Understanding Peak Source and Sink Current Parameters

Mateo Begue, High Power Drivers

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.

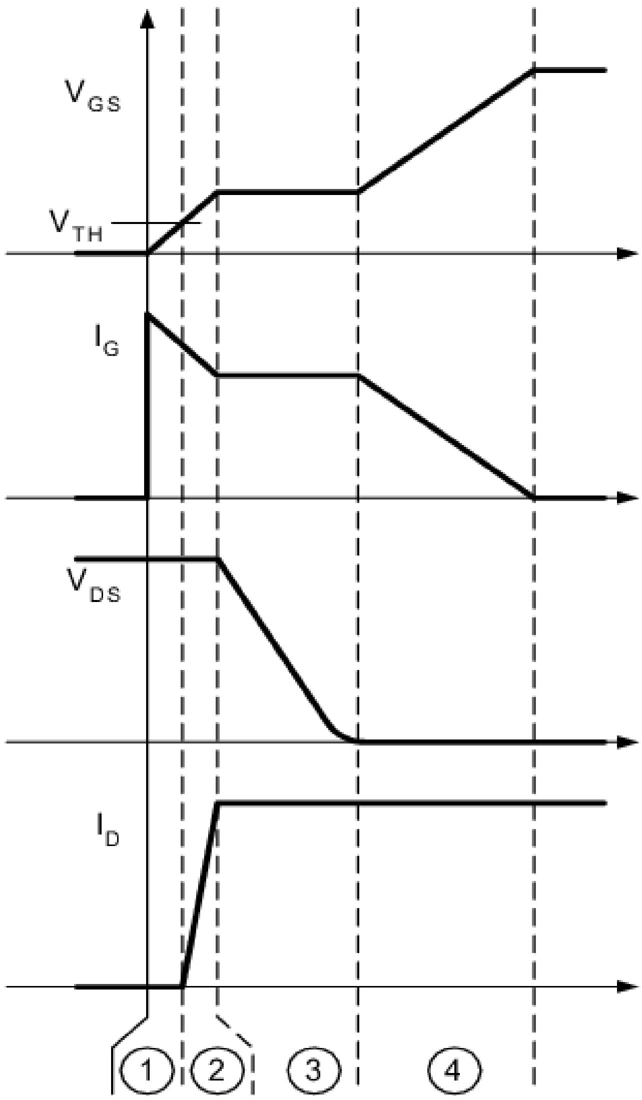

Figure 1. MOSFET Turn-On Time Intervals

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.

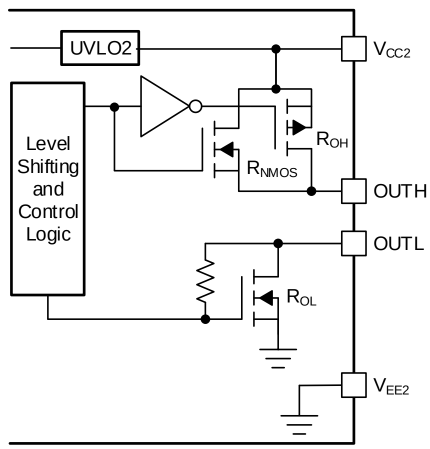

Figure 2. Gate Driver Output Stage

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.

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

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, Δt of approximately 10% of the rise time to determine the current through the load capacitor.

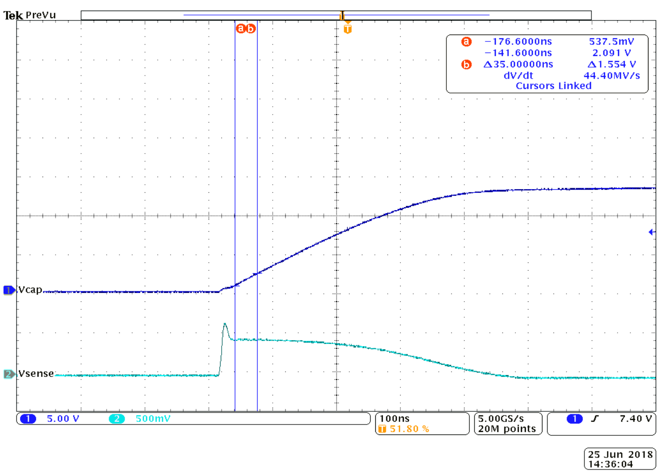

Figure 3. Measuring Peak dV/dt Across Load Capacitor

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

$$I_C = C\frac{dV}{dt} \quad (3)$$

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.

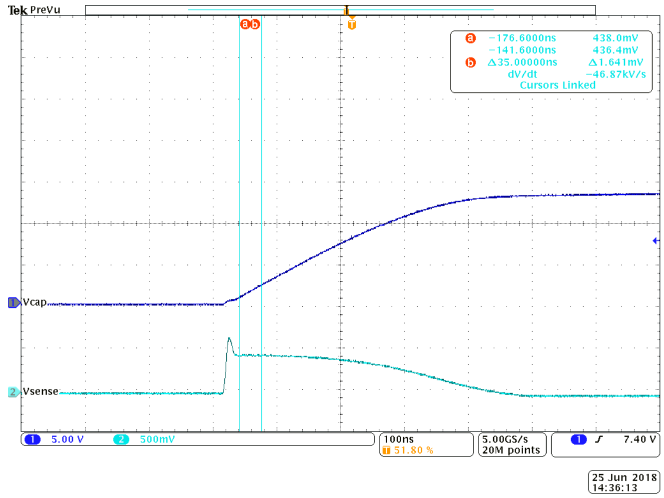

Figure 4. Voltage Across Series Sense Resistor

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 Δt 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: I_{OH} = min[4.30A, 4.44A]	4.30A
Calculated from Measurement	Equation 3: I_C= 102nF(44.4MV/s)	4.53A
Calculated from Measurement	Ohm's Law: I_{OH} = 438mV/102mΩ	4.29A

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