APPLICATION NOTE **on**

Figure 1. onsemi IGBT Part Numbering Key

Brief

This section provides a description of the device and lists its key features and typical applications.

Absolute Maximum Ratings

The absolute maximum ratings shown in Table 1 are typical for an IGBT. This table sets the limits, both electrical and thermal, beyond which the functionality is no longer guaranteed and at which physical damage may occur. The absolute maximum rating does not guarantee that the device will meet the data sheet specifications when it is within that range. The specific voltage, temperature, current and other limitations are called out in the Electrical Characteristics table.

shown in Figure 1. Many of the device rating described in the part number and can be u this code.

Table 1. ABSOLUTE MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector−emitter voltage	V_{CES}	600	V
Collector current @ T_C = 25°C @ T_C = 100°C	I_C	 30 15	A
Pulsed collector current, T_{pulse} limited by T_{Jmax}			

The collector current can be stated in the following equation form:

$$I_C = \frac{T_J - T_C}{R_{th(j-c)(IGBT)} \cdot V_{CE(sat)}}$$

where $R_{th(j-c)}$ is the thermal resistance of the package and $V_{CE(sat)}$ is the on−state voltage at the specified current, I_C. Since it is the current being sought after, and $V_{CE(sat)}$ is a function of current, the equation must be solved iteratively. An estimate of the $V_{CE(sat)}$ for a given collector current and temperature can found in the typical datasheet curves, discussed later.

It is very important to understand that the absolute maximum collector current is defined based on very specific electrical and thermal conditions. The capability of the IGBT to conduct current without exceeding the absolute maximum junction temperature is highly dependent on the thermal performance of the system, including heatsinks and airflow.

Pulsed Collector Current, I_{CM}

The pulsed collector current describes the peak collector current pulse above the rated collector current specification that can flow while remaining below the maximum junction temperature. The maximum allowable pulsed current in turn depends on the pulse width, duty cycle and thermal conditions of the device.

Diode Forward Current, I_F

The diode forward current is the maximum continuous current that can flow at a fixed case temperature, T_C, while remaining under the maximum junction temperature, T_J. This is determined in similar fashion to the $V_{CE(sat)}$, above.

$$I_F = \frac{T_J - T_C}{R_{th(j-c)(diode)} \cdot V_F}$$

The equation relating I_F and V_F to the temperature rise is the same, although the $R_{th(j-c)}$ for the diode is specified separately.

Diode Pulsed Current, I_{FM}

The pulsed diode current describes the peak diode current pulse above the rated collector current specification that can flow while the junction remains below its maximum temperature. The maximum allowable pulsed current in turn depends on the pulse width, duty cycle and thermal conditions of the device.

Gate−Emitter Voltage, V_{GE}

The gate−emitter voltage, V_{GE} describes maximum voltage to be applied from gate to emitter under fault conditions. The gate−emitter voltage is limited by the gate oxide material properties and thickness. The oxide is typically capable of withstanding greater than 80V before the oxide ruptures, but to ensure reliability over the lifetime of the device, and to allow for transient overvoltage conditions in the application, this voltage is limited to well below the gate rupture voltage.

Power Dissipation, P_D

The maximum power dissipation is determined using the following equation:

$$P_D = \frac{T_J - T_C}{R_{th(j-c)}}$$

where $R_{th(j-c)}$ is the thermal resistance of the package. The maximum power dissipation is given at case temperatures of 25°C and 100°C, where the maximum junction temperature is 150°C.

Short Circuit Withstand Time, t_{sc}

The short circuit withstand time describes the ability of

Collector−Emitter Breakdown Voltage, $V_{(BR)CES}$

This is the minimum off−state forward blocking voltage guaranteed over the operating temperature range. It is specified with the gate terminal tied to the emitter with a specified collector current large enough to place the device into avalanche.

Collector−Emitter Saturation Voltage, $V_{CE(sat)}$

$V_{CE(sat)}$ is an important figure of merit, since it is directly related to the conduction losses of the device. This is the voltage drop from collector to emitter for a specified gate voltage and collector current. Both a typical value and a maximum value are specified in the electrical table for both 25°C and 150°C.

In addition to the electrical limits in the table, the datasheet includes a graph describing the dependence of $V_{CE(sat)}$ on temperature, as shown in Figure 3. The graph describes the typical part and does not guarantee performance, but it can be used as a starting point to determine the $V_{CE(sat)}$ for a given temperature. The curves are given for V_{GE} = 15 V and various collector currents.

