Keysight Technologies

Internal Gate Resistance Measurement Using the B1505A

Application Note

Introduction

Power MOSFET and IGBT internal gate resistance is an important device paramteter, since it can limit the maximum switching frequency or determine the driving loss in switching converters and inverters. For the lower totem pole transistor of the converter output, it is also important to minimize the internal gate resitance to prevent device self turn-on. Device self turn-on is caused by transient currents injected into the gate terminal of the lower totem pole transistor through capacitive coupling when the upper totem pole transistor turns on (refer to figure 1).

Since this phenomena can cause device destruction, controlling internal gate resistance variations is as important as minimizing the absolute gate resistance value. Unfortunately, most data sheets only show typical values for the internal gate resitance. Since the internal gate resitance has a strong temperature dependence, measuring it for many devices under actual use conditions is necessary to understand its true value and temperature behavior.

Internal gate resistance is typically measured at a specific frequency using an LCR meter. The Keysight Technologies, Inc. B1505A power device analyzer/curve tracer has an LCR meter module option for power device capacitance measurement. This module therefore gives the B1505A the ability to also measure internal gate resistance. This application note explains how to measure internal gate resistance using the B1505A and also shows an actual example measurement.

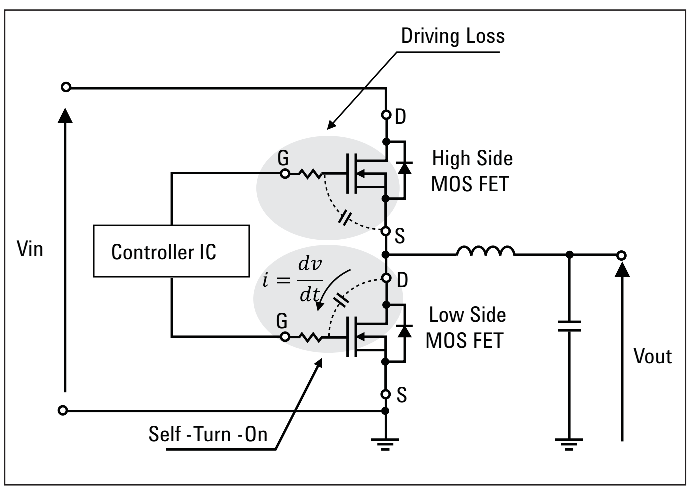


FIGURE 1. Driving loss and self-turn-on induced by internal gate resistance in a DC-DC converter

Measurement Fundamentals

Figure 2 shows the simplified cross section of a trench gate type power MOSFET. Cgd is the gate to drain capacitance, Cgs is the gate to source capacitance, and Cds is the drain to source capacitance. In addition to these capacitances, the gate to channel capacitance (Cgc) is also shown. The internal gate resistance, Rg(int), is in series with Cgd, Cgs and Cgc.

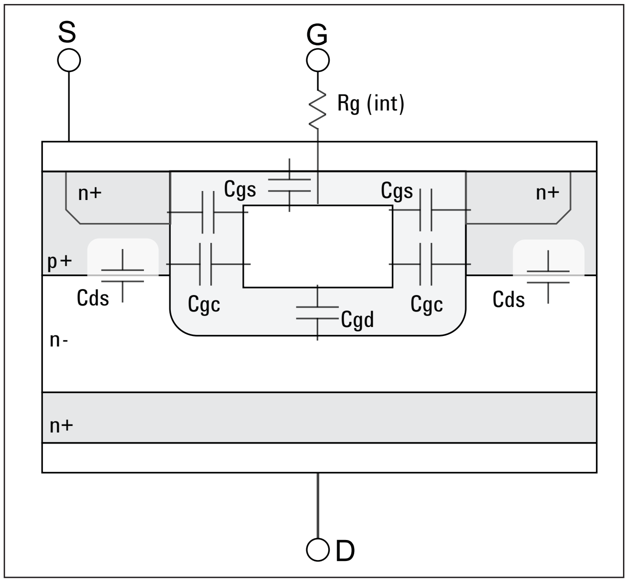


FIGURE 2. Terminal capacitances and internal gate resistance of trench MOS-FET

An LCR meter extracts device capacitance and resistance using an equivalent circuit model such as Cp-Rp, Cp-G or Cs-Rs (refer to figure 3).

To measure the internal gate resistance the Cs-Rs mode is used. However, to accurately measure the internal gate resistance, it is important to use the appropriate connections, bias conditions and measurement frequency.

