

## Short Circuit Behaviour of IGBT<sup>3</sup> 600 V

With the development of eupec's and Infineon's latest 600 V IGBT<sup>3</sup> technology the short circuit specification of this new chip generation was changed compared to the other eupec / Infineon chip generations. This is a result of extensive discussions with customers about application requirements.

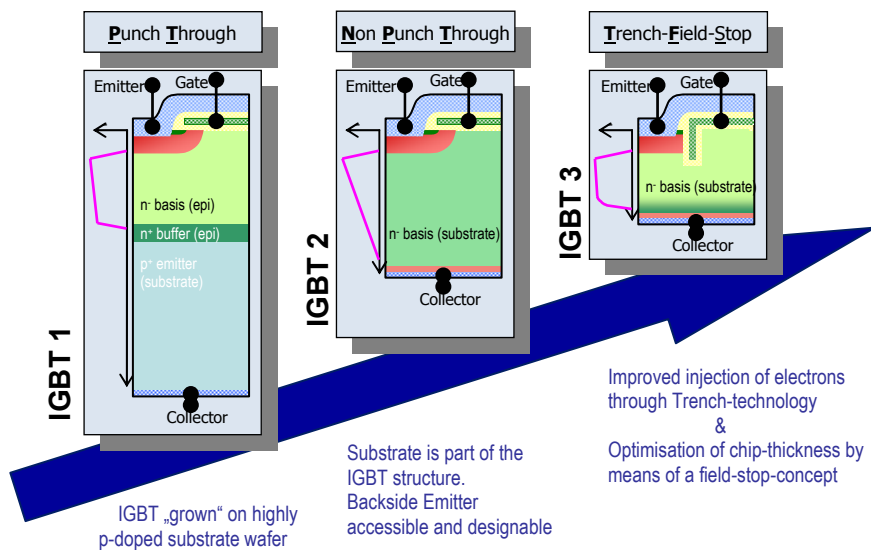
The short circuit withstand time of the IGBT<sup>3</sup> 600 V is specified at 6  $\mu$ s. This is the best choice between low on-state losses and short circuit withstand time in order to deliver maximum possible device efficiency to the customer. Modern short circuit detection methods are fast enough to recognise and turn-off a short circuit within 6  $\mu$ s.

### IGBT<sup>3</sup> Technology:

For the 1200 V voltage class, the IGBT chip of the third generation is well established.

With additional benefits, an IGBT<sup>3</sup> 600 V chip is available. Both, IGBT<sup>3</sup> 600 V and its corresponding free wheeling diode EmCon3 are qualified for a maximum junction temperature of 175 °C and a maximum operating junction temperature under switching conditions of 150 °C. This is an increase by 25 K compared to former chip generations.

The IGBT chip of the third generation has a trench structure and combines the advantages of PT and NPT technologies thanks to an additional n-doped layer, known as the Field Stop (FS) layer, within the NPT structure.



**Fig. 1: Evolution of IGBT chip technologies**

The IGBT<sup>3</sup> technology allows both, static and dynamic losses to be minimised. In combination with higher current density and higher junction temperature of the IGBT<sup>3</sup>, an increased current range of eupec IGBT modules and higher inverter power ratings can be realised.

## Short Circuit Specification:

The IGBT<sup>3</sup> 600 V is specified with a short circuit robustness up to  $t_{SCmax} = 6 \mu s$  at  $T_j = 150 \text{ }^\circ\text{C}$ ,  $V_{GE} = 15 \text{ V}$  and  $V_{CC} = 360 \text{ V}$  and also up to  $t_{SCmax} = 8 \mu s$  at  $T_j = 25 \text{ }^\circ\text{C}$ ,  $V_{GE} = 15 \text{ V}$  and  $V_{CC} = 360 \text{ V}$ . Between this to temperatures a linear approximation is allowed. In comparison to the IGBT<sup>2</sup>, the temperature has been increased by 25 K (according to the increased max. operation temperature) and the guaranteed short circuit withstand time has been reduced from 10  $\mu s$  to 6  $\mu s$ .

The reduction of the short circuit withstand time is a well chosen operational point on the trade-off curve between device performance (e.g. losses under operation conditions) and short circuit withstand time.

