

## FGH60N6S2

### 600V, SMPS II Series N-Channel IGBT

#### General Description

The FGH60N6S2 is a Low Gate Charge, Low Plateau Voltage SMPS II IGBT combining the fast switching speed of the SMPS IGBTs along with lower gate charge and plateau voltage and avalanche capability (UIS). These LGC devices shorten delay times, and reduce the power requirement of the gate drive. These devices are ideally suited for high voltage switched mode power supply applications where low conduction loss, fast switching times and UIS capability are essential. SMPS II LGC devices have been specially designed for:

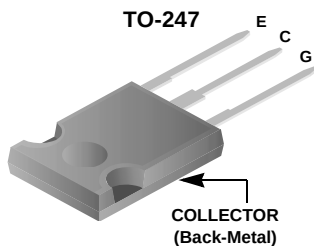
- Power Factor Correction (PFC) circuits
- Full bridge topologies
- Half bridge topologies
- Push-Pull circuits
- Uninterruptible power supplies
- Zero voltage and zero current switching circuits

#### Features

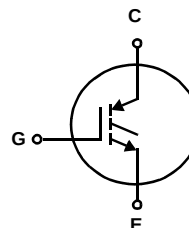
- 100kHz Operation at 390V, 52A
- 200kHz Operation at 390V, 31A
- 600V Switching SOA Capability
- Typical Fall Time. . . . . 77ns at  $T_J = 125^{\circ}\text{C}$
- Low Gate Charge . . . . . 140nC at  $V_{GE} = 15\text{V}$
- Low Plateau Voltage . . . . . 6.5V Typical
- UIS Rated . . . . . 700mJ
- Low Conduction Loss

Formerly Developmental Type TA49346.

#### Package



#### Symbol



#### Device Maximum Ratings $T_C = 25^{\circ}\text{C}$ unless otherwise noted

| Symbol     | Parameter                                                                                   | Ratings      | Units                 |
|------------|---------------------------------------------------------------------------------------------|--------------|-----------------------|
| $BV_{CES}$ | Collector to Emitter Breakdown Voltage                                                      | 600          | V                     |
| $I_{C25}$  | Collector Current Continuous, $T_C = 25^{\circ}\text{C}$                                    | 75           | A                     |
| $I_{C110}$ | Collector Current Continuous, $T_C = 110^{\circ}\text{C}$                                   | 75           | A                     |
| $I_{CM}$   | Collector Current Pulsed (Note 1)                                                           | 320          | A                     |
| $V_{GES}$  | Gate to Emitter Voltage Continuous                                                          | $\pm 20$     | V                     |
| $V_{GEM}$  | Gate to Emitter Voltage Pulsed                                                              | $\pm 30$     | V                     |
| SSOA       | Switching Safe Operating Area at $T_J = 150^{\circ}\text{C}$ , Figure 2                     | 200A at 600V |                       |
| $E_{AS}$   | Pulsed Avalanche Energy, $I_{CE} = 20\text{A}$ , $L = 1.3\text{mH}$ , $V_{DD} = 50\text{V}$ | 700          | mJ                    |
| $P_D$      | Power Dissipation Total $T_C = 25^{\circ}\text{C}$                                          | 625          | W                     |
|            | Power Dissipation Derating $T_C > 25^{\circ}\text{C}$                                       | 5            | W/ $^{\circ}\text{C}$ |
| $T_J$      | Operating Junction Temperature Range                                                        | -55 to 150   | $^{\circ}\text{C}$    |
| $T_{STG}$  | Storage Junction Temperature Range                                                          | -55 to 150   | $^{\circ}\text{C}$    |

CAUTION: Stresses above those listed in "Device Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTE:

1. Pulse width limited by maximum junction temperature.

## Package Marking and Ordering Information

| Device Marking | Device    | Package | Reel Size | Tape Width | Quantity |
|----------------|-----------|---------|-----------|------------|----------|
| 60N6S2         | FGH60N6S2 | TO-247  | Tube      | N/A        | 30       |

## Electrical Characteristics $T_J = 25^\circ\text{C}$ unless otherwise noted

| Symbol     | Parameter                              | Test Conditions                       | Min | Typ | Max       | Units         |
|------------|----------------------------------------|---------------------------------------|-----|-----|-----------|---------------|
| $BV_{CES}$ | Collector to Emitter Breakdown Voltage | $I_C = 250\mu\text{A}$ , $V_{GE} = 0$ | 600 | -   | -         | V             |
| $BV_{ECS}$ | Emitter to Collector Breakdown Voltage | $I_C = -10\text{mA}$ , $V_{GE} = 0$   | 20  | -   | -         | V             |
| $I_{CES}$  | Collector to Emitter Leakage Current   | $V_{CE} = 600\text{V}$                | -   | -   | 250       | $\mu\text{A}$ |
|            |                                        | $T_J = 125^\circ\text{C}$             |     |     | 3         | $\text{mA}$   |
| $I_{GES}$  | Gate to Emitter Leakage Current        | $V_{GE} = \pm 20\text{V}$             | -   | -   | $\pm 250$ | $\text{nA}$   |

