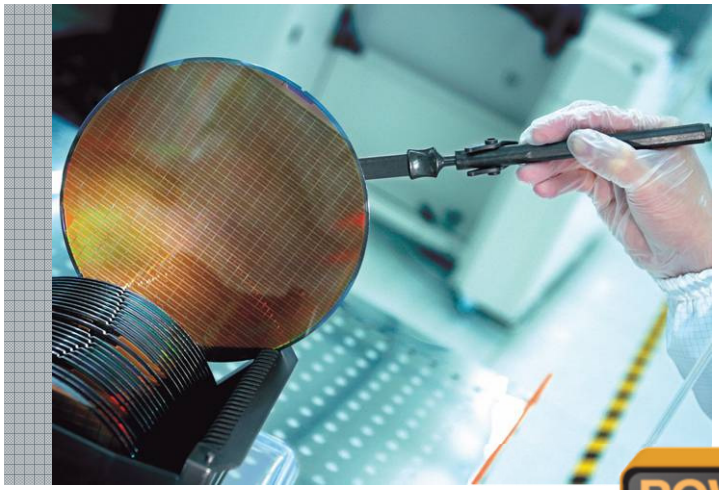
Make your test easier by understanding what source measure unit is



David Kwon

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FORCE of the FUTURE

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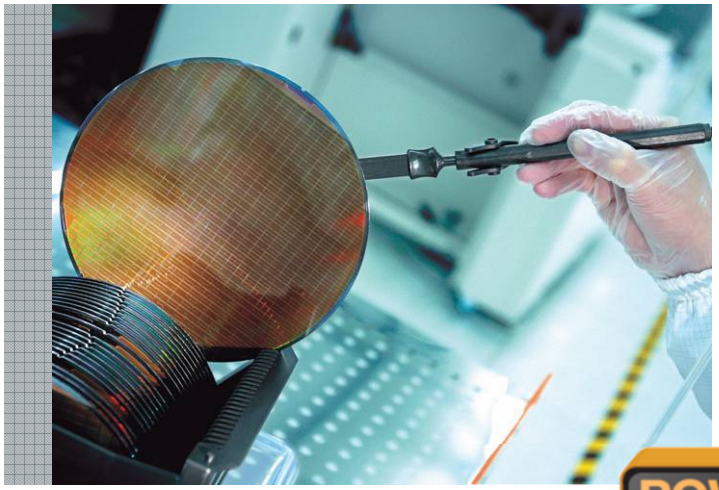
Contents

- SMU instrument basics
- Measurement terminology
- Key Considerations for Selecting a SMU Instrument
- Applications

SMU Instrument Basics



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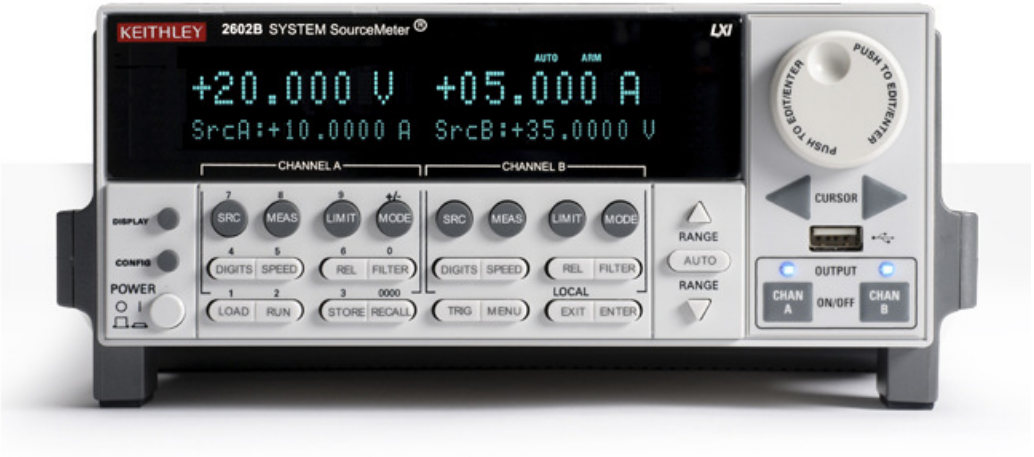
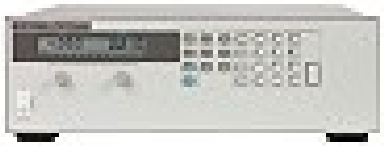
SourceMeter® SMU Instruments

- SMUs are precision instruments which are used for sourcing current or voltage and simultaneously measuring current, voltage and/or resistance with high speed and accuracy.





