

### Features

- High breakdown voltage to 650V for improved reliability
- Trench-stop technology offering:
  - High speed switching
  - High ruggedness, temperature stable behavior
  - Short circuit withstand time: 10μs
  - Low  $V_{CE(SAT)}$   
 $V_{CE(SAT)} = 1.50V$  (Typ.) @  $I_C = 20A$
  - Easy parallel switching capability due to positive temperature coefficient in  $V_{CE(SAT)}$
- Enhanced avalanche capability
- Very soft, fast recovery antiparallel diode
- RoHS compliant with Halogen-free

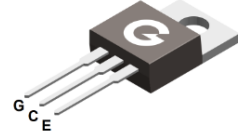
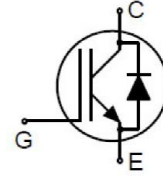
HF

### Applications

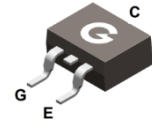
- Servo drives
- General purpose drives (GPD)
- Motor control

### Mechanical Data

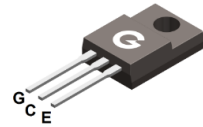
- Case: TO-220AB, TO-263, ITO-220AB, TO-247
- Molding Compound: UL Flammability Classification Rating 94V-0
- Terminals: Matte tin-plated leads; solderability-per MIL-STD-202, Method 208



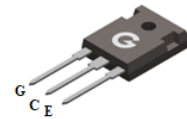
TO-220AB



TO-263



ITO-220AB



TO-247

### Ordering Information

| Part Number | Package   | Shipping Quantity                      | Marking Code |
|-------------|-----------|----------------------------------------|--------------|
| GKP20N65ES5 | TO-220AB  | 50 pcs / Tube                          | KP20N65ES5   |
| GKB20N65ES5 | TO-263    | 50 pcs / Tube or 800 pcs / Tape & Reel | KB20N65ES5   |
| GKF20N65ES5 | ITO-220AB | 50 pcs / Tube                          | KF20N65ES5   |
| GKU20N65ES5 | TO-247    | 30 pcs / Tube                          | KU20N65ES5   |

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

| Parameter                                                                                 | Symbol            | Value           | Unit             |
|-------------------------------------------------------------------------------------------|-------------------|-----------------|------------------|
| Collector-to-Emitter Voltage                                                              | $V_{CES}$         | 650             | V                |
| Gate-Emitter Voltage                                                                      | $V_{GES}$         | $\pm 20$        | V                |
| DC Collector Current ( $T_C = 25^\circ\text{C}$ , limited by maximum $T_J$ )              | $I_C$             | 40              | A                |
| DC Collector Current ( $T_C = 100^\circ\text{C}$ , limited by maximum $T_J$ )             |                   | 20              | A                |
| Diode Continuous Forward Current ( $T_C = 25^\circ\text{C}$ , limited by maximum $T_J$ )  | $I_F$             | 40              | A                |
| Diode Continuous Forward Current ( $T_C = 100^\circ\text{C}$ , limited by maximum $T_J$ ) |                   | 20              | A                |
| Pulsed Collector Current (Pulse width limited by maximum $T_J$ , $V_{GE} = 15\text{V}$ )  | $I_{CM}$          | 80              | A                |
| Pulsed Source-Drain Current (Pulse width limited by maximum $T_J$ )                       | $I_{FM}$          | 80              | A                |
| Short Circuit Withstand Time ( $V_{GE} = 15\text{V}$ , $V_{CE} \leq 400\text{V}$ )        | $T_{SC}$          | 10              | $\mu\text{s}$    |
| Soldering Temperature, Wave Soldering 1.6mm (0.063in.) from case for 10s                  | $T_{\text{sold}}$ | 260             | $^\circ\text{C}$ |
| Power Dissipation ( $T_C = 25^\circ\text{C}$ , TO-220AB, TO-263)                          | $P_D$             | 93              | W                |
| Power Dissipation ( $T_C = 25^\circ\text{C}$ , ITO-220AB)                                 |                   | 194             |                  |
| Power Dissipation ( $T_C = 25^\circ\text{C}$ , TO-247)                                    |                   | 42              |                  |
| Operating Junction Temperature Range                                                      | $T_J$             | $-55 \sim +175$ | $^\circ\text{C}$ |
| Storage Temperature Range                                                                 | $T_{STG}$         | $-55 \sim +150$ | $^\circ\text{C}$ |

