STATIC CHARACTERISTICS OF IGBT

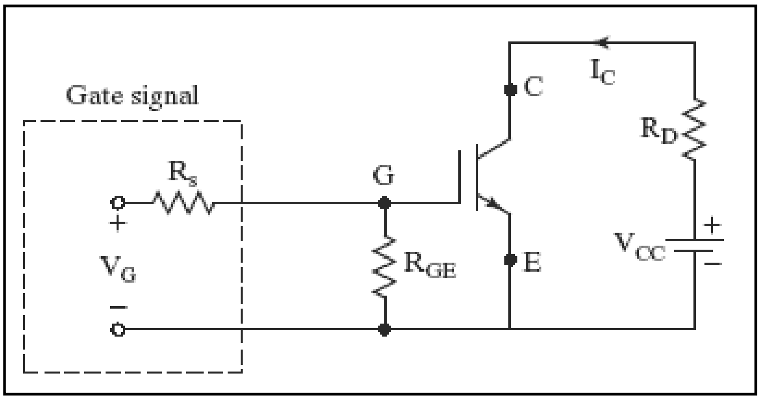


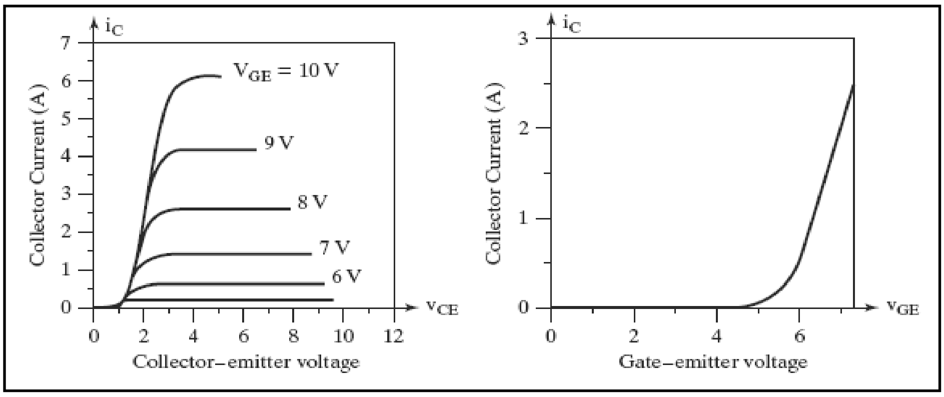
Fig.2.22: IGBT bias circuit

Static V-I characteristics (I_C versus V_{CE})

Same as in BJT except control is by V_{GE}. Therefore IGBT is a voltage controlled device.

Transfer Characteristics (I_C versus V_{GE})

Identical to that of MOSFET. When $V_{GE} < V_{GET}$, IGBT is in off-state.



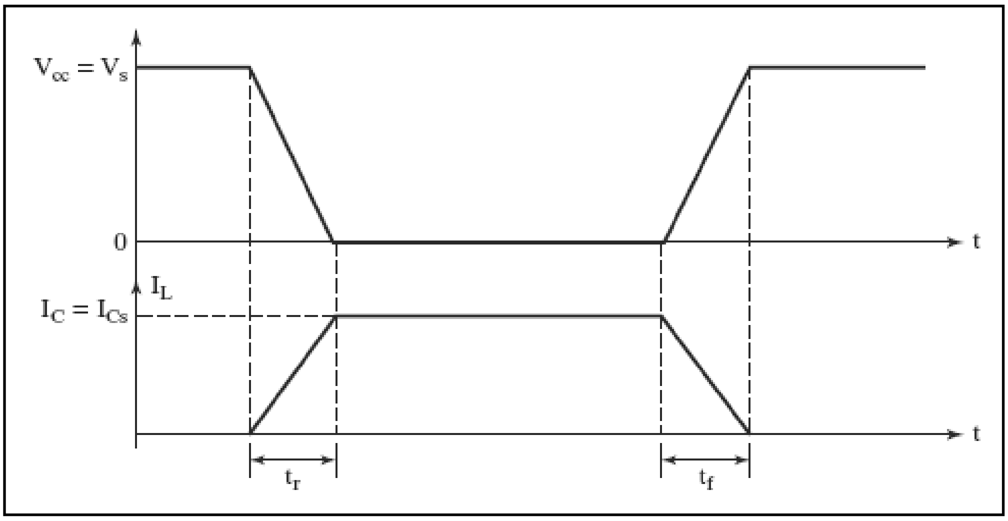
Applications

Widely used in medium power applications such as DC and AC motor drives, UPS systems, Power supplies for solenoids, relays and contractors.

Though IGBT's are more expensive than BJT's, they have lower gate drive requirements, lower switching losses. The ratings up to 1200V, 500A.

2.8 di/dt and dv/dt Limitations

Transistors require certain turn-on and turn-off times. Neglecting the delay time t_d and the storage time t_s, the typical voltage and current waveforms of a BJT switch is shown below.



