

# Technical Information

## Source Measurement Unit (SMU) Instruments

All of Keithley's source measurement unit (SMU) instruments can source voltage while measuring current and source current while measuring voltage. Some also measure resistance. All are fully programmable instruments that can stand alone as complete source, measurement, and automation solutions. They are also easy to integrate into larger systems.

Keithley's SMU instruments are faster, easier to use, and more economical than using individual power supplies and measurement instruments that are harnessed together. Additionally, they provide more accurate and repeatable results. Keithley's SMU instruments are ideal for production and automation, yet precise and sensitive enough for laboratory applications.

Keithley's SMU instruments include our Series 2400 SourceMeter® instruments, Series 2600A System SourceMeter instruments, Model 237 High-Voltage Source-Measure unit, and Model 4200-SCS Semiconductor Characterization System.

### How does an SMU instrument work?

SMU instruments can be used as stand-alone constant voltage or constant current sources and as stand-alone voltmeters or ammeters. However, their real strength is their ability to simultaneously source and measure—applying voltage to a device under test (load) and measuring the current flowing through it, or supplying current to a load and measuring the voltage drop across it.

The SMU instrument topology (Figure 1) protects the device under test (DUT) from damage due to accidental overloads, thermal runaway, and other problems. Both the current and voltage source are programmable with readback to maximize device measurement integrity. If the readback reaches a programmed compliance limit, then the source is clamped at the limit, providing fault protection.

