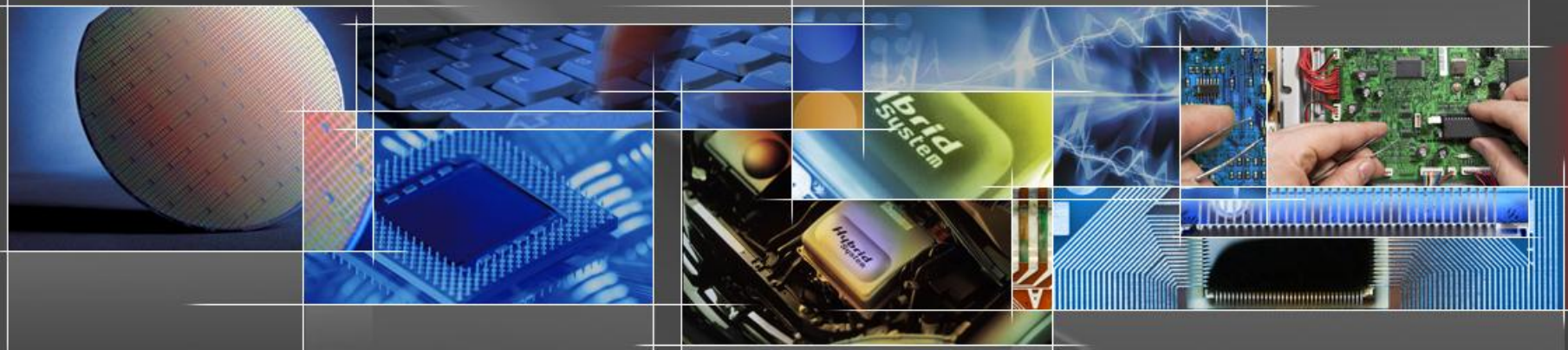
What is an SMU Instrument, and How Do You Decide Which One is Right for Your Application?

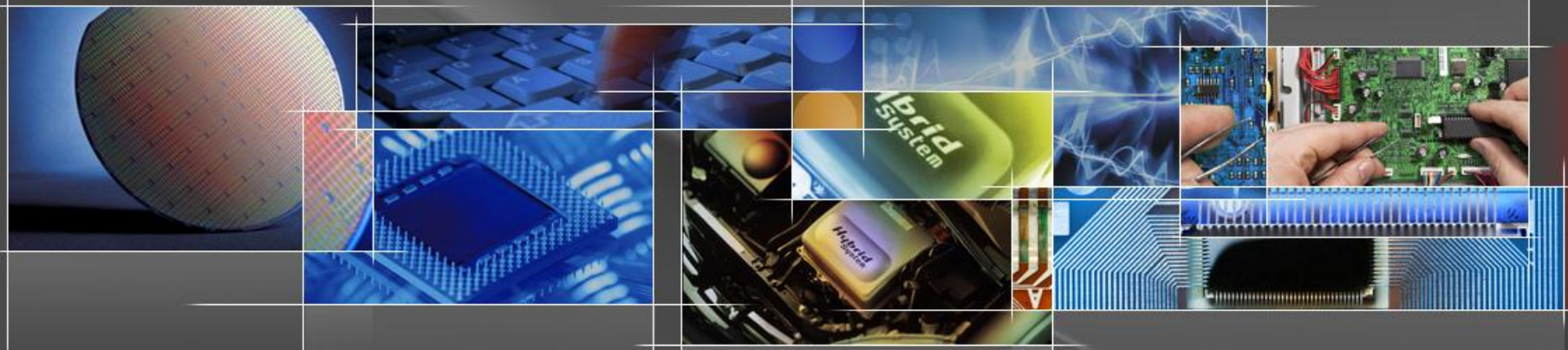
KEITHLEY



Lishan Weng
Keithley Instruments, Inc.

