

# Application Overview: Simplified I/V Characterization of Solar Cells

## What is a SMU?

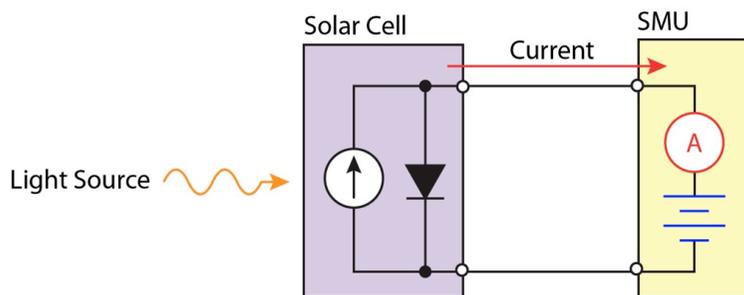
Source measure units (SMUs) are an all-in-one solution for current voltage (I/V) characterization with the combined functionality of a precision power supply, high precision DMM, and electronic load. Keithley pioneered the development of individual, compact, bench-top SMU instruments and is the leading supplier of these instruments today.

## Testing a Solar Cell

A major focus of solar cell researchers and users is improving cell efficiency and maximizing energy extraction. This requires I/V measurements to characterize performance of a solar cell. Keithley's SourceMeter® SMU Instruments are the industry standard for photovoltaic I/V characterization. They are ideal for solar cell testing because:

- They have the ability to act as a sink.
- They can act as a high precision electronic load.
- They provide the industry's widest dynamic range and have high and low current capability.

**Figure 1** below shows a SMU instrument in use for I/V characterization of a solar cell.

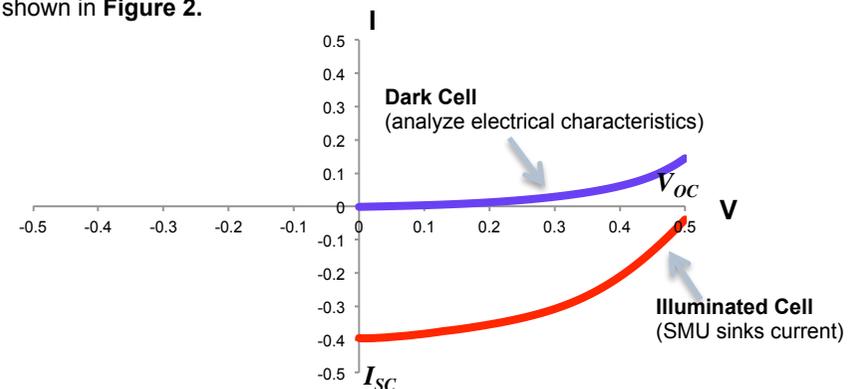


**Figure 1:** Circuit diagram showing a SMU in use for I/V characterization of a solar cell.

## Common Measurements Made in I/V Characterization of Solar Cells

- **Open Circuit Voltage ( $V_{OC}$ )** - The open-circuit voltage ( $V_{OC}$ ) is the maximum voltage available from a solar cell, and this occurs at zero current. The open-circuit voltage is shown on the IV curve below.
- **Short Circuit Current ( $I_{SC}$ )** - The short-circuit current is the current through the solar cell when the voltage across the solar cell is zero (i.e., when the solar cell is short circuited). The short circuit current is shown on the IV curve below.
- **Other common measurements include:**
  - Shunt resistance ( $R_{SH}$ )
  - Conversion efficiency ( $\eta$ )
  - Maximum power output ( $P_{max}$ )
  - Voltage at Pmax ( $V_{max}$ )
  - Resistivity
  - Fill factor (ff)
  - Series resistance ( $R_s$ )

Dark I/V measurements are commonly used to analyze the electrical characteristics of solar cells. Dark I/V measurements are more sensitive than light I/V measurements in determining parameters such as series resistance, shunt resistance, diode factor, and diode saturation currents. The I/V curves of a dark and illuminated cell obtained using a Keithley SMU instrument is shown in **Figure 2**.

