

TRADE-OFF CONSIDERATIONS BETWEEN EFFICIENCY AND SHORT CIRCUIT CAPABILITY IN IGBTs

By Rahul Chokhawala

The switching devices are selected by system designers to reliably handle circuit currents under normal as well as estimated overload conditions. Under fault conditions however, a device is subjected to very high surge currents - with magnitude limited mainly by its own gain. Only timely control and removal of the fault current by some external means would save the switching device from failure. In applications where system fault is a possibility, external protection circuits are used to sense the fault and turn-off the transistors by shutting down the base/gate drive in a time duration shorter than the short circuit withstand time - a measure of how long a device would survive under specified fault conditions.

There is a fundamental device trade-off between short circuit withstand time, t_{sc} , and transistor current-gain. The higher the gain of the transistor, higher will be the fault current magnitude and the shorter will be the t_{sc} ¹. The on-state voltage drop directly depends on the current-gain. High gain IGBTs have lower $V_{CE(sat)}$ but shorter t_{sc} . The lower gain IGBTs on the other hand boast of longer t_{sc} but only at the expense of the operating frequency. The generalized plot in Figure 1 clearly illustrates this trade-off.

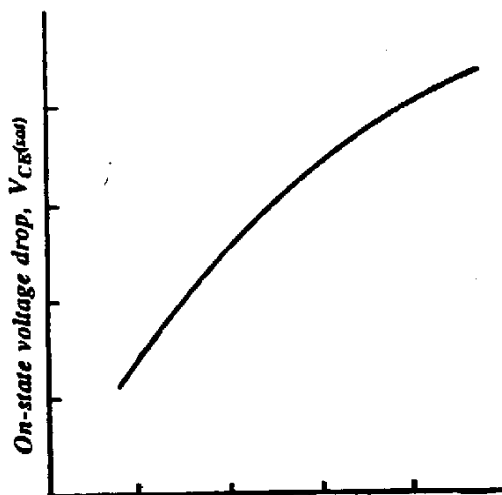


Figure 1 - Short Circuit time, t_{sc}

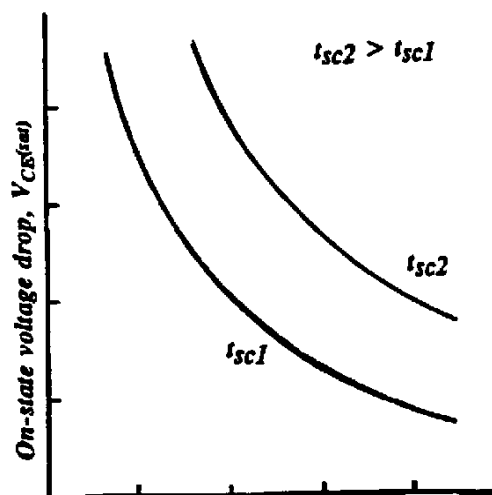


Figure 2 - Turn-Off Losses, E_{off} (a measure of stored charge)

¹ "A Discussion on IGBT Short Circuit Behavior and Fault Protection Schemes."

There also exists a device trade-off between the current-gain and the minority carrier life-time. The latter influences the amount of trapped charge in the IGBT; the shorter the carrier life-time the faster the free-charge recombination process. The consequence is shorter turn-off current tail and therefore lower turn-off losses, E_{off} . The curves in Figure 2 show generalized relationship between $V_{CE(sat)}$ and E_{off} for two different values of t_{sc} . As seen from this figure, the trade-off between $V_{CE(sat)}$ and E_{off} is improved as the short circuit withstand time requirement is relaxed.

The above trade-offs result in IGBTs with more relaxed t_{sc} constraint be able to handle higher load currents. Figure 3 shows generalized trends in allowable load current against switching frequency for IGBTs with "low" and "high" short circuit times. The shape of the curves strictly depend on the $V_{CE(sat)}$ versus E_{off} trade-off.

In applications like uninterruptible power supplies, where the fault current is limited by the circuit components, the principal criteria for selection is the efficiency of the switching device. For such applications, devices not rated for long short circuit time but designed to be more efficient should be selected.

It should be noted that fast reacting protection circuits are now available² to protect most efficient IGBTs, despite their shorted short circuit endurance times. Usage of such circuits in association with high efficiency IGBTs would enhance circuit efficiency without sacrificing system reliability.

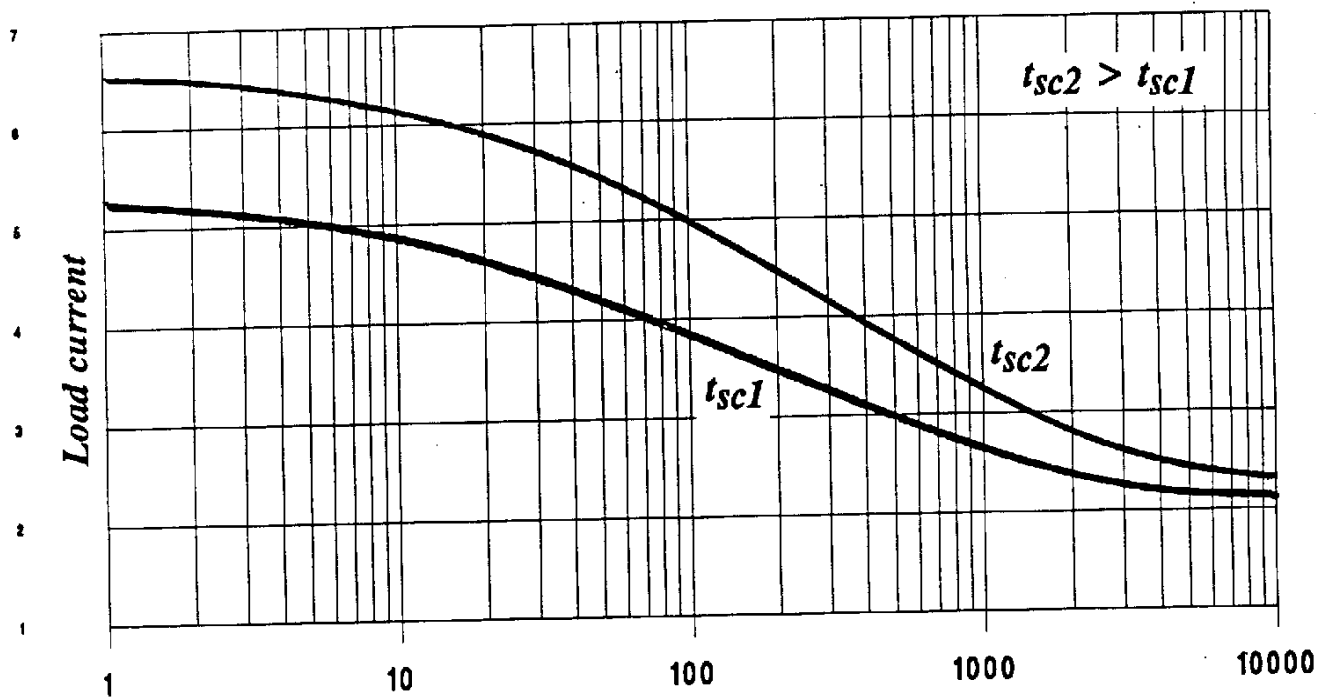


Figure 3 - Switching Frequency

² "IGBT Fault Current Limiting Current."