Precision Power Source

+

Precision DMM

+ More =

SourceMeter

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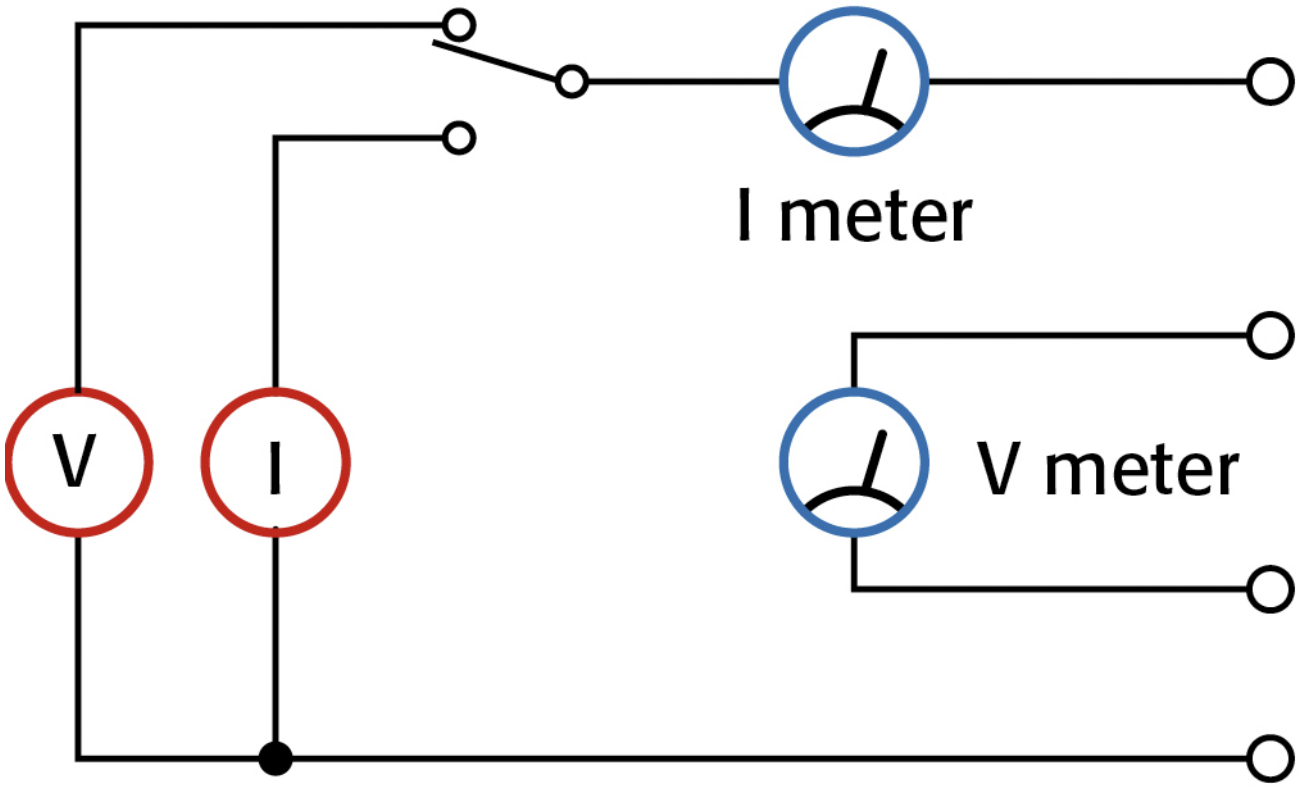
Basic SMU Topology



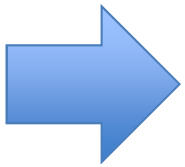
Why SMU?

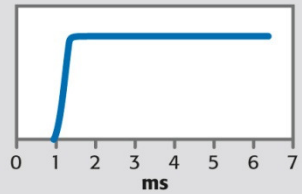
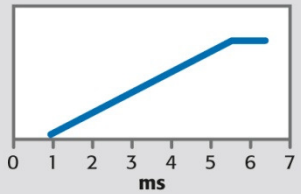
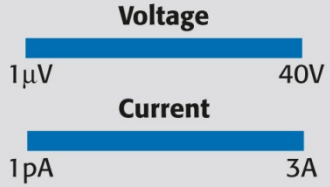
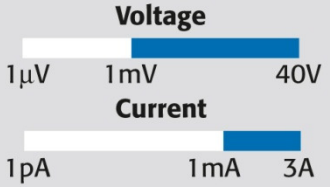
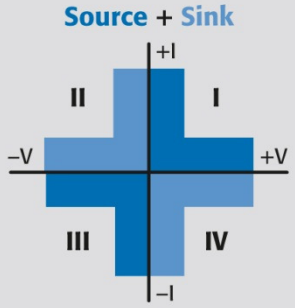
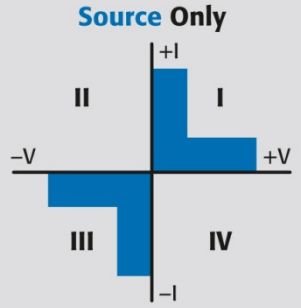
Energy is becoming “Greener”
- Emerging technologies such as photovoltaic generation

More advance features
- Small, but complex
- Lower power consumption
- Lower cost in manufacturing devices

SMU is a perfect solution performing electrical measurement with accuracy and speed