SMU Instrument Basics

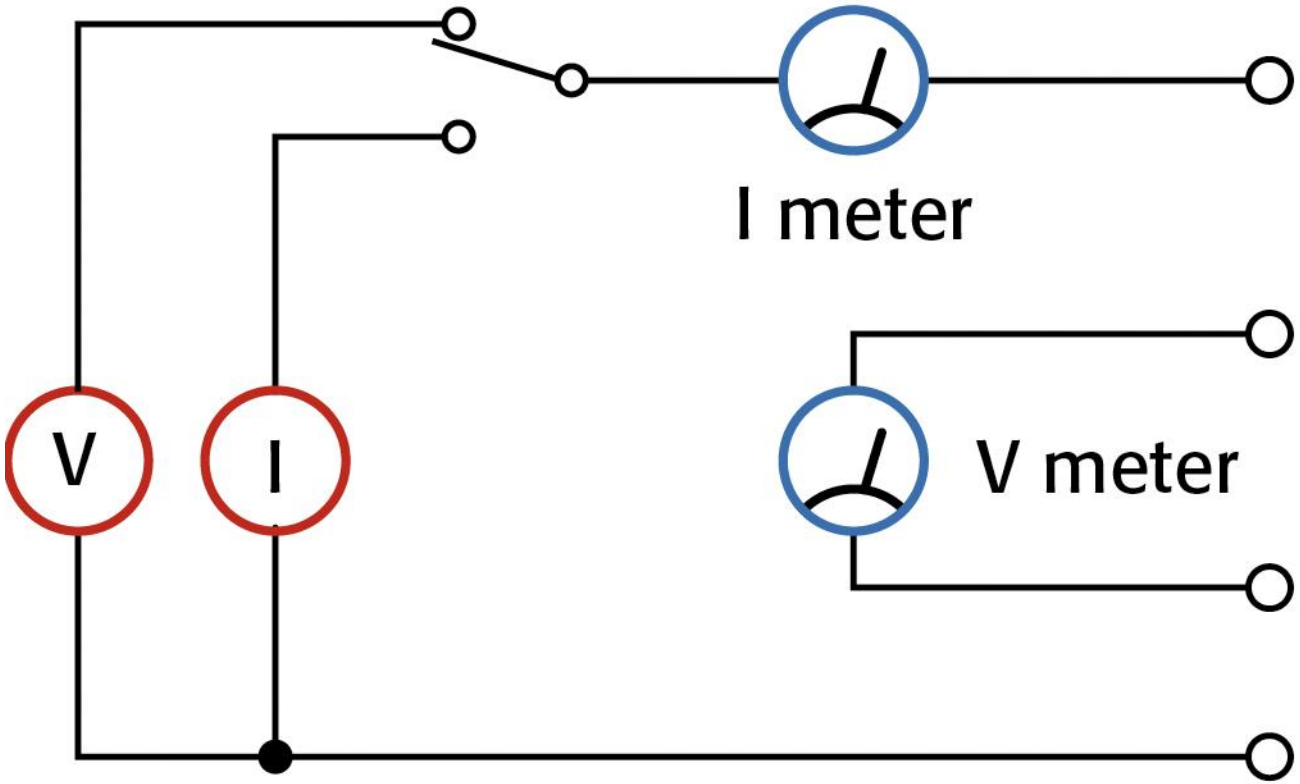
KEITHLEY



A GREATER MEASURE OF CONFIDENCE

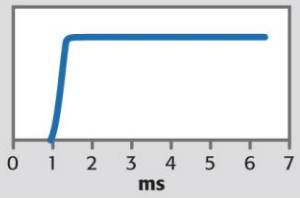
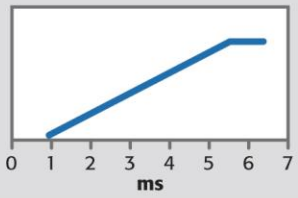
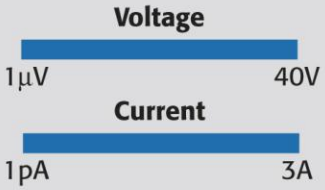
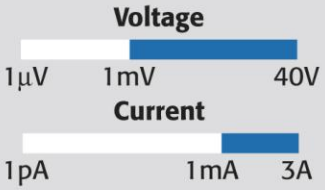
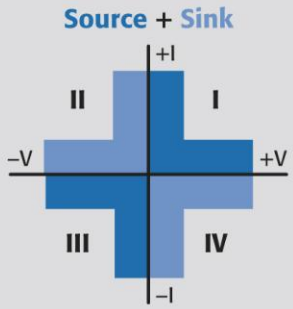
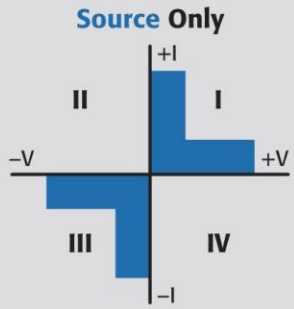
KEITHLEY

Basic SMU Topology

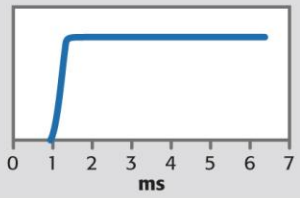
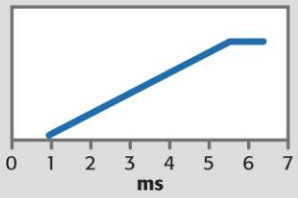
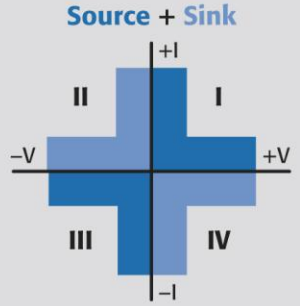
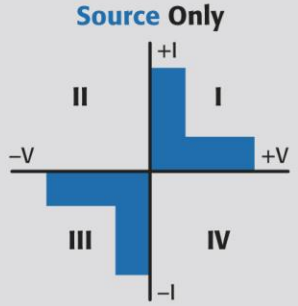


KEITHLEY

SMUs compared to Power Supplies

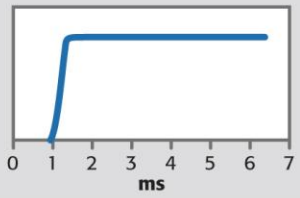
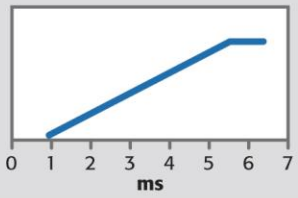
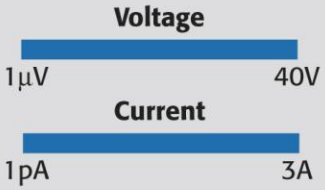
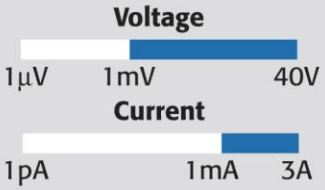
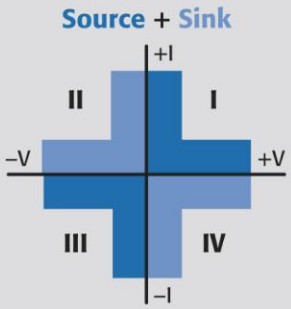
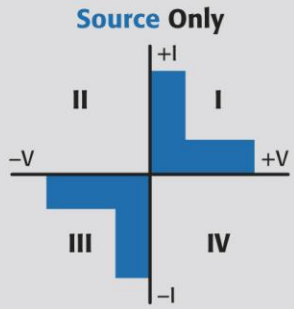
	2602A SourceMeter Instrument	Typical Power Supply
Speed		
Source/ Measure Precision	10µA measurement uncertainty = 5nA	10µA measurement uncertainty = 2500nA
Voltage and Current Resolution		
4 Quadrant Operation		

SMUs compared to Power Supplies

	2602A SourceMeter Instrument	Typical Power Supply
Speed		
Source/ Measure Precision	10µA measurement uncertainty = 5nA	10µA measurement uncertainty = 2500nA
Voltage and Current Resolution	Voltage: 1µV … 40V Current: 1pA … 3A	Voltage: 1µV, 1mV … 40V Current: 1pA … 1mA, 3A
4 Quadrant Operation		

KEITHLEY

SMUs compared to Power Supplies

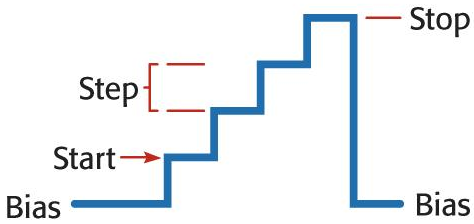
	2602A SourceMeter Instrument	Typical Power Supply
Speed		
Source/ Measure Precision	10µA measurement uncertainty = 5nA	10µA measurement uncertainty = 2500nA
Voltage and Current Resolution		
4 Quadrant Operation		