### Thermal Characteristics

| Parameter                                  | Symbol          | TO-220AB | TO-263 | ITO-220AB | TO-247 | Unit               |
|--------------------------------------------|-----------------|----------|--------|-----------|--------|--------------------|
| Thermal Resistance Junction-to-Case, IGBT  | $R_{\theta JC}$ | 1.60     | 1.60   | 3.57      | 0.77   | $^\circ\text{C/W}$ |
| Thermal Resistance Junction-to-Case, Diode |                 | 2.38     | 2.38   | 4.47      | 2.05   |                    |
| Thermal Resistance Junction-to-Air         | $R_{\theta JA}$ | 24       | 24     | 62.5      | 40     | $^\circ\text{C/W}$ |

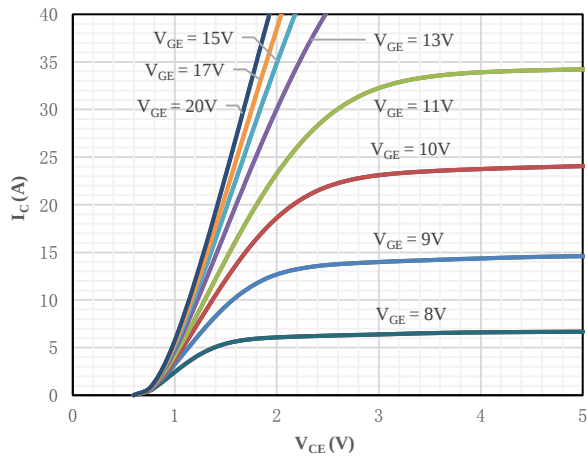
### Electrical Characteristics of the IGBT (@ $T_J = 25^\circ\text{C}$ unless otherwise specified)

| Symbol                           | Parameter                            | Test Condition                                                                                   | Min. | Typ. | Max.      | Unit     |
|----------------------------------|--------------------------------------|--------------------------------------------------------------------------------------------------|------|------|-----------|----------|
| <b>Static Characteristics</b>    |                                      |                                                                                                  |      |      |           |          |
| $V_{(BR)CES}$                    | Collector-Emitter Breakdown Voltage  | $V_{GE} = 0V, I_C = 250\mu A$                                                                    | 650  | -    | -         | V        |
| $I_{CES}$                        | Collector-Emitter Leakage Current    | $V_{CE} = 650V, V_{GE} = 0V$                                                                     | -    | -    | 1         | $\mu A$  |
| $I_{GES}$                        | Gate to Emitter Leakage Current      | $V_{GE} = \pm 20V, V_{CE} = 0V$                                                                  | -    | -    | $\pm 100$ | nA       |
| $V_{CE(sat)}$                    | Collector-Emitter Saturation Voltage | $V_{GE} = 15V, I_C = 20A, T_J = 25^\circ\text{C}$                                                | -    | 1.5  | 1.8       | V        |
|                                  |                                      | $V_{GE} = 15V, I_C = 20A, T_J = 175^\circ\text{C}$                                               | -    | 1.86 | -         | V        |
| $V_{GE(th)}$                     | Gate Threshold Voltage               | $V_{CE} = V_{GE}, I_C = 250\mu A$                                                                | 4.4  | 5.1  | 6.0       | V        |
| $R_G$                            | Gate Resistance                      | $V_{GS} = 0V, f = 1\text{MHz}$                                                                   | -    | 2.1  | -         | $\Omega$ |
| <b>Dynamic Characteristics</b>   |                                      |                                                                                                  |      |      |           |          |
| $Q_G$                            | Total Gate-Charge                    | $V_{CC} = 520V, V_{GE} = 15V, I_C = 20A$                                                         | -    | 42.3 | -         | nC       |
| $C_{ies}$                        | Input Capacitance                    | $V_{CE} = 25V$                                                                                   | -    | 1035 | -         | pF       |
| $C_{oes}$                        | Output Capacitance                   | $V_{GE} = 0V$                                                                                    | -    | 50   | -         |          |
| $C_{res}$                        | Reverse Transfer Capacitance         | $f = 1\text{MHz}$                                                                                | -    | 5    | -         |          |
| $I_{C(SC)}$                      | Short Circuit Collector Current      | $V_{GE} = 15V, t_{SC} \leq 10\mu s$<br>$V_{CC} = 400V, T_J = 25^\circ\text{C}$                   | -    | 124  | -         | A        |
| <b>Switching Characteristics</b> |                                      |                                                                                                  |      |      |           |          |
| $t_{d(on)}$                      | Turn-on Delay Time                   | $V_{CE} = 400V$<br>$V_{GE} = 15V$<br>$I_C = 20A$<br>$R_G = 10\Omega$<br>$T_J = 25^\circ\text{C}$ | -    | 45   | -         | ns       |
| $t_r$                            | Turn-on Rise Time                    |                                                                                                  | -    | 50   | -         |          |
| $t_{d(off)}$                     | Turn-Off Delay Time                  |                                                                                                  | -    | 86   | -         |          |
| $t_f$                            | Turn-Off Fall Time                   |                                                                                                  | -    | 111  | -         |          |
| $E_{on}$                         | Turn-On Switching Loss               |                                                                                                  | -    | 0.40 | -         | mJ       |
| $E_{off}$                        | Turn-Off Switching Loss              |                                                                                                  | -    | 0.49 | -         |          |