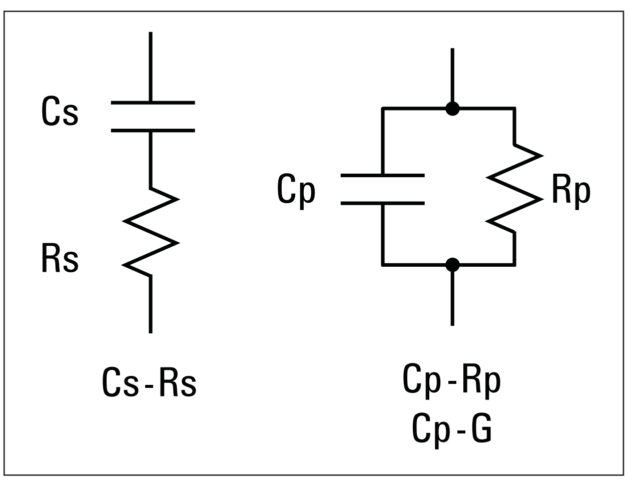


FIGURE 3. Equivalent LCR meter circuit models to extract capacitance and resistance

Measurement Examples

Connections

Figure 4 shows a connection diagram to measure internal gate resistance using the B1505A's Multi-Frequency Capacitance Measurement Unit (MFCMU) and N1259A test fixture. The N1259A has two AUX inputs, which have BNC connectors. The outputs of the MFCMU are connected to the N1259A's AUX inputs via BNC-T connectors.

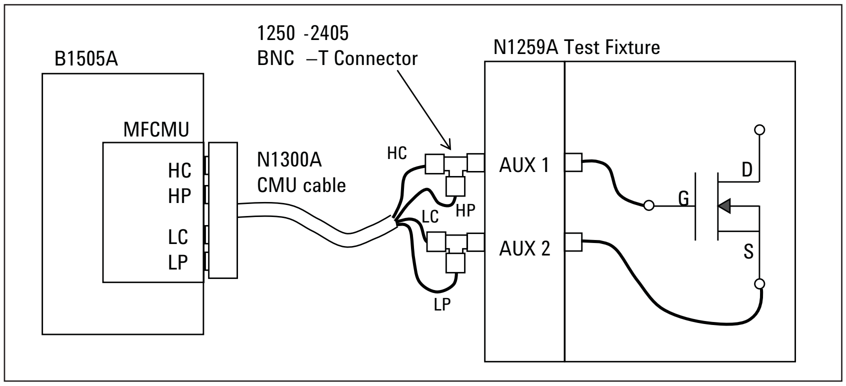


FIGURE 4. Connection to measure Rg(int) of power MOSFET with the N1259A test fixture

The HC and HP output of the MFCMU are connected to AUX 1, and the LC and LP outputs are connected to AUX 2. The outer shields of the MFCMU's outputs are connected at the AUX inputs of the N1259A to create a current return path. In the interior of the N1259A, connect AUX 1 to the gate terminal and AUX 2 to the source terminal of the device to be measured. The drain terminal of the device should be left open.

Measurement Examples *continued*

Compensation

Since the value of the internal gate resistance is on the order of a few ohms, the influence of cable parasitics cannot be ignored. Therefore, to measure the internal gate resistance accurately, it is necessary to perform short correction as well as phase and open correction. In addition, when using a switching matrix or a bias-T, it is also necessary to perform a load correction.

Figure 5 shows connection examples to perform open, short and load correction using the N1259A test fixture's in-line socket module.

