# *Understanding Peak Source and Sink Current Parameters*

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TEXAS INSTRUMENTS

Gate drivers are often confused as continuous current sources because of the $I_{OH}$ and $I_{OL}$ specifications in the datasheet. For example, designers looking at the UCC5320SC might read the parameters 4.3-A source and 4.4-A sink and mistakenly believe these devices are capable of providing these currents continuously. Gate drivers do not need to provide constant current because they only have to source/sink current when switching the gate of the MOSFET or IGBT. Refer to Figure 1 for the turn-on waveforms.

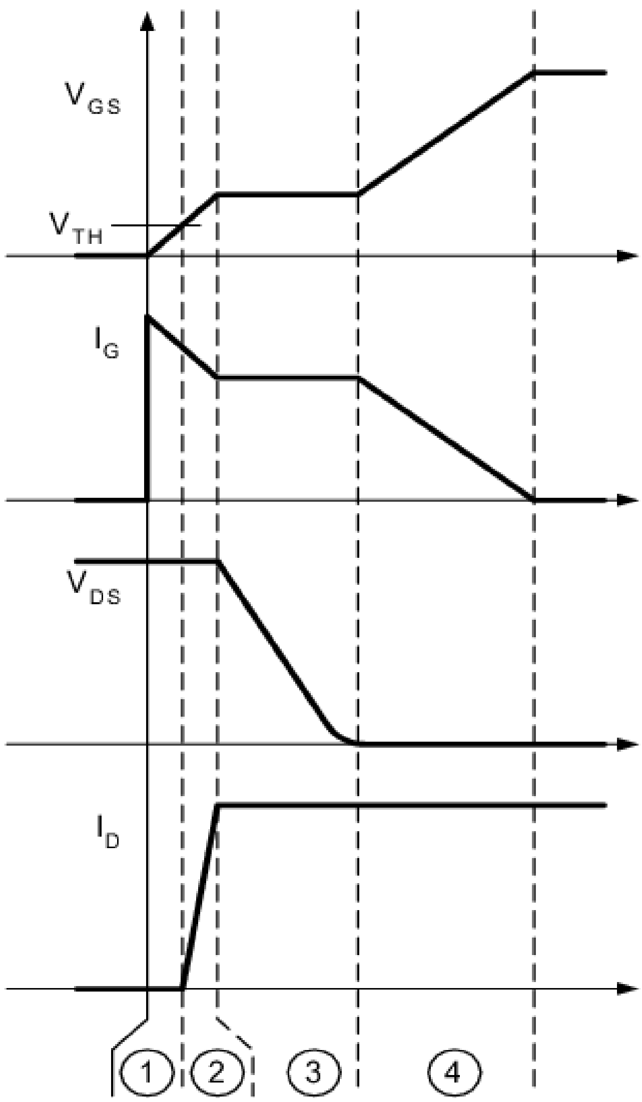


**Figure 1. MOSFET Turn-On Time Intervals**

In order to understand the $I_{OH}$ and $I_{OL}$ specifications, we need to look at the pull-up and pull-down structures inside the device. The output stage of a gate driver typically comes in some variation of Figure 2. UCC5320SC is offered in a split output pinout that gives designers more control of the rise and fall times without adding extra components like schottky diodes.

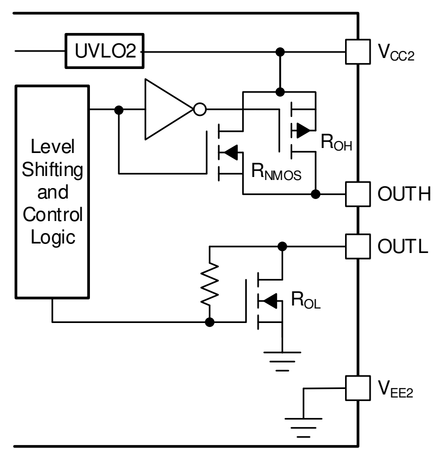


**Figure 2. Gate Driver Output Stage**

Under a no load condition, $I_{OH}$ is determined by $V_{CC2}$ and the parallel combination of $R_{NMOS}$ and $R_{OH}$ while $I_{OL}$ is set by $V_{CC2}$ and $R_{OL}$. $R_{NMOS}$ helps the pull-up structure deliver the peak current with a brief boost in peak-sourcing current during the Miller plateau region shown as interval 3 in Figure 1. This is done by turning on the N-channel MOSFET during a narrow instant when the output is changing states from low to high.

When driving MOSFETs and IGBTs high, the external gate resistor $R_{ON}$ and the transistor's internal gate resistance $R_{GFET\_Int}$ , reduce the peak output current as shown in Equation 1.

$$I_{OH} = \min\left(4.3\ A, \frac{V_{CC2}}{R_{NMOS} \,||\, R_{OH} + R_{ON} + R_{GFET\_Int}}\right) \quad (1)$$

Likewise, the peak sink current is limited by the external gate resistor $R_{OFF}$ in series with $R_{OL}$ and $R_{GFET\_int}$ and is determined by Equation 2

$$I_{OL} = \min\left(4.4\ A, \frac{V_{CC2}}{R_{OL} + R_{OFF} + R_{GFET\_Int}}\right) \quad (2)$$

This TI TechNote will use the isolated single-channel gate driver, UCC5320SC and a 100-nF capacitive load to demonstrate different techniques to determine the peak drive current. The first method calculates the expected peak currents based on Equation 1 and Equation 2. Use these equations to estimate the peak drive current when selecting a gate driver for your system.

