Faster FET testing with SMUs

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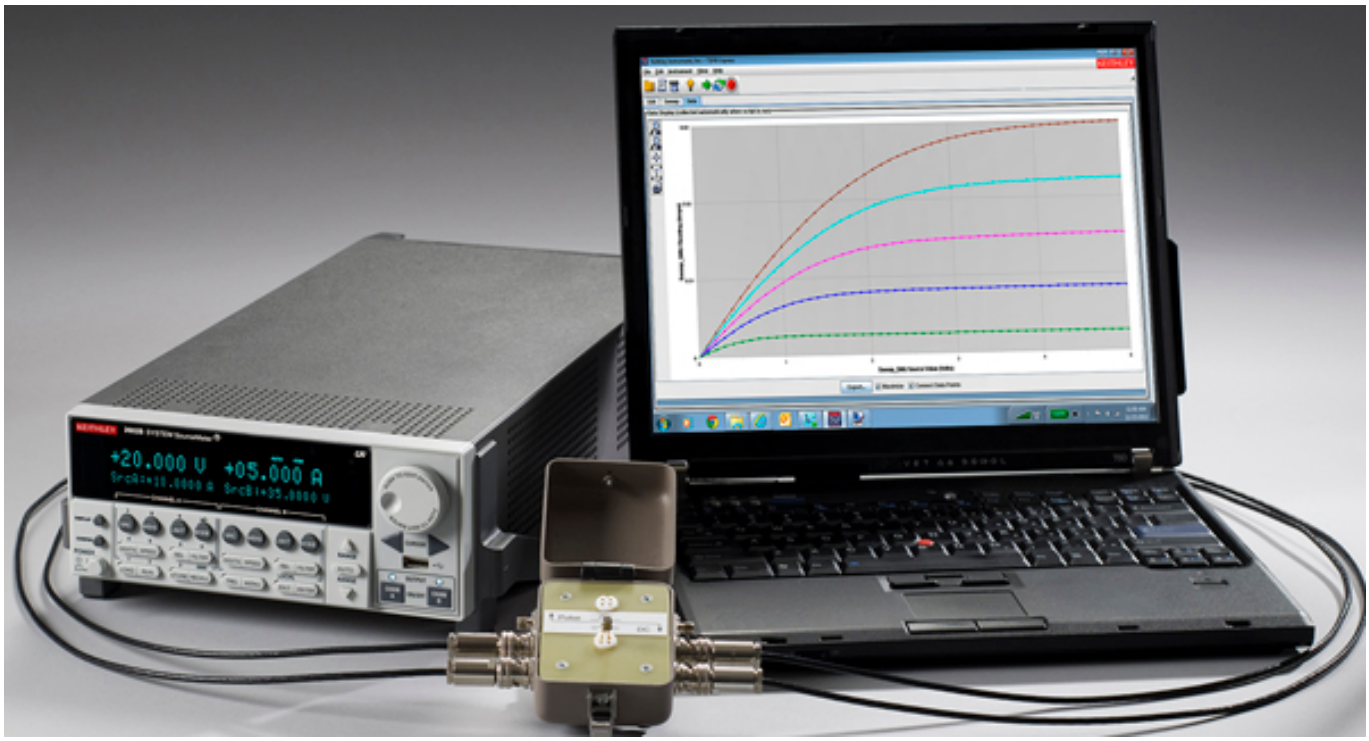
Field effect transistors (FETs) are important semiconductor devices because they are fundamental components of many devices and electronic instruments. Some of the countless applications for FETs include their use as amplifiers, memory devices, switches, logic devices, and sensors.

Characterizing their current-voltage (I-V) parameters is crucial to ensuring FETs meet specifications and work properly in their intended applications. These I-V tests may include gate leakage, breakdown voltage, threshold voltage, transfer characteristics, drain current, on-resistance, etc. FET testing often involves programming and synchronizing several instruments, including a sensitive ammeter and multiple voltage sources, which can be tedious and time consuming. Although a turnkey semiconductor characterization system solves the integration problem, systems of this type typically cost tens of thousands of dollars. A third approach involves using Source Measurement Units (SMUs), instruments that can quickly and accurately source and measure both current and voltage. The number of SMUs required in the test usually depends on the number of FET terminals that must be biased and/or measured.