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		

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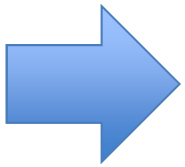
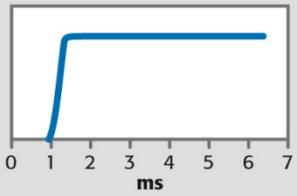
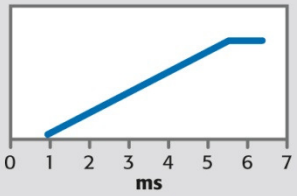
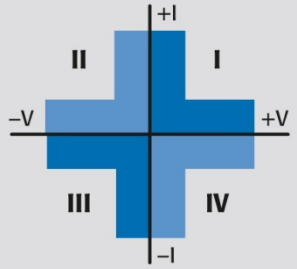
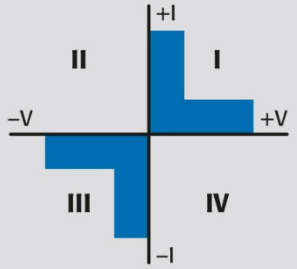
SMUs compared to Power Supplies



	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	Source + Sink 	Source Only 

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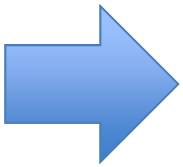
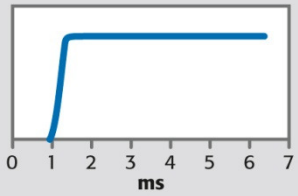
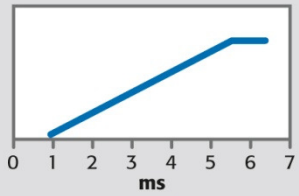
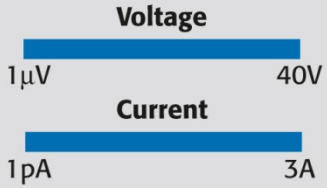
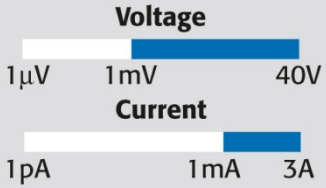
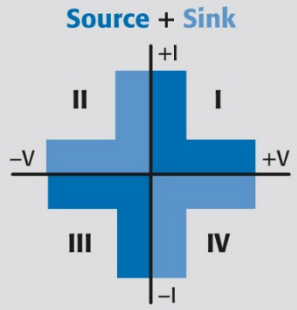
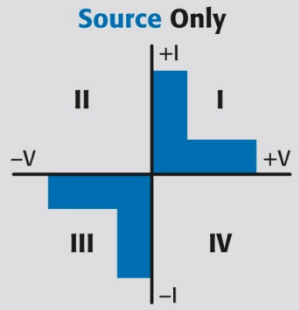
SMUs compared to Power Supplies



	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		

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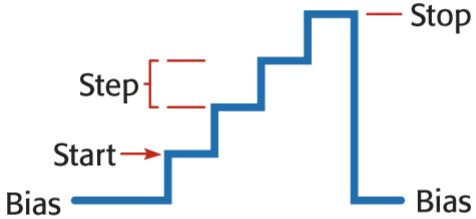
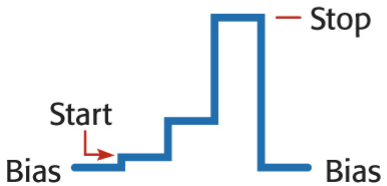
Built-in Sweeps