## On State Characteristics

|                      |                                         |                                               |                           |   |      |     |   |
|----------------------|-----------------------------------------|-----------------------------------------------|---------------------------|---|------|-----|---|
| $V_{CE(\text{SAT})}$ | Collector to Emitter Saturation Voltage | $I_C = 40\text{A}$ ,<br>$V_{GE} = 15\text{V}$ | $T_J = 25^\circ\text{C}$  | - | 1.9  | 2.5 | V |
|                      |                                         |                                               | $T_J = 125^\circ\text{C}$ | - | 1.65 | 2.2 | V |

## Dynamic Characteristics

|                     |                                   |                                                |                       |     |     |     |             |
|---------------------|-----------------------------------|------------------------------------------------|-----------------------|-----|-----|-----|-------------|
| $Q_{G(\text{ON})}$  | Gate Charge                       | $I_C = 40\text{A}$ ,<br>$V_{CE} = 300\text{V}$ | $V_{GE} = 15\text{V}$ | -   | 140 | 175 | $\text{nC}$ |
|                     |                                   |                                                | $V_{GE} = 20\text{V}$ | -   | 180 | 225 | $\text{nC}$ |
| $V_{GE(\text{TH})}$ | Gate to Emitter Threshold Voltage | $I_C = 250\mu\text{A}$ , $V_{CE} = V_{GE}$     |                       | 3.5 | 4.3 | 5.0 | V           |
| $V_{GEP}$           | Gate to Emitter Plateau Voltage   | $I_C = 40\text{A}$ , $V_{CE} = 300\text{V}$    |                       | -   | 6.5 | 8.0 | V           |

## Switching Characteristics

|                             |                             |                                                                                                                                                                             |                                             |     |     |     |               |
|-----------------------------|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-----|-----|-----|---------------|
| SSOA                        | Switching SOA               | $T_J = 150^\circ\text{C}$ , $R_G = 3\Omega$ , $V_{GE} = 15\text{V}$ , $L = 100\mu\text{H}$ , $V_{CE} = 600\text{V}$                                                         |                                             | 200 | -   | -   | A             |
| $t_{d(\text{ON})\text{I}}$  | Current Turn-On Delay Time  | IGBT and Diode at $T_J = 25^\circ\text{C}$ ,<br>$I_{CE} = 40\text{A}$ ,<br>$V_{CE} = 390\text{V}$ ,<br>$V_{GE} = 15\text{V}$ ,<br>$R_G = 3\Omega$ ,<br>$L = 100\mu\text{H}$ |                                             | -   | 18  | -   | $\text{ns}$   |
| $t_{r\text{I}}$             | Current Rise Time           |                                                                                                                                                                             |                                             | -   | 15  | -   | $\text{ns}$   |
| $t_{d(\text{OFF})\text{I}}$ | Current Turn-Off Delay Time |                                                                                                                                                                             |                                             | -   | 70  | -   | $\text{ns}$   |
| $t_{f\text{I}}$             | Current Fall Time           |                                                                                                                                                                             |                                             | -   | 50  | -   | $\text{ns}$   |
| $E_{\text{ON}1}$            | Turn-On Energy (Note 2)     |                                                                                                                                                                             |                                             | -   | 400 | -   | $\mu\text{J}$ |
| $E_{\text{ON}2}$            | Turn-On Energy (Note 2)     | Test Circuit - Figure 20                                                                                                                                                    |                                             | -   | 490 | -   | $\mu\text{J}$ |
| $E_{\text{OFF}}$            | Turn-Off Energy (Note 3)    |                                                                                                                                                                             |                                             | -   | 310 | 450 | $\mu\text{J}$ |
| $t_{d(\text{ON})\text{I}}$  | Current Turn-On Delay Time  |                                                                                                                                                                             | IGBT and Diode at $T_J = 125^\circ\text{C}$ | -   | 27  | -   | $\text{ns}$   |
| $t_{r\text{I}}$             | Current Rise Time           |                                                                                                                                                                             |                                             | -   | 32  | -   | $\text{ns}$   |
| $t_{d(\text{OFF})\text{I}}$ | Current Turn-Off Delay Time |                                                                                                                                                                             |                                             | -   | 110 | 150 | $\text{ns}$   |
| $t_{f\text{I}}$             | Current Fall Time           |                                                                                                                                                                             |                                             | -   | 77  | 90  | $\text{ns}$   |
| $E_{\text{ON}1}$            | Turn-On Energy (Note 2)     |                                                                                                                                                                             |                                             | -   | 400 | 450 | $\mu\text{J}$ |
| $E_{\text{ON}2}$            | Turn-On Energy (Note 2)     |                                                                                                                                                                             |                                             | -   | 750 | 850 | $\mu\text{J}$ |
| $E_{\text{OFF}}$            | Turn-Off Energy (Note 3)    |                                                                                                                                                                             |                                             | -   | 688 | 950 | $\mu\text{J}$ |