This article outlines how to simplify I-V measurements on FETs using the latest generation of SMU instruments, a growing number of which are equipped with embedded software tools that simplify device characterization and curve tracing (Figure 1).



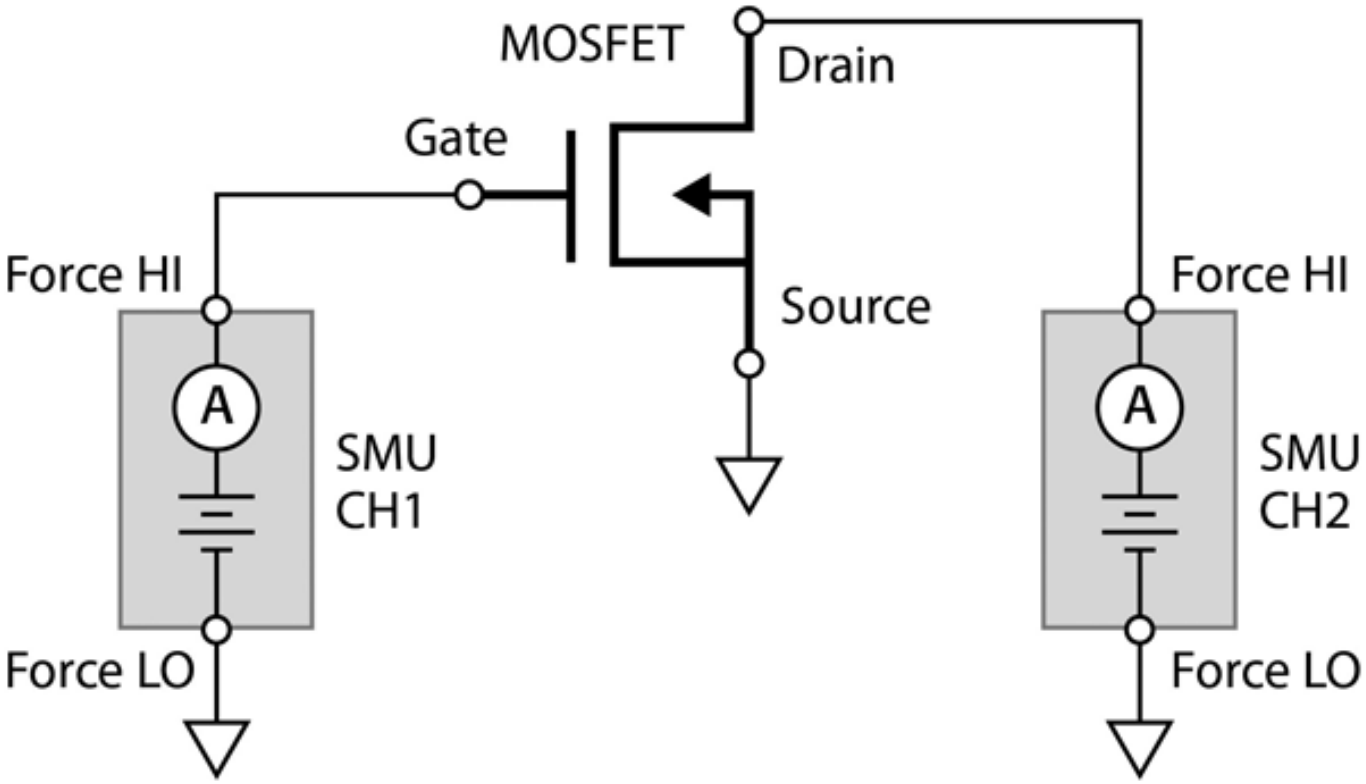
Field effect transistors

AFET is a majority charge-carrier device in which the current-carrying capability is varied by an applied electric field. It has three main terminals: the gate, the drain, and the source. A voltage applied to the gate terminal (VG) controls the current that flows from the source (IS) to the drain (ID) terminals.

There are many types of FETs, including the MOSFET (metal-oxide-semiconductor),MESFET (metal-semiconductor), JFET (junction),OFET (organic), GNRFET (graphene nano-ribbon), and CNTFET(carbon nanotube). These FETs differ in the design of their channels.