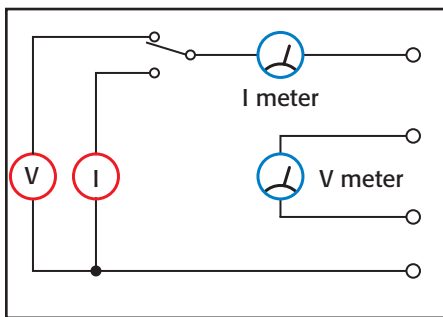


Figure 1. Basic SMU instrument topology

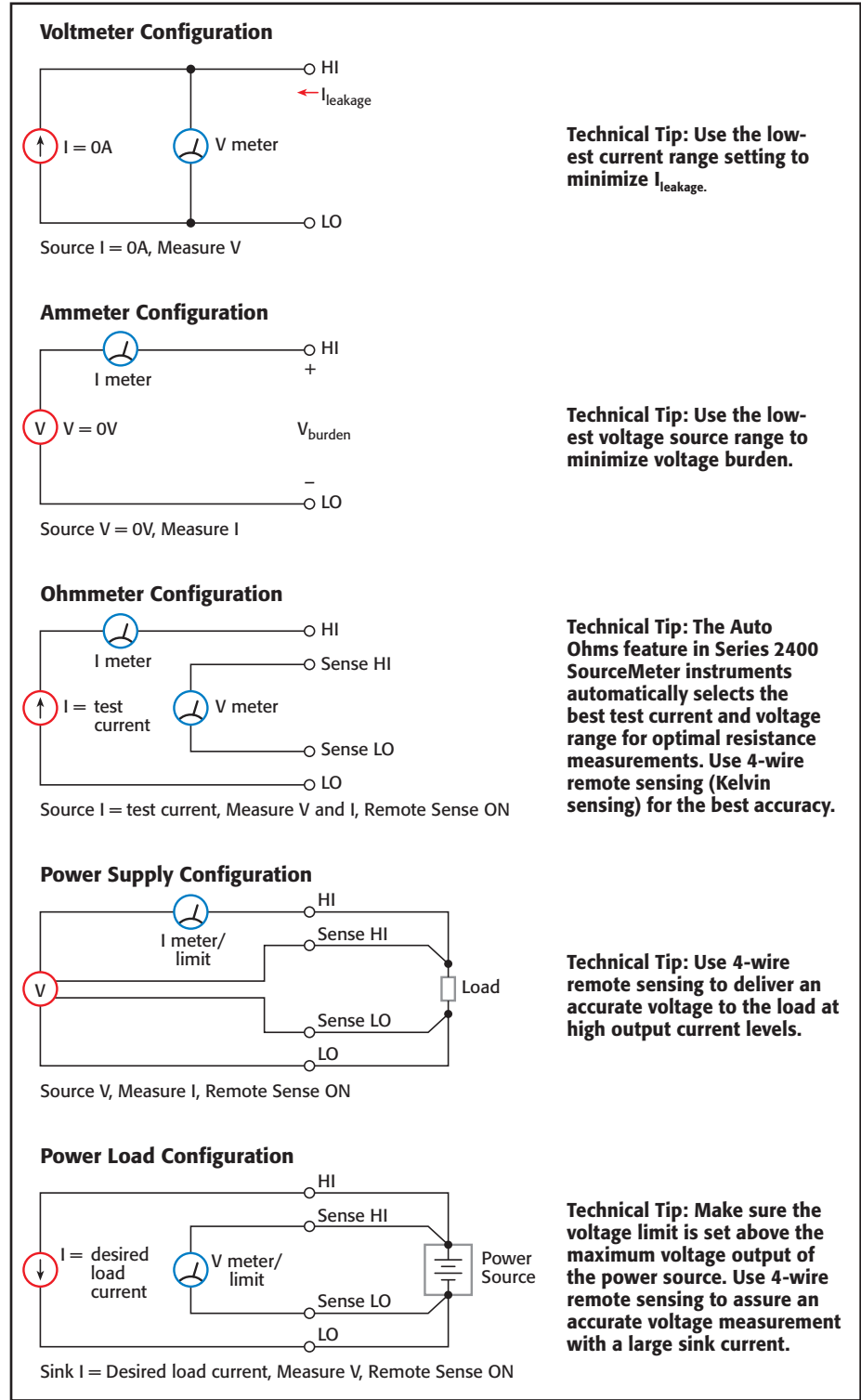


Figure 2. SMU instrument configurations

**Technical Tip:** Use the lowest current range setting to minimize  $I_{leakage}$ .

**Technical Tip:** Use the lowest voltage source range to minimize voltage burden.

**Technical Tip:** The Auto Ohms feature in Series 2400 SourceMeter instruments automatically selects the best test current and voltage range for optimal resistance measurements. Use 4-wire remote sensing (Kelvin sensing) for the best accuracy.

**Technical Tip:** Use 4-wire remote sensing to deliver an accurate voltage to the load at high output current levels.

**Technical Tip:** Make sure the voltage limit is set above the maximum voltage output of the power source. Use 4-wire remote sensing to assure an accurate voltage measurement with a large sink current.

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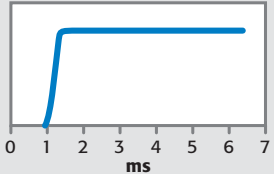
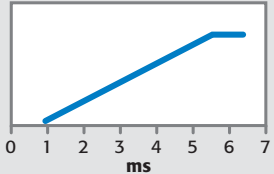
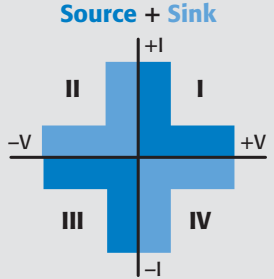
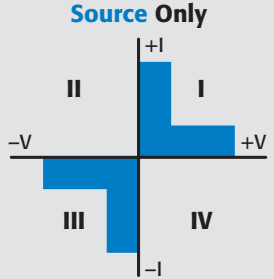
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	2602A SourceMeter Instrument	Typical Power Supply
<b>Speed</b>		
<b>Source/Measure Precision</b>	10 $\mu$ A measurement uncertainty = 5nA	10 $\mu$ A measurement uncertainty = 2500nA
<b>Voltage and Current Resolution</b>	<p><b>Voltage</b></p> <p>1<math>\mu</math>V to 40V</p> <p><b>Current</b></p> <p>1pA to 3A</p>	<p><b>Voltage</b></p> <p>1<math>\mu</math>V to 40V</p> <p><b>Current</b></p> <p>1pA to 3A</p>
<b>4 Quadrant Operation</b>		

SMU instruments are optimized for speed and precision. In most models, both the source voltages and source currents settle to within 0.01% of the specified accuracy in as little as 50 $\mu$ s. This is 50 times faster than what a conventional power supply can provide.