## Thermal Characteristics

|                       |                                  |        |   |   |     |                    |
|-----------------------|----------------------------------|--------|---|---|-----|--------------------|
| $R_{\theta\text{JC}}$ | Thermal Resistance Junction-Case | TO-247 | - | - | 0.2 | $^\circ\text{C/W}$ |
|-----------------------|----------------------------------|--------|---|---|-----|--------------------|

NOTE:

2. Values for two Turn-On loss conditions are shown for the convenience of the circuit designer.  $E_{\text{ON}1}$  is the turn-on loss of the IGBT only.  $E_{\text{ON}2}$  is the turn-on loss when a typical diode is used in the test circuit and the diode is at the same  $T_J$  as the IGBT. The diode type is specified in figure 20.

3. Turn-Off Energy Loss ( $E_{\text{OFF}}$ ) is defined as the integral of the instantaneous power loss starting at the trailing edge of the input pulse and ending at the point where the collector current equals zero ( $I_{CE} = 0\text{A}$ ). All devices were tested per JEDEC Standard No. 24-1 Method for Measurement of Power Device Turn-Off Switching Loss. This test method produces the true total Turn-Off Energy Loss.

# Typical Performance Curves $T_J = 25^\circ\text{C}$ unless otherwise noted

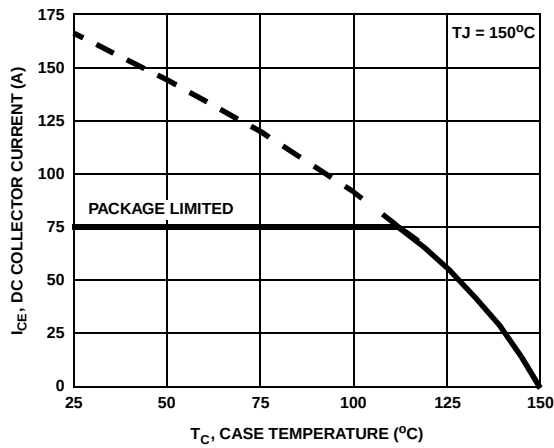


Figure 1. DC Collector Current vs Case Temperature

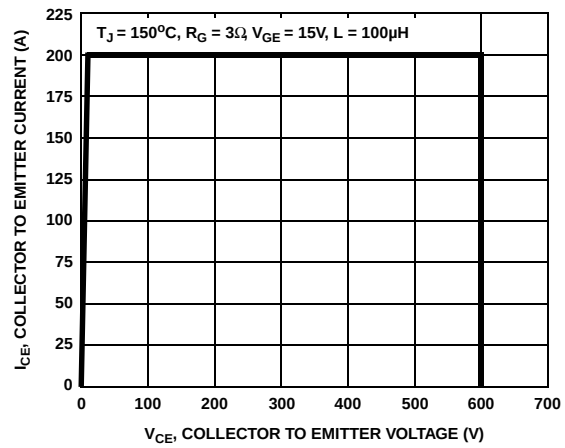


Figure 2. Minimum Switching Safe Operating Area

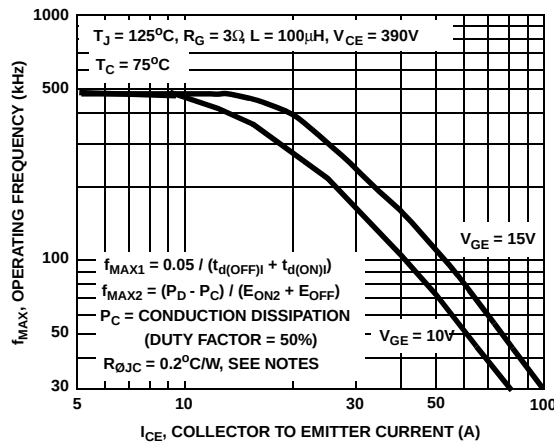


Figure 3. Operating Frequency vs Collector to Emitter Current

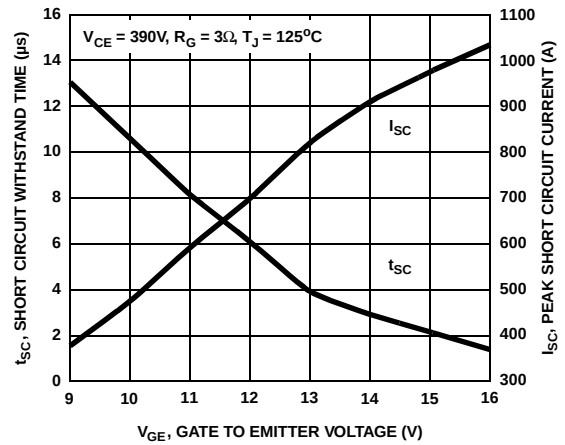


Figure 4. Short Circuit Withstand Time

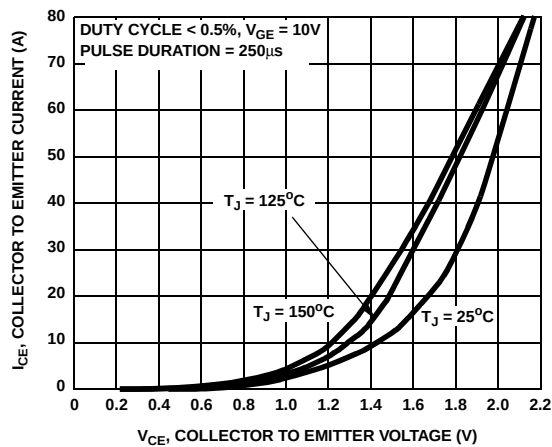


Figure 5. Collector to Emitter On-State Voltage

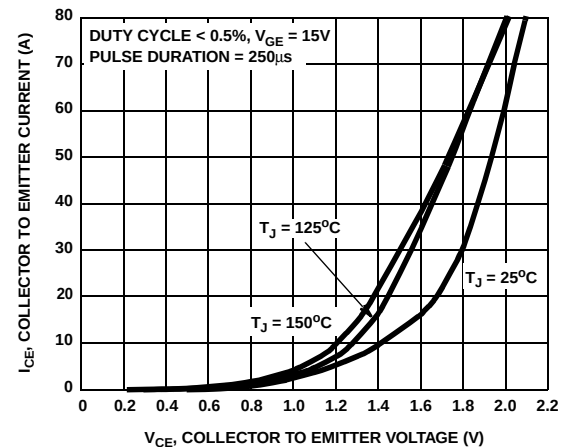


Figure 6. Collector to Emitter On-State Voltage

# Typical Performance Curves $T_J = 25^\circ\text{C}$ unless otherwise noted

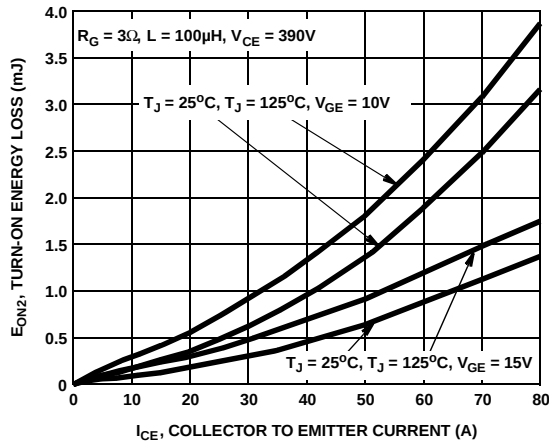


Figure 7. Turn-On Energy Loss vs Collector to Emitter Current

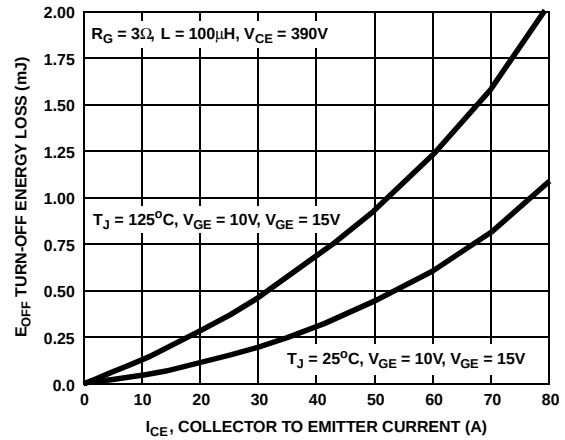


Figure 8. Turn-Off Energy Loss vs Collector to Emitter Current

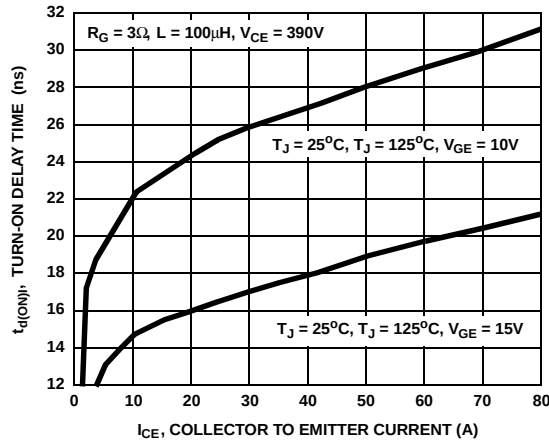


Figure 9. Turn-On Delay Time vs Collector to Emitter Current

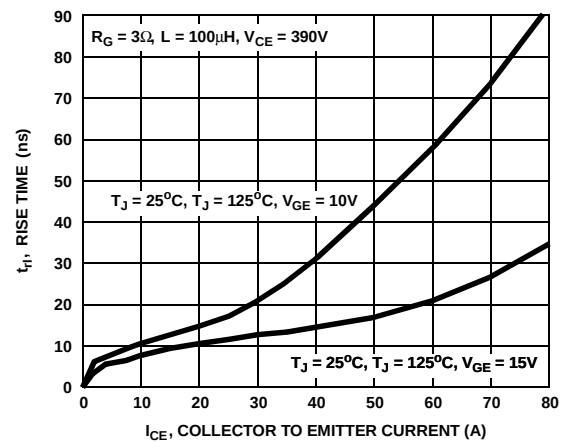


Figure 10. Turn-On Rise Time vs Collector to Emitter Current

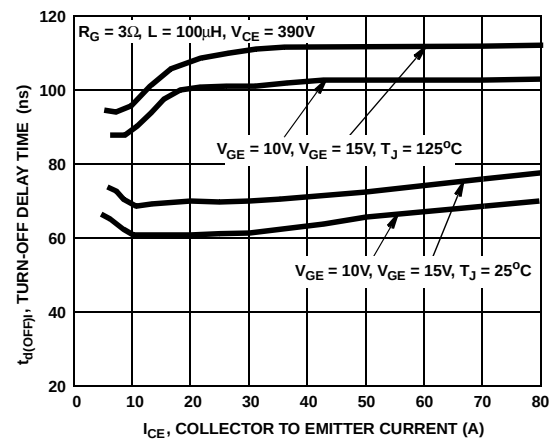


