

## General questions about gate drivers

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### Selection of suitable gate driver

#### Question

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Besides the output current, what other aspects have to be considered when selecting a suitable gate driver for a certain application?

#### Answer

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There are several requirements that shall be met:

- As you said, the driver must be able to provide the necessary gate current (output current / output power). The maximum average output current of the driver ( $I_{outAVmax}$ ) must be higher than the calculated value.
- The maximum peak gate current of the driver ( $I_{outPEAK}$ ) must be equal to or higher than the maximum calculated peak gate current.
- The output capacitors of the driver must be able to deliver the gate charge needed to charge and discharge the gate of the IGBT. In most drivers' data sheets, the maximum charge per pulse is given ( $Q_{out/pulse}$ ).
- Insulation voltage and  $dv/dt$  (rate of rise and fall of voltage secondary to primary side) capability.
- Number of independent output channels.
- Max switching frequency.

### Troubleshooting of gate driver

#### Question

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Enumerate the typical problems caused by a wrong driver configuration or gate resistors, together with the corresponding possible solutions.

Answer

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**1) Problem: Increased switching losses**

The selected gate resistor value is too high, causing excessive losses. The gate resistor should be reduced, bearing in mind the switching performance of the whole application.

**2) Problem: Excessive voltage spike at IGBT**

Inductance in the DC-link is too high or a small turn-off gate resistor is used, leading to a higher di/dt. The inductance should be minimized or the turn-off gate resistor increased. To reduce voltage spike in the event of a short-circuit, a soft turn-off circuit may be used.

**3) Problem: Overheated / burned gate resistor**

The power dissipation as well as the peak power capability of the resistor is not sufficient. A non-surge-proof resistor is in use.

**4) Problem: EMI (Electromagnetic interference) noises**

Very small gate resistors are used, leading to higher dv/dt or di/dt values. As a result, more EMI is produced.

Too high gate resistance values cause the IGBTs to operate for a long time in linear mode during switching and finally results in gate oscillation.

**5) Problem: Oscillation at the gate**

Wiring between gate resistors and IGBT module is too long. This leads to higher inductance in the gate-emitter path and forms with the input capacitance of the IGBT a resonant circuit. The oscillation can be damped by shorter wiring.

The main current is coupled inductive into the control circuit. Avoid parallel gate wires to main terminals. Use twisted wires.

## Factors that limit the max switching frequency

Question

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All drivers have a maximum switching frequency (for example  $f_s=50\text{kHz}$ ). I would like to know which factors limit the switching frequency and how they affect to this parameter.

Answer

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First of all it's necessary to point out that, on the one hand, although ideally IGBTs can be controlled just with the gate voltage, some current is also necessary to charge/discharge the gate capacitor (the charge depends on the IGBT's chip size and the DC-link and gate voltages).

On the other hand, drivers have a limited output current, for example an average output current of  $I_{\text{out\_av\_max}}=50\text{mA}$ . This current is quite constant until relatively high temperatures (typically  $70^\circ\text{C}$ ).

The maximum switching frequency ( $f_{\text{sw\_max}}$ ) can be calculated dividing the maximum output average current by the gate charge ( $Q_g$ ) of the driven IGBT:

$$f_{\text{sw\_max}} (\text{kHz}) = I_{\text{out\_av\_max}} (\text{mA}) / Q_g (\mu\text{C})$$

To see this relation graphically please refer to a data sheet, for example that of the SKYPER 32R

(page 6).

Comments on the diagram:

The maximum switching frequency is limited (50kHz in this case), although for gate charges smaller than 1 $\mu$ C a higher frequency could be possible.  
External boost capacitors can be deployed to significantly increase the maximum gate charge per pulse.

## Influence of gate resistors on IGBT's performance

### Question

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I would be grateful if someone could give a short description on how a change of the IGBT gate resistor influences the performance of the IGBT module.

Is there any rule of thumb for the dimensioning of gate resistors?

### Answer

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Below there is a description on how an increase of gate resistors influence different characteristics of the power module (a decrease of the gate resistors will cause the opposite influence).