KEITHLEY

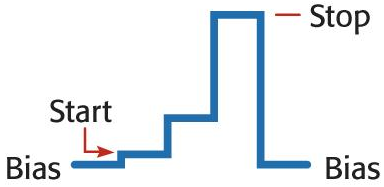
Built-in Sweeps

DC

Fixed Level

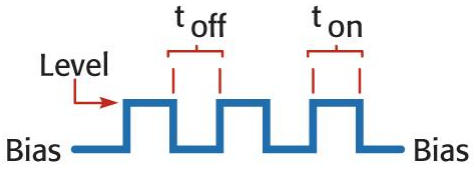


Linear Stair

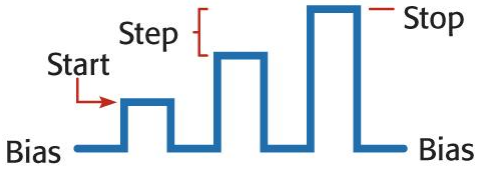


Logarithmic Stair

Pulse



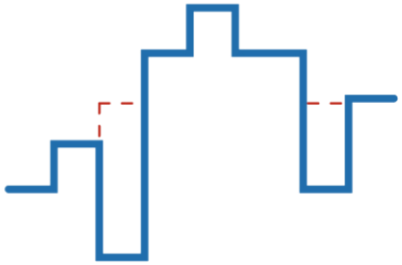
Pulse



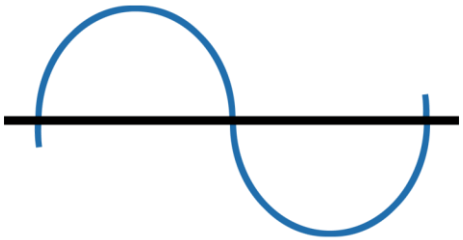
Linear Stair Pulse

Logarithmic Stair Pulse

Custom



Arbitrary

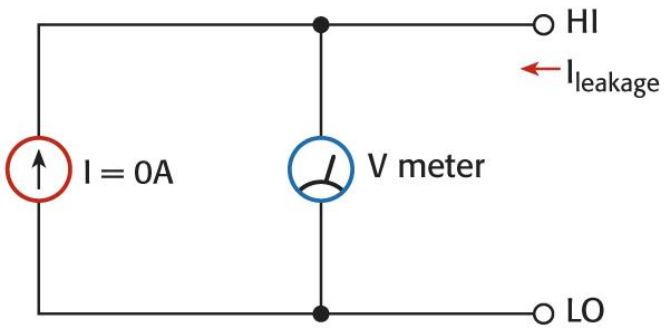


Sine Wave

KEITHLEY

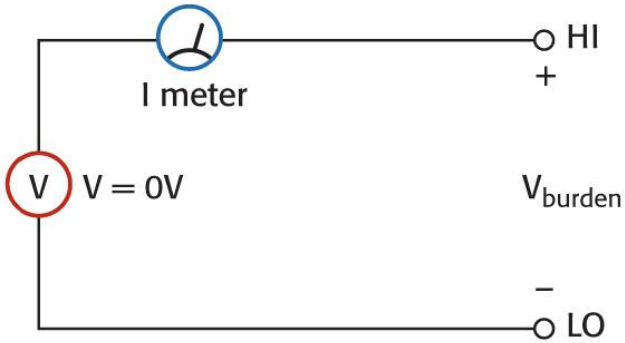
SMUs compared to DMMs

Voltmeter Configuration



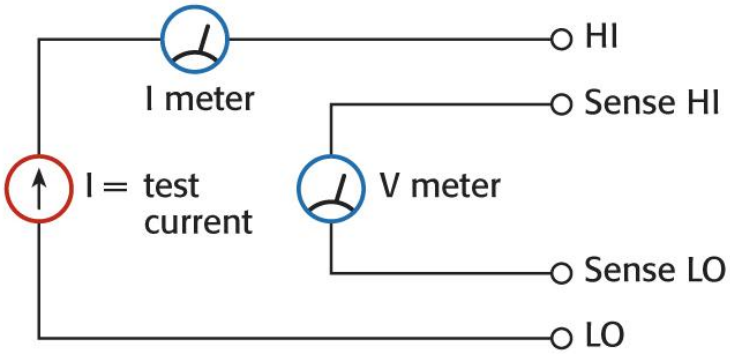
Source I = 0A, Measure V

Ammeter Configuration



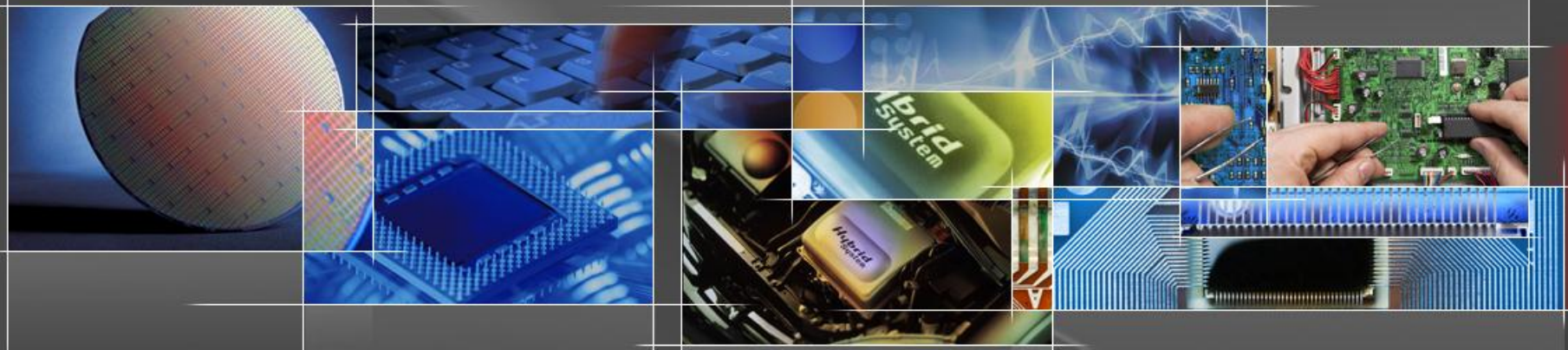
Source V = 0V, Measure I

Ohmmeter Configuration



Measurement Terminology

KEITHLEY



A GREATER MEASURE OF CONFIDENCE

KEITHLEY

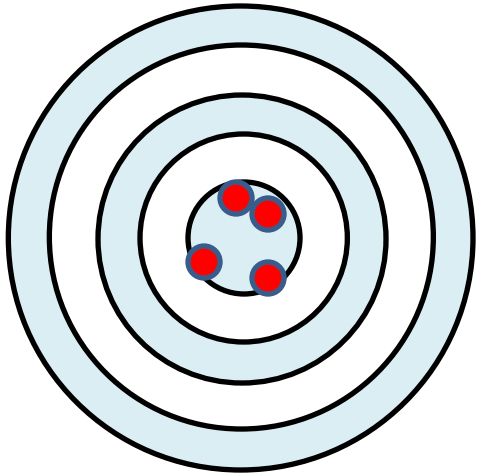
Measurement Terminology

- Accuracy
- Repeatability
- Resolution
- Sensitivity
- A/D Converter Integration Time (NPLC)

KEITHLEY

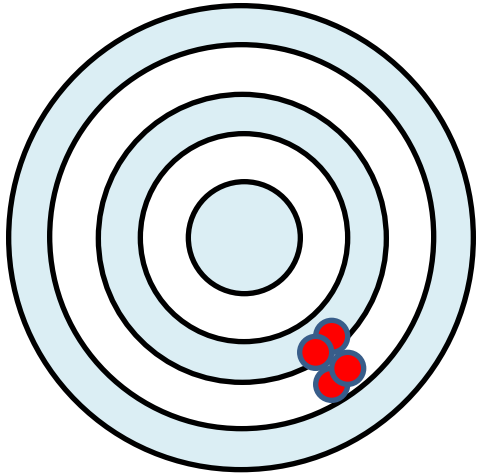
Measurement Terminology

Accuracy



The closeness of agreement between the result of a measurement and it's true value or accepted *standard value.*

Repeatability



The closeness of agreement between *successive* measurements carried out under the same conditions.