## Short Circuit Destruction Modes:

The following short circuit destruction modes of IGBTs are known:

- a) Destruction during turn-off due to a latch-up which is related to the device over-temperature.
- b) Destruction during the current pulse (current destruction mode) which is not related to the device temperature.
- c) Destruction after a successful turn-off (energy destruction) due to a thermal runaway of the device as a consequence of the dissipated energy within this pulse. This destruction mode obviously largely depends on the device temperature prior to the short circuit.

Due to a latch-up free cell design the destruction mode a) is not crucial for the IGBT<sup>3</sup> 600 V. The robust chip design also avoids destruction mode b).

With the IGBT<sup>3</sup> 600 V only destruction mode c) can be observed.

## IGBT<sup>3</sup> 600 V Short Circuit Performance Trade-Off:

The  $V_{CEsat}$  value is depending, among others, on the MOS channel width. An increased MOS channel width will lead to a lower  $V_{CEsat}$  value (lower on-state losses), but also to higher turn-off losses as well as higher short circuit currents and consequently to a decreased short circuit withstand time.

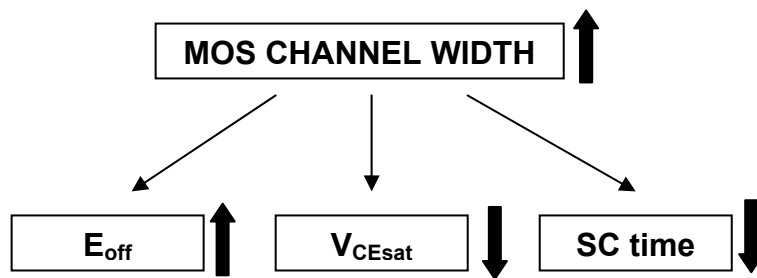


Fig. 2:  $E_{off}$ ,  $V_{CEsat}$  and SC time as a function of MOS channel width

Fig. 3 shows the trade-off curves  $E_{off} = f(V_{CEsat})$  (for a given thickness and a fixed backside emitter of the chip) and  $t_{SC} = f(V_{CEsat})$  in principle. For minimised turn-off losses and also minimised on-state losses a SC time of 6  $\mu s$  is the best choice to get the best performance.