DC

Fixed Level

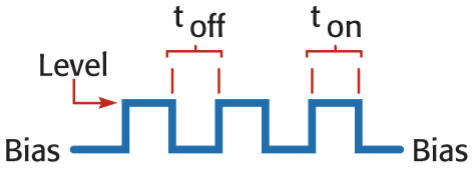


Linear Stair

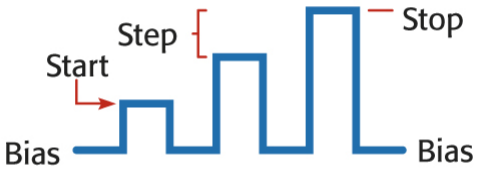


Logarithmic Stair

Pulse



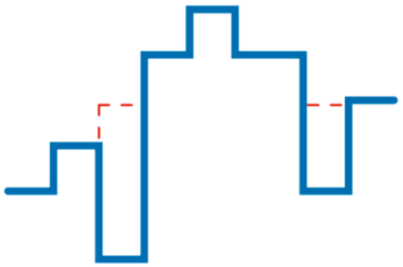
Pulse



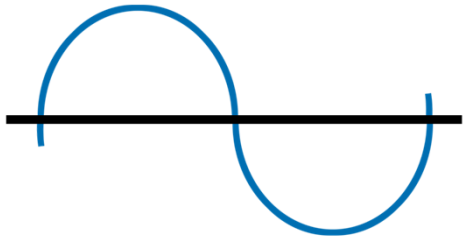
Linear Stair Pulse

Logarithmic Stair Pulse

Custom



Arbitrary



Sine Wave

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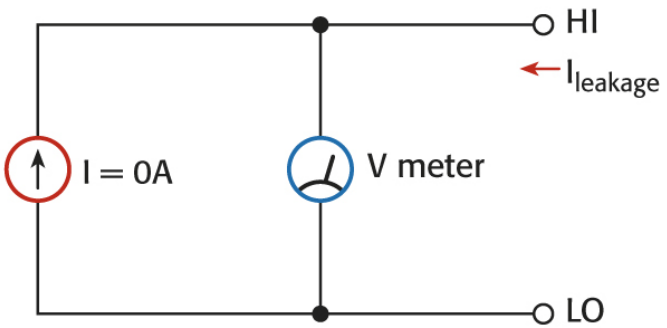
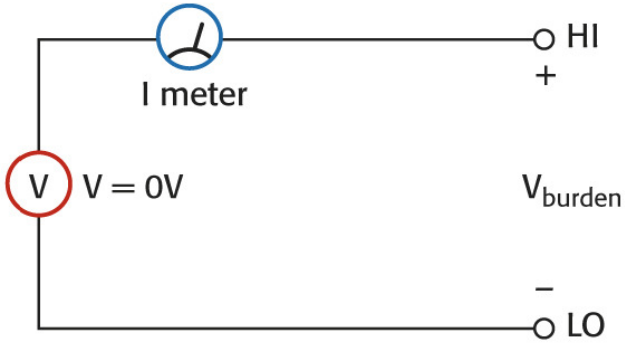
SMUs compared to DMMs