Figure 11. Turn-Off Delay Time vs Collector to Emitter Current

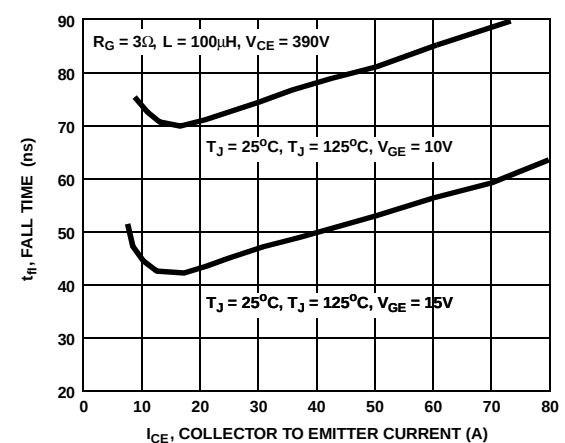


Figure 12. Fall Time vs Collector to Emitter Current

# Typical Performance Curves $T_J = 25^\circ\text{C}$ unless otherwise noted

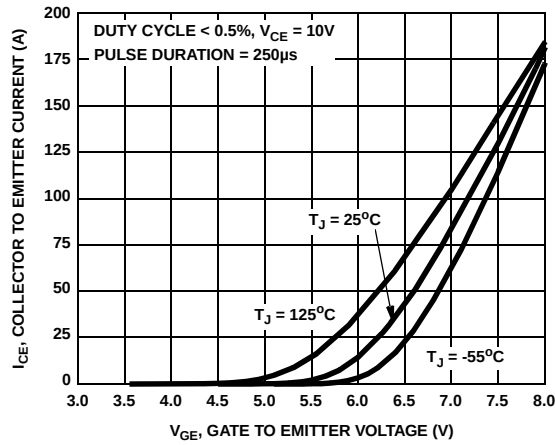


Figure 13. Transfer Characteristic

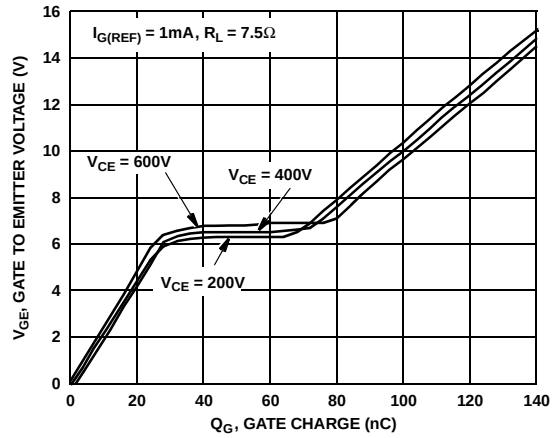


Figure 14. Gate Charge

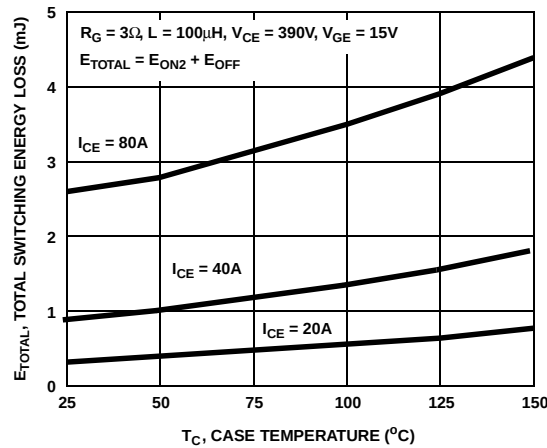


Figure 15. Total Switching Loss vs Case Temperature

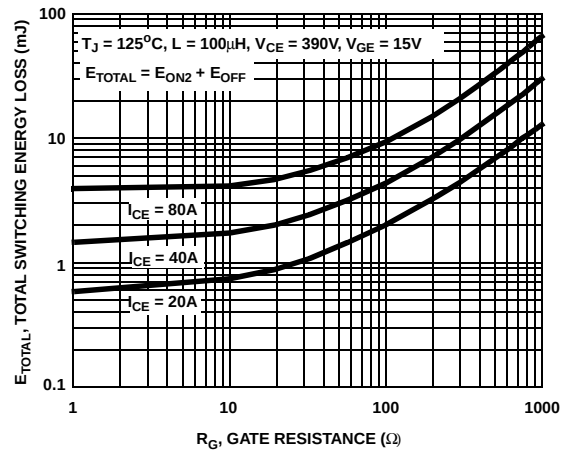


Figure 16. Total Switching Loss vs Gate Resistance

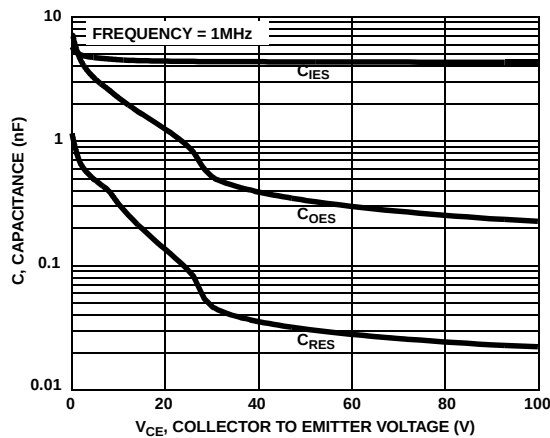


Figure 17. Capacitance vs Collector to Emitter Voltage

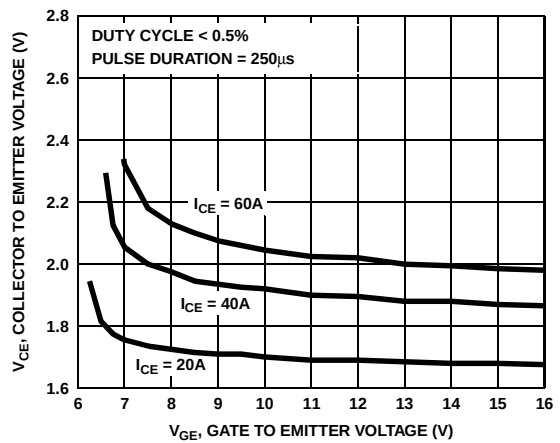


Figure 18. Collector to Emitter On-State Voltage vs Gate to Emitter Voltage

# Typical Performance Curves $T_J = 25^\circ\text{C}$ unless otherwise noted

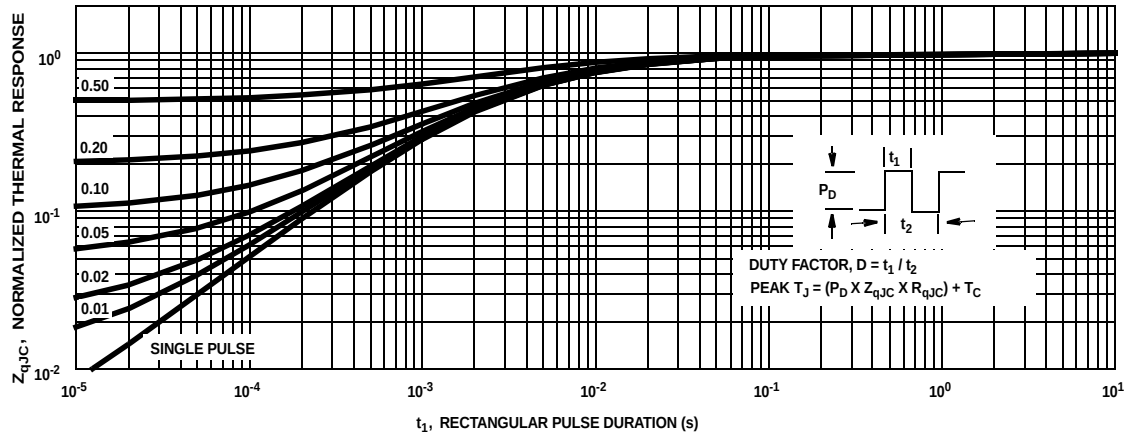


Figure 19. IGBT Normalized Transient Thermal Impedance, Junction to Case

## Test Circuit and Waveforms

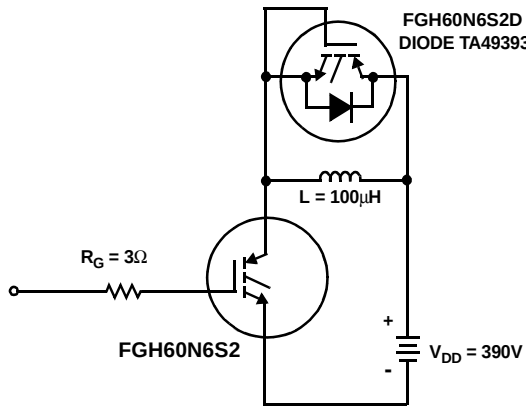


Figure 20. Inductive Switching Test Circuit

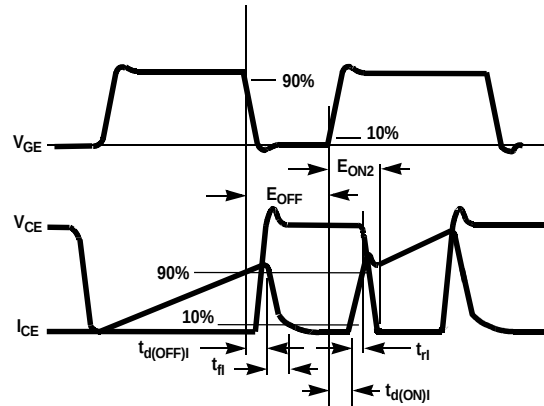


Figure 21. Switching Test Waveforms