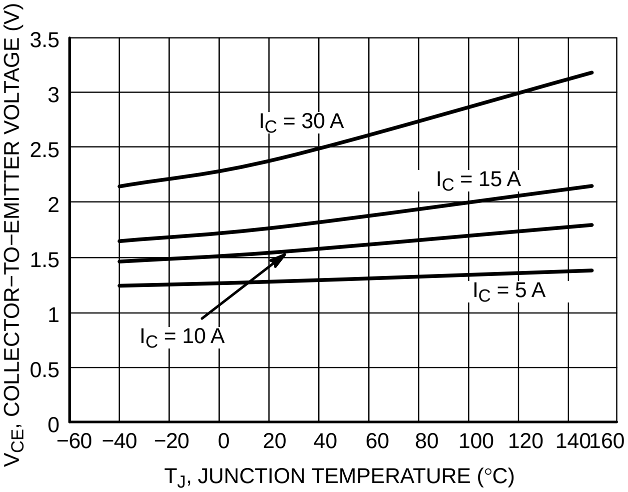

Figure 3. Graph of the Temperature Dependence of $V_{CE(sat)}$

The $V_{CE(sat)}$ values in the electrical parameter table are only given for V_{GE} = 15 V. If the gate of the IGBT is being driven by a different voltage, the output characteristics shown in Figure 4 can also be useful in approximating the $V_{CE(sat)}$. This chart shows the I_C dependence on V_{CE} for various gate−emitter voltages. The datasheet contains output characteristics for T_A = −40, 25, and 150°C.

Forward Transconductance, g_{fs}

This is the amount of change in collector current for an incremental change in the gate to emitter voltage, measured in Siemens (or Mhos). It is specified at the room temperature rated current of the device, and typically with the device in full saturation, where a further increase in collector−emitter voltage no longer leads to an additional increase in collector current. A typical collector−emitter voltage used for this test is 20 V. Figure 5 illustrates the g_{fs} measurement.

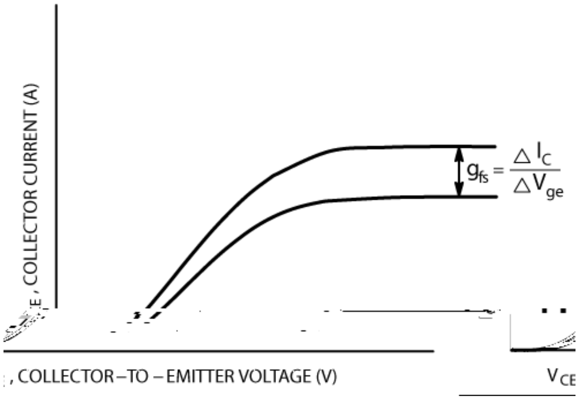

Figure 5. Illustration of the Measurement of IGBT g_{fs}

Dynamic Characteristics

Table 4. IGBT Dynamic Electrical Characteristics

Parameter	Test Conditions	Symbol	Min	Typ	Max	Unit
DYNAMIC CHARACTERISTIC						
Input capacitance	V_{CE} = 20 V, V_{GE} = 0 V, f = 1 MHz	C_{ies}	−	2600	−	pF
Output capacitance		C_{oes}	−	64	−	
Reverse transfer capacitance		C_{res}	−	42	−	
Gate charge total	V_{CE} = 480 V, I_C = 15 A, V_{GE} = 15 V	Q_g		80		nC
Gate to emitter charge		Q_{ge}		24		
Gate to collector charge		Q_{gc}		33		

The dynamic electrical characteristics which include device capacitances and gate charge are given in the electrical table, as shown in Table 4.

IGBT capacitances are similar to those described for power MOSFETs. The datasheet describes the measurable terminal capacitances, C_{ies}, C_{oes}, and C_{res}. They are specified in the electrical table at a fixed collector bias voltage; however, the capacitances are voltage dependant,

Figure 7. Pin−to−pin Capacitances of the IGBT

$C_{ies} = C_{ge} + C_{gc}$ with C_{ce} shorted

$C_{oes} = C_{gc} + C_{ce}$

$C_{res} = C_{gc}$

and the falling collector current. Because the IGBT is a minority carrier device, the collector current continues to flow after the time where the collector voltage has fully risen. This residual current, called tail current, eventually decays to zero. It is customary to add a fixed length of time to the end of the turn−off time to capture the energy lost during the entire tail current. This added time is denoted as xμs in Figure 10.