If bigger (>) R<sub>g</sub>:

- > t<sub>on</sub>
- > t<sub>off</sub>
- > E<sub>on</sub>
- > E<sub>off</sub>
- < Turn-on peak current
- < Turn-off peak current diode
- < dV/dt
- < dI/dt
- < Voltage spike
- < EMI noise

Hints on gate resistor dimensioning:

- Typically, IGBT modules with:  
large current rating --> driven with smaller gate resistors;  
small current rating --> driven with larger gate resistors;
- Generally, the value of an optimised gate resistor will be somewhere between the value indicated in the IGBT data sheet and roughly twice this value:  
R<sub>g</sub> data sheet (min) < R<sub>g</sub> optimized < 2 x R<sub>g</sub> data sheet
- In most applications, the turn-on gate resistor R<sub>g</sub> (on) is smaller than the turn-off gate resistor R<sub>g</sub> (off). Depending on the individual parameters, R<sub>g</sub> (off) can be roughly twice the R<sub>g</sub> (on) value.
- It is important to minimize parasitic inductance, especially in the DC-link circuit. This is necessary to keep the turn-off overvoltage at the IGBT within the limits specified in the IGBT data sheet.  
A simple way of reducing the overvoltage in short-circuit conditions is to use a soft turn-off circuit. In the event of a short-circuit, the soft turn-off circuit increases the resistance in series with R<sub>g</sub> (off) and turns off the IGBT more slowly.

## Dynamic value of Vce voltage for desaturation monitoring

### Question

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The drivers that have the IGBT desaturation feature measure the current Vce voltage between the collector and emitter of the IGBT, and then this value is compared with a reference voltage (Vref). This reference is chosen so that Vce under this reference value can be considered as saturation voltage.

So far I understand how this feature works. But what happens in the instant when the IGBT commutates to On-state (the so-called "gating time", typically 10us)?

In the transition between off-state and saturation in on-state, Vce falls from a big voltage value to a very small one (e.g. 3V). If we have e.g. a value of Vref = 6V, theoretically every time a commutation takes place the desaturation monitoring should report a "desaturation error".

How is this avoided in practice?

### Answer

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The key to the problem is a dynamic value of Vref.

At the very beginning of the turn-on, Vref can be e.g. 15V, and after that the value falls exponentially until it stabilizes at e.g. 6V.

The falling speed of Vref can be controlled by an external capacitor CCE, which is connected in parallel to a RCE resistor. It controls the blanking time which passes after turn-on of the IGBT before the VCE monitoring is activated (so guaranteeing that always  $VCE < Vref$  during monitoring). This makes an adaptation to any IGBT switching behaviour possible.

Note that the blanking time should not be too large, since otherwise the capability of reacting to a short circuit will be reduced.

## Minimization of interference on control signals

### Question

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Control signals for the gate driver should not be compromised by interference. I know that electrical interference can arise from different reasons, one of them being high di/dt and dv/dt as a result of IGBT switching.

What design recommendations should I follow to minimize interference?

### Answer

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The following design tips can help:

- Tracks on the printed circuit board should be kept as short as possible. Loops should be avoided.
- Length of cable should be as short as possible and should not exceed three metres. Twisted pair cable should be used.
- Control signals (low-power signal) are not to be grouped with high-power signals (power supply). Use signal ground and power supply ground separately. Both should be tied at one point only (in most cases at the driver) to avoid looping.

- Signal cable should be placed as far away as possible from power terminals, power cables, ground cables, DC-link capacitors and all other noise sources.
- Control signal cable should not run parallel to power cable. The minimum distance between control signal cable and power cable should be 30cm and the cables should cross vertically only.
- It is recommended that all cables be kept close to ground (e.g. heat sink or the likes).
- In noise intensive applications, it is recommended that shielded cables or fibre optic interfaces be used to improve noise immunity.
- Use a low value capacitor (1nF) between signal and power supply ground of the gate driver for differential mode noise suppression.
- The use of an open collector drive is not recommended.
- The input capacitor between the controller and driver for high noise immunity is not compulsory but recommendable. The drawback of this capacitor is that with current limited line drivers, it can cause a small delay. It has to be placed as close to the gate driver interface as possible.
- Three different components between the driver and the IGBT module:
  - a) RGE: In order to ensure IGBT locking even when the driver supply voltage is turned off and voltage is being applied to the power circuit, a resistor (RGE) has to be integrated.
  - b) Suppressor diode: A suppressor diode should be placed very close to the IGBT module, which can protect the IGBT gate in overvoltage conditions as well as limit the short circuit current should a short circuit occur.
  - c) CGE: A gate emitter capacitor is used as a smoothing capacitor, especially in the event of a short circuit, in order to reduce oscillation at the IGBT gate.
- An advantageous solution is to mount the gate driver directly onto the IGBT module, like for example a SKYPER 32R driver on a SEMiX IGBT module through a specific adapter board.