SMU instruments offer a much broader range of voltage and current resolution than conventional power supplies. This allows you to use SMU instruments in many more types of applications.

A conventional power supply sources (supplies) voltage and/or current. An SMU instrument also sources power, but it can additionally sink (dissipate) power. It provides four-quadrant operation. In quadrants I and III it sources power to a load and in quadrants II and IV it sinks power from a load. (Voltage, current, and resistance can be measured during source or sink operations.) A conventional power supply only functions in quadrant IV.

Figure 3. Precision power supplies vs. SMUs

## Advantages

Many advantages are achieved by combining source and measurement circuitry into a single unit:

- Supports faster test times with improved accuracy and repeatability
- Allows you to source voltage or current while making time-stamped voltage, current, and resistance measurements without changing connections
- Eliminates many of the complex synchronization, connection, and programming issues associated with using multiple instruments
- Minimizes the time required for test station development, setup, and maintenance
- Lowers the overall cost of system ownership

## What are the most popular SMU instrument configurations?

The fully isolated, floating configuration of Keithley's SMU instruments provide maximum flexibility in configuring test setups. SMU instruments can be configured as many different instruments (Figure 2). This makes them invaluable tools in flexible product test racks and in R&D test bench tools.

## How does an SMU instrument compare to a precision power supply?

The power supply capabilities of Keithley's SMU instruments surpass those provided by conventional power supplies. This is illustrated in Figure 3. In addition to the highly stable DC power source, low noise, and readback, Keithley's SMU instruments include other features not usually available on conventional power supplies. For example, most SMU instru-

ments offer a Pulse mode, include programmable delays, and provide a test sequencer that allows you to set up and execute tests without PC intervention. Figure 4 illustrates a typical precision power supply test that uses an SMU instrument.

## I-V characterization

Keithley's SMU instruments are core instruments for I-V characterization tests. Their ability to source voltage while simultaneously measuring current or source current while simultaneously measuring voltage can be combined with both DC and sweep operations to perform measurements such as forward voltage ( $V_F$ ), reverse leakage, and reverse breakdown voltage ( $V_B$ ) without changing a single connection to the device under test (Figure 5).

Built-in features allow multiple SMU instruments to be synchronized for parametric measure-

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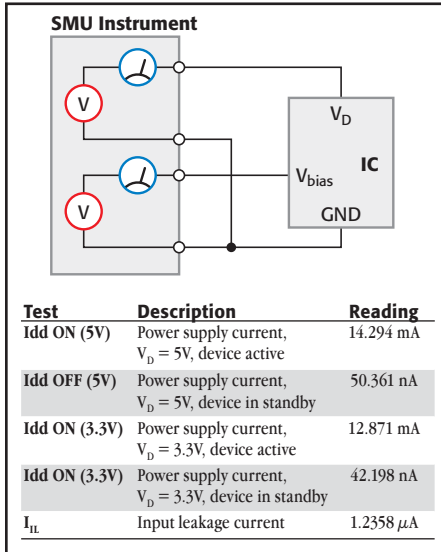


Figure 4. Typical precision power supply tests

ments like threshold voltage, beta, and transconductance. Output interlocks provide controlled access to a test fixture, which is particularly important for the extended voltage range of the Model 237 (up to 1100V). Guarded 4-wire connections provide high quality measurements over a wide range (1fA to 10A).