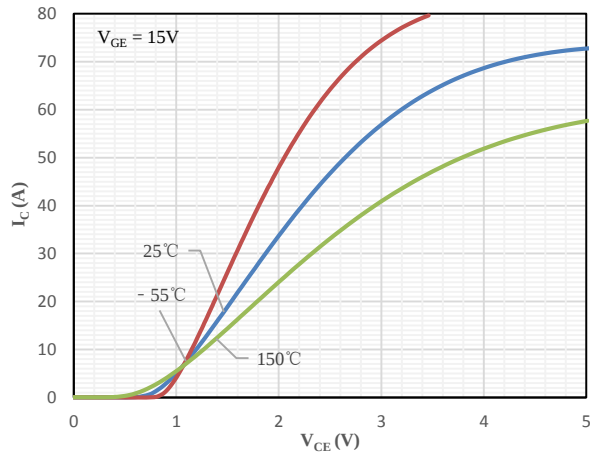
### Electrical Characteristics of the Diode (@ $T_J = 25^\circ\text{C}$ unless otherwise specified)

| Symbol                         | Parameter                     | Test Condition                                   | Min. | Typ. | Max. | Unit |
|--------------------------------|-------------------------------|--------------------------------------------------|------|------|------|------|
| <b>Dynamic Characteristics</b> |                               |                                                  |      |      |      |      |
| $V_{FM}$                       | Diode Forward Voltage         | $I_F = 20A, V_{GE} = 0V$                         | -    | 1.7  | 2.5  | V    |
| $t_{rr}$                       | Reverse recovery time         | $V_{GE} = 0V, I_F = 20A$<br>$di/dt = 300A/\mu s$ | -    | 82   | -    | ns   |
| $Q_{rr}$                       | Reverse recovery charge       |                                                  | -    | 179  | -    | nC   |
| $I_{rrm}$                      | Peak Reverse Recovery Current |                                                  | -    | 4.09 | -    | A    |

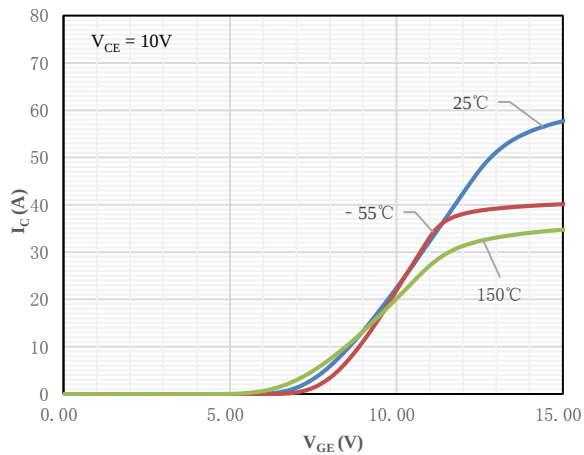
**Ratings and Characteristics Curves** (@  $T_A = 25^\circ\text{C}$  unless otherwise specified)