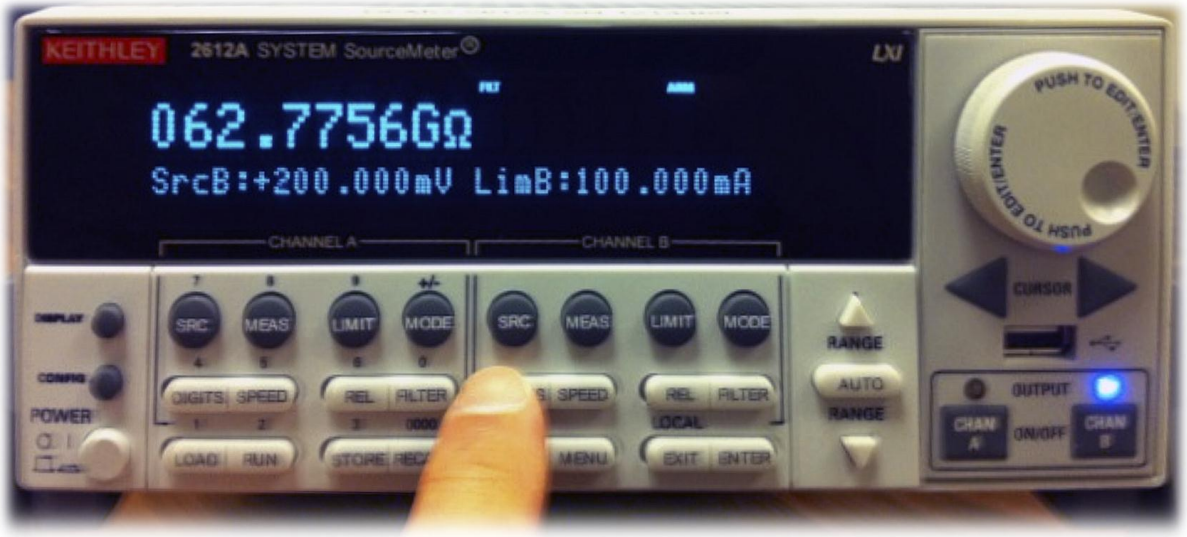
Measurement Terminology

Resolution

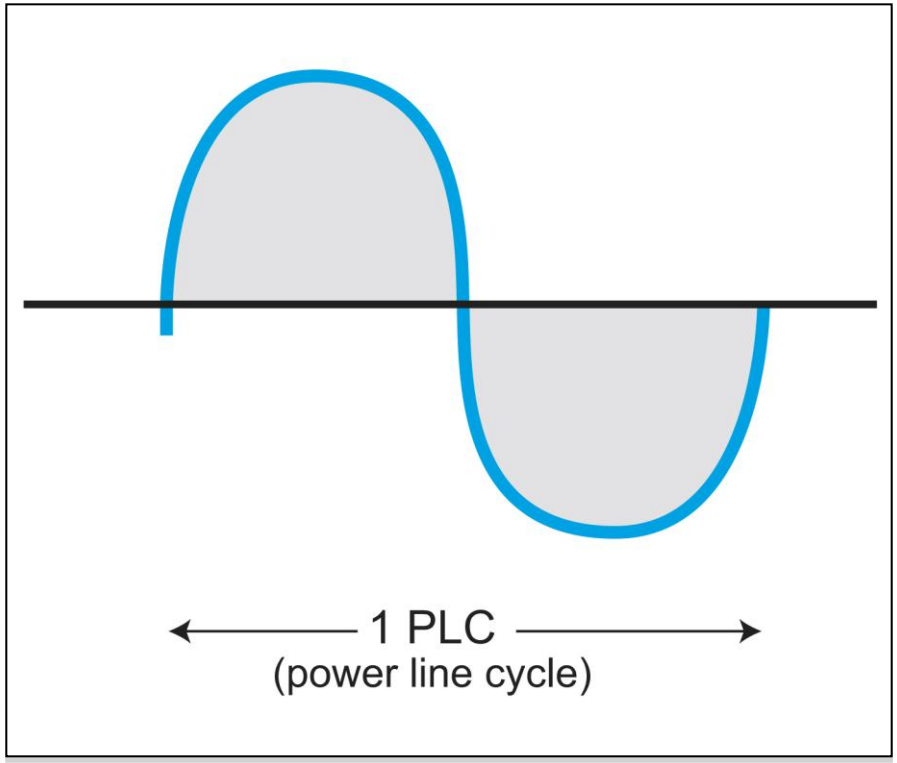
The smallest *portion* of the signal that can be observed.

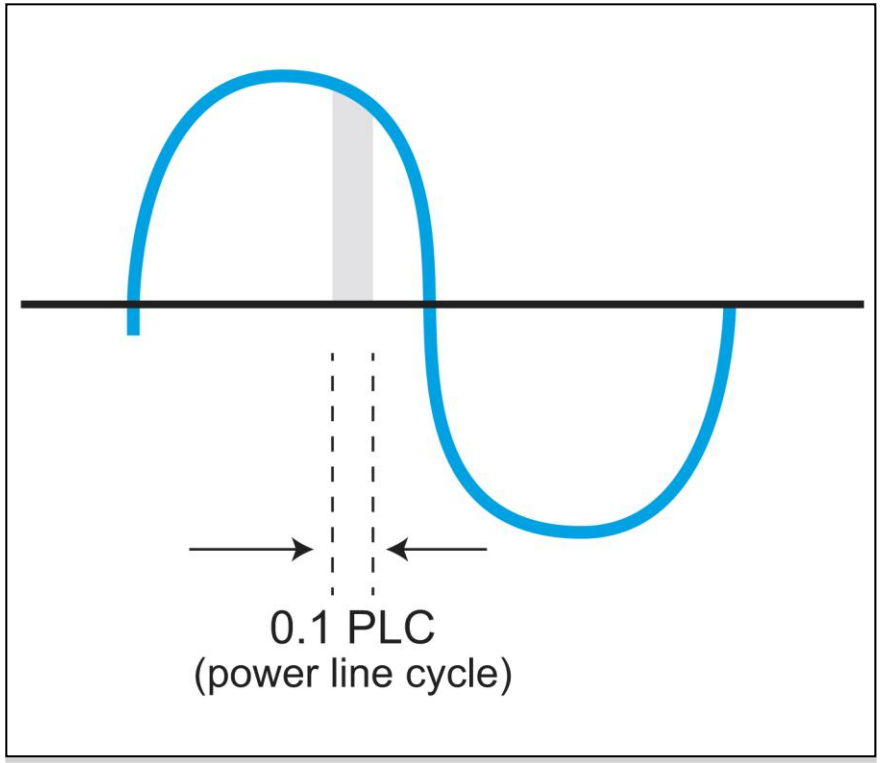
Sensitivity

The smallest *change* in the signal that can be detected.