A family of semiconductor curves can be obtained with just two SMU instruments (Figure 6). At each step of base current from SMU1, SMU2 sweeps V<sub>CE</sub> and measures I<sub>C</sub>. An SMU instrument can store data from a sweep in its buffer, thus reducing data transfer time to a computer. A family of curves could also be produced using pulse-sweeps to reduce power dissipation within a device.

### Built-In Sweeps

Keithley's SMU instruments simplify capturing the data needed to characterize a wide range of devices with the SMU instruments' built-in pulsed and DC sweeps, including linear staircase, logarithmic staircase, and custom sweeps (Figure 7). Sweeps coupled with other throughput enhancements like built-in limit inspection, digital I/O, and a component handling interface are ideal for high speed, nonstop production environments. All sweep configurations can be programmed for single-event or continuous operation.

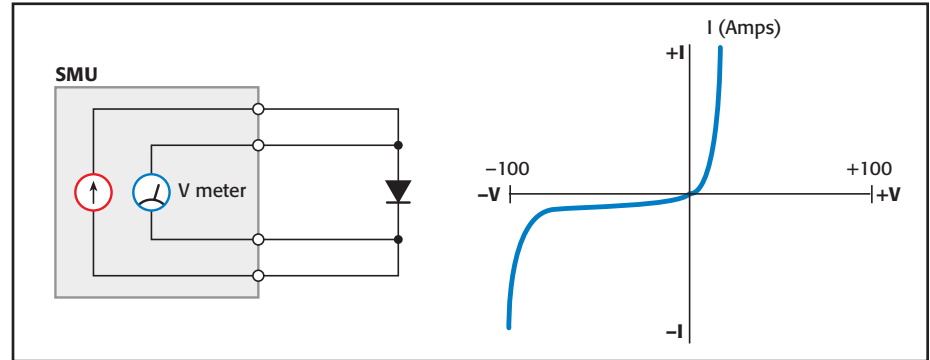


Figure 5. Typical diode characterization

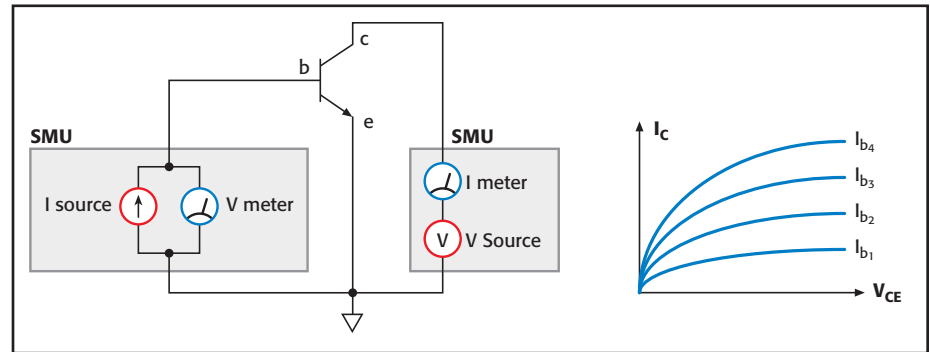


Figure 6. Typical family of curves for transistors

### Instrumentation and software solutions for I-V characterization

Figure 8 illustrates various hardware and software solutions for I-V characterization. In the first example, Series 2400 SourceMeter instruments are connected to a PC.

In the second example, Series 2600A SourceMeter instruments are connected to a PC with TSP-Link® technology. TSP-Link technology seamlessly integrates multiple Series 2600A instruments into a single system that can be programmed and controlled as a single instrument through the master 2600A instrument or the PC.

The third example is the Model 4200-SCS Semiconductor Characterization System. This system includes an embedded PC, Windows® operating system, and mass storage. It is a complete DC characterization solution for semiconductor devices and test structures. It supports up to nine SMU modules and provides an array of Windows based software that is so intuitive that even a novice can use the system with ease. This point-and-click software supplies a full range of functionality, including: managing tests,

generating reports, automating test sequencing, and creating user libraries. The Model 4200-SCS is a complete one box solution that combines sub-femtoamp resolution with real-time plotting and analysis. Key capabilities include instrument and prober drivers, interfaces to popular modeling/circuit simulation software, and WLR test capabilities.