Voltmeter Configuration



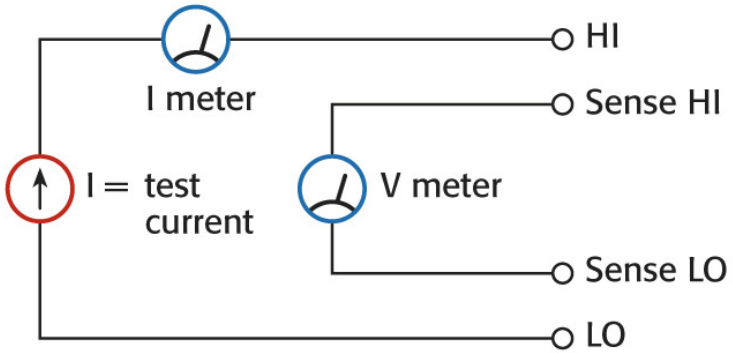
Source I = 0A, Measure V

Ammeter Configuration

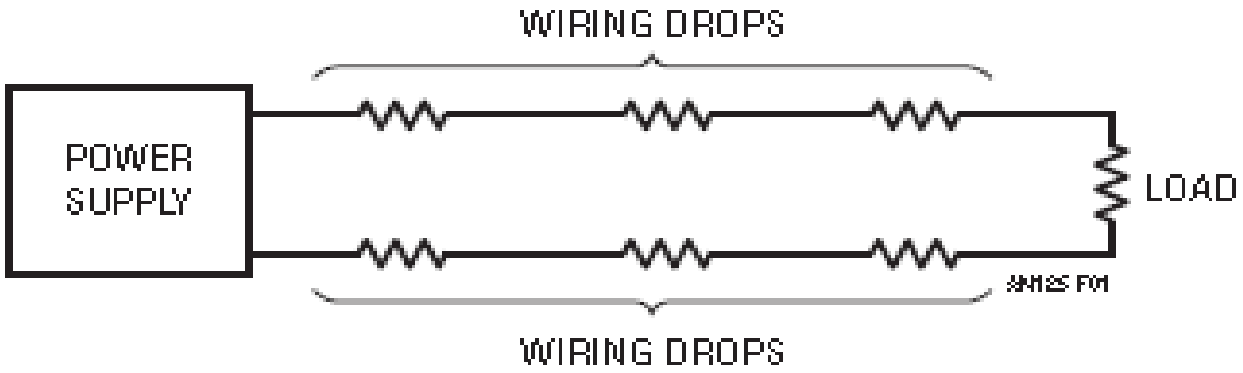


Source V = 0V, Measure I

Ohmmeter Configuration

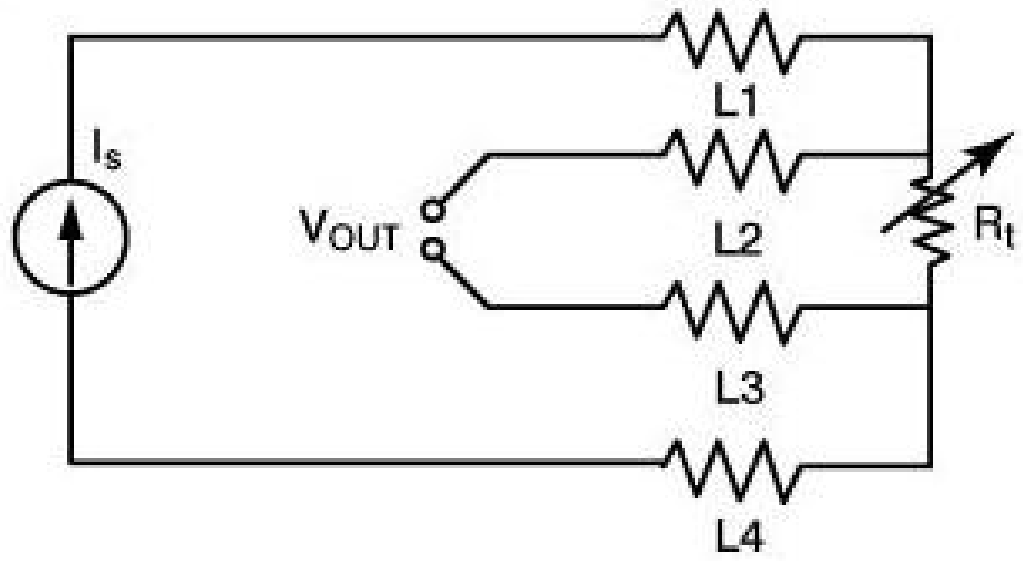


Remote Sensing



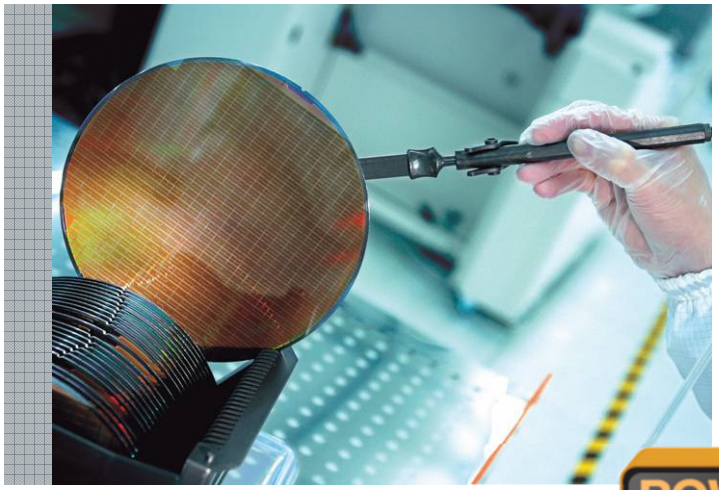
- Wires and connectors have resistance
- Prominent when smaller wires with longer distances
- Devices with small operation voltage can be critical error

Remote Sensing



- Apply current and measure voltage drop across DUT
- Can eliminate line resistance worries
- Called remote sensing or 4 wire sensing

Measurement Terminology



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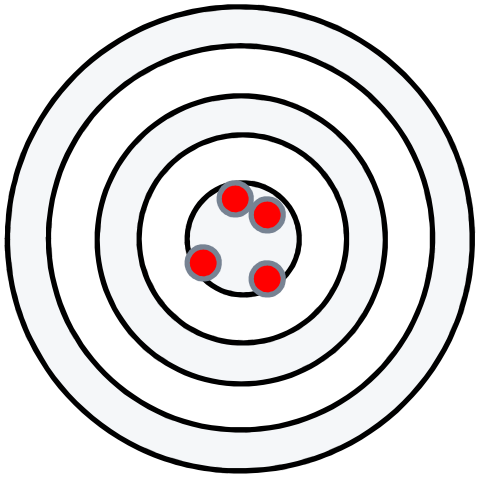
Measurement Terminology

