RGS60TS65D
650V 30A Field Stop Trench IGBT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector - Emitter Voltage</td>
<td>$V_{CES}$</td>
<td>650</td>
<td>V</td>
</tr>
<tr>
<td>Gate - Emitter Voltage</td>
<td>$V_{GES}$</td>
<td>±30</td>
<td>V</td>
</tr>
<tr>
<td>Collector Current</td>
<td>$I_C$, $T_C = 25^\circ$C</td>
<td>56</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>$I_C$, $T_C = 100^\circ$C</td>
<td>30</td>
<td>A</td>
</tr>
<tr>
<td>Pulsed Collector Current</td>
<td>$I_{CP}^*1$</td>
<td>90</td>
<td>A</td>
</tr>
<tr>
<td>Diode Forward Current</td>
<td>$I_F$, $T_C = 25^\circ$C</td>
<td>56</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>$I_F$, $T_C = 100^\circ$C</td>
<td>30</td>
<td>A</td>
</tr>
<tr>
<td>Diode Pulsed Forward Current</td>
<td>$I_{FP}^*1$</td>
<td>90</td>
<td>A</td>
</tr>
<tr>
<td>Power Dissipation</td>
<td>$P_D$, $T_C = 25^\circ$C</td>
<td>223</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td>$P_D$, $T_C = 100^\circ$C</td>
<td>111</td>
<td>W</td>
</tr>
<tr>
<td>Operating Junction Temperature</td>
<td>$T_j$</td>
<td>–40 to +175</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>$T_{stg}$</td>
<td>–55 to +175</td>
<td>°C</td>
</tr>
</tbody>
</table>

*1 Pulse width limited by $T_{jmax}$. 

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**Features**
1) Low Collector - Emitter Saturation Voltage
2) Short Circuit Withstand Time 8μs
3) Qualified to AEC-Q101
4) Built in Very Fast & Soft Recovery FRD
5) Pb - free Lead Plating ; RoHS Compliant

**Applications**
General Inverter
for Automotive and Industrial Use

**Absolute Maximum Ratings** (at $T_C = 25^\circ$C unless otherwise specified)
### Thermal Resistance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Resistance IGBT Junction - Case</td>
<td>( R_{\theta(j-c)} )</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thermal Resistance Diode Junction - Case</td>
<td>( R_{\theta(j-c)} )</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### IGBT Electrical Characteristics (at \( T_j = 25°C \) unless otherwise specified)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector - Emitter Breakdown Voltage</td>
<td>( BV_{CES} )</td>
<td>( I_C = 10\mu A, V_{GE} = 0V )</td>
<td>650</td>
<td>V</td>
</tr>
<tr>
<td>Collector Cut - off Current</td>
<td>( I_{CES} )</td>
<td>( V_{CE} = 650V, V_{GE} = 0V ) ( T_j = 25°C ) ( T_j = 175°C )</td>
<td>- 10 5 μA mA</td>
<td></td>
</tr>
<tr>
<td>Gate - Emitter Leakage Current</td>
<td>( I_{GES} )</td>
<td>( V_{GE} = \pm 30V, V_{CE} = 0V )</td>
<td>- ±200 nA</td>
<td></td>
</tr>
<tr>
<td>Gate - Emitter Threshold Voltage</td>
<td>( V_{GE(th)} )</td>
<td>( V_{CE} = 5V, I_C = 1.5mA )</td>
<td>5.0 6.0 7.0 V</td>
<td></td>
</tr>
<tr>
<td>Collector - Emitter Saturation Voltage</td>
<td>( V_{CE(sat)} )</td>
<td>( I_C = 30A, V_{GE} = 15V ) ( T_j = 25°C ) ( T_j = 175°C )</td>
<td>1.65 2.10 V</td>
<td></td>
</tr>
</tbody>
</table>
### IGBT Electrical Characteristics (at $T_j = 25^\circ C$ unless otherwise specified)