### High-Speed I-V Functional Testing

Keithley's SMU instruments are designed for maximum throughput on the production floor. Each SMU instrument provides high-speed measurements, an internal pass/fail comparator, programmable test sequencing, and digital I/O to control material handlers (Figure 9). Single- or multi-point pass/fail testing can be performed on a wide range of components, such as: network devices, circuit protection devices, active discrete devices, and sensors. The onboard pass/fail comparator simplifies high-speed pass/fail tests by avoiding the delay caused by computer and GPIB bus interaction. The buffer memory stores results, again avoiding the computer/GPIB bus interaction delay.

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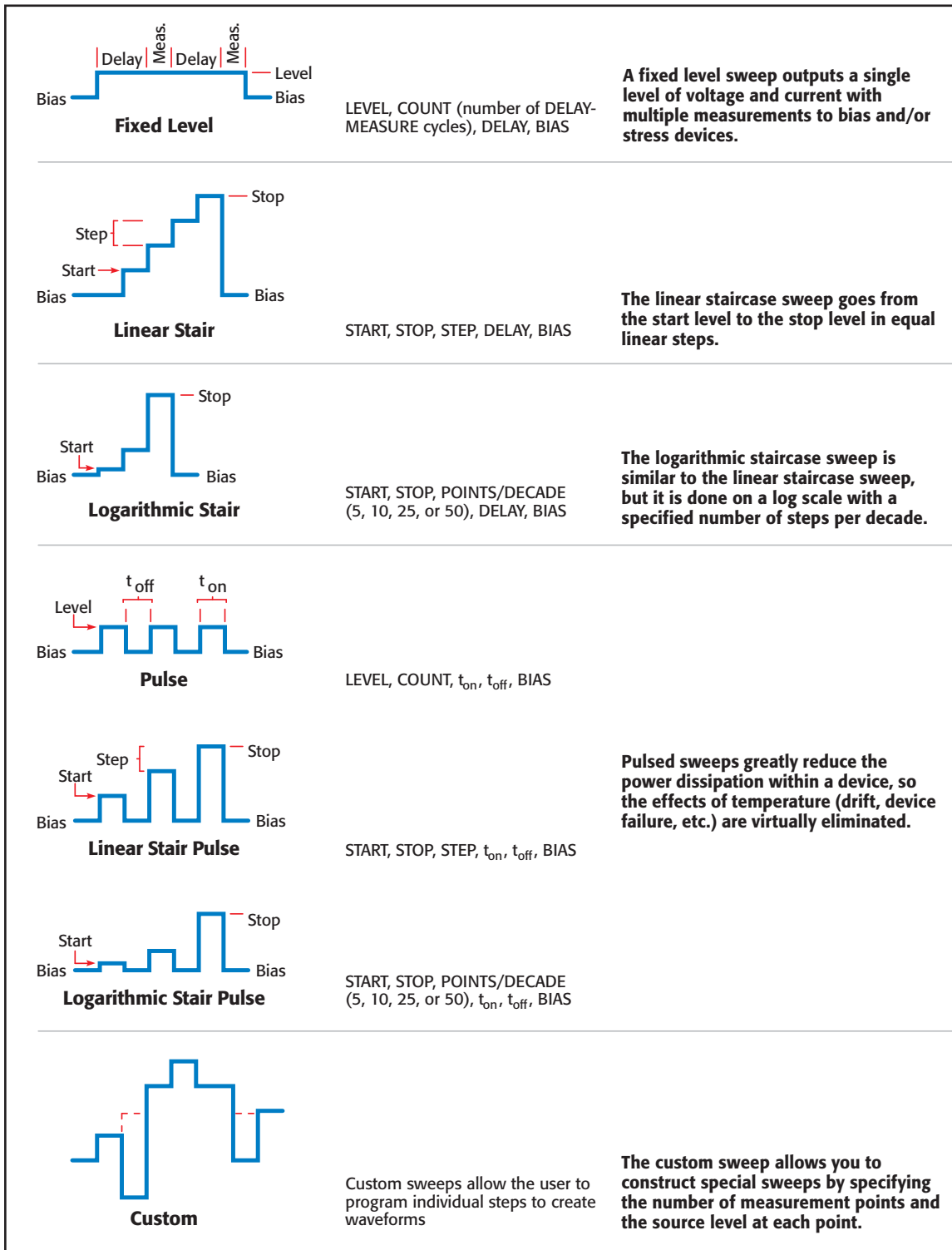