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

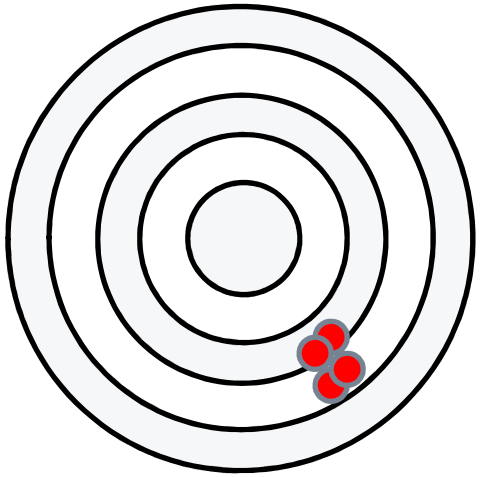
Measurement Terminology

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

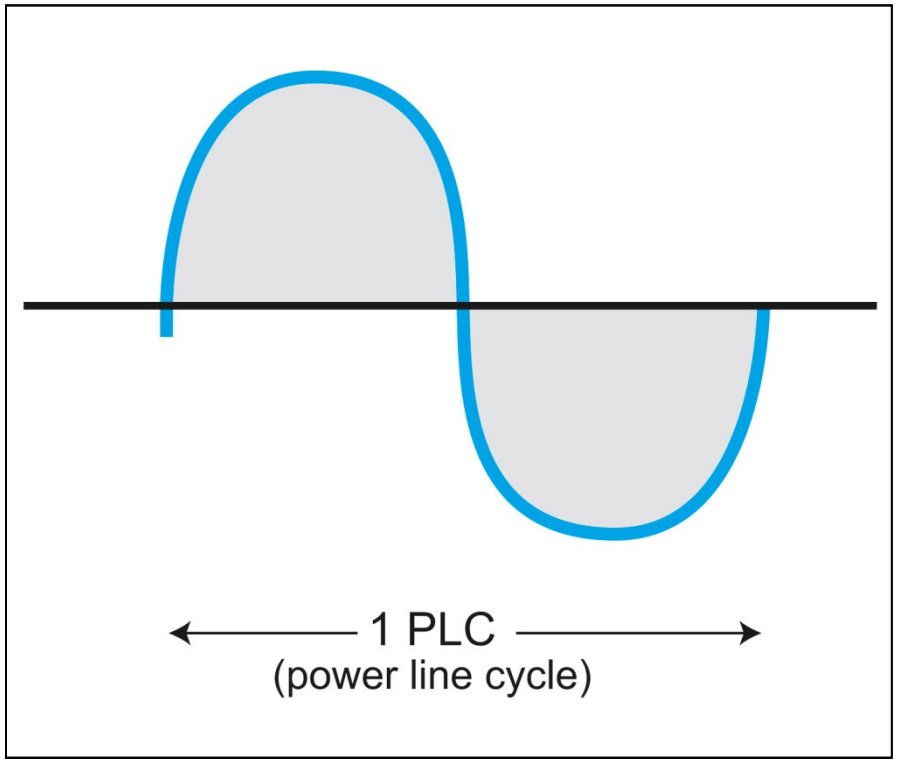
Resolution

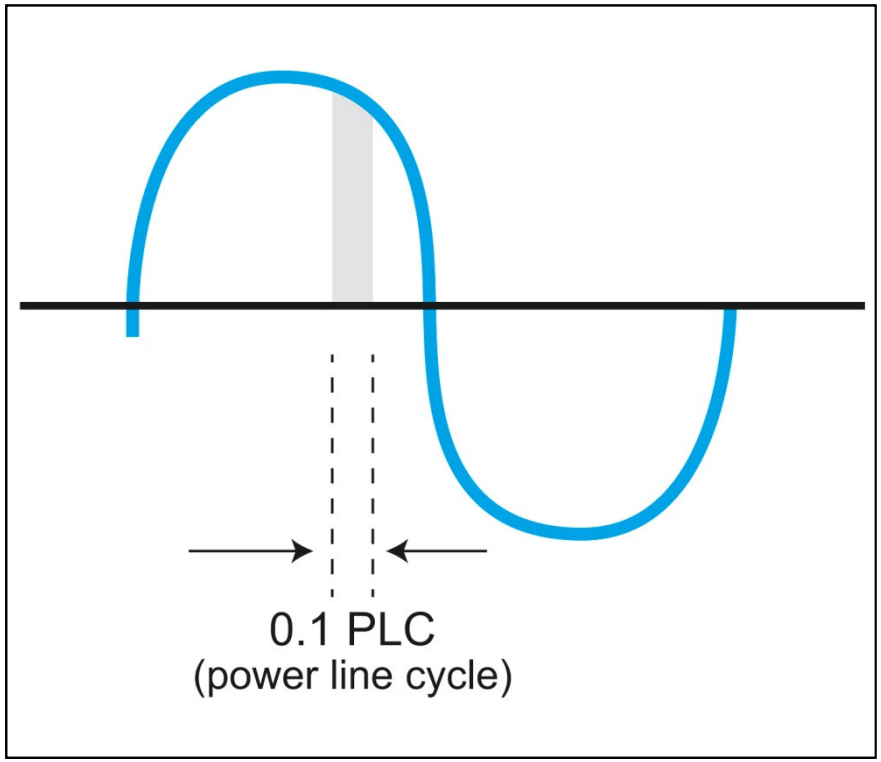
The smallest *portion* of the signal that can be observed.

Sensitivity

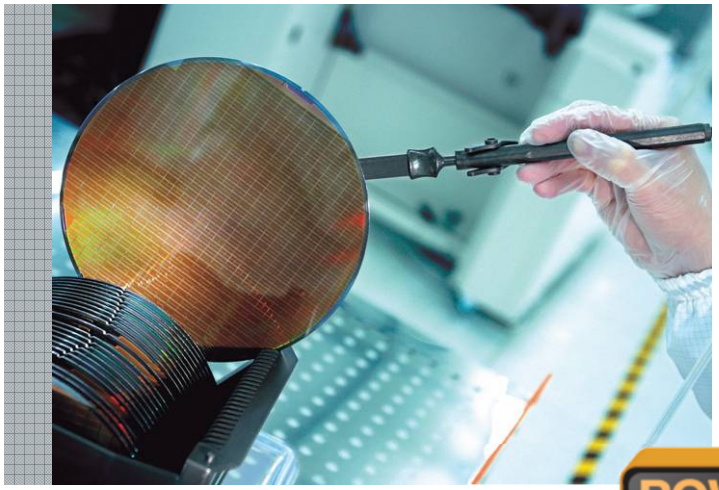
The smallest *change* in the signal that can be detected.

