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ON Semiconductor®

December 2016

# FGAF40N60SMD

## 600 V, 40 A Field Stop IGBT

### Features

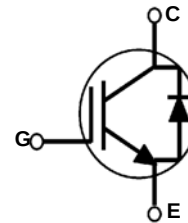
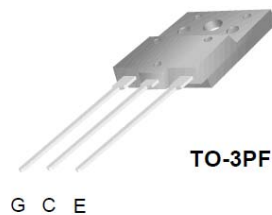
- Maximum Junction Temperature :  $T_J = 175^{\circ}\text{C}$
- Positive Temperature Co-efficient for easy Parallel Operating
- High Current Capability
- Low Saturation Voltage:  $V_{CE(sat)} = 1.9 \text{ V(Typ.) @ } I_C = 40 \text{ A}$
- High Input Impedance
- Fast Switching:  $E_{OFF} = 6.5 \text{ uJ/A}$
- Tightened Parameter Distribution
- RoHS Compliant

### Applications

- Sewing Machine, CNC
- Home Appliances, Motor-Control

### General Description

Using novel field stop IGBT technology, ON semiconductor's new series of field stop 2<sup>nd</sup> generation IGBTs offer the optimum performance for solar inverter, UPS, welder and PFC applications where low conduction and switching losses are essential.



### Absolute Maximum Ratings

| Symbol      | Description                                                             | Ratings     | Unit               |
|-------------|-------------------------------------------------------------------------|-------------|--------------------|
| $V_{CES}$   | Collector to Emitter Voltage                                            | 600         | V                  |
| $V_{GES}$   | Gate to Emitter Voltage                                                 | $\pm 20$    | V                  |
| $I_C$       | Collector Current @ $T_C = 25^{\circ}\text{C}$                          | 80*         | A                  |
|             | Collector Current @ $T_C = 100^{\circ}\text{C}$                         | 40*         | A                  |
| $I_{CM(1)}$ | Pulsed Collector Current                                                | 120*        | A                  |
| $I_F$       | Diode Forward Current @ $T_C = 25^{\circ}\text{C}$                      | 40*         | A                  |
|             | Diode Forward Current @ $T_C = 100^{\circ}\text{C}$                     | 20*         | A                  |
| $I_{FM(1)}$ | Pulsed Diode Maximum Forward Current                                    | 120*        | A                  |
| $P_D$       | Maximum Power Dissipation @ $T_C = 25^{\circ}\text{C}$                  | 115         | W                  |
|             | Maximum Power Dissipation @ $T_C = 100^{\circ}\text{C}$                 | 58          | W                  |
| $T_J$       | Operating Junction Temperature                                          | -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 seconds | 300         | $^{\circ}\text{C}$ |

#### Notes:

\*Drain current limited by maximum junction temperature

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

## Thermal Characteristics

| Symbol                        | Parameter                               | Typ. | Max. | Unit                        |
|-------------------------------|-----------------------------------------|------|------|-----------------------------|
| $R_{\theta JC}(IGBT)$         | Thermal Resistance, Junction to Case    | -    | 1.3  | $^{\circ}\text{C}/\text{W}$ |
| $R_{\theta JC}(\text{Diode})$ | Thermal Resistance, Junction to Case    | -    | 3.27 | $^{\circ}\text{C}/\text{W}$ |
| $R_{\theta JA}$               | Thermal Resistance, Junction to Ambient | -    | 40   | $^{\circ}\text{C}/\text{W}$ |

## Package Marking and Ordering Information

| Device Marking | Device       | Package | Reel Size | Tape Width | Quantity |
|----------------|--------------|---------|-----------|------------|----------|
| FGAF40N60SMD   | FGAF40N60SMD | TO-3PF  | -         | -          | 30       |

