SOURCE-MEASURE UNITS INCREASE PRODUCTIVITY AND ACCURACY IN AUTOMATED TESTING

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Introduction

Source-Measure Units (SMUs) are more than the next generation of power supplies; they are fast-response, read-back voltage and current sources with high accuracy measurement capabilities, all tightly integrated in a single enclosure. They are designed for circuit and device evaluation where a DC signal must be applied to a device under test (DUT) and the response to that signal measured. Many are capable of 4-quadrant operation, acting as a positive or negative DC source or as a sink (load). They also provide highly repeatable measurements, typically with 61/2-digit resolution. Figure 1 illustrates a typical SMU measurement circuit.

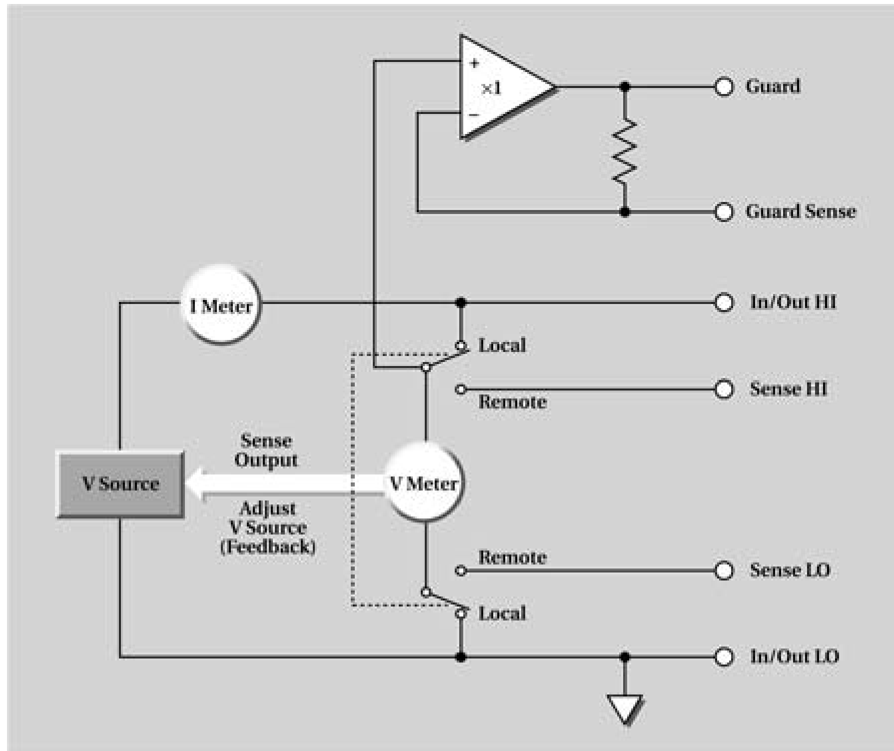

Figure 1. Simplified block diagram of an SMU configured to source V, measure I. The system can also be configured as a current source and parallel voltmeter.

Traditionally, a combination of bench top instruments, such as voltage or current sources and digital multimeters or picoammeters, have been used for material testing and component characterization. A common type of data collection project is generation of current-voltage (I-V) curves to describe component or material behavior in a circuit. Using separate instruments to do this requires a significant amount of work to program each individual instrument, resolve timing issues, and properly connect signal and triggering cables.

Using an integrated source-measure instrument can reduce the effort required to acquire data, generate I-V curves, and otherwise characterize device performance. Because source and measurement functions are designed simultaneously for tightly coupled operation, they have features that simplify set-up and operation. For example, this tight integration allows easy programming of source and measurement functions, such as speed and noise rejection tradeoffs.

Most SMUs also have built-in voltage and current sweep features for automatic collection of I-V data, and a compliance limit function that assures the safety of a DUT and test personnel.

As a rule, SMU measurement capabilities exceed those of almost any combination of similar individual instruments. This is particularly true when it comes to throughput and accuracy. The intimate knowledge of both source and measurement circuitry during design, and feedback between those circuits during operation, allows compensation techniques that produce excellent instrument characteristics. This includes nearly perfect input and output impedances that can be dynamically adjusted for specific operating conditions. Such tight integration allows fast source-measurement cycles with superior resolution.