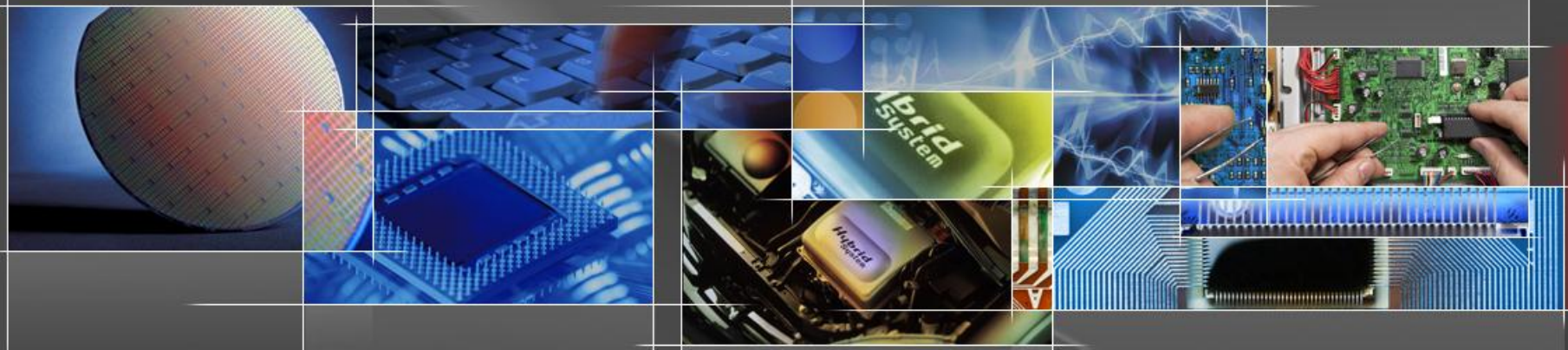
A/D Converter Integration Time (NPLC)





Key Considerations for Selecting a SMU Instrument

KEITHLEY



A GREATER MEASURE OF CONFIDENCE

KEITHLEY

Key Considerations for Selecting a SMU Instrument

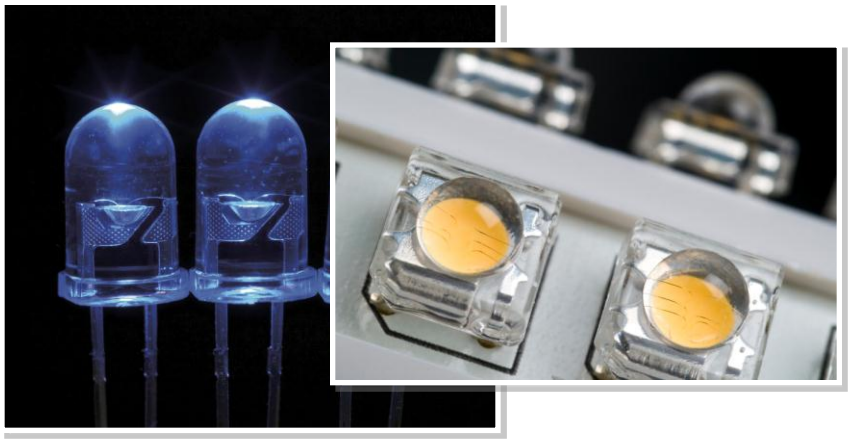
- System-level Speed / Throughput
- Source Resolution vs. Stability
- Measure Settling Time, Offset Error, Noise
- Cabling and Connections

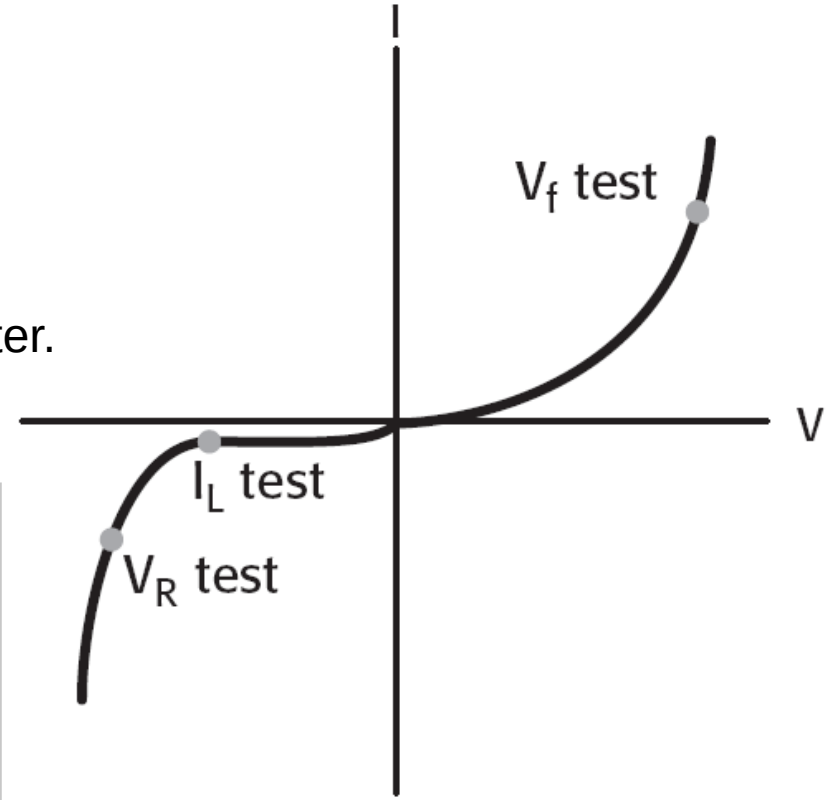
KEITHLEY

System-level Speed / Throughput

Example: Diode / LED Test

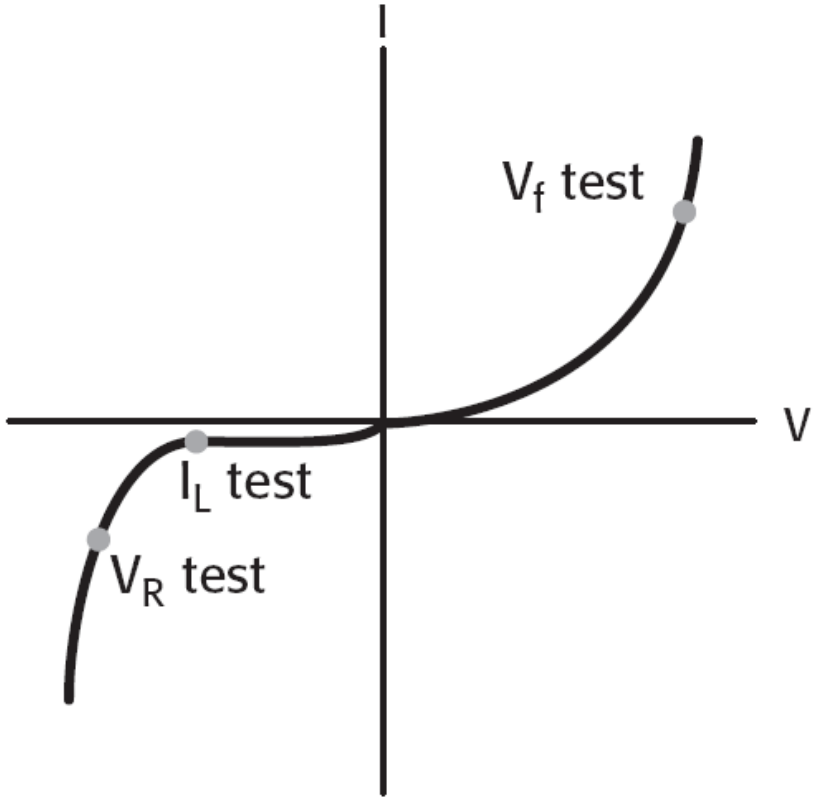
- Three Measurements
  - V_f – Forward Voltage
  - V_R – Reverse Breakdown Voltage
  - I_L – Reverse Leakage Current
- Measurements are compared against upper and lower limits for each parameter.