## 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> = 0V, I <sub>C</sub> = 250μA                                                                                     | 600  | -    | -    | V    |
| $\frac{\Delta BV_{CES}}{\Delta T_J}$ | Temperature Coefficient of Breakdown Voltage | V <sub>GE</sub> = 0V, I <sub>C</sub> = 250μA                                                                                     | -    | 0.6  | -    | V/°C |
| I <sub>CES</sub>                     | Collector Cut-Off Current                    | V <sub>CE</sub> = V <sub>CES</sub> , V <sub>GE</sub> = 0V                                                                        | -    | -    | 250  | μA   |
| I <sub>GES</sub>                     | G-E Leakage Current                          | V <sub>GE</sub> = V <sub>GES</sub> , V <sub>CE</sub> = 0V                                                                        | -    | -    | ±400 | nA   |
| On Characteristics                   |                                              |                                                                                                                                  |      |      |      |      |
| V <sub>GE(th)</sub>                  | G-E Threshold Voltage                        | I <sub>C</sub> = 250μA, V <sub>CE</sub> = V <sub>GE</sub>                                                                        | 3.5  | 4.5  | 6.0  | V    |
| V <sub>CE(sat)</sub>                 | Collector to Emitter Saturation Voltage      | I <sub>C</sub> = 40A, V <sub>GE</sub> = 15V                                                                                      | -    | 1.9  | -    | V    |
|                                      |                                              | I <sub>C</sub> = 40A, V <sub>GE</sub> = 15V, T <sub>C</sub> = 175°C                                                              | -    | 2.1  | -    | V    |
| Dynamic Characteristics              |                                              |                                                                                                                                  |      |      |      |      |
| C <sub>ies</sub>                     | Input Capacitance                            | V <sub>CE</sub> = 30V, V <sub>GE</sub> = 0V, f = 1MHz                                                                            | -    | 1880 | -    | pF   |
| C <sub>oes</sub>                     | Output Capacitance                           |                                                                                                                                  | -    | 180  | -    | pF   |
| C <sub>res</sub>                     | Reverse Transfer Capacitance                 |                                                                                                                                  | -    | 50   | -    | pF   |
| Switching Characteristics            |                                              |                                                                                                                                  |      |      |      |      |
| t <sub>d(on)</sub>                   | Turn-On Delay Time                           | V <sub>CC</sub> = 400V, I <sub>C</sub> = 40A, R <sub>G</sub> = 6Ω, V <sub>GE</sub> = 15V, Inductive Load, T <sub>C</sub> = 25°C  | -    | 12   | -    | ns   |
| t <sub>r</sub>                       | Rise Time                                    |                                                                                                                                  | -    | 20   | -    | ns   |
| t <sub>d(off)</sub>                  | Turn-Off Delay Time                          |                                                                                                                                  | -    | 92   | -    | ns   |
| t <sub>f</sub>                       | Fall Time                                    |                                                                                                                                  | -    | 13   | 17   | ns   |
| E <sub>on</sub>                      | Turn-On Switching Loss                       |                                                                                                                                  | -    | 0.87 | -    | mJ   |
| E <sub>off</sub>                     | Turn-Off Switching Loss                      |                                                                                                                                  | -    | 0.26 | 0.34 | mJ   |
| E <sub>ts</sub>                      | Total Switching Loss                         |                                                                                                                                  | -    | 1.13 | -    | mJ   |
| t <sub>d(on)</sub>                   | Turn-On Delay Time                           | V <sub>CC</sub> = 400V, I <sub>C</sub> = 40A, R <sub>G</sub> = 6Ω, V <sub>GE</sub> = 15V, Inductive Load, T <sub>C</sub> = 175°C | -    | 15   | -    | ns   |
| t <sub>r</sub>                       | Rise Time                                    |                                                                                                                                  | -    | 22   | -    | ns   |
| t <sub>d(off)</sub>                  | Turn-Off Delay Time                          |                                                                                                                                  | -    | 116  | -    | ns   |
| t <sub>f</sub>                       | Fall Time                                    |                                                                                                                                  | -    | 16   | -    | ns   |
| E <sub>on</sub>                      | Turn-On Switching Loss                       |                                                                                                                                  | -    | 0.97 | -    | mJ   |
| E <sub>off</sub>                     | Turn-Off Switching Loss                      |                                                                                                                                  | -    | 0.60 | -    | mJ   |
| E <sub>ts</sub>                      | Total Switching Loss                         |                                                                                                                                  | -    | 1.57 | -    | mJ   |

**Electrical Characteristics of the IGBT** (Continued)

| Symbol   | Parameter                | Test Conditions                               | Min. | Typ. | Max | Unit |
|----------|--------------------------|-----------------------------------------------|------|------|-----|------|
| $Q_g$    | Total Gate Charge        | $V_{CE} = 400V, I_C = 40A,$<br>$V_{GE} = 15V$ | -    | 119  | -   | nC   |
| $Q_{ge}$ | Gate to Emitter Charge   |                                               | -    | 13   | -   | nC   |
| $Q_{gc}$ | Gate to Collector Charge |                                               | -    | 58   | -   | nC   |