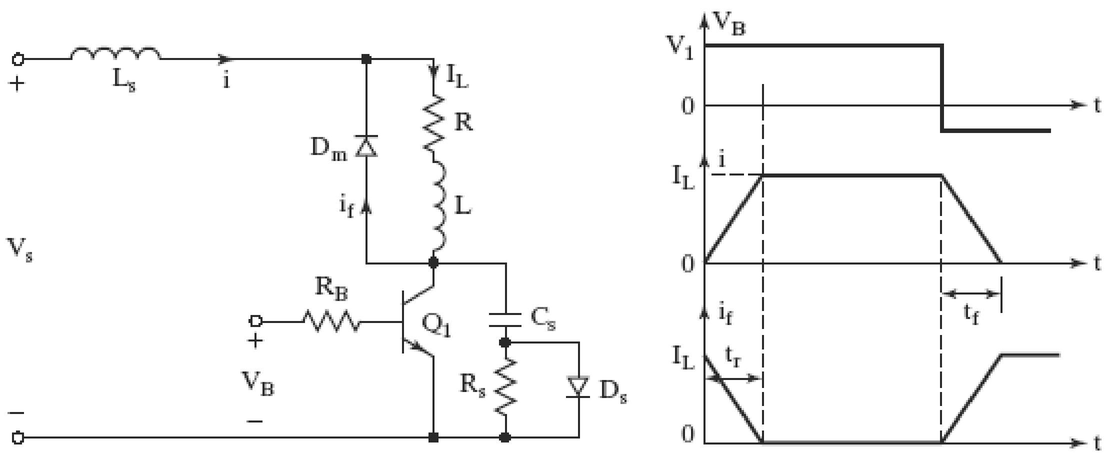
During turn-on, the collector rise and the di/dt is

$$\frac{di}{dt} = \frac{I_L}{t_r} = \frac{I_{cs}}{t_r} \quad ...(1)$$

During turn off, the collector emitter voltage must rise in relation to the fall of the collector current, and is

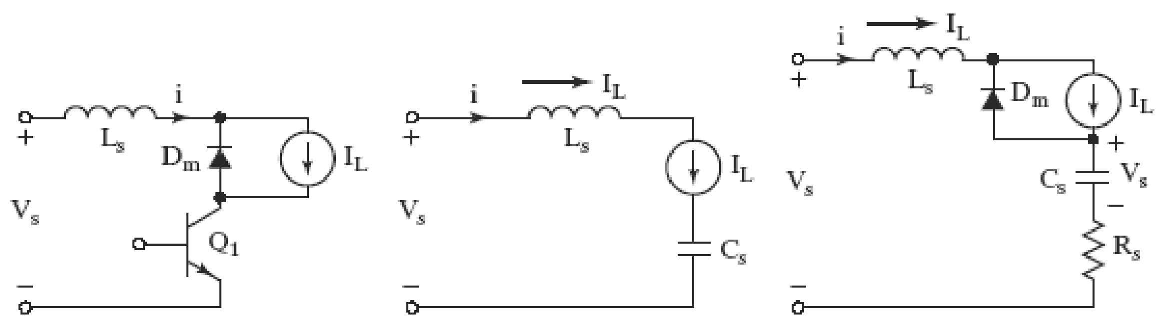
$$\frac{dv}{dt} = \frac{V_s}{t_f} = \frac{V_{cc}}{t_f} \quad ...(2)$$

The conditions di/dt and dv/dt in equation (1) and (2) are set by the transistor switching characteristics and must be satisfied during turn on and turn off. Protection circuits are normally required to keep the operating di/dt and dv/dt within the allowable limits of transistor. A typical switch with di/dt and dv/dt protection is shown in figure (a), with operating wave forms in figure (b). The RC network across the transistor is known as the snubber circuit or snubber and limits the dv/dt. The inductor L_S, which limits the di/dt, is sometimes called series snubber.



(a) Protection circuits (b) Waveforms

Let us assume that under steady state conditions the load current I_L is freewheeling through diode D_m, which has negligible reverse reco`very time. When transistor is turned on, the collector current rises and current of diode D_m falls, because D_m will behave as short circuited. The equivalent circuit during turn on is shown in figure below



(a) Mode 1 (b) Mode 2 (c) Mode 3

The turn on di/dt is

$$\frac{di}{dt} = \frac{V_s}{L_s} \qquad ...(3)$$

Equating equations (1) and (3) gives the value of L_s

$$L_s = \frac{V_s t_r}{I_L} \qquad ...(4)$$

During turn off, the capacitor C_s will charge by the load current and the equivalent circuit is shown in figure. The capacitor voltage will appear across the transistor and the dv/dt is

$$\frac{dv}{dt} = \frac{I_L}{C_s} \qquad ...(5)$$

Equating equation (2) to equation (5) gives the required value of capacitance,

$$C_s = \frac{I_L t_f}{V_s} \qquad ...(6)$$

Once the capacitor is charge to V_s, the freewheeling diode will turn on. Due to the energy stored in L_s, there will be damped resonant circuit as shown in figure . The RLC circuit is normally made critically damped to avoid oscillations. For unity critical damping, $\delta = 1$, and equation $\delta = \frac{\alpha}{\omega_0} = \frac{R}{2}\sqrt{\frac{C}{L}}$ yields

$$R_s = 2\sqrt{\frac{L_s}{C_s}}$$

The capacitor C_s has to discharge through the transistor and the increase the peak current rating of the transistor. The discharge through the transistor can be avoided by placing resistor R_s across C_s instead of placing R_s across D_s.

The discharge current is shown in figure below. When choosing the value of R_s, the discharge time, $R_s C_s = \tau_s$ should also be considered. A discharge time of one third the switching period, T_s is usually adequate.

$$3R_s C_s = T_s = \frac{1}{f_s}$$

$$R_s = \frac{1}{3 f_s C_s}$$