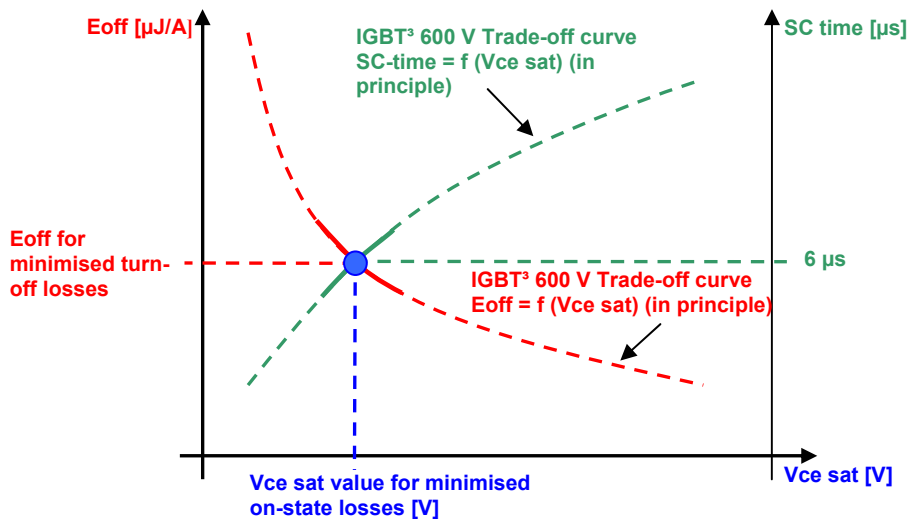
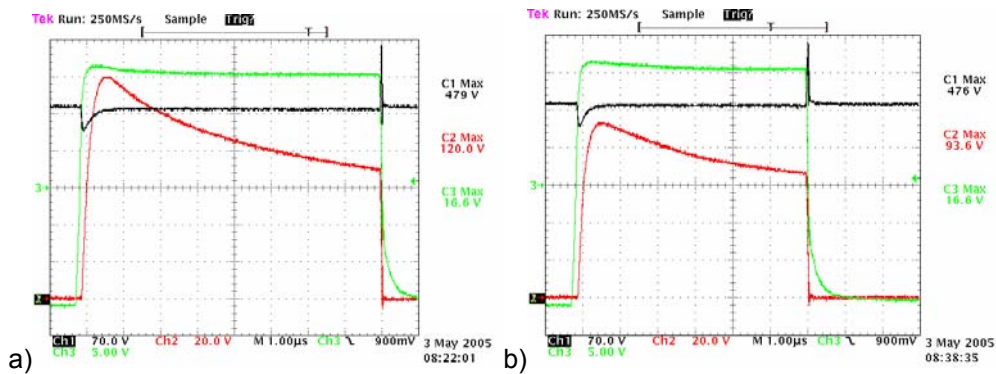
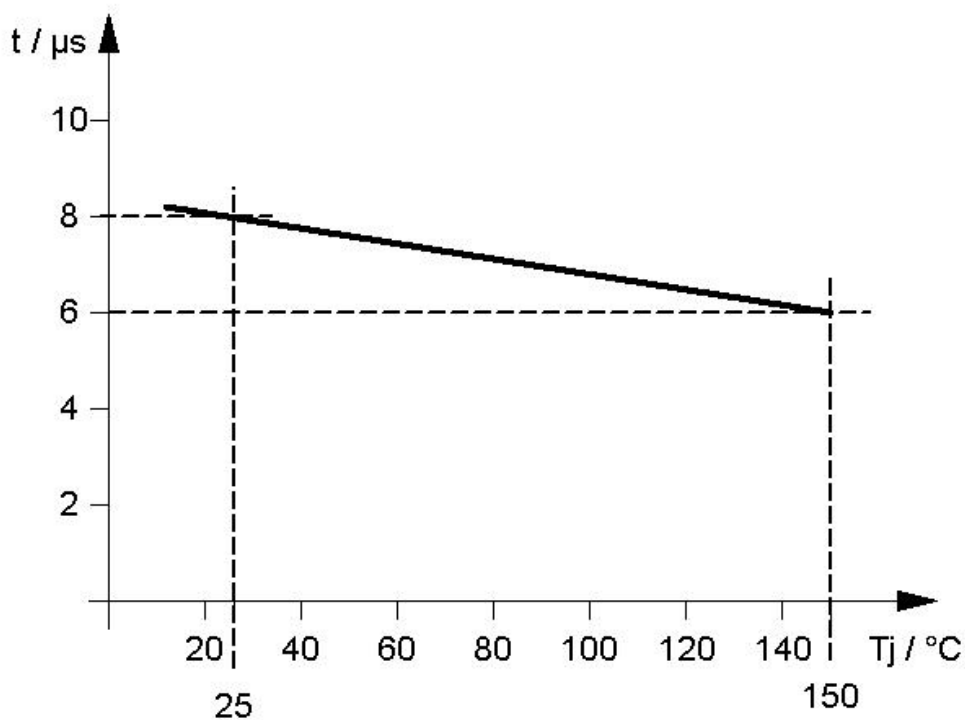


Fig. 3: IGBT<sup>3</sup> Trade-off curves in principle



**Fig. 4:** IGBT<sup>3</sup> - 600 V (15 A – Chip) Specified minimum short circuit capability ( $V_{CE} = 360 \text{ V}$ ;  $V_{GE} = 15 \text{ V}$ ;  $T_{vj} = 25 \text{ }^\circ\text{C}$  (a);  $T_{vj} = 150 \text{ }^\circ\text{C}$  (b);  $t_{SC} = 8 \text{ } \mu\text{s}$  (a);  $t_{SC} = 6 \text{ } \mu\text{s}$  (b)) Red:  $I_C$ ; Green:  $V_{GE}$ ; Blue:  $V_{CE}$

Fig. 4 displays the specified minimum short circuit capability @  $T_{vj} = 25 \text{ }^\circ\text{C}$  as well as the short circuit capability @  $T_{vj} = 150 \text{ }^\circ\text{C}$ . Between these two values a linear interpolation is allowed (Fig. 5).



**Fig. 5** Derating of the Short Circuit time as a function of the Junction Temperature  $t_{sc} = f(T_j)$

## Conclusion:

The above explanation clarifies that - once the IGBT technology is short-circuit robust - the further adjustment of a short circuit withstand time is a matter of definition.

In agreement with a variety of customers it has been decided to take into account the fact that modern short circuit detection methods are fast enough to recognise and turn-off a short circuit within 6  $\mu$ s.

The device shows an excellent switching and short circuit robustness, with the specified short circuit time having been adjusted to 6  $\mu$ s on a trade-off versus optimised device losses.