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

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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, the higher will be the fault current magnitude and the shorter will be the tsc1. The on-state voltage drop depends directly on the current-gain. High gain IGBTs have lower $V_{CE(sat)}$ but shorter t_{sc}. The lower-gain IGBTs, on the other hand, have a longer tsc but only at the expense of the $V_{CE(sat)}$. The generalized plot in Figure 1 illustrates this trade-off.
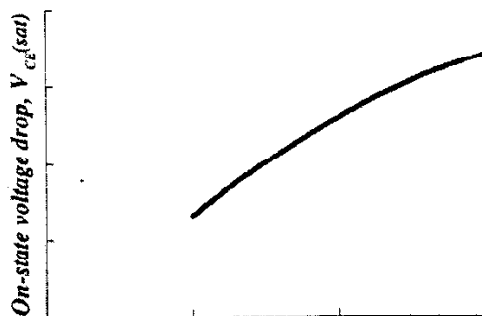
There also exists a device trade-off between current-gain and minority carrier life-time. The latter influences the amount of trapped charge in the IGBT — the shorter the carrier life-time, the faster the free-charge recombination process. The consequence is shorter turn-off current tail and, therefore, lower turn-off losses (E_{off}). The curves in Figure 2 show the 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 a more relaxed t_{sc} constraint being able to handle higher load currents.
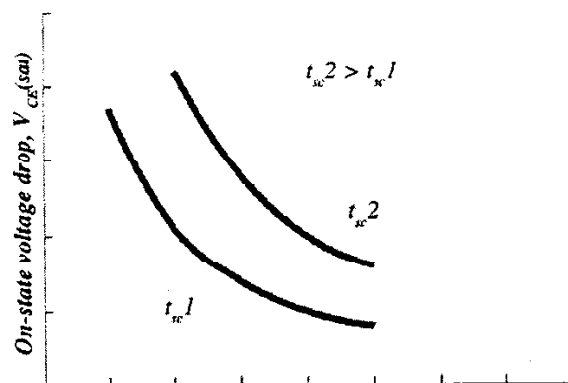

Fig.2 - Turn-Off Losses, E_{off}
(a measure of stored charge)

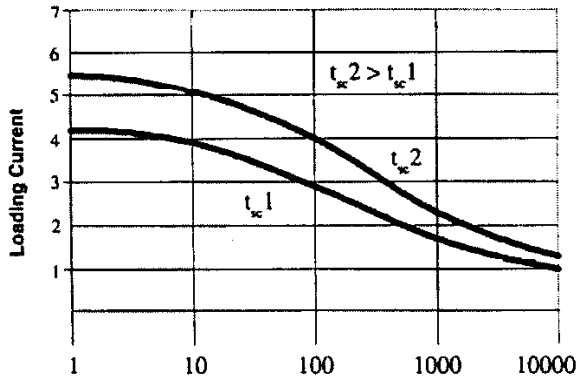Fig. 1 - Short Circuit time, t_{sc}

Fig. 3 - Current vs. Frequency graph comparing standard IGBTs to short circuit rated IGBTs

Figure 3 shows generalized trends in allowable load current against switching frequency for IGBTs with "low" and "high" short circuit times. The shapes 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 criterion 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 available[2] to protect most efficient IGBTs, despite their reduced short circuit endurance times. Use of such circuits in association with high-efficiency IGBTs would enhance circuit efficiency without sacrificing system reliability.

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[1] "A Discussion on IGBT Short Circuit Behavior and Fault Protection Schemes", presented at the APEC'93 conference.

[2] "IGBT Fault Current Limiting Current", presented at the IAS'93 Conference.