Nowhere are these advantages more apparent than in semiconductor measurements, which are conducted on work-in-process wafers, as well as on finished products. In addition to measuring I-V characteristics, these applications often require calculation of resistance, and derivation of other parameters based on the measurements. Many of these applications require instruments with outputs and measurement sensitivity covering a very wide dynamic range. SMUs are ideal instruments for these applications since they can simultaneously apply and measure current and voltage from microvolts and femtoamps up to more than 1000V or 10A.

When low-leakage devices must be tested, there are SMUs available with noise floors as low as 0.4fA p-p, and their guard circuits can alleviate measurement errors due to stray leakage in cables and fixtures. To reduce these leakage currents, the SMU guard buffer (upper right area of Figure 1) creates a low impedance point in the circuit that is nearly the same potential as the high impedance point to be guarded. The Guard Sense lead is used to detect the potential at that point.

SMUs were designed with such applications in mind. For instance, at the low end

of the current range, SMUs can be used to source voltage and measure femptoamp levels of gate or drain (Iddq) leakage as part of a wafer level test monitoring program. In the testing of finished diode products, SMUs easily interface with switching systems for automatic parts binning operations. In these operations, the diodes are connected through the switching system between In/Out HI and In/Out LO (Figure 1). A sweep of voltage is done in the reverse-bias region of a diode to determine leakage current at a known voltage, then a sweep of current is done in the forward-bias region to control power in the device. The effect of incident light or temperature on the diode can be examined by generating a family of I-V curves for different levels of these variables.

For production applications of this type, SMUs have program memory that can rapidly execute a whole series (100 or so) of such tests without tying up an external data bus and remote computer controlling the measurements. Each test sequence can have totally different test conditions, measurements, embedded math functions, pass/fail or binning criteria, and conditional branching.

Usually, SMUs designed for production applications also have a digital I/O interface that lets you link the unit directly to a component handler. I/O signal capabilities include start of test, end of test, category bits, and a 5V relay control output. A hard-wired trigger link between the SMU, component handler, and switching system will further reduce external bus traffic, speed up testing, and help assure adequate setting time between source application and DUT response measurements. With these features and the data buffers in most SMUs, they can be programmed for source-measure sweep cycles at rates up to 2000 readings per second.

When high power pulses are required in applications such as varistor and power MOSFET testing, there are source-measure instruments that can supply up to 1kW amplitudes. In these and many other test set-ups, there can be significant voltage drops in test leads due to the high currents. In this case, you can use an

SMU's 'Remote' test connections, where voltage is measured or controlled between the Sense HI and Sense LO terminals to insure accurate readings.

For example, in the case of a power MOSFET, the drain current is controlled by the gate-source voltage, but as drain current increases, the source voltage tends to increase (i.e., is driven above ground potential) due to test lead resistance. If you are driving 1A through the MOSFET and there is 0.5_ in the test lead, the source can come off ground by 0.5V. The remote sense feature of an SMU can detect this and automatically adjust the output by -0.5V to hold the source at ground, thereby allowing more accurate measurements.

While most SMUs are built for general use, some are designed with a particular application focus. For example, in pulsed testing and other time-sensitive applications, the source must have a fast response to load changes. While general purpose power supplies typically use large output capacitance to maintain a stable voltage, SMUs use an entirely different design that minimizes output capacitance and allows high slew rates. This is essential in pulsed testing of laser diode chips, and for this applications there are SMUs that have current pulse rise and fall times as short as 60ns, with pulse widths as narrow as 500 ns. For laser diode testing, the SMU also has multiple measurement channels. One channel measures voltage across the laser diode, and two voltage-biased current measurement channels are used for simultaneous measurement of front and back photodiode detector outputs, which are needed to characterize edge-emitting lasers.

The wide array of capabilities and functions in SMUs reduce the principle costs associated with many DC data collection projects, i.e., instrument purchases, system integration costs, and testing time. The many models available provide a wide range of features, from simple low-cost units to specialized instruments for highly demanding applications. These instruments provide a fast, easy, and cost-effective method for characterizing a wide array of devices and materials. To

learn more about SMU applications, please review the technical papers available on the Web at www.keithley.com/2400.

About the Author

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