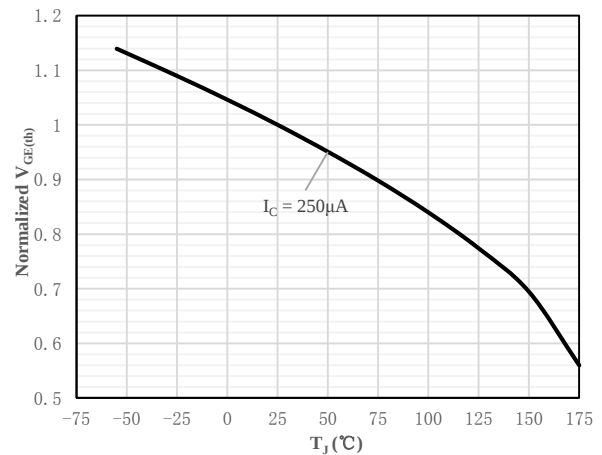
**Fig 1 Typical Output Characteristics**



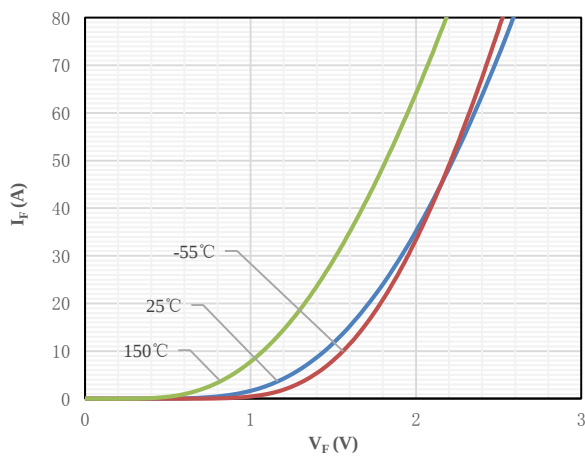
**Fig 2 Saturation Voltage Characteristics**



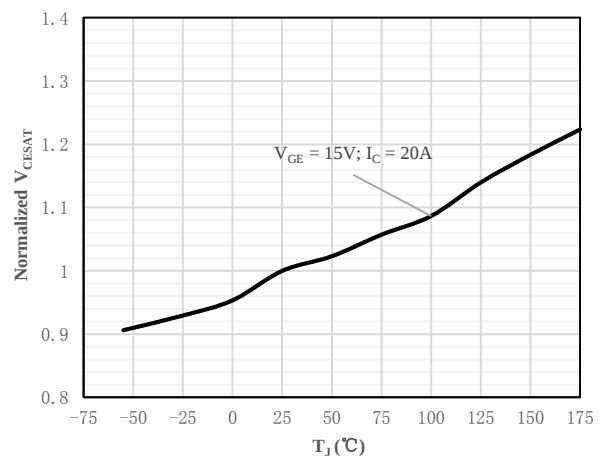
**Fig 3 Transfer Characteristics**



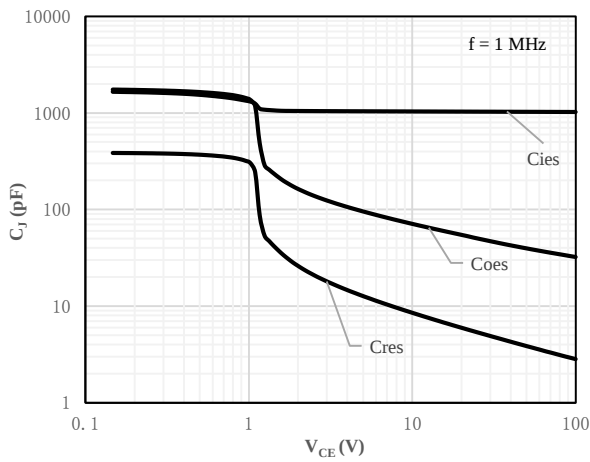
**Fig 4 Normalized  $V_{GE(th)}$  vs. Junction Temperature**



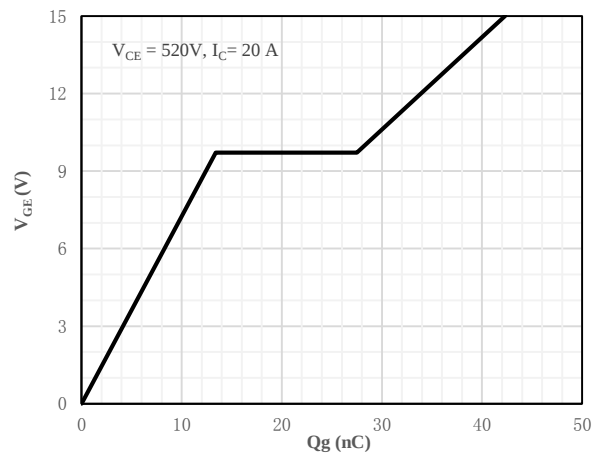
**Fig 5 Diode forward current as a function of forward voltage  $V_F$  vs.  $I_F$**