## Handling Precautions for IGBTs

Insulated Gate Bipolar Transistors are susceptible to gate-insulation damage by the electrostatic discharge of energy through the devices. When handling these devices, care should be exercised to assure that the static charge built in the handler's body capacitance is not discharged through the device. With proper handling and application procedures, however, IGBTs are currently being extensively used in production by numerous equipment manufacturers in military, industrial and consumer applications, with virtually no damage problems due to electrostatic discharge. IGBTs can be handled safely if the following basic precautions are taken:

1. Prior to assembly into a circuit, all leads should be kept shorted together either by the use of metal shorting springs or by the insertion into conductive material such as "ECCOSORB<sup>TM</sup> LD26" or equivalent.
2. When devices are removed by hand from their carriers, the hand being used should be grounded by any suitable means - for example, with a metallic wristband.
3. Tips of soldering irons should be grounded.
4. Devices should never be inserted into or removed from circuits with power on.
5. **Gate Voltage Rating** - Never exceed the gate-voltage rating of  $V_{GEM}$ . Exceeding the rated  $V_{GE}$  can result in permanent damage to the oxide layer in the gate region.
6. **Gate Termination** - The gates of these devices are essentially capacitors. Circuits that leave the gate open-circuited or floating should be avoided. These conditions can result in turn-on of the device due to voltage buildup on the input capacitor due to leakage currents or pickup.
7. **Gate Protection** - These devices do not have an internal monolithic Zener diode from gate to emitter. If gate protection is required an external Zener is recommended.

## Operating Frequency Information

Operating frequency information for a typical device (Figure 3) is presented as a guide for estimating device performance for a specific application. Other typical frequency vs collector current ( $I_{CE}$ ) plots are possible using the information shown for a typical unit in Figures 5, 6, 7, 8, 9 and 11. The operating frequency plot (Figure 3) of a typical device shows  $f_{MAX1}$  or  $f_{MAX2}$ ; whichever is smaller at each point. The information is based on measurements of a typical device and is bounded by the maximum rated junction temperature.