System-level Throughput Considerations

- Must consider and optimize all elements of speed:
  - Trigger In Time
  - Range Change Time
  - Function Change Time
  - Source Settling Time
  - A/D Converter (NPLC)
  - Measurement Speed
  - Trigger Out Time
  - Program Execution Time



Test Throughput: Actual Parts per Second

(more is better!)

	1 NPLC	0.1 NPLC	0.01 NPLC	0.001 NPLC	0.00048 NPLC
Non-Keithey SMU instrument	6.1	8.1	8.2	8.2	8.2
Keithley 2600A Series	13.3	33.2	37.8	38.2	N/A

Most accurate ⟷ Least accurate

Test Throughput: Actual Parts per Second

(more is better!)

	1 NPLC	0.1 NPLC	0.01 NPLC	0.001 NPLC	0.00048 NPLC
Non-Keithey SMU instrument	6.1	8.1	8.2	8.2	8.2
Keithley 2600A Series	13.3	33.2	37.8	38.2	N/A

Most accurate ⟷ Least accurate

Test Throughput: Actual Parts per Second

(more is better!)

	1 NPLC	0.1 NPLC	0.01 NPLC	0.001 NPLC	0.00048 NPLC
Non-Keithey SMU instrument	6.1	8.1	8.2	8.2	8.2
Keithley 2600A Series	13.3	33.2	37.8	38.2	N/A

Most accurate ⟷ Least accurate

KEITHLEY

Test Throughput: Actual Parts per Second

(more is better!)

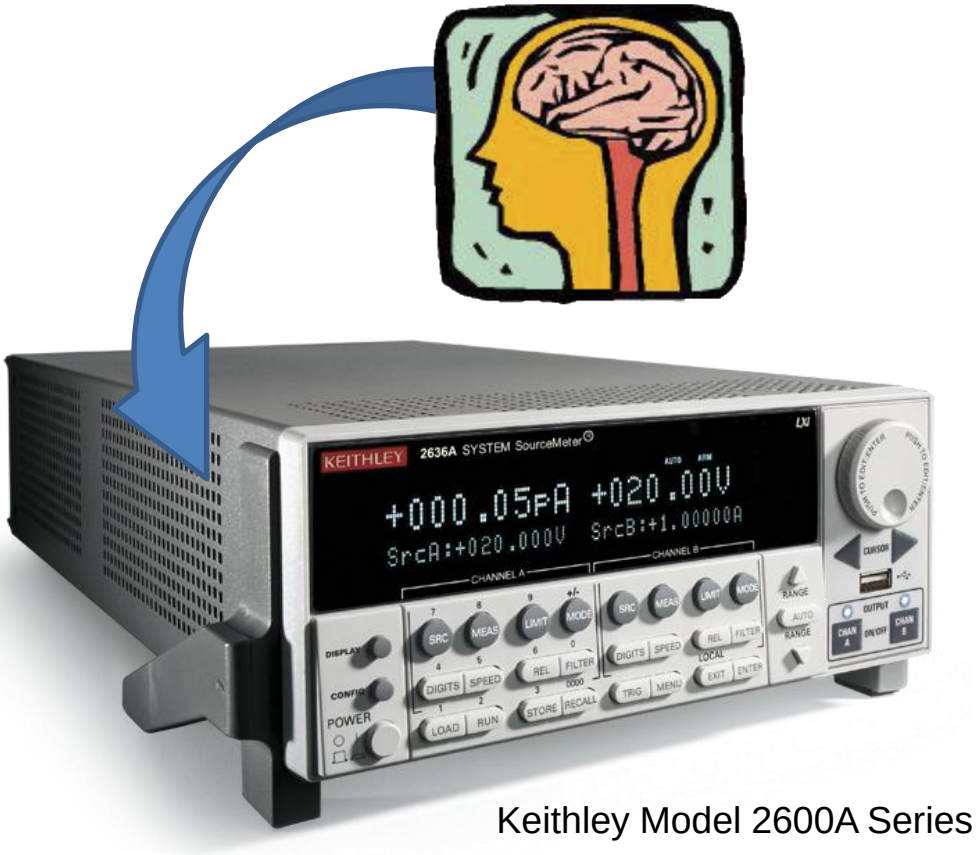
	1 NPLC	0.1 NPLC	0.01 NPLC	0.001 NPLC	0.00048 NPLC
Non-Keithey SMU instrument	6.1	8.1	8.2	8.2	8.2
Keithley 2600A Series	13.3	33.2	37.8	38.2	N/A

Most accurate ⟷ Least accurate

A SourceMeter running at 0.1 NPLC A/D conversion time is 4x faster and much more accurate than a SMU instrument running at 0.00048 NPLC

Keithley TSP® Technology

- **The SourceMeter® SMU Instrument has embedded intelligence!**



Keithley Model 2600A Series SourceMeter

Example TSP script:

```
for Voltage = 1,10 do
   smua.source.levelv = Voltage
   delay(1)
   Current = smua.measure.i()
   Resistance = Voltage / Current
   print ("Resistance=",Resistance)
End
```

Source Programming Resolution vs. Stability

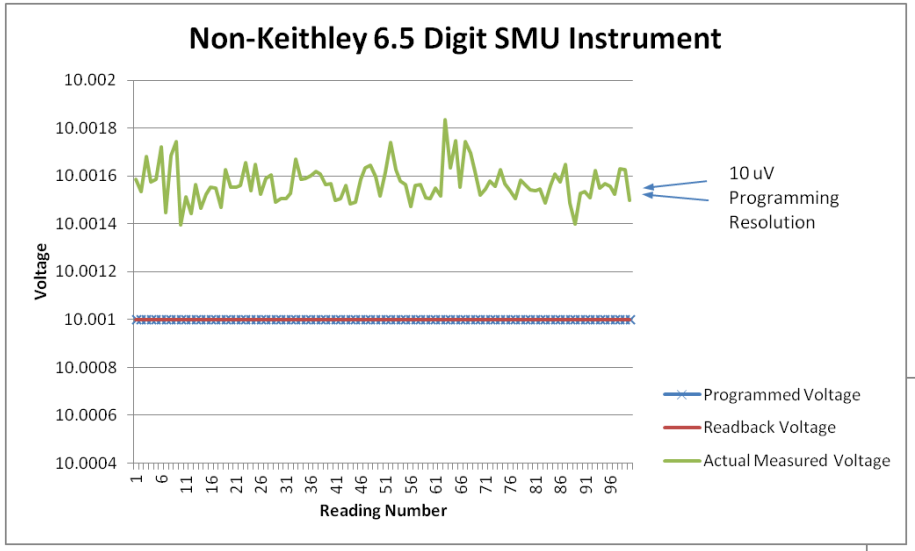
Spec sheet (Programming Resolution):