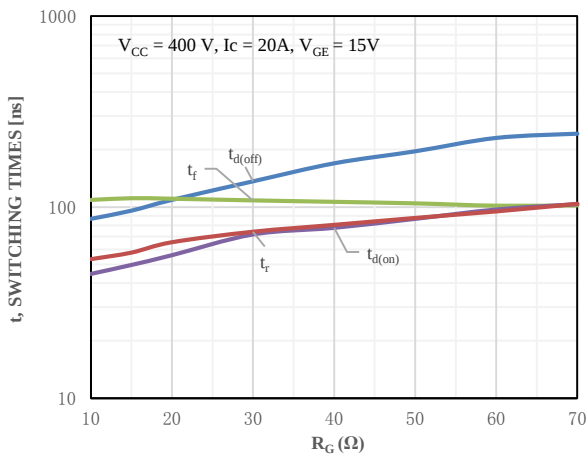
**Fig 6 Normalized Collector-Emitter Saturation Voltage vs. Junction Temperature**



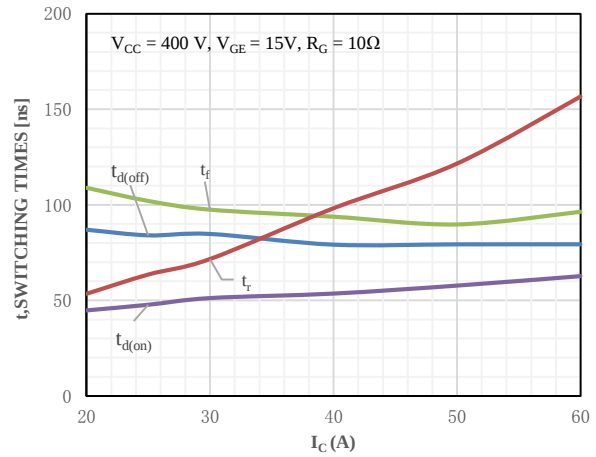
**Fig 7 Capacitance Characteristics**



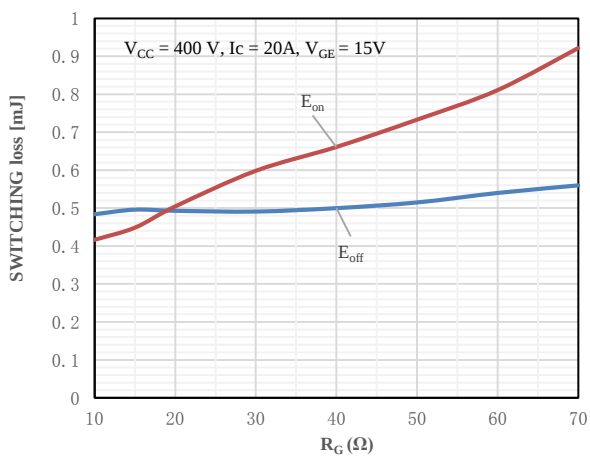
**Fig 8 Gate-Charge Characteristics**



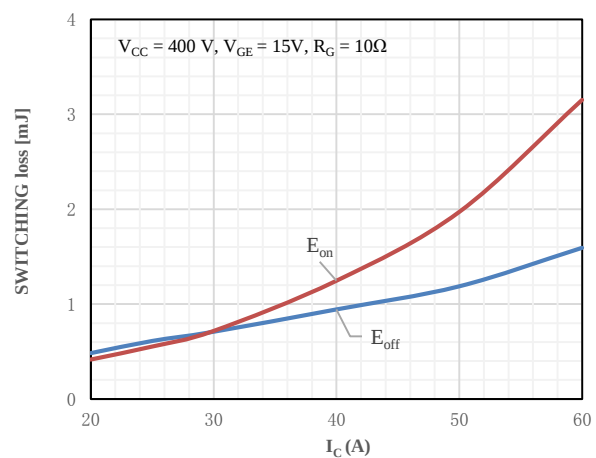
**Fig 9 Switching Times vs. Gate Resistor**