A/D Converter Integration Time (NPLC)





Key Considerations for Selecting a SMU Instrument



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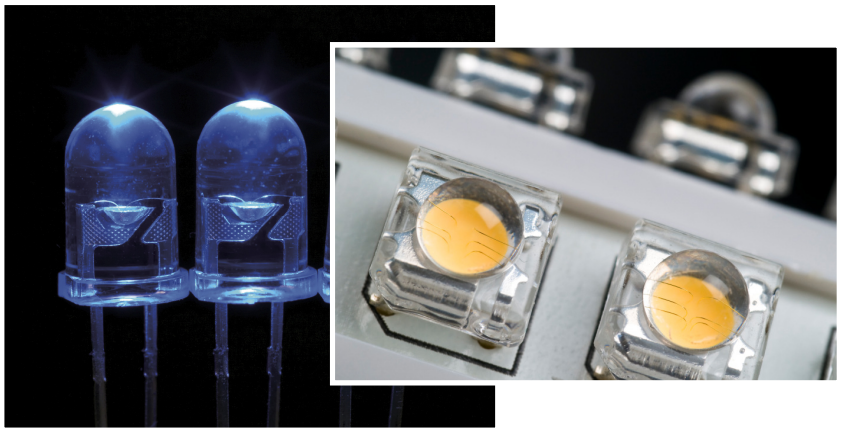
Key Considerations for Selecting a SMU Instrument

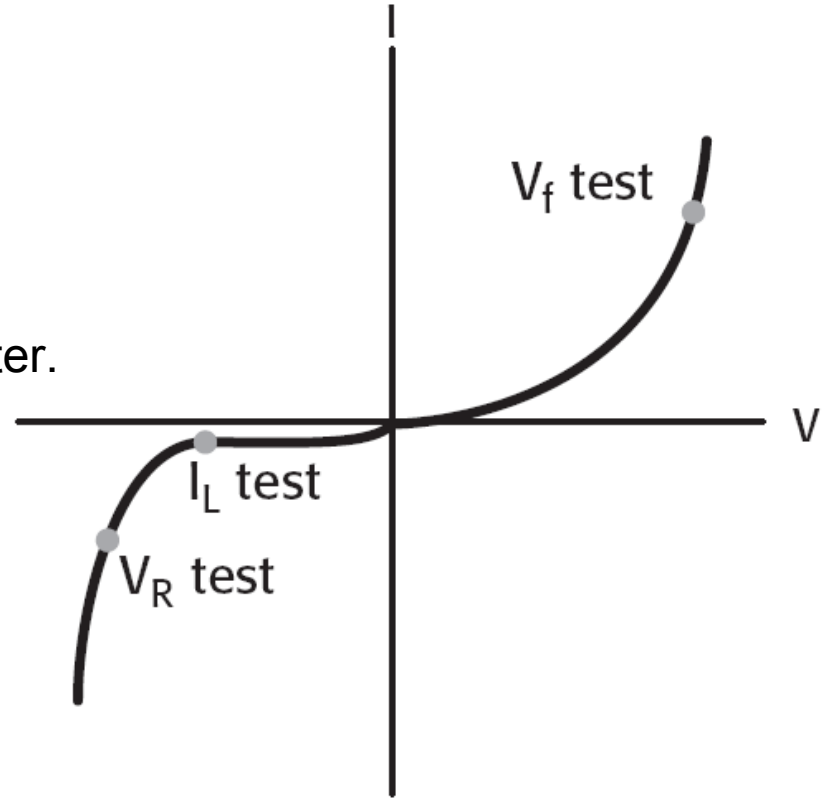
- System-level Speed / Throughput
- Source Resolution vs. Stability
- Measure Settling Time, Offset Error, Noise
- Cabling and Connections

System-level Speed / Throughput

Example: Diode / LED Test

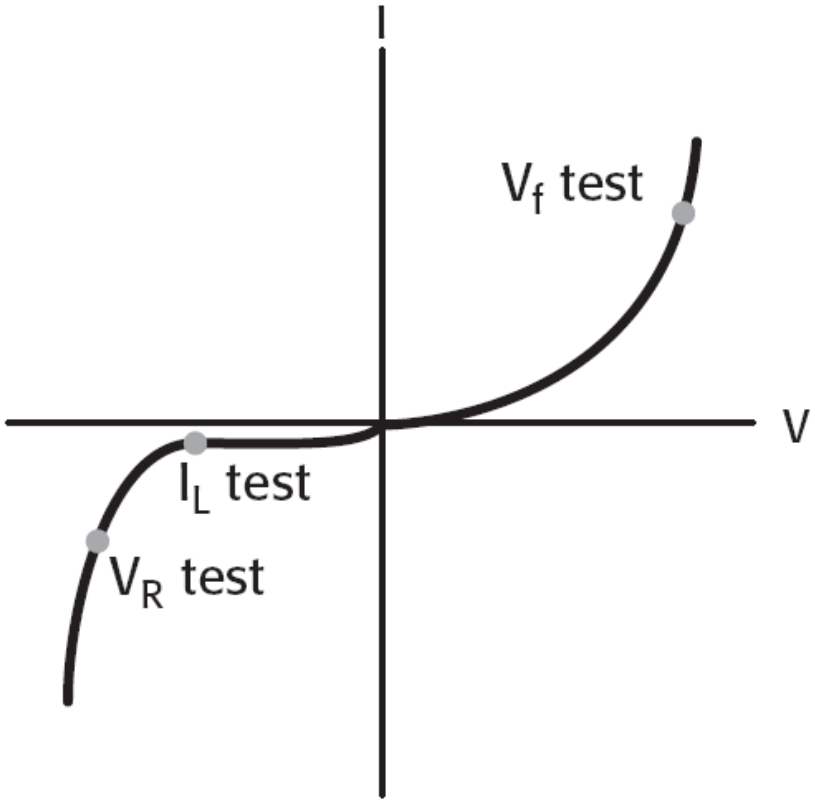
- Three Measurements
  - V_f – Forward Voltage
  - V_R – Reverse Breakdown Voltage
  - I_L – Reverse Leakage Current
- Measurements are compared against upper and lower limits for each parameter.