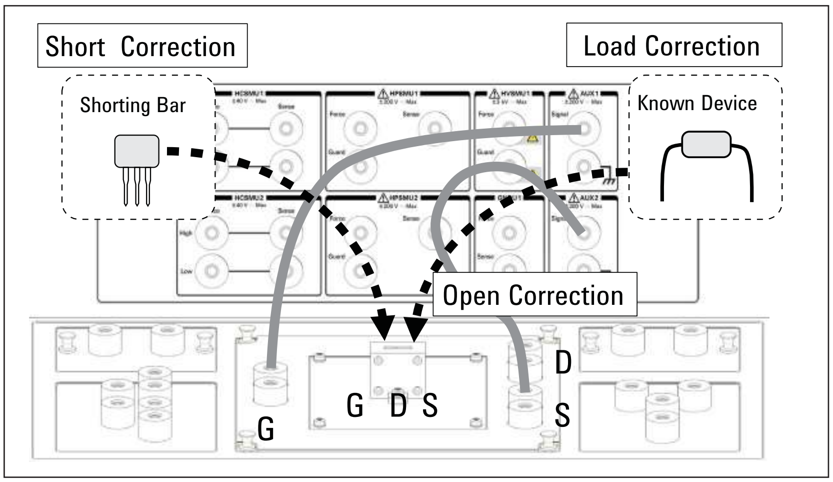


FIGURE 5. Connection to perform open, short and load correction

Phase and open correction factors should be measured with the socket empty after completing the cabling. To perform the short compensation, a shorting bar must be inserted into the socket. Note: The shorting bar is furnished with the socket module. However, if one is not available then shorting the gate and source together using a wire is also acceptable. To measure load compensation, a device with known impedance must be inserted between the gate and source terminals. In addition, the impedance value of the standard device must be entered as the load reference (see figure 6). The load reference window is found in the advanced section of the CMU calibration panel. If the load reference setting does not match the impedance of the load standard, then the load correction measurements will be invalid.

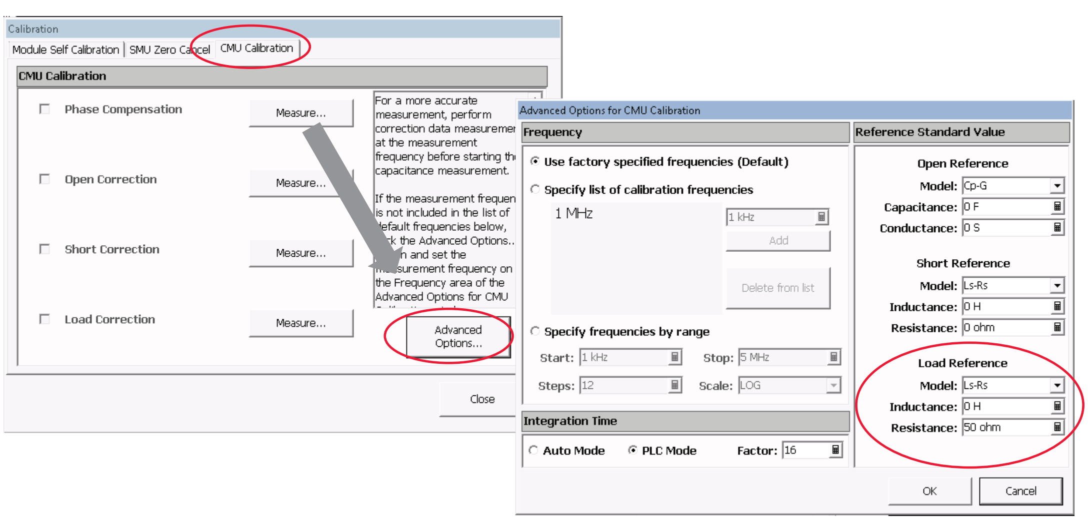
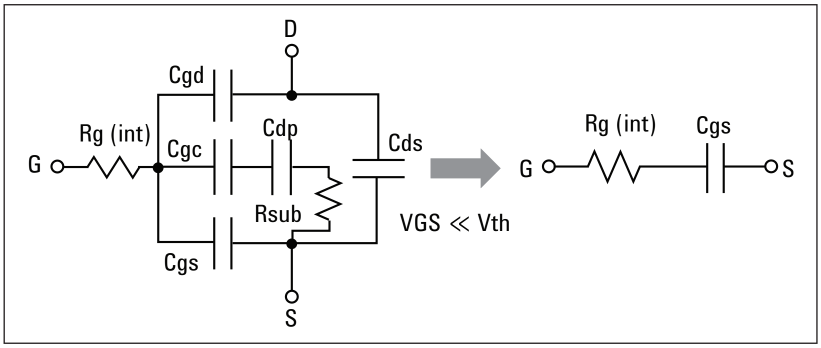