**Fig 10 Switching Times vs. Collector Current**



**Fig 11 Switching Loss vs. Gate Resistor**



**Fig 12 Switching Loss vs. Collector Current**

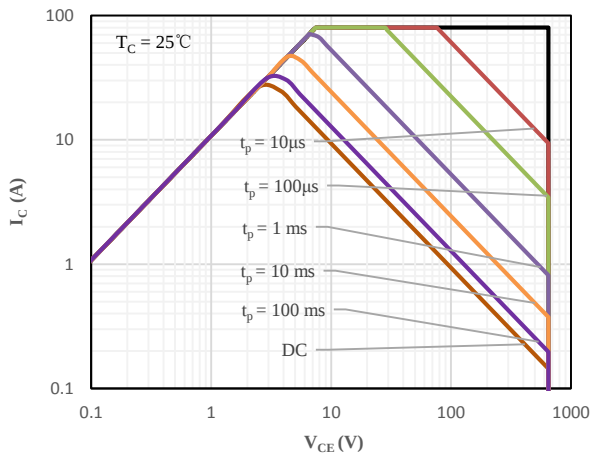


Fig 13 SOA characteristics (TO-263)

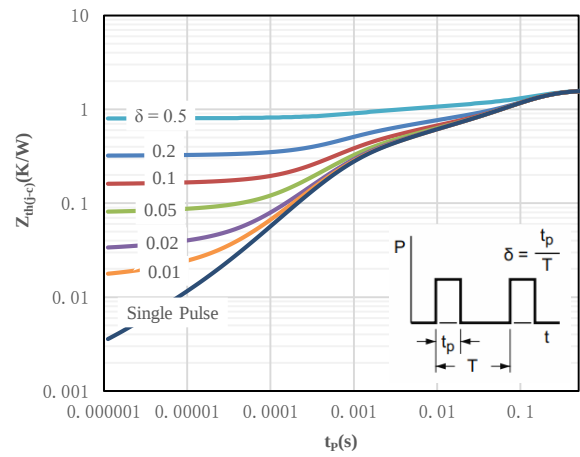


Fig 14 Maximum transient thermal impedance (TO-263)