$f_{MAX1}$  is defined by  $f_{MAX1} = 0.05 / (t_{d(OFF)I} + t_{d(ON)I})$ . Deadtime (the denominator) has been arbitrarily held to 10% of the on-state time for a 50% duty factor. Other definitions are possible.  $t_{d(OFF)I}$  and  $t_{d(ON)I}$  are defined in Figure 27. Device turn-off delay can establish an additional frequency limiting condition for an application other than  $T_{JM}$ .  $t_{d(OFF)I}$  is important when controlling output ripple under a lightly loaded condition.

$f_{MAX2}$  is defined by  $f_{MAX2} = (P_D - P_C) / (E_{OFF} + E_{ON2})$ . The allowable dissipation ( $P_D$ ) is defined by  $P_D = (T_{JM} - T_C) / R_{\theta JC}$ . The sum of device switching and conduction losses must not exceed  $P_D$ . A 50% duty factor was used (Figure 3) and the conduction losses ( $P_C$ ) are approximated by  $P_C = (V_{CE} \times I_{CE}) / 2$ .

$E_{ON2}$  and  $E_{OFF}$  are defined in the switching waveforms shown in Figure 27.  $E_{ON2}$  is the integral of the instantaneous power loss ( $I_{CE} \times V_{CE}$ ) during turn-on and  $E_{OFF}$  is the integral of the instantaneous power loss ( $I_{CE} \times V_{CE}$ ) during turn-off. All tail losses are included in the calculation for  $E_{OFF}$ ; i.e., the collector current equals zero ( $I_{CE} = 0$ ).

## TRADEMARKS

The following are registered and unregistered trademarks Fairchild Semiconductor owns or is authorized to use and is not intended to be an exhaustive list of all such trademarks.

|                                      |                     |               |                     |                 |
|--------------------------------------|---------------------|---------------|---------------------|-----------------|
| ACEx™                                | FACT Quiet Series™  | LittleFET™    | Power247™           | SuperSOT™-6     |
| ActiveArray™                         | FAST®               | MICROCOUPLER™ | PowerTrench®        | SuperSOT™-8     |
| Bottomless™                          | FASTr™              | MicroFET™     | QFET®               | SyncFET™        |
| CoolFET™                             | FRFET™              | MicroPak™     | QS™                 | TinyLogic®      |
| CROSSVOLT™                           | GlobalOptoisolator™ | MICROWIRE™    | QT Optoelectronics™ | TINYOPTO™       |
| DOME™                                | GTO™                | MSX™          | Quiet Series™       | TruTranslation™ |
| EcoSPARK™                            | HiSeC™              | MSXPro™       | RapidConfigure™     | UHC™            |
| E <sup>2</sup> CMOS™                 | I <sup>2</sup> C™   | OCX™          | RapidConnect™       | UltraFET®       |
| EnSigna™                             | ImpliedDisconnect™  | OCXPro™       | SILENT SWITCHER®    | VCX™            |
| FACT™                                | ISOPPLANAR™         | OPTOLOGIC®    | SMART START™        |                 |
| Across the board. Around the world.™ | OPTOPLANAR™         | SPM™          |                     |                 |
| The Power Franchise™                 | PACMAN™             | Stealth™      |                     |                 |
| Programmable Active Droop™           | POP™                | SuperSOT™-3   |                     |                 |

## DISCLAIMER

FAIRCHILD SEMICONDUCTOR RESERVES THE RIGHT TO MAKE CHANGES WITHOUT FURTHER NOTICE TO ANY PRODUCTS HEREIN TO IMPROVE RELIABILITY, FUNCTION OR DESIGN. FAIRCHILD DOES NOT ASSUME ANY LIABILITY ARISING OUT OF THE APPLICATION OR USE OF ANY PRODUCT OR CIRCUIT DESCRIBED HEREIN; NEITHER DOES IT CONVEY ANY LICENSE UNDER ITS PATENT RIGHTS, NOR THE RIGHTS OF OTHERS.

## LIFE SUPPORT POLICY

FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF FAIRCHILD SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, or (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

## PRODUCT STATUS DEFINITIONS

### Definition of Terms

| Datasheet Identification | Product Status         | Definition                                                                                                                                                                                                            |
|--------------------------|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Advance Information      | Formative or In Design | This datasheet contains the design specifications for product development. Specifications may change in any manner without notice.                                                                                    |
| Preliminary              | First Production       | This datasheet contains preliminary data, and supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design. |
| No Identification Needed | Full Production        | This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.                                                       |
| Obsolete                 | Not In Production      | This datasheet contains specifications on a product that has been discontinued by Fairchild semiconductor. The datasheet is printed for reference information only.                                                   |