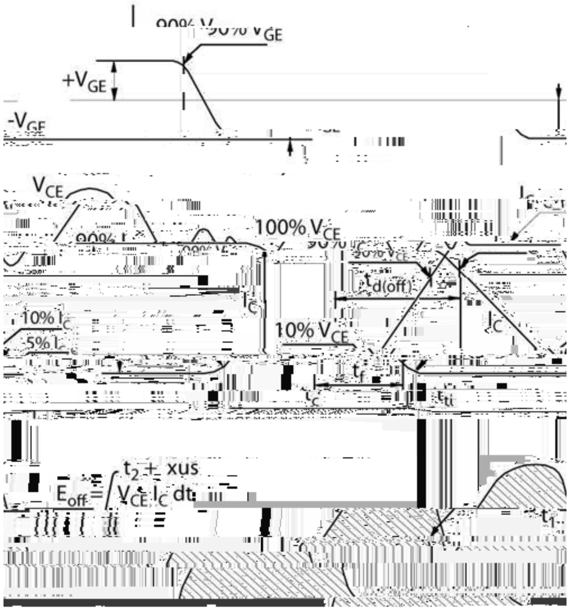

Figure 10. Turn−off Switching Illustration Showing the Definitions of the Turn−off Switching Characteristics

Total Switching Loss, E_{ts}

The total switching losses comprise the sum of the turn−on and turn−off switching losses.

Typical switching time and switching energy loss graphs are given that describe the dependence of the switching characteristics on a variety of system variables. The dependence on junction temperature, collector current, collector−emitter voltage, and gate resistance are all provided to aid in the design process.

Diode Characteristics

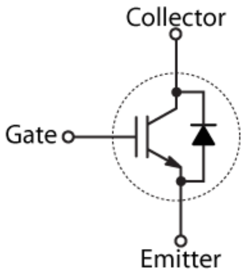

Figure 11. Copackaged IGBT and Freewheeling Diode

IGBTs are frequently used in applications where the load is inductive, such as motor control. These applications are hard switching and require that the IGBT be in parallel with a freewheeling diode. **onsemi** offers copackaged IGBT and diode devices. The diode cathode and IGBT collector are connected together and the diode anode and IGBT emitter are also connected, as shown in Figure 11. The freewheeling diode takes the place of the body diode that otherwise exists in a power MOSFET. For IGBTs that are copackaged with a freewheeling rectifier diode, the datasheet will also include electrical specifications for the diode, as shown in Table 6.

Table 6. ELECTRICAL CHARACTERISTICS OF THE DIODE

Parameter	Test Conditions	Symbol	Min	Typ	Max	Unit
DIODE CHARACTERISTIC						
Forward voltage	V_{GE} = 0 V, I_F = 15 A V_{GE} = 0 V, I_F = 15 A, T_J = 150°C	V_F		1.6 1.6	1.85	V
Reverse recovery time	T_J = 25°C I_F = 15 A, V_R = 200 V di_F/dt = 200 A/μs					

Forward Voltage, V_F

The forward voltage of the rectifier is measured while the IGBT gate and emitter terminals are tied together, ensuring the IGBT is in its off−state. A forcing current enters the emitter terminal and the emitter−collector (anode−cathode) voltage is measured.

Forward voltage is an important parameter in hard switching applications. V_F is specified in the electrical table for a given current and is specified at T_J = 25 and 150°C. The datasheet also includes a graph showing the I_F−V_F relationship for a typical part at T_J = −40, 25, and 150°C, as shown in Figure 12.

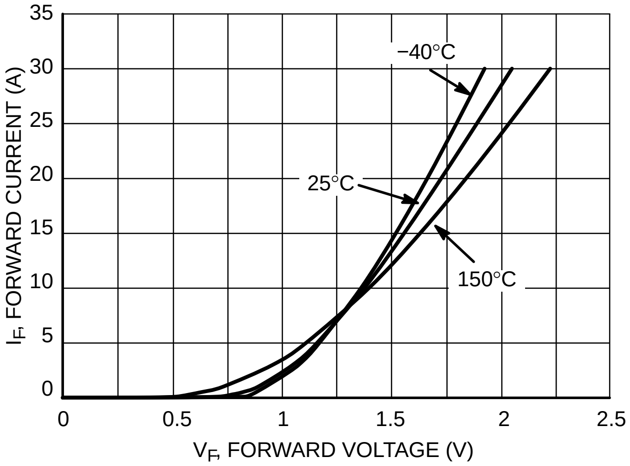

Figure 12. Diode Forward Characteristic Curves for T_J = −40, 25, and 150°C

Reverse Recovery Time, t_{rr}

The reverse recovery time, t_{rr}, defines the time the diode takes to enter the reverse blocking state after conducting in