Using an SMU for FET testing

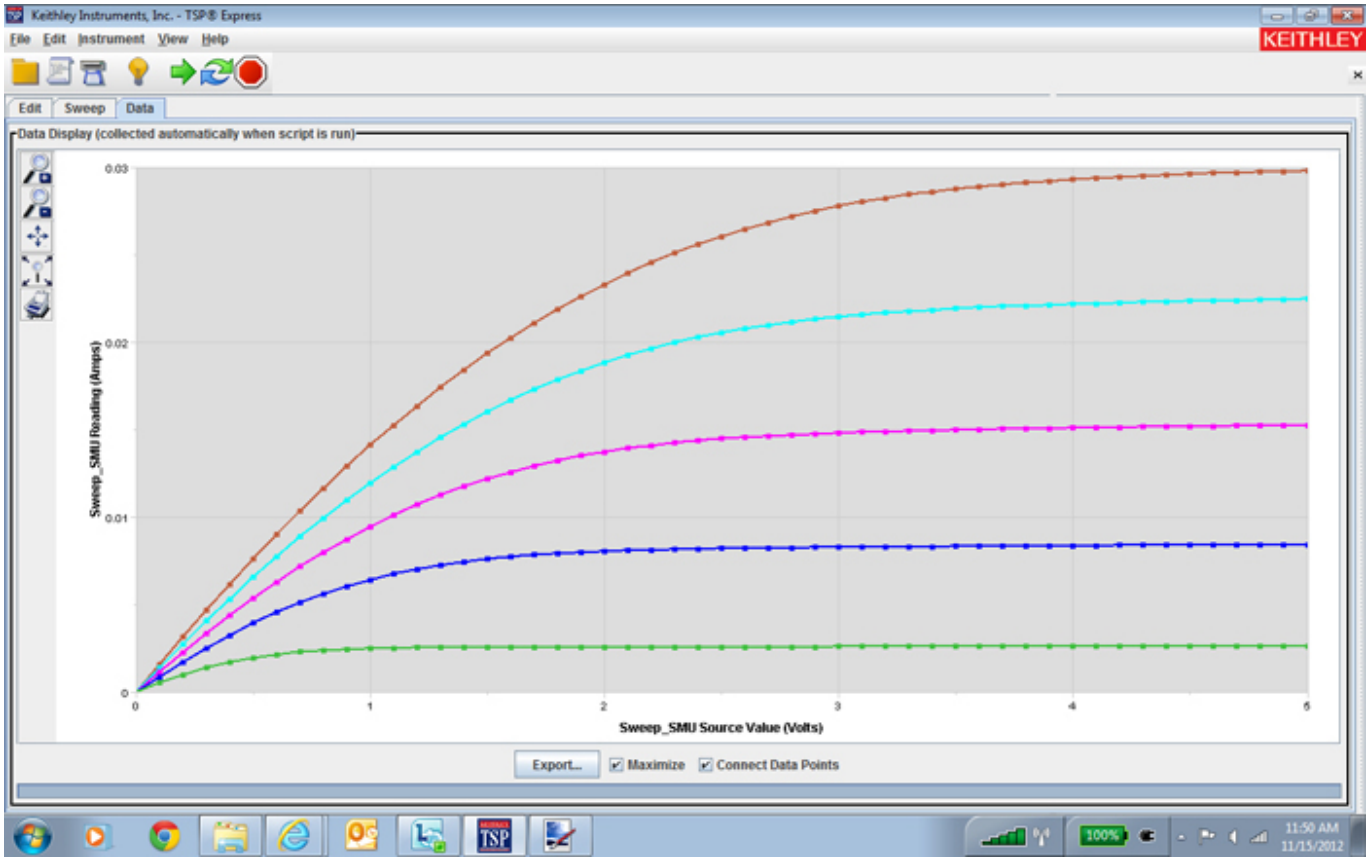
A FET's I-V characteristics can be used to extract many device parameters, to study the effects of fabrication techniques and process variations, and to determine the quality of the contacts. Figure 2illustrates a DC I-V test configuration for a MOSFET using a two-channel SMU (CH1 and CH2). Here, the Force HI terminal of SMU CH1is connected to the gate of the MOSFET and the Force HI terminal of SMU CH2 is connected to the drain. The source terminal of the MOSFET is connected to the Force LO terminals of both SMU channels or to a third SMU channel if it is necessary to source and measure from all three terminals of the MOSFET.



