

# 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.

#### 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).

#### 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.

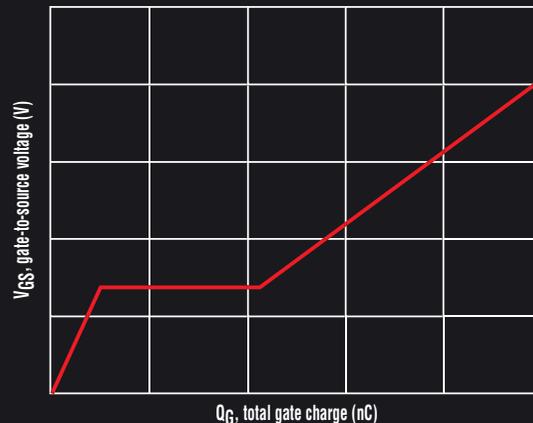
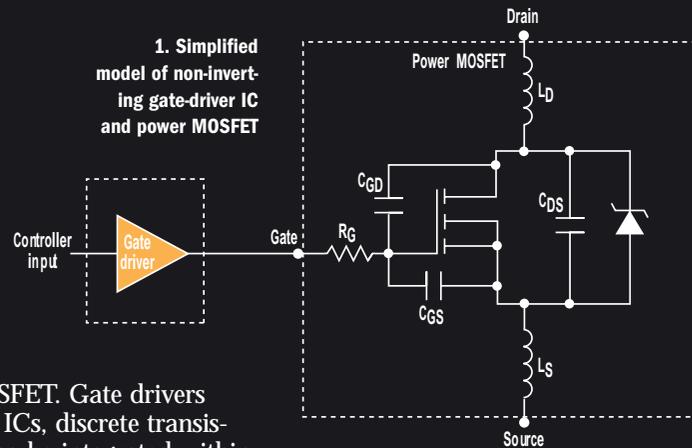
#### What about discrete drivers?

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 pro-



2. Power MOSFET gate-drive characteristics

# PRODUCT Q&As

duce 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**

## NATIONAL'S HIGH-VOLTAGE GATE DRIVER FAMILY

### LM5100/01 Gate Drivers

The LM5100/LM5101 are high-voltage gate drivers for the high-side and low-side n-channel MOSFETs in a synchronous buck or bridge configuration. The floating high-side driver can operate with supplies up to 100 V. Outputs are independently controlled with CMOS input thresholds (LM5100) or TTL-input thresholds (LM5101). Both the low-side and the high-side power rails include undervoltage lockout. Turn-off propagation delay is 25 ns (typical), and the ICs can drive 1000-pF loads with 15-ns rise and fall times.

### LM5102 With Programmable Delay

The LM5102 is similar to the LM5100 with the addition of a programmable delay for adjusting driver dead time. The LM5102 offers the flexibility of an independent programmable delay of the rising edge for both high- and low-side driver outputs. Delays are set with external resistors and can be adjusted from 100 ns to 600 ns. The wide delay programming range provides the flexibility to optimize drive signal timing for a broad range of MOSFETs and applications. In addition, the timer can be terminated midway through a sequence.

### LM5104 With Adaptive Delay

The LM5104 is similar to the LM5100 with the addition of an adaptive delay to prevent shoot-through. The high-side and low-side gate drivers are controlled from a single input. Each change in state is controlled in an adaptive manner to turn off one MOSFET before the other is turned on. Besides the adaptive transition timing, an additional delay time can be added, inversely proportional to an external setting resistor. The adaptive control and additional delay of the timer prevent lower and upper MOSFETs from conducting simultaneously.

### LM5110 Dual-Gate Driver

The LM5110 replaces industry-standard gate drivers with improved peak output current and efficiency. Each "compound" output driver stage includes MOS and bipolar transistors operating in parallel that together sink more than 5-A peak from capacitive loads. Combining the unique characteristics of MOS and bipolar devices reduces drive current variation with voltage and temperature. Separate input and output ground pins provide negative drive capability, allowing the user to drive MOSFET gates with positive and negative  $V_{GS}$ . The gate driver control inputs are referenced to a dedicated input ground.



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