Figure 7. Various sweeps supported by SMU instruments.

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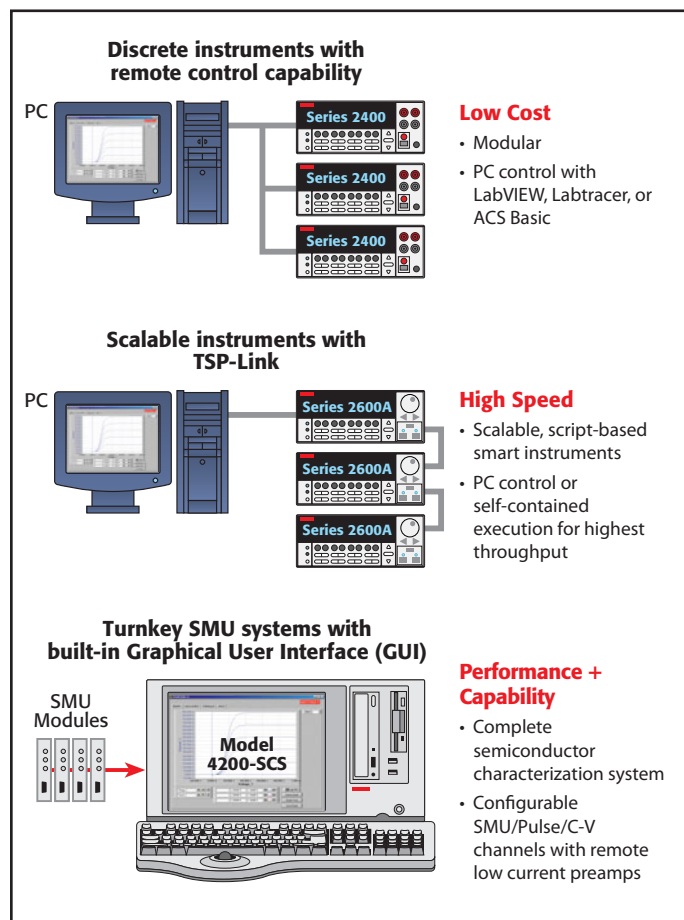


Figure 8. Examples of I-V characterization solutions

## Need more test pins?

Keithley's new TSP-Link technology is a high speed interface for system expansion. It allows you to connect a virtually unlimited number of Series 2600A SourceMeter instruments in a master/slave configuration (Figure 10). All connected Series 2600A instruments can be programmed and operated under the control of the master instrument. TSP-Link technology provides an easy way to scale your system's channel count up or down to match changing application needs. There is no chassis involved.

In Series 2400 SourceMeter instruments, Trigger Link can be used to coordinate multiple instruments with hardware triggers.

## Parallel test capability

Series 2600A instruments support true parallel testing. Each 2600A in a system can run its own test sequences, so the number of devices that can be tested in parallel is equivalent to the number of 2600A instruments in the system. Parallel testing coupled with the 20,000 rdgs/s of each 2600A creates a system that offers extremely high throughput.