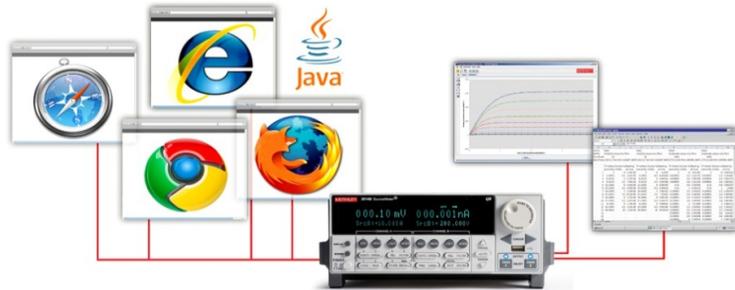


**Figure 2:** I/V curve of a solar cell.

## What are Series 2600B SourceMeter SMU Instruments?

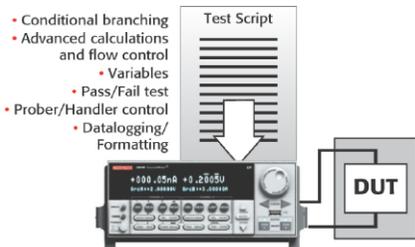
The Series 2600B are the industry's leading current/voltage source and measure solutions, and are built from Keithley's 3<sup>rd</sup> generation SMU technology. The Series 2600B offers single-and dual-channel models that significantly boost productivity in applications ranging from bench-top I/V characterization through highly-automated production test.

### Browser-based Testing



The Series 2600B are the only SMU Instruments to feature built-in, Java-based test software that enables true plug & play I/V characterization through any browser, on any computer, from anywhere in the world. Simply connect the Series 2600B instrument to the Internet via the supplied LAN cable, open a browser, type in the Series 2600B instrument's I.P. address, and begin testing. Resulting data can then be exported to a spreadsheet, such as Excel, for further analysis and formatting, or for inclusion in other documents & presentations.

### Automated Testing without Control of a PC



For test applications that demand the highest levels of automation and throughput, the Series 2600B's test script processor (TSP®) technology delivers industry-best performance by fully embedding and then executing complete test programs from within the SMU instrument itself. This virtually eliminates all the time-consuming bus communications to and from the PC controller, and thus dramatically improves overall test times.

## Key Specifications of the Series 2600B SourceMeter SMU Instruments

Features	2601B / 2611B Single Channel	2602B / 2612B Dual Channel	2604B / 2614B Dual Channel Bench-Top	2634B / 2635B / 2636B Low Current Single Channel (2635B) Dual Channel (2634B, 2636B)
# of Channels	1 (optional expansion to 32 via TSP-Link)	2 (optional expansion to 64 via TSP-Link)	2	1 – 2 (optional expansion to 32 or 64 via TSP-Link. Not available for 2634B)
Current Max / Min	10A pulse / 100fA	10A pulse / 100fA	10A pulse / 100 fA	10A pulse / 0.1fA for 2635B 10A pulse / 0.1fA for 2636B 10A pulse/ 1fA for 2634B
Voltage Max / Min	40V / 100nV for 2601B 200V / 100nV for 2611B	40V / 100nV for 2602B 200V / 100nV for 2612B	40V / 100nV for 2604B 200V / 100nV for 2614B	200V / 100nV
Power	30 – 40W	30 – 40W per channel	30 – 40W per channel	30W per channel
Max readings / sec	20,000	20,000	20,000	20,000
Computer Interface	GPIB, LAN (LXI), USB 2.0, RS-232			
Connectors/ Cabling	Screw terminal; adaptors available for banana or triax	Screw terminal; adaptors available for banana or triax	Screw terminal; adaptors available for banana or triax	Triax
System-level automation	Digital I/O, TSP-Link, Contact Check	Digital I/O, TSP-Link, Contact Check	Not available	Digital I/O, TSP-Link, Contact Check (not available on 2634B)

For additional information, please refer to Keithley's website at [www.keithley.com](http://www.keithley.com) for:

- Detailed Series 2600B specifications
- Application notes
- White papers

For other information, please contact your local applications engineer.