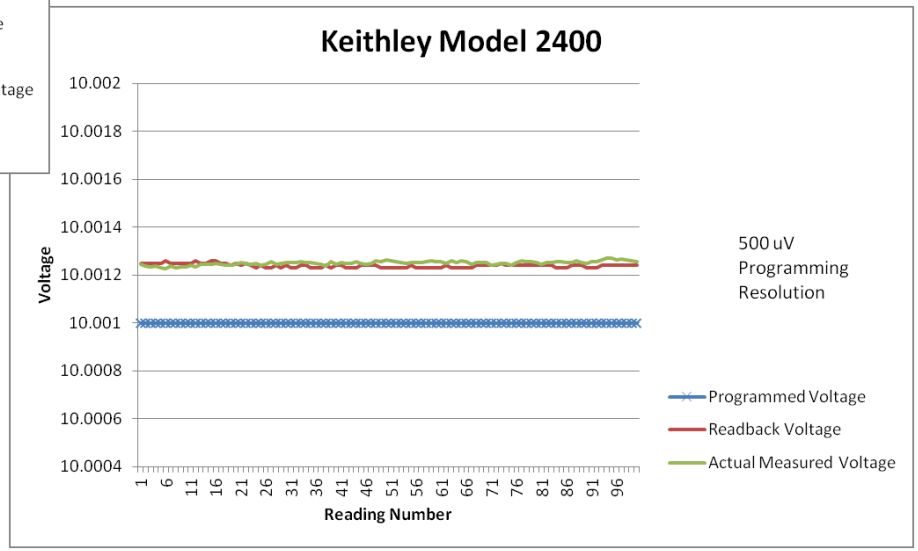
	Programming Resolution 20 V range
Non-Keithley 6.5 Digit SMU instrument	10 uV
Keithley Model 2400	500 uV

Actual Output (Stability):

Source Value = 10.001V	Source Readback Displayed Value (pk-pk variation)	Actual Measured Value of Source Output (pk-pk variation)
Non-Keithley 6.5 Digit SMU instrument	0.0 uV	438.7 uV
Keithley Model 2400	30.0 uV	42.9 uV

Actual Source Performance: Programming Resolution vs. Stability





Open Circuit Offset Current at 200V: 10nA Range

KEITHLEY

Comparing Specifications and Performance

Spec table:

SMU	Lowest range	Total accuracy*	Resolution
Non-Keithley	10nA	±(0.10% + 50pA)	10fA
Keithley 2636A	100pA	±(0.15% + 120fA)	1fA

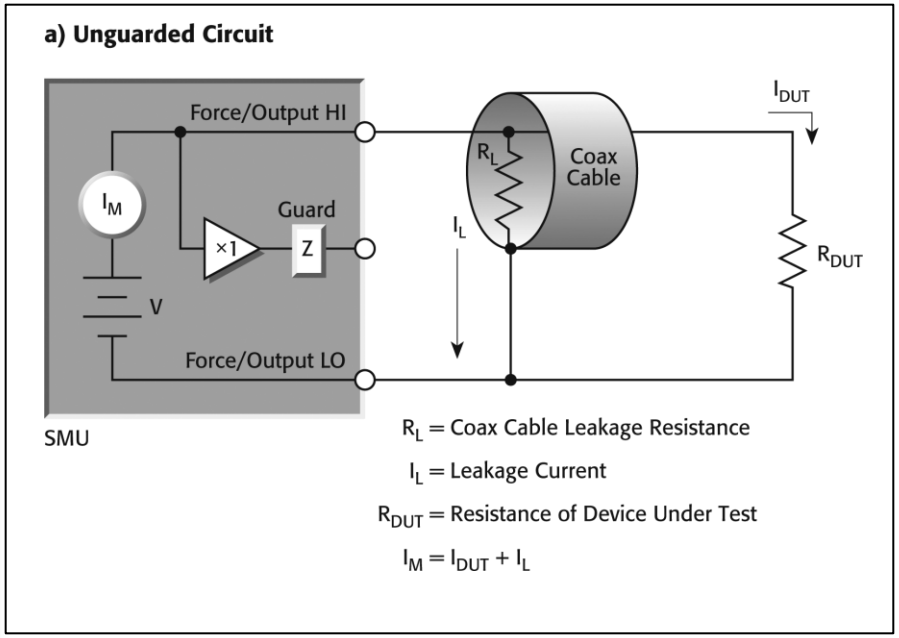
*Total accuracy = Gain accuracy (%) + Offset accuracy

Lowest Current Range	nA	pA	fA
Non-Keithley 6.5 Digit SMU:	10	050	00x
Keithley 2636A		100	120