**Electrical Characteristics of the Diode**  $T_C = 25^\circ C$  unless otherwise noted

| Symbol           | Parameter                     | Test Conditions                                    |                                     | Min. | Typ. | Max | Unit |
|------------------|-------------------------------|----------------------------------------------------|-------------------------------------|------|------|-----|------|
| V <sub>FM</sub>  | Diode Forward Voltage         | I <sub>F</sub> = 20A                               | T <sub>C</sub> = 25 <sup>o</sup> C  | -    | 2.3  | -   | V    |
|                  |                               |                                                    | T <sub>C</sub> = 175 <sup>o</sup> C | -    | 1.67 | -   |      |
| E <sub>rec</sub> | Reverse Recovery Energy       | I <sub>F</sub> =20A, dI <sub>F</sub> /dt = 200A/μs | T <sub>C</sub> = 175 <sup>o</sup> C | -    | 48.9 | -   | uJ   |
| t <sub>rr</sub>  | Diode Reverse Recovery Time   |                                                    | T <sub>C</sub> = 25 <sup>o</sup> C  | -    | 36   | -   | ns   |
|                  |                               |                                                    | T <sub>C</sub> = 175 <sup>o</sup> C | -    | 110  | -   |      |
| Q <sub>rr</sub>  | Diode Reverse Recovery Charge |                                                    | T <sub>C</sub> = 25 <sup>o</sup> C  | -    | 46.8 | -   | nC   |
|                  |                               |                                                    | T <sub>C</sub> = 175 <sup>o</sup> C | -    | 445  | -   |      |