## Advanced automation for system throughput

### Series 2600A TSP® Technology

Any Series 2600A instrument or 2600A-based system can run high speed, embedded test scripts with Test Script Processor (TSP) technology. The test sequence is processed and run on the embedded computer in the instrument, rather than from an external PC controller, so delays due to GPIB traffic congestion are eliminated (Figure 11). TSP test scripts allow throughput gains of up to 10x over equivalent PC-based programs controlling the same instruments via GPIB. TSP test scripts can be loaded and run from the front panel or over the system's GPIB interface. A single TSP test script, running on the master 2600A unit, can control all Series 2600A channels and acquire data from any Series 2600A instrument connected to the system with TSP-Link technology.

A Series 2600A-based system can stand alone as a complete measurement and automation solution for semiconductor device or component testing with the master 2600A unit controlling sourcing, measurements, pass/fail decisions, test sequence flow control, binning, the component handler, prober, and much more.

### Series 2400 Source-Memory List

The Source-Memory List in Series 2400 SourceMeter instruments is a key feature for production testing. This programmable sequencer lets you set up a complete sequence of up to 100 tests. Each test can contain totally different test conditions, measurements, math, pass/fail, and binning criteria. The tests are executed sequentially without additional external commands. Conditional branching leads to different points on the test list, depending on the results.

The Source-Memory Sweep feature allows you to store up to 100 unique source and measure configurations in nonvolatile memory. This feature makes it possible to sweep through a group of source memory locations and execute a complete test sequence all at one time.

## Digital I/O

Digital communication is one of the most common requirements of a production test system because of the need to communicate with handlers, binning equipment, and user controls. The SMU instruments' digital I/O can also be used to interact with racks of instruments to trigger events, start readings, and collect results. Digital triggering and response enable fast and reliable results that are not dependent on the communication bus in use. (Digital I/O is not available on the Model 2401.)

## Contact check

The optional Contact Check function eliminates measurement errors and false product failures by verifying good connections to the DUT quickly and easily before testing begins. In just 350µs (Series 2400) or 1ms (Series 2600A), this function's verification and notification routine ensures that you have good contact to a device before sending energy through it and spending time testing it (Figure 12). (The Contact Check function is not available on the Model 2401.)

Some of the problems this function can detect while verifying connector, fixture, and test harness integrity are contact fatigue, breakage, contamination, corrosion, loose or broken connections, and relay failures. If a bad contact is detected, it can abort the measurement, protecting the DUT. Three methods of fault notification are provided.

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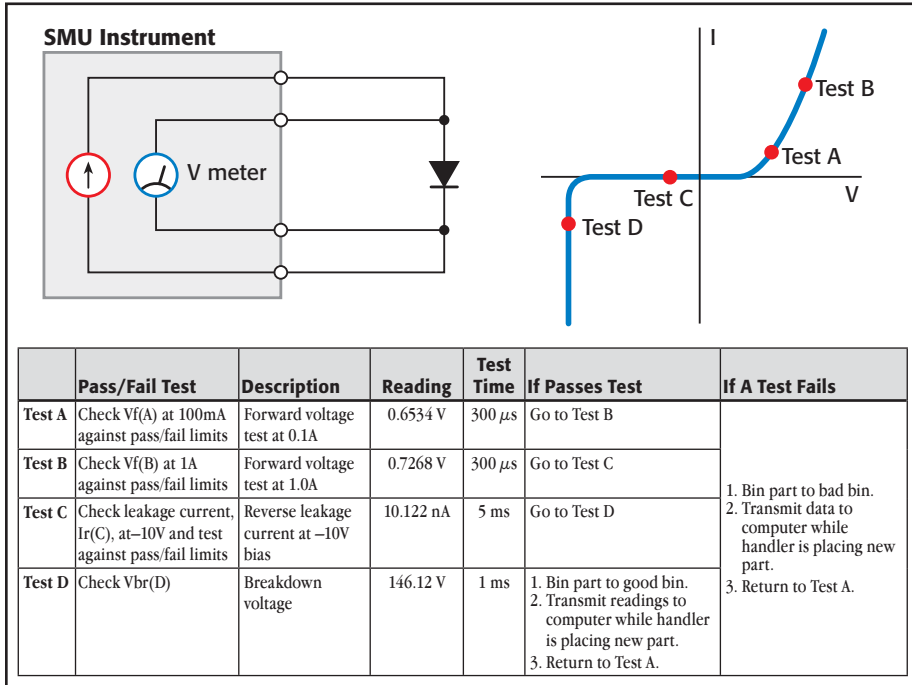