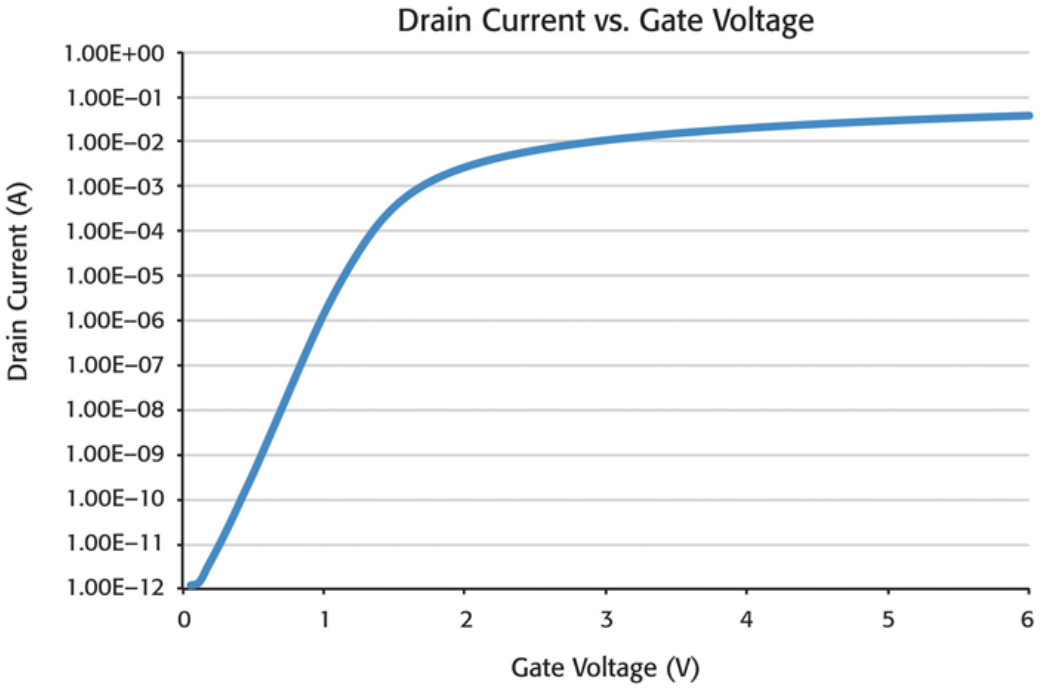
Once the device is set up and connected to the SMU, the control software, often an embedded software tool, must be configured to automate the measurements. After connecting the instrument to any computer with an Ethernet cable, entering the IP address of the SMU into the URL line of any web browser will open the instrument's web page. From that page, the user can launch the embedded software and configure the desired test or tests, which can often be saved and recalled for future use.

One I-V test commonly performed on a MOSFET is the drain family of curves (VDS-

ID). With this test, SMU CH1steps the gate voltage (VG) while SMU CH2sweeps the drain voltage (VD) and measures the resulting drain current (ID). Once the two SMU channels are configured to perform the test, the data can be generated and plotted on the screen in real time. Figure 3shows a MOSFET drain family of curves created by using a two-channel SMU optimized for low current measurements. Once exported to a .csv file, this I-V data can be imported into a spreadsheet for further analysis or displayed in table view.



Another common I-VFET test this same configuration supports is Drain Current (ID) as a function of Gate Voltage (VG). For this test, the gate voltage is swept and the resulting drain current is measured at a constant drain voltage. Figure 4 shows the results of an ID-VG curve at a constant drain voltage. However, in this case, the generated data was exported to a file and plotted on a semi-log graph. This test can be easily reconfigured to step the drain voltage as the gate voltage is swept. The ID-VG data shows the many decades of drain current that the SMU measured, from



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1E-12 to 1E-2 amps.