## Typical Performance Characteristics

Figure 1. Typical Output Characteristics

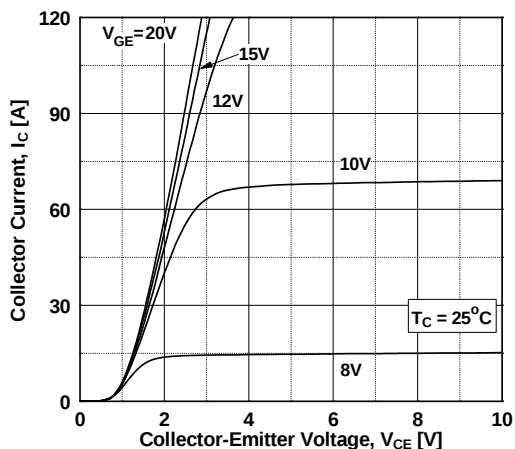


Figure 2. Typical Output Characteristics

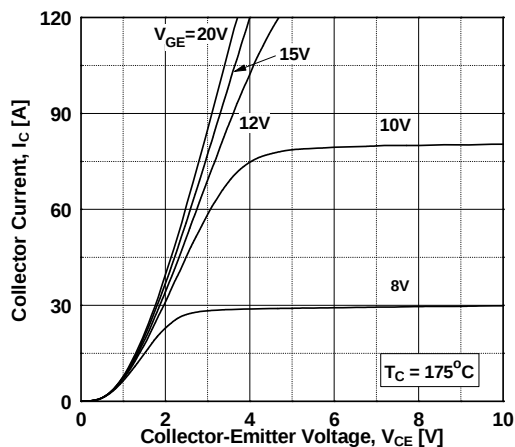


Figure 3. Typical Saturation Voltage Characteristics

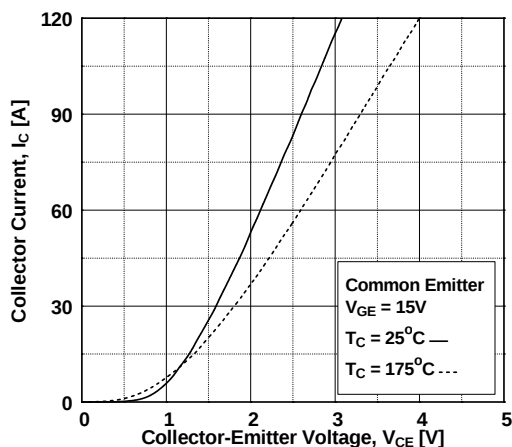


Figure 4. Transfer Characteristics

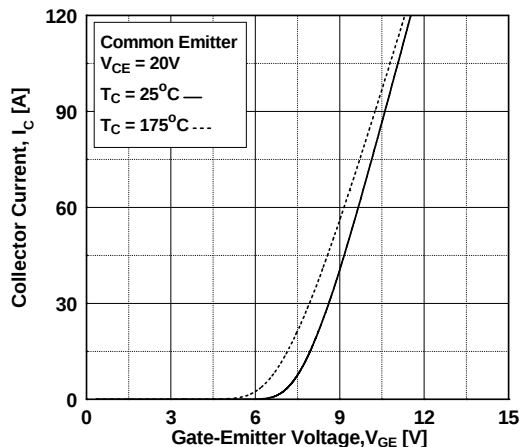


Figure 5. Saturation Voltage vs. Case Temperature at Variant Current Level

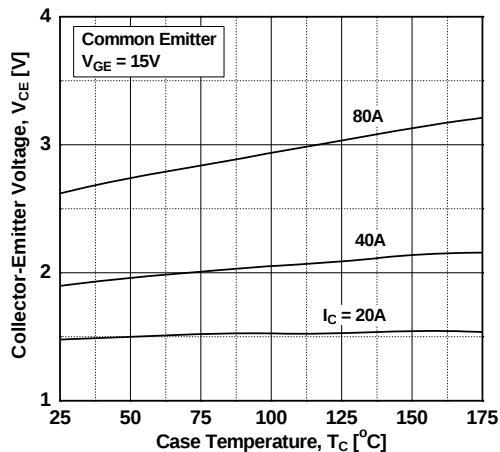
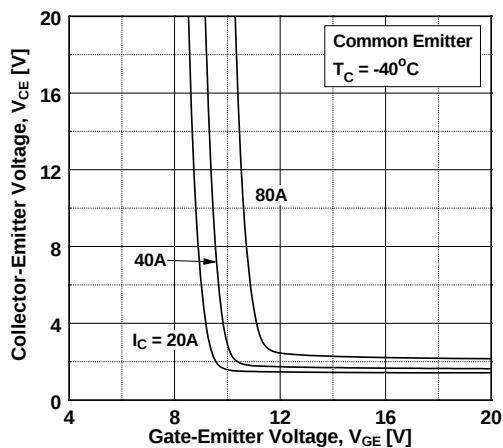


