POWER DESIGN FAQs

Frequently Asked Questions:

POWER-MOSFET GATE DRIVERS

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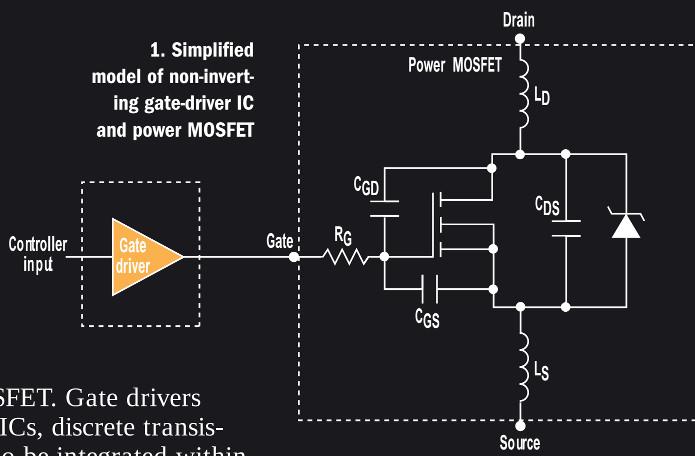
What is a power-MOSFET gate driver?

It is a power amplifier that accepts a low-power input from a controller IC and produces the appropriate high-current gate drive for a power MOSFET. A gate driver is used when a pulse-width-modulation (PWM) controller cannot provide the output current required to drive the gate capacitance of the associated MOSFET. Gate drivers may be implemented as dedicated ICs, discrete transistors, or transformers. They can also be integrated within a controller IC. Partitioning the gate-drive function off the PWM controller allows the controller to run cooler and be more stable by eliminating the high peak currents and heat dissipation needed to drive a power MOSFET at very high frequencies.



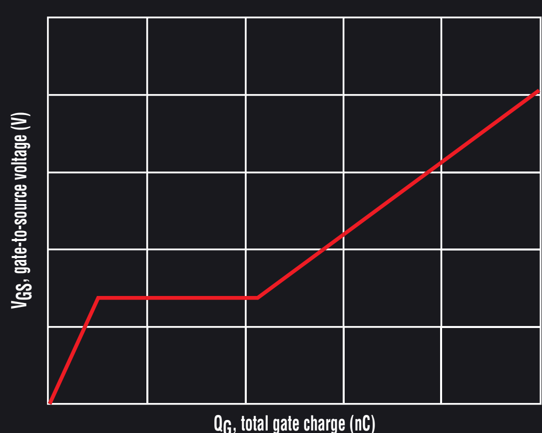
1. Simplified model of non-inverting gate-driver IC and power MOSFET

What's the circuit model for a gate driver and power MOSFET?

Figure 1 shows the simplified model, including the parasitic components that influence high-speed switching, gate-to-source capacitance (C_{GS}), the gate-to-drain capacitance (C_{GD}), and drain-to-source capacitance (C_{DS}). Values of the source inductance (L_S) and drain inductance (L_D) depend on the MOSFET's package. The other parasitic component is R_G, the resistance associated with the gate signal distribution within the MOSFET that affects switching times.

What are the primary gate-driver design considerations?

An important attribute for the gate driver is its ability to provide sufficient drive current to quickly pass through the Miller Plateau Region of the power-MOSFET's switching transition. This interval occurs when the transistor is being driven on or off, and the voltage across its gate-to-drain parasitic capacitor (C_{GD}) is being charged or discharged by the gate driver. Figure 2 plots total gate charge as a function of the gate-drive voltage of a power MOSFET. Total gate charge (Q_G) is how much must be supplied to the MOSFET gate to achieve full turn-on. It is usually specified in nanocoulombs (nC).



2. Power MOSFET gate-drive characteristics

How does the gate driver affect MOSFET switching speed?

The Miller effect produced by MOSFET C_{GD} is what predominantly limits switching speed. A MOSFET responds instantaneously to changes in gate voltage and begins to conduct when the gate reaches the threshold voltage (V_{GS}). To address a wide range of applications, suppliers offer a variety of power MOSFETs that transition at different gate thresholds, such as logic-level MOSFETs with lower threshold voltage. Gate waveforms indicate a plateau at a gate voltage above the threshold voltage. The time required to drive the gate through this plateau region depends on the amount of drive current available, which determines the MOSFET's drain-voltage rise and fall times.

What about discrete drivers?

Discrete gate drivers constructed with bipolar npn and pnp emitter-followers can achieve reasonable drive capability, but they're not as space-efficient as gate-driver ICs. Implementing delay and other housekeeping functions needed for safe operation is cumbersome and costly with a discrete circuit. The gate-driver IC overcomes these limitations.

What about IC drivers?

Gate-driver ICs include a logic input buffer that drives sufficient current-gain stages to produce a high-current output. In addition, the dedicated gate-driver IC can include the housekeeping functions needed for safe operation. Also, it can be easily placed closer to the power MOSFET, thereby reducing noise interference and voltage-distribution drops across the pc-board trace.

Single versus dual channels?

There are single gate-driver ICs whose output is either inverting or non-inverting with respect to the controller input. Some single-channel gate drivers provide both inverting and non-inverting inputs. In addition, there are dual gate-driver ICs with either two inverting, two non-inverting, or one inverting and one non-inverting channel.

What influences gate-driver-IC lifetime and performance?

Load power requirements, thermal characteristics of the semiconductor package and its cooling method determine the lifetime and performance of a gate-driver IC. The device's junction temperature must be kept within the rated limit at all times.

What about designing for synchronous rectification?

Shoot-through current is a potential problem for MOSFETs used in synchronous rectification. Because the gate driver must turn on and off not only the power switch but also the rectifier switch, a low impedance may be presented to the input voltage source during switching transitions. This low transition impedance can allow a shoot-through current to be conducted through both the power-switching MOSFET and the synchronous-rectifier MOSFETs. High shoot-through currents result in greater electromagnetic interference, more noise on the input voltage source, lower efficiency, and reduced reliability.

Some gate-driver ICs include a non-overlap circuit that prevents shoot-through current. Other ICs specify a minimum amount of non-overlap, or dead-time. That is, a minimum time at the switching transitions (two per operating cycle) where both MOSFETs are turned off. Maintaining the dead-time prevents the problem of shoot-through current but reduces circuit efficiency from its optimum value. ED Online 8415