



# Too fast to handle for you? New Generation of Fast 650 V IGBT

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## *Subtitle description:*

*Power semiconductors are getting thinner, smaller and faster. And the challenges for manufacturers that employ the latest chip technology in their power modules are getting bigger.*

A sure-fire way to decrease losses and increase power density is to improve switching behavior. From the perspective of a device designer seeking to boost a power-converting system's energy efficiency, this is certainly the best choice of parameters. The power module manufacturer will have to incorporate state-of-the-art IGBT technology into the product to afford designers the option of tweaking these parameters.

The IGBT powered by Infineon TRENCHSTOP™5 H5 is designed for a 15-to-80 kHz carrier switching frequency range with a maximum blocking voltage of 650 V. Available in discrete housings such as the TO-247, it is designed for systems with a stray inductance of 30 to 50 nH for the PCB tracks. [1].

Vincotech is a manufacturer that uses these very fast devices, rather than discrete packages, in power modules. The *flow* family of modules can handle IGBT's performance. The company builds power modules with low internal stray inductance that can accommodate many different types of fast-switching power semiconductors, including this 650 V chip.

## **1 Housing**

The *flow* family's special housing technology has enabled Vincotech to rise to the challenge of incorporating the latest chip technology in a power module with features that include

- No baseplate
- Low internal stray inductance
- Freely positioned auxiliary pins (solder, press-fit)
- DC capacitors built into the module



The *flow 1* housing pictured in figure 1 features very fast dies in a neutral point clamped (NPC) inverter topology. Also known as I-type topology, it is deployed in three-level converters designed mainly for solar and UPS applications. The combination of fast switching IGBTs, fast diodes and integrated DC capacitors ensures highest efficiency and fast switching capability in a compact power module (item code 10-FY07NPA200SM02-L366F08).

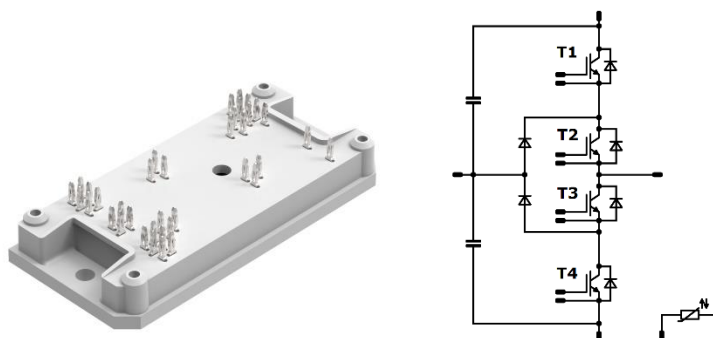


Fig. 1: flowNPC 1 with integrated DC capacitors, 650 V very fast IGBT, fast diodes and a temperature sensor [2]

## 2 Measurements: Impact of DC caps

The nature of an IGBT's design makes it all but impossible for the gate-resistor  $R_g$  to control turn-off behavior. The corresponding collector-emitter voltage peak ( $V_{cep}$ ) during turn-off depends on the turn-off speed of the current and on the stray inductance  $L$  between the capacitors and the semiconductor at a given collector-emitter voltage  $V_{ce}$ . The equation

$$\Delta V_{cep} = V_{ce} + L \cdot \left(-\frac{dI}{dt}\right)$$

describes the voltage overshoot  $\Delta V_{cep}$  at turn-off, a relationship that is very well known. This equation tells us that decreasing the stray inductance or the turn-off rate will reduce the voltage overshoot across the IGBT.

The following Fig. 2 shows the integrated DC capacitors' impact on the collector-emitter peak voltage in a power module. The measurements with an integrated DC capacitor (orange) and without it (blue) were taken under the same testing conditions. The chart clearly indicates that without an integrated DC capacitor, the collector-emitter voltage  $V_{ce}$  oscillates after a turn-off voltage peak of around 218% of the applied DC link voltage of 350 V from neutral point to DC. The integrated DC capacitor not only reduces the  $V_{cep}$  to 137% of the DC link voltage; it also suppresses oscillation.

Placing a DC capacitor as close to the IGBT as possible is definitely the smart move for very fast switching power semiconductors.

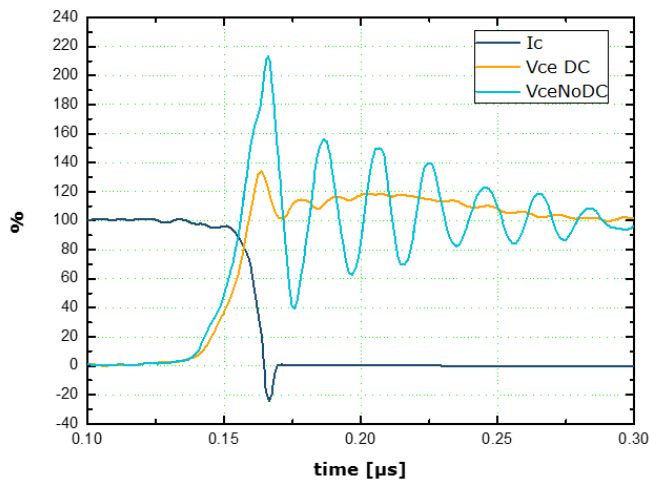


Fig.2: Two power modules' turn-off waveform at the given current  $I_c$  with an integrated DC capacitor (orange) and without (blue)