Figure 6. Saturation Voltage vs. V\_GE



## Typical Performance Characteristics

Figure 7. Saturation Voltage vs.  $V_{GE}$

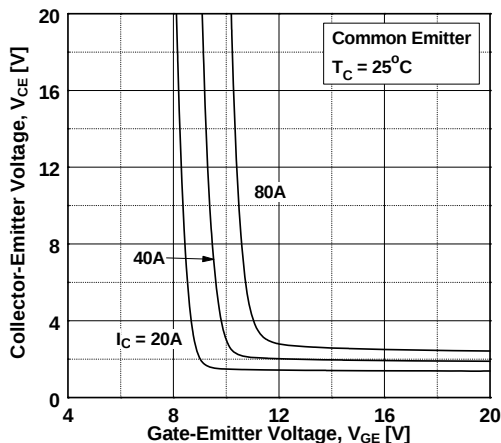


Figure 8. Saturation Voltage vs.  $V_{GE}$

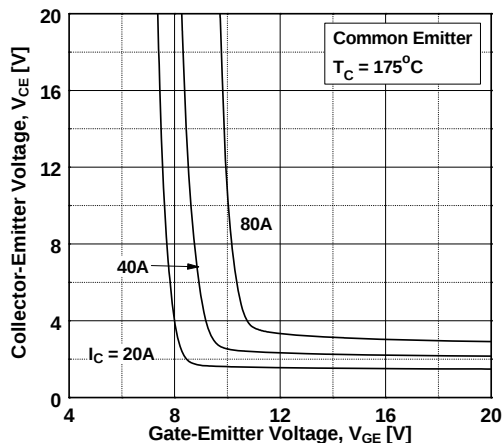


Figure 9. Capacitance Characteristics

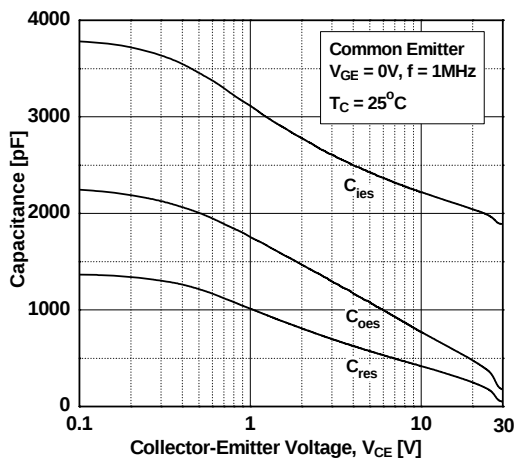


Figure 10. Gate charge Characteristics

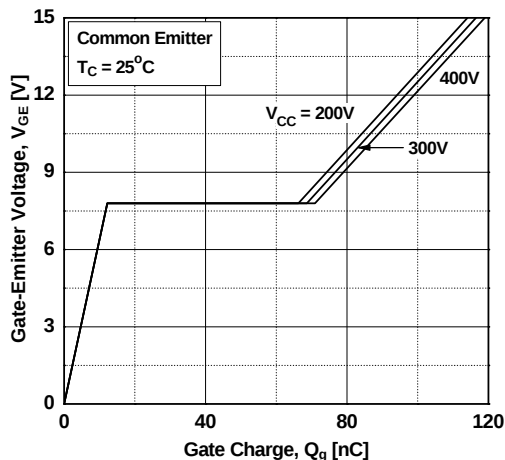


Figure 11. SOA Characteristics

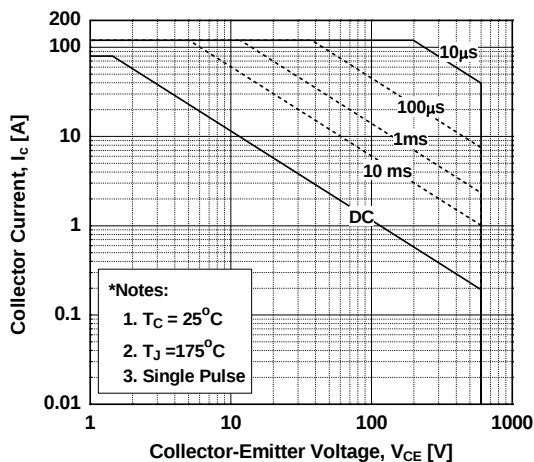
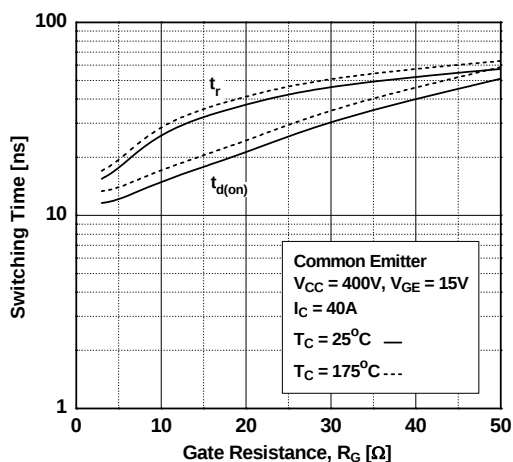