FIGURE 6. Load reference setup page of B1505A

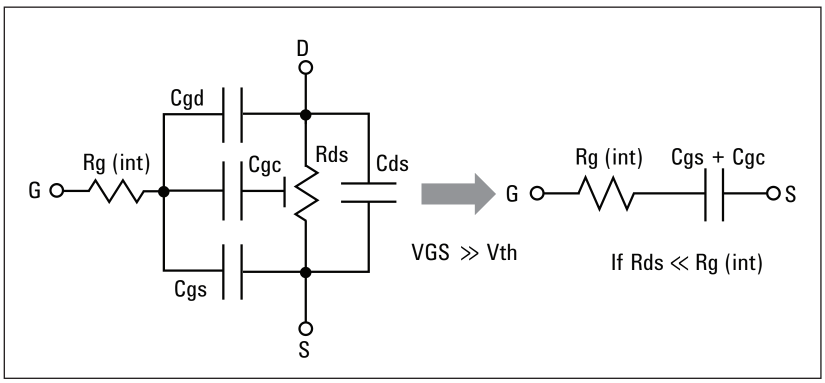
Measurement Examples *continued*

Bias condition

To measure the device in Cs-Rs mode, an appropriate gate bias condition needs to be determined and applied. In general, it is best to select a gate voltage that turns off the device completely because then Cgs becomes the dominant factor in the series capacitance (see figure 7a). However, if the device's on-resistance is small compared to that of the internal gate resistance, it is acceptable to use a gate voltage that turns on the device completely (see figure 7b).



(a) VGS is less than Vth



(b) VGS is greater than Vth

FIGURE 7. Equivalent circuit model under different bias conditions

Applying a gate voltage close to the threshold voltage should be avoided, since in depletion mode the relatively high substrate resistance of the depletion layer capacitance makes it difficult to measure Rg.

In addition to the previous recommendations, higher frequencies typically yield better gate resistance measurement results since they minimize the impedance of the series capacitance. A measurement frequency of at least 100 kHz should be used to measure internal gate resistance.

Measurement Examples *continued*

Bias condition *continued*

Figure 8 shows an internal gate resistance measurement example using 10 kHz, 100 kHz and 1 MHz measurement frequencies. The integration time was set at 1 PLC (power line cycle) to reduce power line noise. The device is a low voltage power MOSFET which has typical values of 6.8 Ω and 1.5 mΩ for its internal gate resistance and on-resistance (respectively). Its threshold voltage is around 4 V.

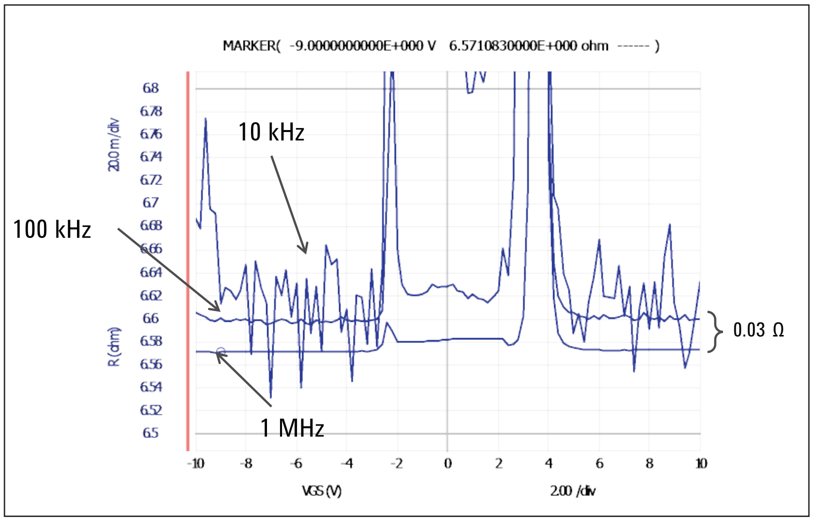


FIGURE 8. Internal gate resistance measurement example

When VGS is close to the threshold volts, the measured internal gate resistance shows clear frequency dependence. The best explanation for this is that in this situation the internal device capacitances and resistances are not following the Cs-Rs model, but instead are following some other intermediate model. The measured internal gate resistances at high and low VGS are almost identical, because the on-resistance of this device is negligibly small.

This example shows that measurement results obtained using higher measurement frequencies are less noisy due to the lower impedance of the series capacitance. The discrepancies in the measured internal gate resistance values are most likely due to the increased measurement error at lower measurement frequencies.

Conclusion

The Keysight B1505A Power device Analyzer/Curve Tracer is a next generation curve tracer that can measure current and voltage characteristics up to 1500 A and 10 kV. It can also perform precise sub-milliohm on-resistance measurements and obtain iso-thermal characteristics using its 10 µs pulsing capability. In addition, the B1505A can measure terminal capacitances and internal gate resistance using its multi-frequency capacitance measurement unit.

In this application note, the measurement of power device internal gate resistance using the B1505A was demonstrated using an actual measurement example.

As was also shown in this application note, obtaining an accurate value for the internal gate resistance requires choosing the correct connections, compensation, bias condition and measurement frequency. aining an accurate value for the internal gate resistance requires choosing the correct connections, compensation, bias condition and measurement frequency.

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Published in USA, August 4, 2014
5991-4656EN
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