### 3 Measurements: Characterizing switching behavior

Dynamic characteristics need to be analyzed regardless of the low inductive package's design. The slopes of the collector-emitter voltage  $V_{ce}$  and the nominal current  $I_c$  during turn-on and turn-off have to be handled, particularly when using a fast IGBT. This is why the measurements focus on these switching slopes, respectively  $dV/dt$  and  $dI/dt$  of the T3 (fig. 1). Slowing down power semiconductor's switching speed decreases the switching slopes, thereby increasing power loss.

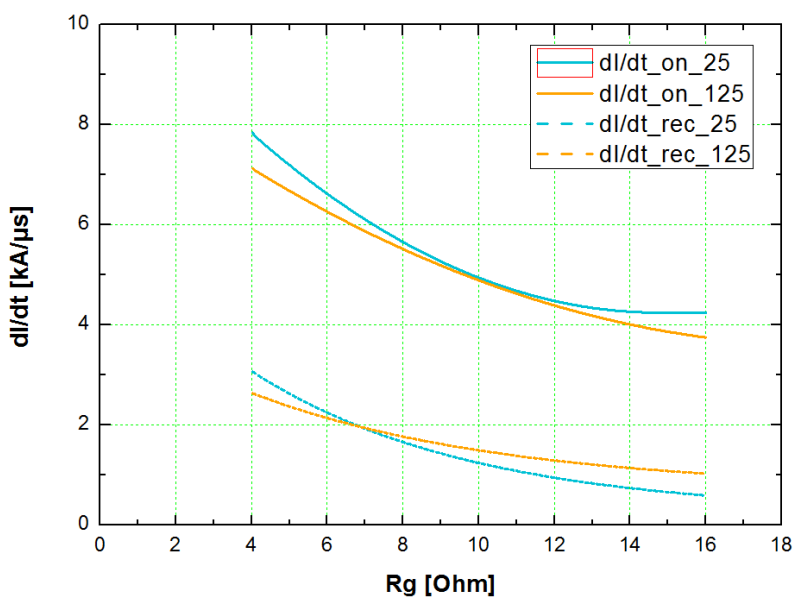


Fig. 3: Turn-on  $dI/dt$  at 25°C (blue) and 125°C (orange). Reverse recovery  $dI/dt$  at 25°C (black) and 125°C (orange)



Figure 3 shows the turn-on current slope  $dI/dt_{on}$  (solid lines) and the reverse recovery  $dI/dt_{rec}$  (dashed lines) behavior in accordance with the gate resistance  $R_g$  at room temperature (blue) and 125°C (orange).

Values below 4  $\Omega$  are not shown because of measurement noise.

The turn-on speed at 25°C drops from 4  $\Omega$  onwards down to around 45% of the peak value at 16  $\Omega$ . Temperature has a slight but discernible impact on the turn-on current slope, as the  $dI/dt_{on}$  values at 125°C attest: They remain below values measured at 25°C. The turn-on speed's reduction from the peak to the lowest value at 125°C amounts to around 47%.

Fig. 3 also shows the reverse recovery current slope  $dI/dt_{rec}$ ; that is, the curve's post-peak current trajectory. Temperature has very little impact; the curves are very similar and practically identical at around 7  $\Omega$ .

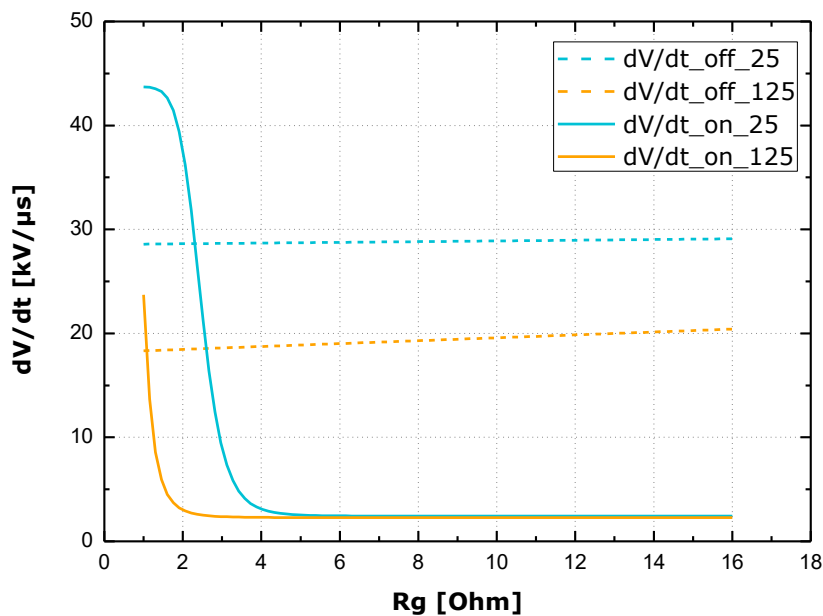


Fig. 4: Turn-on (solid lines) and turn-off (dashes)  $dV/dt$  at 25°C (blue) and 125°C (orange)