Figure 12. Turn-on Characteristics vs. Gate Resistance



## Typical Performance Characteristics

Figure 13. Turn-off Characteristics vs. Gate Resistance

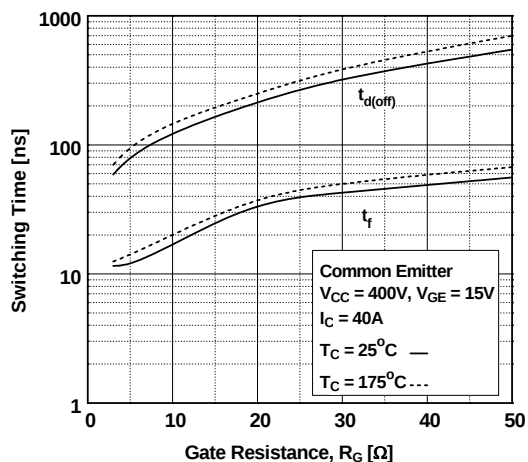


Figure 14. Turn-on Characteristics vs. Collector Current

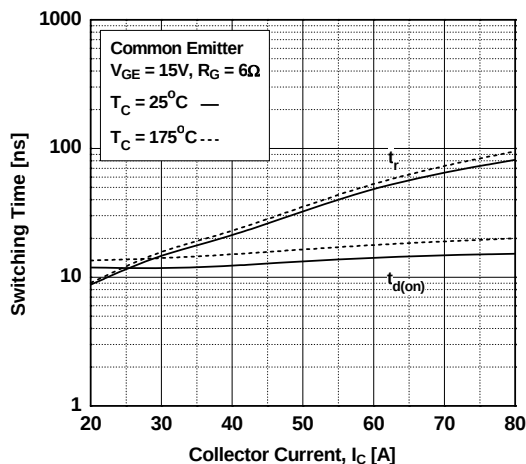


Figure 15. Turn-off Characteristics vs. Collector Current

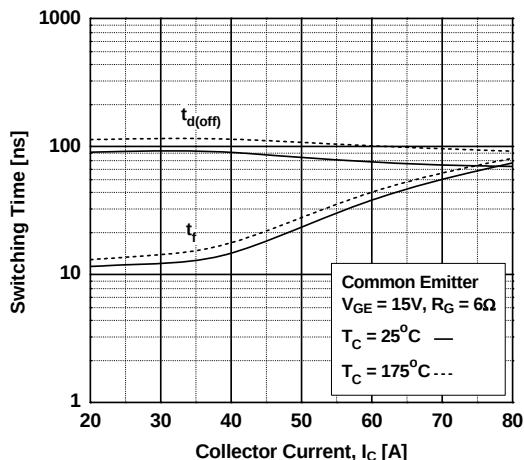


Figure 16. Switching Loss vs. Gate Resistance

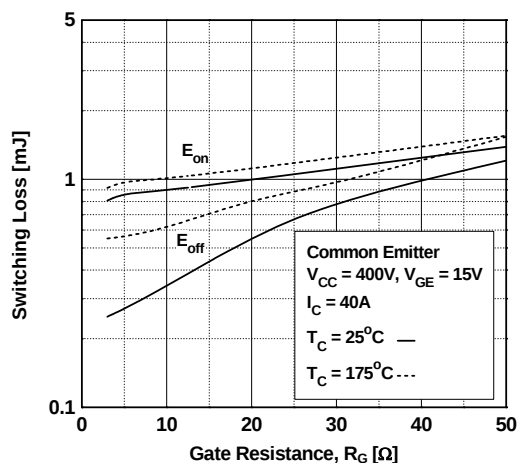


Figure 17. Switching Loss vs. Collector Current

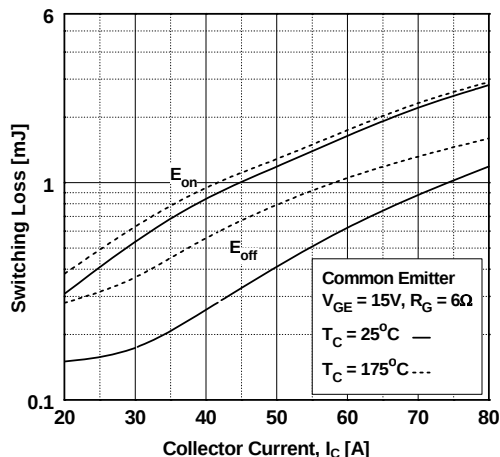
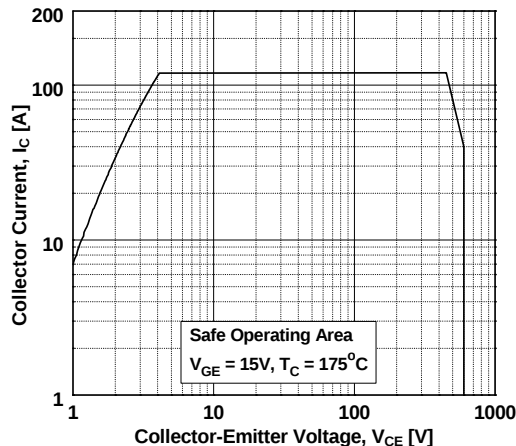