In order to simulate driving a MOSFET or IGBT before installing it onto the PCB, select a load capacitor that is equivalent to the switch's input capacitance, $C_{ISS}$. Determine the input capacitance by looking up the required gate charge from the MOSFET or IGBT's datasheet at the drive voltage condition.

A second technique uses this $C_{ISS}$ value and the dV/dt of the switching waveform to determine the source or sink current. Figure 3 measures the dV/dt using cursors set to a fixed 35-ns interval and swept across the rising edge in order to find the peak dV/dt. As a guideline, set the oscilloscope's cursors to a time interval, $\Delta t$ of approximately 10% of the rise time to determine the current through the load capacitor.

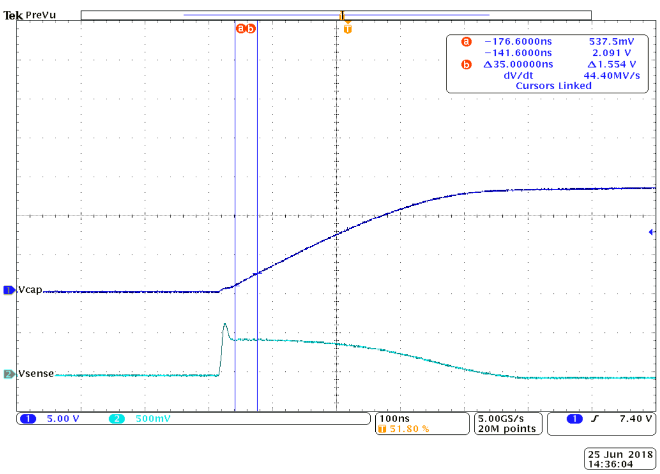


**Figure 3. Measuring Peak dV/dt Across Load Capacitor**

Use the measured peak dV/dt and load capacitor value along with Equation 3 to calculate the peak current.

$$I_C = C\frac{dV}{dt} \tag{3}$$

A third method inserts a 0.1-Ω sense resistor between the capacitor and ground to calculate $I_{OH}$ or $I_{OL}$. Figure 4 shows the voltage waveform across the sense resistor, $V_{SENSE}$ and its measurement coincides with the highest dV/dt value of the $V_{cap}$ waveform.

The results of the three presented techniques are shown in Table 1. Even with the 0.1-Ω sense resistor in series with the capacitor, Equation 1 predicts 4.30-A sourcing current. Equation 3 uses the largest measured dV/dt value in the linear region of the gate drive waveform which gives an estimated 4.53-A. In this same linear region, the voltage across the sense resistor is measured in Figure 4 and Ohm's law is used to determine peak $I_{OH}$ at 4.29-A.

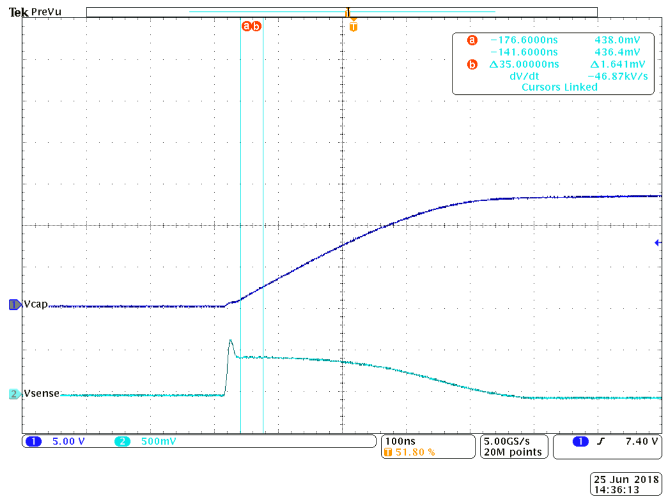


**Figure 4. Voltage Across Series Sense Resistor**

The first method is a good starting point when selecting a gate driver but it is not an actual measured value. The second method relies on the engineer to accurately measure the highest dV/dt by using a fixed $\Delta t$ and sweeping it across the waveform. Lastly, the voltage measured across the 0.1-Ω sense resistor will give the engineer a value calculated from measurement of the peak drive current using Figure 4 and Ohm's law. The key to the third measurement technique is to select a small valued sense resistor to prevent any limitations in the peak output current. All presented methods are acceptable approximations of a gate driver's peak output current.

To reiterate, $I_{OH}$ and $I_{OL}$ are not continuous DC values. The peak current charges or discharges $C_{ISS}$ in an instant and then reduces in value as the switch begins to turn on.

**Table 1. Measurement Comparison**

| Theoretical vs. Measured | Method | Result |
|---|---|---|
| Theoretical | Equation 1:<br>$I_{OH}$ = min[4.30A, 4.44A] | 4.30A |
| Calculated from Measurement | Equation 3:<br>$I_C$= 102nF(44.4MV/s) | 4.53A |
| Calculated from Measurement | Ohm's Law:<br>$I_{OH}$ = 438mV/102mΩ | 4.29A |

## Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Changes from Original (June 2018) to A Revision | Page |
|---|---|
| • Added additional Gate Driver detail. | 1 |