## Waveform definitions

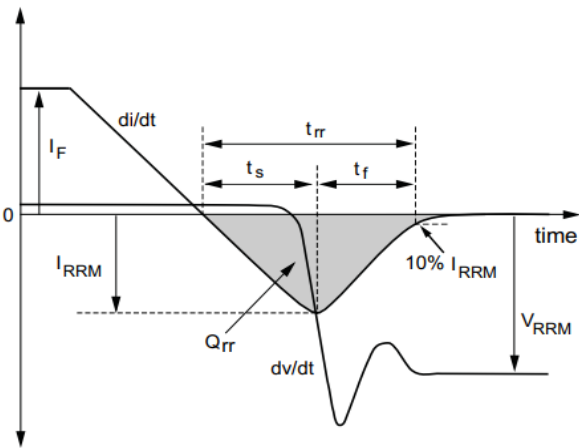


Fig 1 Diode Reverse Recovery Waveform Definitions

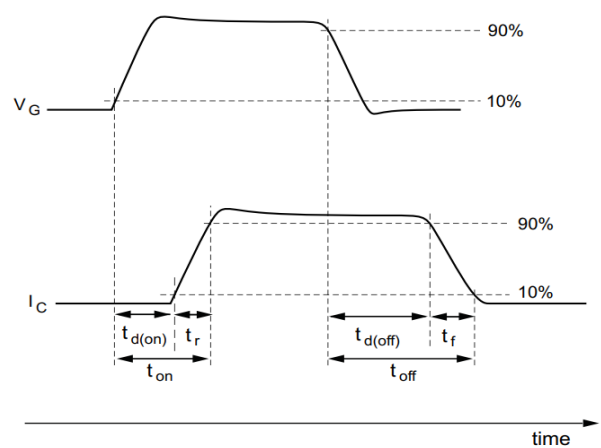


Fig 2 IGBT Switching Times Definitions

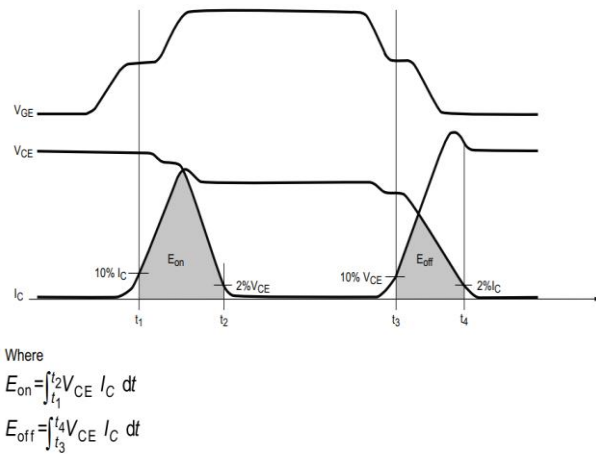
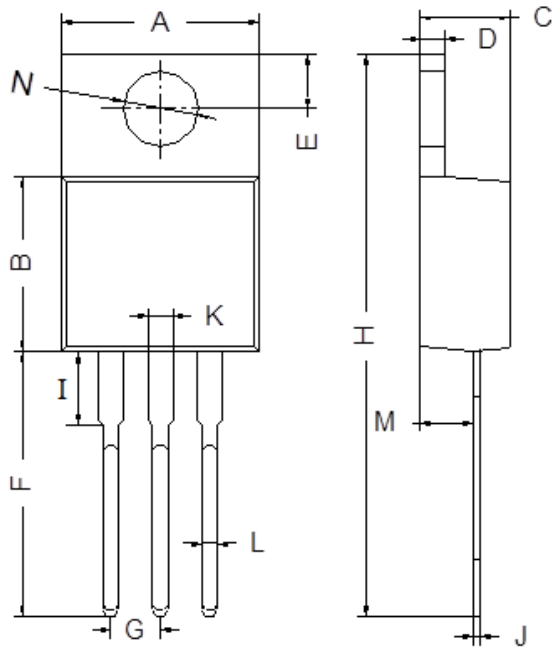
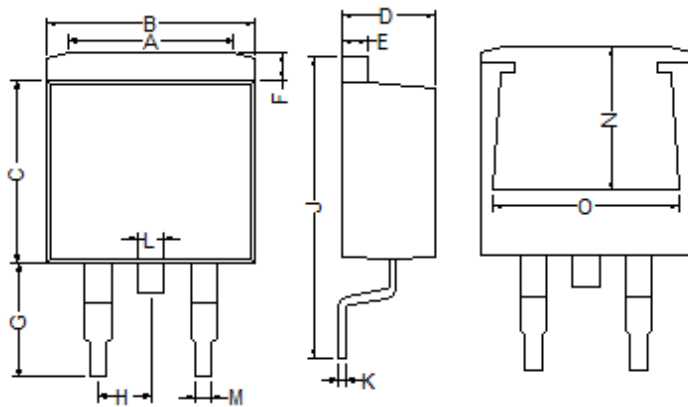


Fig 3 IGBT Switching Energy Loss Definitions

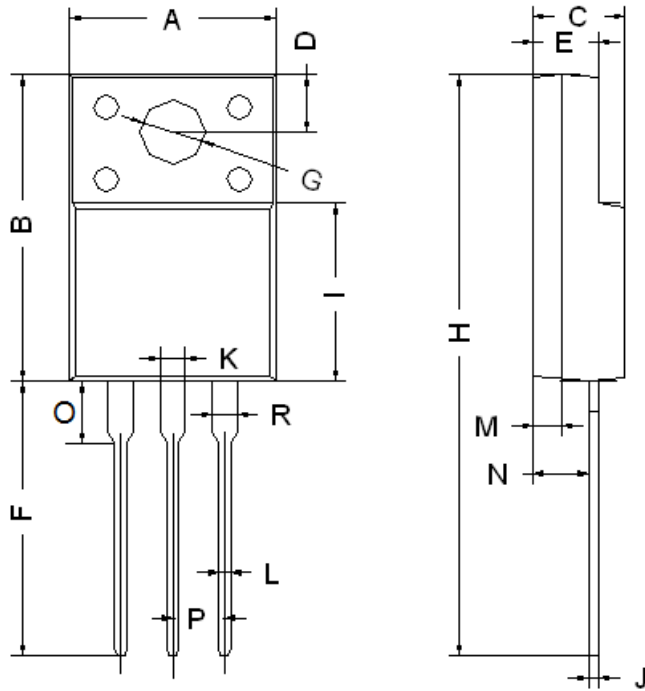
**Package Outline Dimensions** (Unit: mm)



