IXYS COLORADO

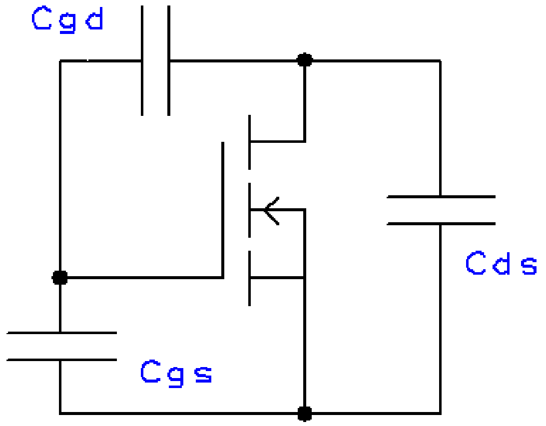
TECHNICIAN NOTE 001

Martin Jones
08-05-2013

Gate Charge

Gate charge is a parameter that can be used to estimate MOSFET turn-on time if the gate current is known, or estimate the gate current required for a desired turn-on time. This parameter is dependent on drain voltage and temperature.

As shown in the figure below, a MOSFET has three intrinsic capacitances: gate-to-source (C_{GS}), gate-to-drain (C_{GD}), and drain-to-source (C_{DS}). The gate-to-source and gate-to-drain capacitances make up the input capacitance value (C_{iss}) listed on the data sheet. The gate-to-drain capacitance is listed as the reverse transfer (C_{rss}) value, and the drain-to-source capacitance is listed as the output (C_{oss}) value.

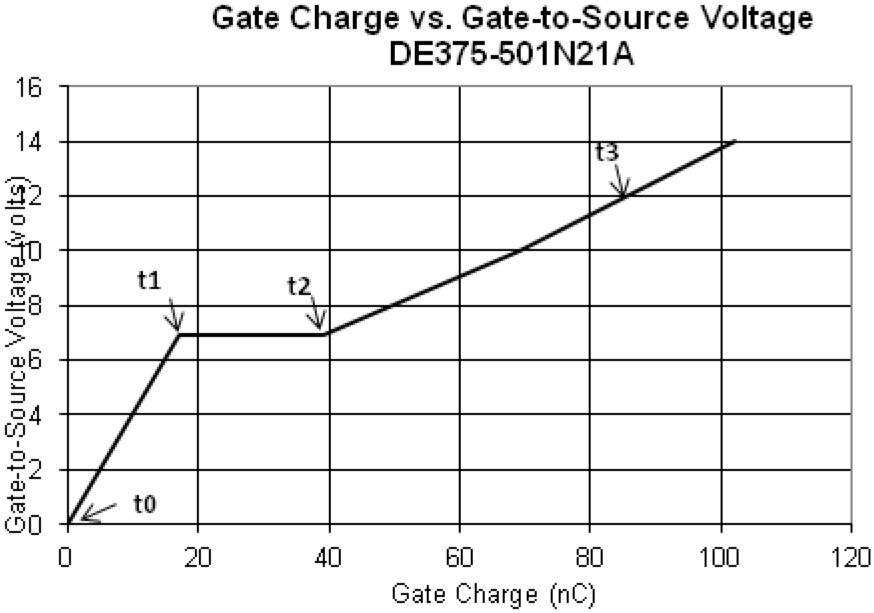


The capacitance values listed on the data sheet can be useful, but they do not paint a complete picture when it comes to switching the device on and off.

For example, the DE375-501N21A has a listed C_{iss} value of 2500 pF. The gate charge that must be transferred can be determined from Q = C • V. Assuming we want to turn the device on with 12 V on the gate, the charge is $(2.5 \times 10^{-9})(12) = 30$ nC.

Assume the desired turn-on time is 10 ns. To determine the current, we'll use I = Q / t = 30 nC / 10 ns = 3 A. But if you use a 3 A source to drive the gate of device, you will quickly discover that the rise time is actually 30 ns. What we failed to account for was the gate-to-drain capacitance, also known as the Miller capacitance (C_{rss}). This capacitance is non-linear and dependent on the drain voltage. This is the reason the gate charge parameter is listed on the data sheet: The designer can determine the correct current source for switching the device on; it's also the same for turn-off.

The following graph shows the gate charge in nanocoulombs (nC) vs. gate-to-source voltage for the DE375-501N21A MOSFET. The first slope on the graph from t_0 to t_1 is the charging of the gate-to-source capacitance. At t_1 the device begins to switch on; C_{GD} begins to charge and the V_{DS} begins to fall. The period between t_1 and t_2 is flat: During this time V_{DS} falls and current begins to flow from drain to source. When this happens C_{GD} begins to increase and all of the drive current flows to the C_{GD}, until V_{GD} is equal to V_{DS} at t_2. From t_2 to t_3 both C_{GS} and C_{GD} charge until the device reaches full conduction, where $V_{DS} = I_D * R_{dsON}$. In most MOSFETs this occurs at 10 V on the gate, but it is recommended that the gate be overcharged to account for differences between MOSFETs. In this example we will charge the gate of a DE375-501N21A to 12 V. The charge required to do this is 90 nC from the chart below.



With this new information, the designer can now choose the proper gate drive circuit to switch the device in 10 ns. The current that will be needed to switch the device into full conduction, I = Q / t, results in a minimum of 9 A. This value of current is three times larger than our previous example when just the charge of a pure capacitance is used. The designer should choose a slightly higher current to ensure the device is driven into full conduction. The same current flows back when the device is switched off due to the discharge of the gate, which is the opposite of the charge to switch the device on.