Figure 18. Turn off Switching SOA Characteristics



## Typical Performance Characteristics

Figure 19. Current Derating

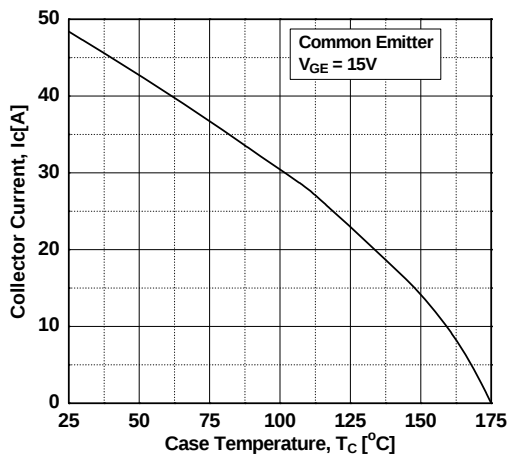


Figure 20. Power Dissipation

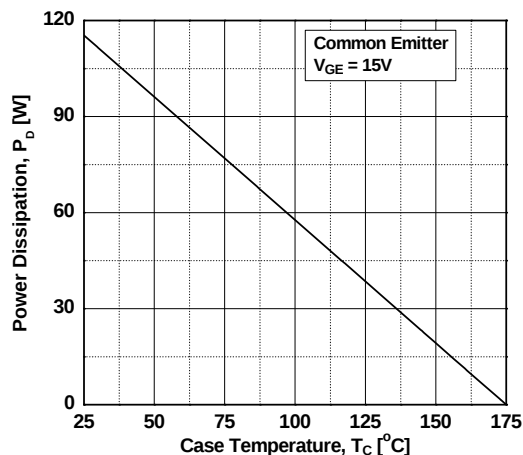


Figure 21. Load Current Vs. Frequency

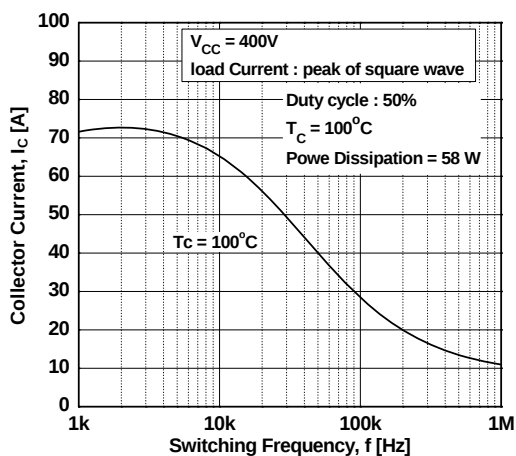


Figure 22. Forward Characteristics

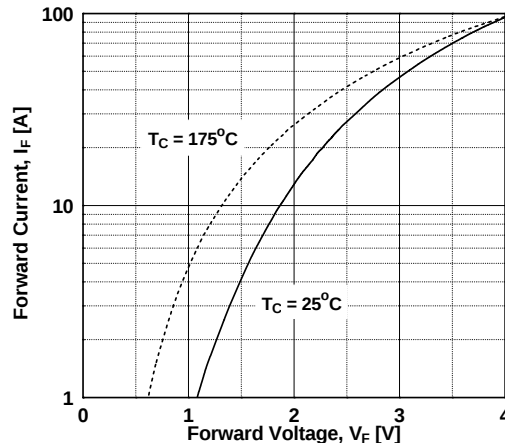


Figure 23. Reverse Current

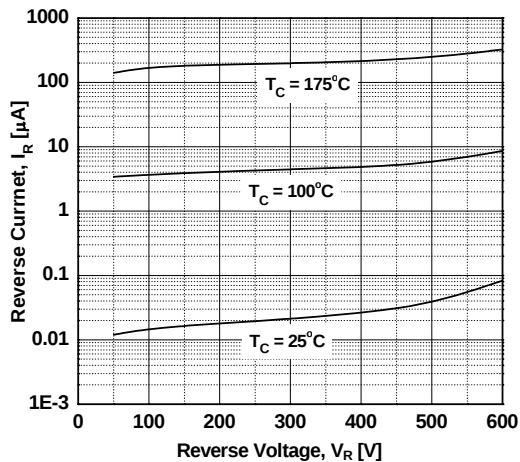
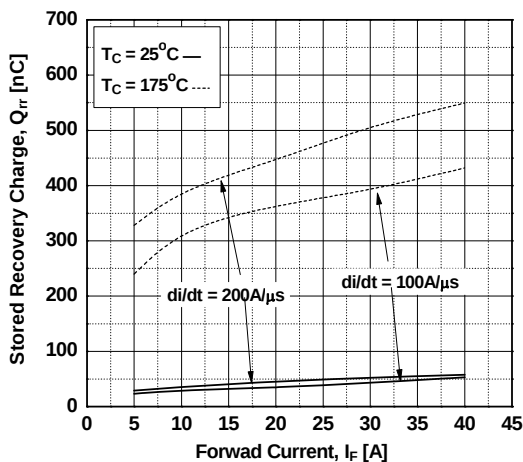