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<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Capacitance</td>
<td>$C_{ies}$</td>
<td>$V_{CE} = 30V$</td>
<td>-</td>
<td>pF</td>
</tr>
<tr>
<td>Output Capacitance</td>
<td>$C_{oes}$</td>
<td>$V_{GE} = 0V$</td>
<td>-</td>
<td>pF</td>
</tr>
<tr>
<td>Reverse Transfer Capacitance</td>
<td>$C_{res}$</td>
<td>$f = 1MHz$</td>
<td>-</td>
<td>pF</td>
</tr>
<tr>
<td>Total Gate Charge</td>
<td>$Q_g$</td>
<td>$V_{CE} = 300V$</td>
<td>-</td>
<td>nC</td>
</tr>
<tr>
<td>Gate - Emitter Charge</td>
<td>$Q_{ge}$</td>
<td>$I_C = 30A$</td>
<td>-</td>
<td>nC</td>
</tr>
<tr>
<td>Gate - Collector Charge</td>
<td>$Q_{gc}$</td>
<td>$V_{GE} = 15V$</td>
<td>-</td>
<td>nC</td>
</tr>
<tr>
<td>Turn - on Delay Time</td>
<td>$t_{d(on)}$</td>
<td>$I_C = 30A$, $V_{CC} = 400V$</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Rise Time</td>
<td>$t_r$</td>
<td>$V_{GE} = 15V$, $R_G = 10\Omega$</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Turn - off Delay Time</td>
<td>$t_{d(off)}$</td>
<td>$T_j = 25^\circ C$</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Fall Time</td>
<td>$t_i$</td>
<td>Inductive Load</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Turn - on Switching Loss</td>
<td>$E_{on}$</td>
<td>$^*E_{on}$ includes diode</td>
<td>-</td>
<td>mJ</td>
</tr>
<tr>
<td>Turn - off Switching Loss</td>
<td>$E_{off}$</td>
<td>reverse recovery</td>
<td>-</td>
<td>mJ</td>
</tr>
<tr>
<td>Turn - on Delay Time</td>
<td>$t_{d(on)}$</td>
<td>$I_C = 30A$, $V_{CC} = 400V$</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Rise Time</td>
<td>$t_r$</td>
<td>$V_{GE} = 15V$, $R_G = 10\Omega$</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Turn - off Delay Time</td>
<td>$t_{d(off)}$</td>
<td>$T_j = 175^\circ C$</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Fall Time</td>
<td>$t_i$</td>
<td>Inductive Load</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Turn - on Switching Loss</td>
<td>$E_{on}$</td>
<td>$^*E_{on}$ includes diode</td>
<td>-</td>
<td>mJ</td>
</tr>
<tr>
<td>Turn - off Switching Loss</td>
<td>$E_{off}$</td>
<td>reverse recovery</td>
<td>-</td>
<td>mJ</td>
</tr>
<tr>
<td>Reverse Bias Safe Operating Area</td>
<td>RBSOA</td>
<td>$I_C = 90A$, $V_{CC} = 520V$ $V_P = 650V$, $V_{GE} = 15V$ $R_G = 50\Omega$, $T_j = 175^\circ C$</td>
<td>FULL SQUARE</td>
<td></td>
</tr>
<tr>
<td>Short Circuit Withstand Time</td>
<td>$t_{sc}$</td>
<td>$V_{CC} \leq 360V$ $V_{GE} = 15V$, $T_j = 25^\circ C$</td>
<td>8</td>
<td>µs</td>
</tr>
<tr>
<td>Short Circuit Withstand Time</td>
<td>$t_{sc}^*$</td>
<td>$V_{CC} \leq 360V$ $V_{GE} = 15V$, $T_j = 150^\circ C$</td>
<td>6</td>
<td>µs</td>
</tr>
</tbody>
</table>

*2 Design assurance without measurement
### FRD Electrical Characteristics (at T<sub>j</sub> = 25°C unless otherwise specified)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
</table>
| Diode Forward Voltage            | V<sub>F</sub> | I<sub>F</sub> = 30A  
T<sub>j</sub> = 25°C  
T<sub>j</sub> = 175°C | ![Table 1](attachment:table_1.png) | ![Table 2](attachment:table_2.png) |
| Diode Reverse Recovery Time      | t<sub>rr</sub> | ![Conditions 1](attachment:conditions_1.png) | ![Values 1](attachment:values_1.png) | ![Unit 1](attachment:unit_1.png) |
| Diode Peak Reverse Recovery Current | I<sub>rr</sub> | I<sub>F</sub> = 30A  
V<sub>CC</sub> = 400V | ![Values 2](attachment:values_2.png) | ![Unit 2](attachment:unit_2.png) |
| Diode Reverse Recovery Charge    | Q<sub>rr</sub> | di<sub>r</sub>/dt = 200A/μs  
T<sub>j</sub> = 25°C | ![Values 3](attachment:values_3.png) | ![Unit 3](attachment:unit_3.png) |
| Diode Reverse Recovery Energy    | E<sub>rr</sub> | ![Conditions 2](attachment:conditions_2.png) | ![Values 4](attachment:values_4.png) | ![Unit 4](attachment:unit_4.png) |
| Diode Reverse Recovery Time      | t<sub>rr</sub> | ![Conditions 3](attachment:conditions_3.png) | ![Values 5](attachment:values_5.png) | ![Unit 5](attachment:unit_5.png) |
| Diode Peak Reverse Recovery Current | I<sub>rr</sub> | I<sub>F</sub> = 30A  
V<sub>CC</sub> = 400V | ![Values 6](attachment:values_6.png) | ![Unit 6](attachment:unit_6.png) |
| Diode Reverse Recovery Charge    | Q<sub>rr</sub> | di<sub>r</sub>/dt = 200A/μs  
T<sub>j</sub> = 175°C | ![Values 7](attachment:values_7.png) | ![Unit 7](attachment:unit_7.png) |
| Diode Reverse Recovery Energy    | E<sub>rr</sub> | ![Conditions 4](attachment:conditions_4.png) | ![Values 8](attachment:values_8.png) | ![Unit 8](attachment:unit_8.png) |
●Electrical Characteristic Curves

