSION b2 DOES NOT INCLUDE DAMBAR PROTRUSION. LEAD WIDTH INCLUDING PROTRUSION SHALL NOT EXCEED 2.20.

| DIM | MILLIMETERS |       |
|-----|-------------|-------|
|     | MIN         | MAX   |
| A   | 5.30        | 5.70  |
| A1  | 2.80        | 3.20  |
| A2  | 3.10        | 3.50  |
| A3  | 1.80        | 2.20  |
| b   | 0.65        | 0.95  |
| b2  | 1.90        | 2.15  |
| b3  | 3.80        | 4.20  |
| c   | 0.80        | 1.10  |
| D   | 24.30       | 24.70 |
| D2  | 24.70       | 25.30 |
| D3  | 3.30        | 3.70  |
| E   | 15.30       | 15.70 |
| e   | 5.35        | 5.55  |
| H1  | 9.80        | 10.20 |
| L   | 19.10       | 19.50 |
| L1  | 4.80        | 5.20  |
| L2  | 1.90        | 2.20  |
| P   | 3.40        | 3.80  |
| Q   | 4.30        | 4.70  |

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DESCRIPTION: TO-3PF-3L

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