Figure 9. Typical high speed I-V functional test

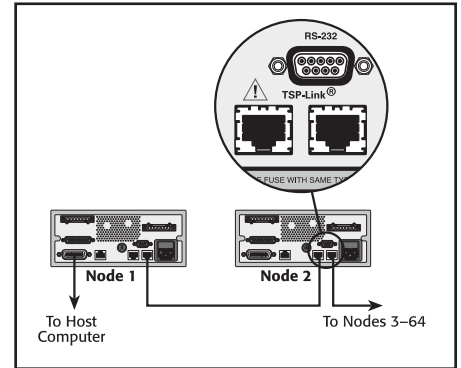


Figure 10. Series 2600A back panel

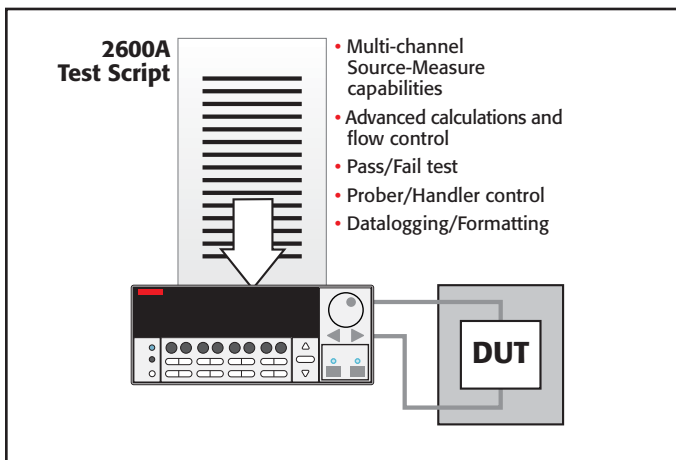


Figure 11. Series 2600A test script

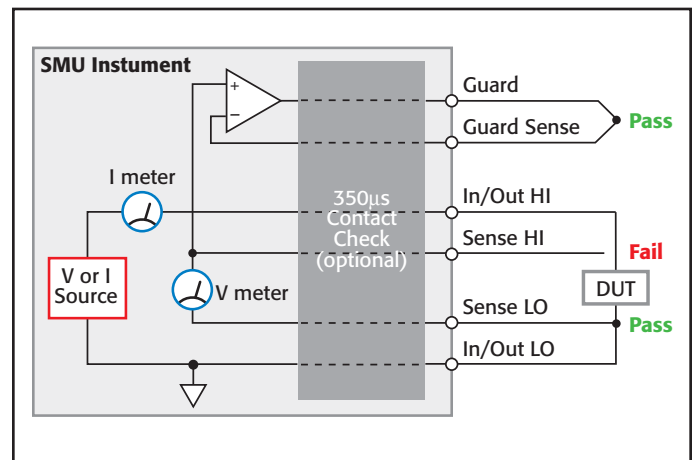


Figure 12. Series 2400 contact check

The Contact Check function was designed for high throughput 4-wire and 6-wire test applications. In Series 2400 SourceMeter instruments, three reference value choices (2 $\Omega$ , 15 $\Omega$ , and 50 $\Omega$ ) are supplied. If the resistance of good connections normally exceeds 50 $\Omega$ , then the built-in contact check

function is not suitable for that application and alternative approaches should be considered. Series 2600A instruments provide more flexibility with programmable values.

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