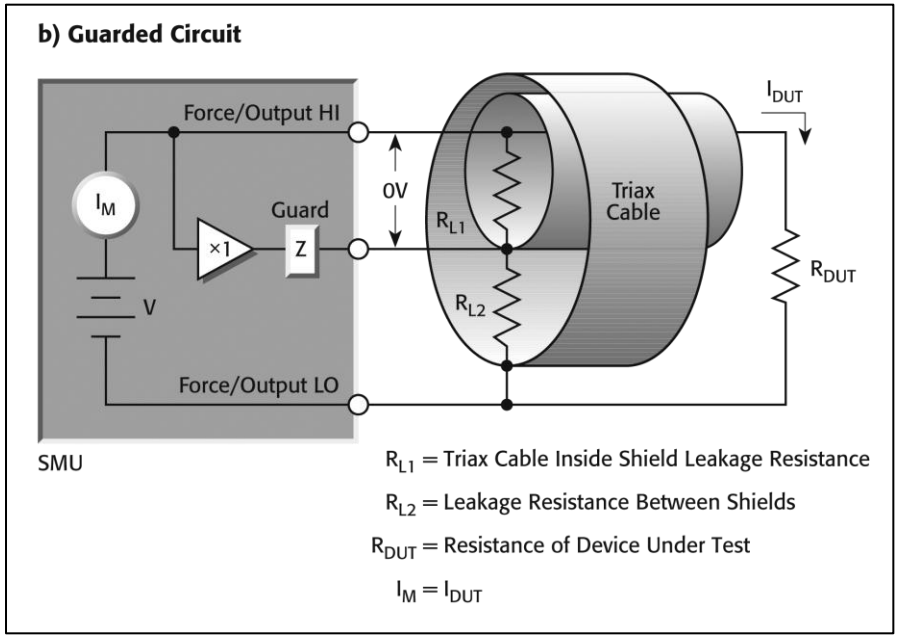
Offset Accuracy Spec

Cable and Connection Considerations

Coax Cable

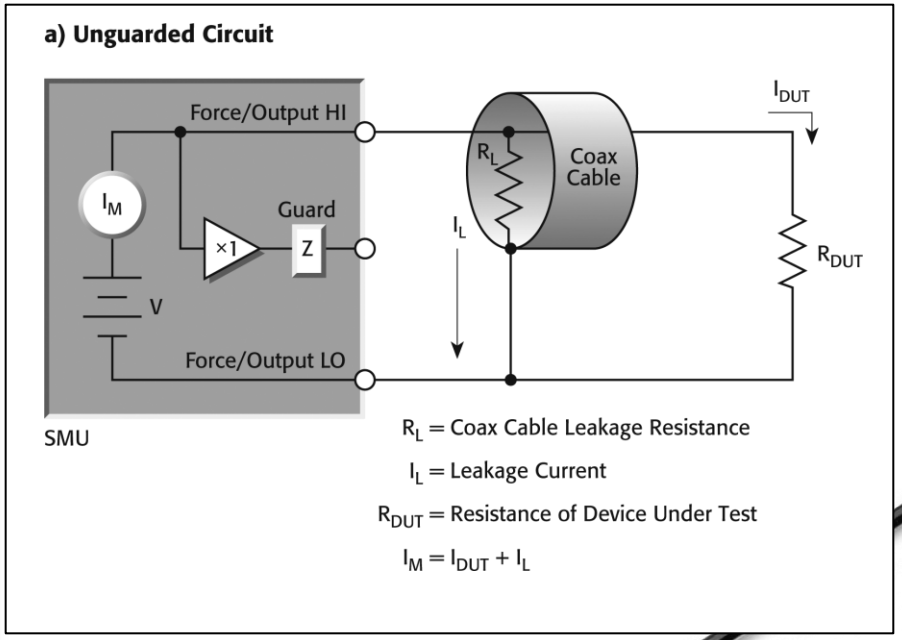


Triax Cable

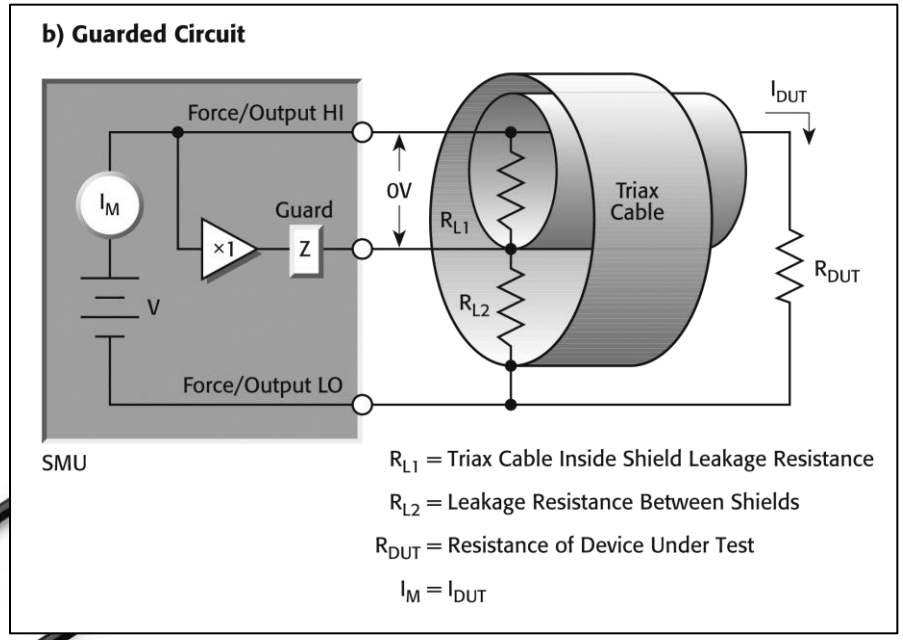


Cable and Connection Considerations

Coax Cable



Triax Cable



Triax cables are included in the price of the 2635A and 2636A SourceMeter SMU Instruments

KEITHLEY

SourceMeter® Source Measurement Unit (SMU) Instruments

Industry Leading I-V Characterization & Test Tools




Feature	High Power SourceMeter Instruments (2651A, 2430)	Low Current SourceMeter Instruments (2635A/36A, 237, 6430)	Series 2600A System SourceMeter Instruments	Series 2400 Bench SourceMeter Instruments
# of Channels	1 (Optional Expansion to 32)	1 – 2 (Optional Expansion to 64)	1 – 2 (Optional Expansion to 64)	1
Current Max/Min	50A pulse / 1pA	10A pulse / 10aA	10A pulse / 1fA	5A / 10pA
Voltage Max/Min	100V / 1uV	1100V / 1uV	200V / 1uV	1100V / 1uV
DC Power	1100 - 2000W (pulse)	2 - 30W per channel	30 – 40W per channel	20 – 110W
Max readings/sec	38,500 1uSec / pt., 18-bit Digitizer	20,000	20,000	2,000
Interfaces	GPIB, LAN (LXI), RS-232, Digital I/O, TSP-Link® Channel Expansion Bus	GPIB, LAN (LXI), RS-232, Digital I/O, TSP-Link® Channel Expansion Bus	GPIB, LAN (LXI), RS-232, Digital I/O, TSP-Link® Channel Expansion Bus	GPIB, RS-232, Digital I/O
Connectors	Screw Terminal, Banana	Triax	Screw Terminal, Adaptors for Banana or Triax	Banana

KEITHLEY

Keithley is the Leader in SMU Instruments

- 20 patents issued for SMU-specific technology
- Numerous industry awards, including *R&D*100, Test of Time, Best in Test, Best Electronic Design, and more
- Thousands and thousands of customers
- Serving Semiconductor, Electronic Components, Optoelectronics, Automotive, Mil/Aero, Medical, Research & Education, and many more industries

Series 2400 SourceMeter Instruments

Series 2600A System SourceMeter Instruments

S500 and S530 Parametric Test Systems

Model 237 High-Voltage SMU

Model 4200-SCS Semiconductor Characterization System

KEITHLEY

SMU Instrument Reference Library

www.keithley.com

- Choosing the Optimal Source Measurement Unit (SMU) Instrument for Your Test and Measurement Application
- Rapidly Expanding Array of Test Applications Continues to Drive Source Measurement Unit Instrument Technology
- Precision Sourcing and Measurement Techniques for Applications from Semiconductor Research and Development to High Throughput Component Test

www.keithley.com/knowledgecenter

- Low Level Measurements Handbook: Precision DC Current, Voltage, and Resistance Measurements (Sixth Edition)

www.keithley.com/events/semconfs/webseminars

www.keithley.com/products/onlinedemo

KEITHLEY

Contact Keithley for Further Information

Worldwide Headquarters Within USA: 1-888-KEITHLEY Outside USA: +1-440-248-0400 Email: applications@keithley.com Additional offices: www.keithley.com	Europe: Germany: (+49) 89 849 307 40 Great Britain: (+44) 118 929 7500 Asia: China: (+86) 10-8447- 5556 Japan: (+81) 3-5733-7555 Korea: (+82) 2-574-7778 Taiwan: (+886) 3-572-9077