Fig. 1 Power Dissipation vs. Case Temperature

![Graph showing power dissipation vs. case temperature.](image)

Fig. 2 Collector Current vs. Case Temperature

![Graph showing collector current vs. case temperature.](image)

Fig. 3 Forward Bias Safe Operating Area

![Graph showing forward bias safe operating area.](image)

Fig. 4 Reverse Bias Safe Operating Area

![Graph showing reverse bias safe operating area.](image)
### Electrical Characteristic Curves

#### Fig. 5 Typical Output Characteristics

![Collector Output Characteristics](image1)

- Collector Current: $I_C$ [A]
- Collector To Emitter Voltage: $V_{CE}$ [V]
- $T_j = 25^\circ C$
- $V_{GE} = 20V$
- $V_{GE} = 15V$
- $V_{GE} = 12V$
- $V_{GE} = 10V$
- $V_{GE} = 8V$

#### Fig. 6 Typical Output Characteristics

![Collector Output Characteristics](image2)

- Collector Current: $I_C$ [A]
- Collector To Emitter Voltage: $V_{CE}$ [V]
- $T_j = 175^\circ C$
- $V_{GE} = 20V$
- $V_{GE} = 15V$
- $V_{GE} = 12V$
- $V_{GE} = 10V$
- $V_{GE} = 8V$

#### Fig. 7 Typical Transfer Characteristics

![Transfer Characteristics](image3)

- Collector Current: $I_C$ [A]
- Gate To Emitter Voltage: $V_{GE}$ [V]
- $T_j = 25^\circ C$
- $T_j = 175^\circ C$
- $V_{GE} = 10V$

#### Fig. 8 Typical Collector To Emitter Saturation Voltage vs. Junction Temperature

![Saturation Voltage](image4)

- Collector To Emitter Saturation Voltage: $V_{CE(sat)}$ [V]
- Junction Temperature: $T_j$ [°C]
- $V_{GE} = 15V$
- $I_C = 60A$
- $I_C = 30A$
- $I_C = 15A$
Electrical Characteristic Curves

Fig.9 Typical Collector To Emitter Saturation Voltage vs. Gate To Emitter Voltage

Collector To Emitter Saturation Voltage
\[ V_{CE(sat)} \text{ [V]} \]

Gate To Emitter Voltage
\[ V_{GE} \text{ [V]} \]

Fig.10 Typical Collector To Emitter Saturation Voltage vs. Gate To Emitter Voltage

Collector To Emitter Saturation Voltage
\[ V_{CE(sat)} \text{ [V]} \]

Gate To Emitter Voltage
\[ V_{GE} \text{ [V]} \]

Fig.11 Typical Switching Time vs. Collector Current

Switching Time
\[ t \text{ [ns]} \]

Collector Current
\[ I_C \text{ [A]} \]

Fig.12 Typical Switching Time vs. Gate Resistance

Switching Time
\[ t \text{ [ns]} \]

Gate Resistance
\[ R_G \text{ [Ω]} \]
● Electrical Characteristic Curves

**Fig. 13** Typical Switching Energy Losses vs. Collector Current

- **Switching Energy Losses [mJ]**
- **Collector Current : I\(_C\) [A]**
- **V\(_{CC}\)=400V, V\(_{GE}\)=15V**
- **R\(_G\)=10Ω, T\(_j\)=175ºC**
- **Inductive load**

**Fig. 14** Typical Switching Energy Losses vs. Gate Resistance

- **Switching Energy Losses [mJ]**
- **Gate Resistance : R\(_G\) [Ω]**
- **V\(_{CC}\)=400V, I\(_C\)=30A**
- **V\(_{GE}\)=15V, T\(_j\)=175ºC**
- **Inductive load**

**Fig. 15** Typical Capacitance vs. Collector To Emitter Voltage

- **Capacitance [pF]**
- **Collector To Emitter Voltage : V\(_{CE}\) [V]**
- **I=1MHz**
- **V\(_{GE}\)=0V**
- **T\(_j\)=25ºC**

**Fig. 16** Typical Gate Charge

- **Gate To Emitter Voltage : V\(_{GE}\) [V]**
- **Gate Charge : Q\(_g\) [nC]**
- **I\(_C\)=30A**
- **T\(_j\)=25ºC**
Electrical Characteristic Curves

Fig.17 Typical Diode Forward Current vs. Forward Voltage

Fig.18 Typical Diode Reverse Recovery Time vs. Forward Current

Fig.19 Typical Diode Reverse Recovery Current vs. Forward Current

Fig.20 Typical Diode Reverse Recovery Energy Losses vs. Forward Current
**Electrical Characteristic Curves**

**Fig.21 IGBT Transient Thermal Impedance**

![IGBT Transient Thermal Impedance Diagram]

**Fig.22 Diode Transient Thermal Impedance**

![Diode Transient Thermal Impedance Diagram]
**Inductive Load Switching Circuit and Waveform**

![Fig.23 Inductive Load Circuit](image1)

![Fig.25 Diode Reverse Recovery Waveform](image2)

![Fig.24 Inductive Load Waveform](image3)
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