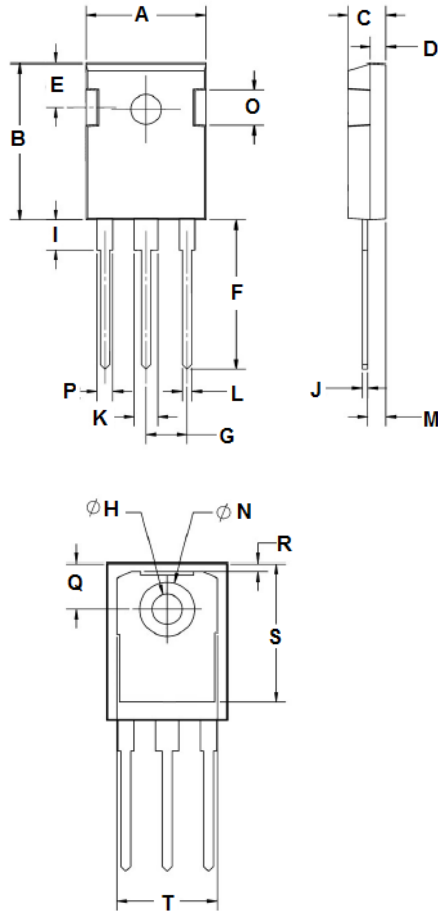
| TO-220AB  |       |       |
|-----------|-------|-------|
| Dimension | Min.  | Max.  |
| A         | 9.80  | 10.30 |
| B         | 8.70  | 9.10  |
| C         | 4.37  | 4.77  |
| D         | 1.07  | 1.47  |
| E         | 2.64  | 2.84  |
| F         | 13.14 | 13.74 |
| G         | 2.44  | 2.64  |
| H         | 28.03 | 28.83 |
| I         | 3.50  | 4.00  |
| J         | 0.28  | 0.48  |
| K         | 1.22  | 1.32  |
| L         | 0.71  | 0.91  |
| M         | 2.40  | 2.60  |
| N         | 3.76  | 3.96  |



| TO-263    |       |       |
|-----------|-------|-------|
| Dimension | Min.  | Max.  |
| A         | 6.00  | 8.00  |
| B         | 9.90  | 10.30 |
| C         | 8.50  | 9.10  |
| D         | 4.37  | 4.77  |
| E         | 1.07  | 1.47  |
| F         | 1.07  | 1.47  |
| G         | 5.05  | 5.74  |
| H         | 2.44  | 2.66  |
| J         | 15.15 | 15.80 |
| K         | 0.28  | 0.48  |
| L         | 1.17  | 1.37  |
| M         | 0.71  | 0.91  |
| N         | 6.55  | 7.68  |
| O         | 7.70  | 8.10  |



| ITO-220AB |       |       |
|-----------|-------|-------|
| Dimension | Min.  | Max.  |
| A         | 9.90  | 10.30 |
| B         | 14.80 | 15.20 |
| C         | 4.30  | 4.70  |
| D         | 2.50  | 2.90  |
| E         | 2.80  | 3.30  |
| F         | 13.00 | 13.60 |
| G         | 3.10  | 3.30  |
| H         | 28.00 | 28.60 |
| I         | 7.90  | 8.90  |
| J         | 0.40  | 0.60  |
| L         | 0.70  | 0.90  |
| M         | 1.30  | 1.50  |
| N         | 2.60  | 2.80  |
| O         | 2.60  | 3.10  |
| P         | 2.45  | 2.65  |
| K/R       | 1.10  | 1.30  |



| TO-247    |       |       |
|-----------|-------|-------|
| Dimension | Min.  | Max.  |
| A         | 15.50 | 16.10 |
| B         | 20.70 | 21.30 |
| C         | 4.70  | 5.30  |
| D         | 1.80  | 2.20  |
| E         | 5.20  | 5.80  |
| F         | 19.70 | 20.30 |
| G         | 5.20  | 5.60  |
| H         | 3.30  | 3.70  |
| I         | 3.90  | 4.30  |
| J         | 0.50  | 0.70  |
| K         | 2.80  | 3.20  |
| L         | 1.00  | 1.40  |
| M         | 2.20  | 2.60  |
| N         | 7.00  | 7.20  |
| O         | 4.90  | 5.30  |
| P         | 1.80  | 2.20  |
| Q         | 5.70  | 5.90  |
| R         | 0.80  | 1.20  |
| S         | 17.00 | 17.80 |
| T         | 13.60 | 14.20 |

## Mounting Pad Layout (Unit: mm)

### TO-263