Fig. 4 shows collector-emitter voltage switching slopes in relation to  $R_g$ . The turn-off voltage slope remains fairly constant above 4  $\Omega$ , which confirms that the physics of semiconductors are such that turn-off behavior can hardly be controlled by  $R_g$ . The turn-off  $dV/dt$  is quite stable throughout gate resistance range; the only discernible impact is to be seen at turn-on. At low  $R_g$ ,  $dV/dt_{on}$  is high. A higher resistance value can bring it down. The turn-on behaviors at 25°C and 125°C (solid lines) are similar. The only difference would appear to be the turn-on  $dV/dt$  reduction that subsequently occurs at 25°C.

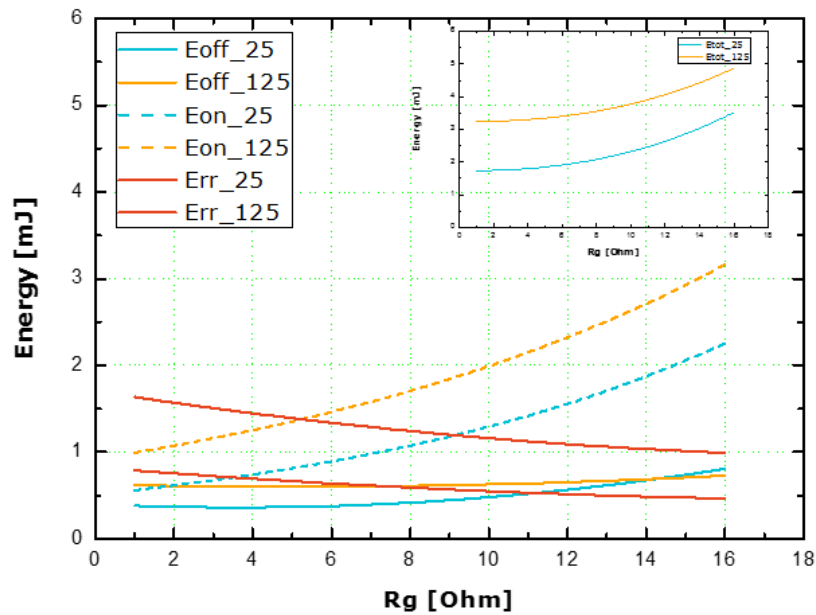


Fig. 5: Switching energies of T13 in relation to Rg at 25°C and 125°C. This graph shows Eoff (solid lines), Eon and Err (dashes lines). The inset graph shows the total energy at 25°C (blue) and 125°C (orange)

Fig. 5 depicts turn-on and turn-off switching energies. The solid lines represent measurements of turn-off energy Eoff; the dashes show the data for turn-on and reverse recovery energy (Eon and Err) at room temperature and 125°C. These readings were taken to investigate to what extent Eon, Eoff and Err depend on Rg. Eon, Eoff and Err similar tendencies at both temperatures. Eon increases with increasing gate resistance because the IGBT slows down and device loss increase. Consequently, reverse recovery energy decreases slightly because of a lower reverse recovery peak, which is in accordance with the  $dI/dt_{rec}$  behavior to be seen in fig. 3. In terms of the  $dI/dt$  steepness and given the total energy Etot at 25°C (blue) and at 125°C (orange) as shown in fig. 5's inset graph, a gate resistor with more than 4  $\Omega$  would appear to be a reasonable proposition. However, this would require a tradeoff between the current slopes and total energy losses because of the loss that increase with increasing gate resistance. As we have seen in fig. 4, the gate resistance has hardly any impact on the turn-off  $dV/dt$  or on Eoff.

## 4 Conclusion

IGBTs are getting faster, which complicates their installation in power modules. Integrated DC capacitors can be very beneficial to this end as they prevent turn-off voltage overshoots. We measured a reduction from 218% to 137%.

Furthermore, designers also have to strike the right balance between switching speed, switching loss and  $dV/dt$ -controlled electromagnetic compatibility for the power-converting



system. Our measurements tell us that they need to choose the right gate resistor to this end. In this case, a resistance value greater than 4 ohms would appear to be the best choice for a tradeoff between total energy loss and switching slopes. However, every system and application is different and the right  $R_g$  value for each has to be determined with the proper measurements.

### *References*

- [1] Infineon, Application Note AN2015-15 Rev. 1.0, TRENCHSTOP™ 5 S5 Infineon's low  $V_{ce(sat)}$  high-speed soft-switching IGBT
- [2] Datasheet of 10-FY07NPA200SM02-L366F08, [www.vincotech.com](http://www.vincotech.com)