Figure 24. Stored Charge



## Typical Performance Characteristics

Figure 25. Reverse Recovery Time

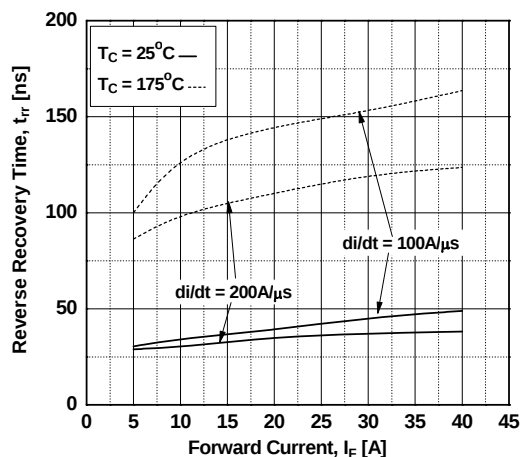


Figure 26. Transient Thermal Impedance of IGBT

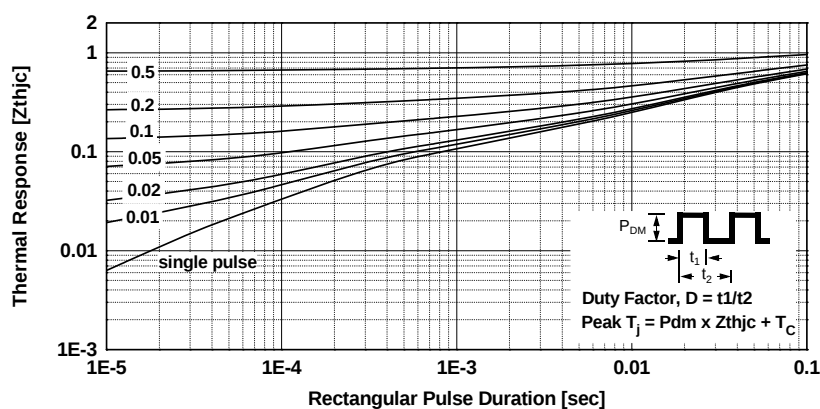
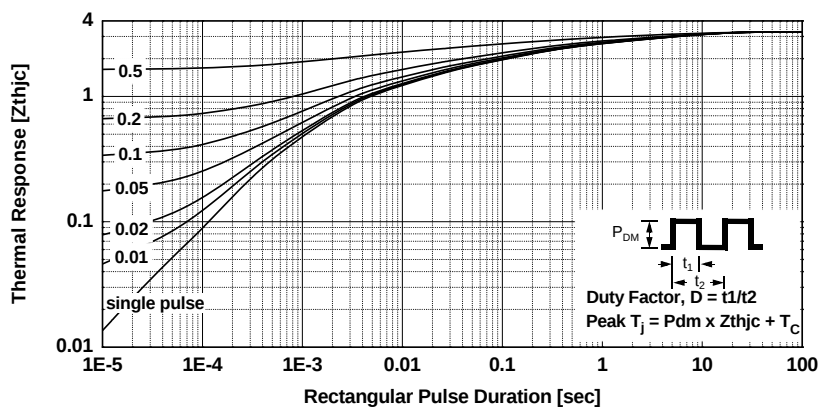
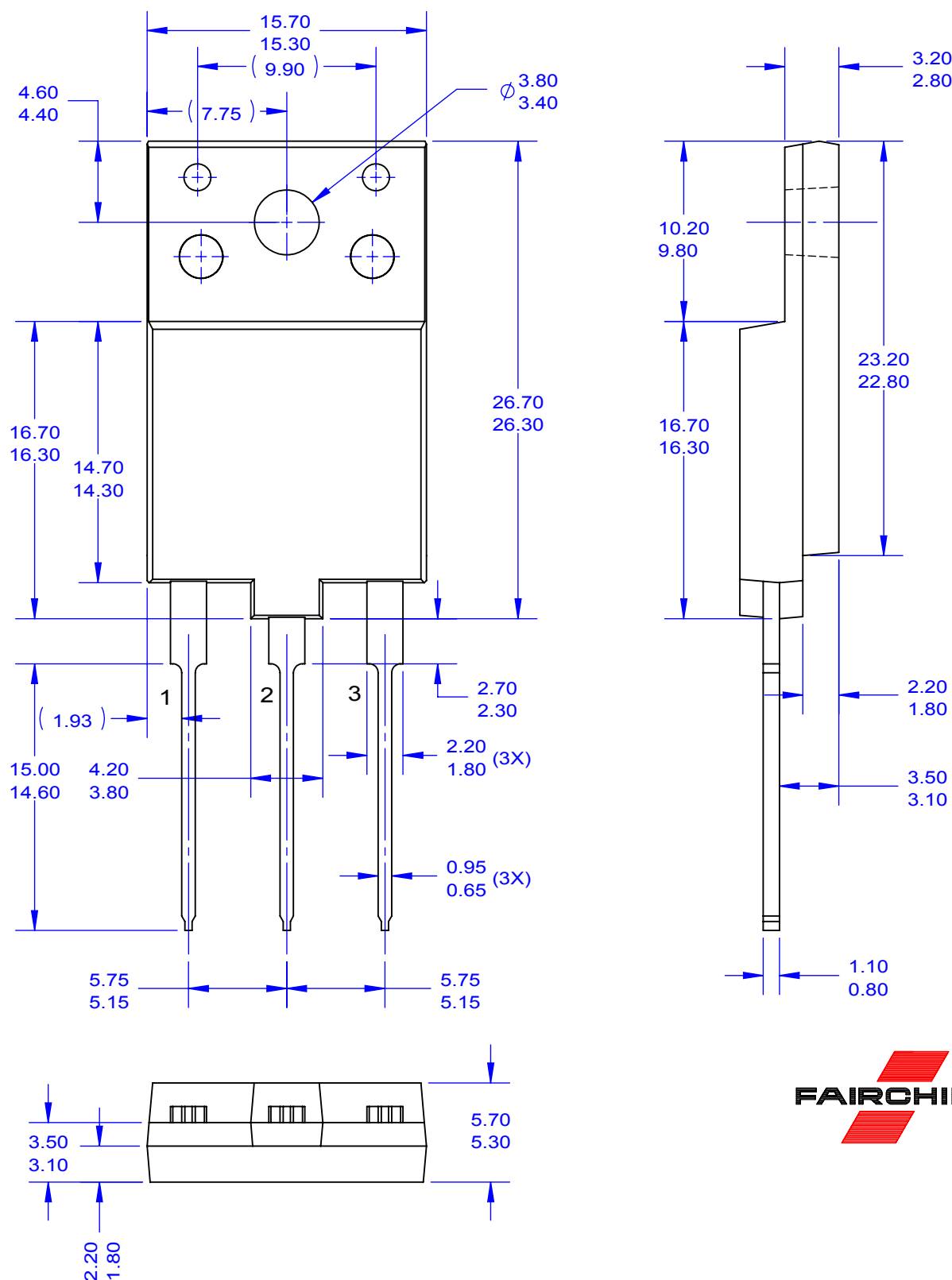


Figure 27. Transient Thermal Impedance of Diode





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- B. ALL DIMENSIONS ARE IN MILLIMETERS.
- C. DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH AND TIE BAR PROTRUSIONS.
- D. PIN 2 CONNECTS TO DAP.
- E. DRAWING FILE NAME: TO3PFA03REV2

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