

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.

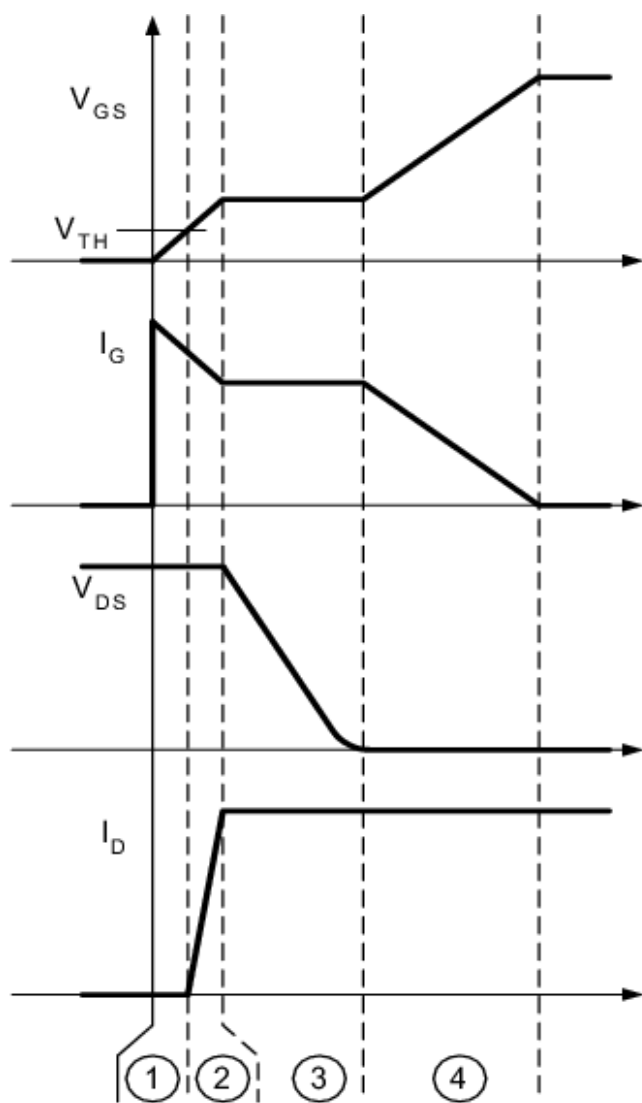


Figure 1. MOSFET Turn-On Time Intervals

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.

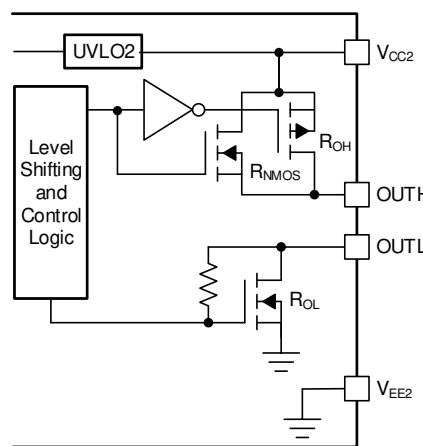


Figure 2. Gate Driver Output Stage

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.

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

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

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

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.

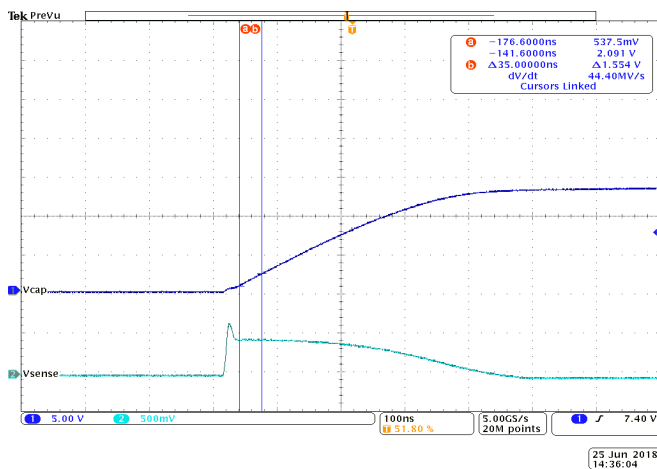


Figure 3. Measuring Peak dV/dt Across Load Capacitor

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.

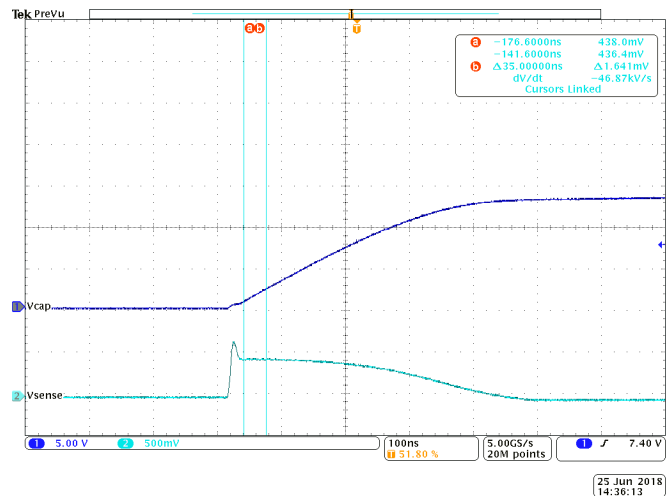


Figure 4. Voltage Across Series Sense Resistor

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: $I_{OH} = 438mV/102m\Omega$	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

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2020, Texas Instruments Incorporated