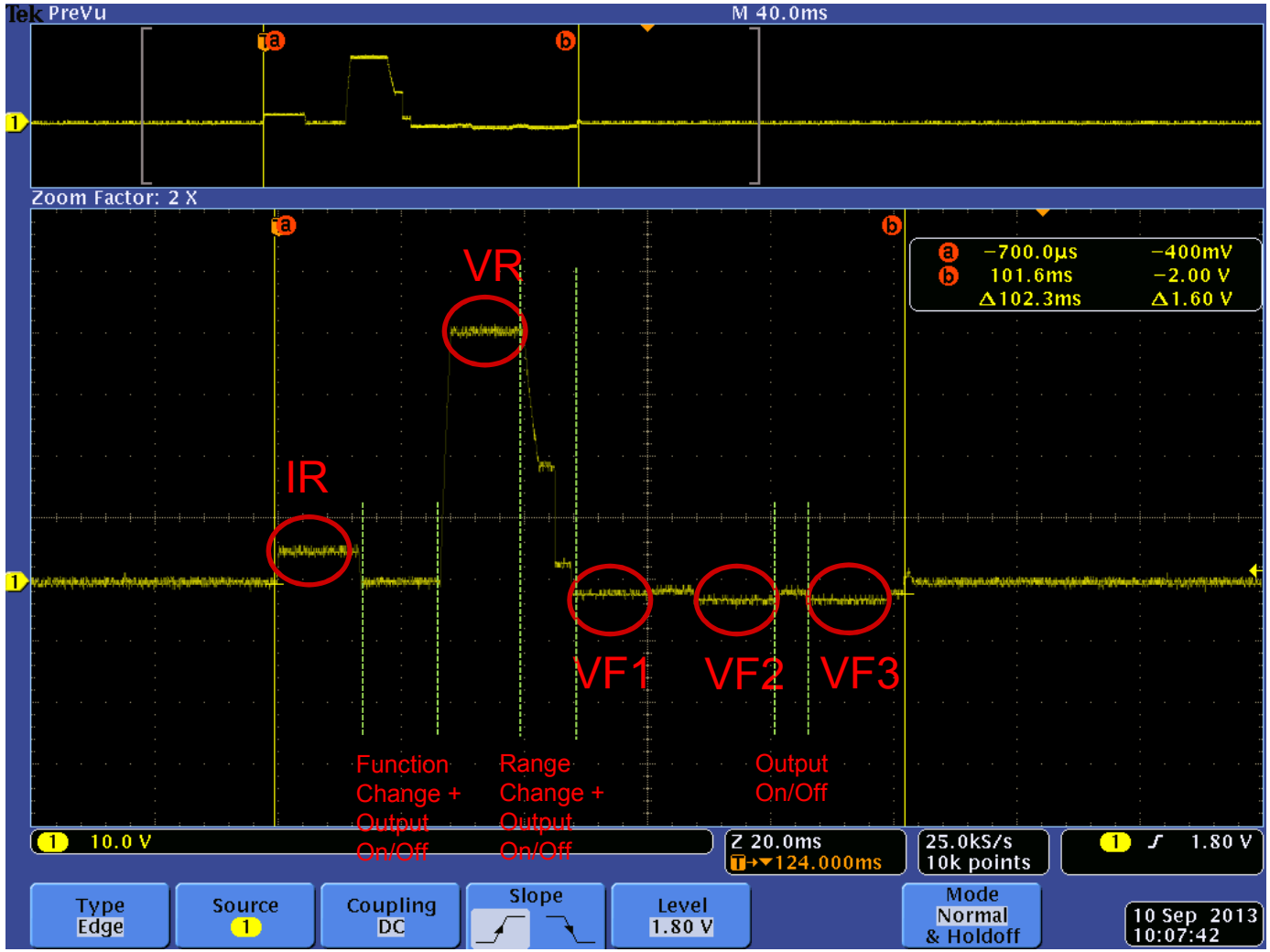


System-level Throughput Considerations

- 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



System-level Throughput Considerations



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Test Throughput: Actual Parts per Second

(more is better!)

	1 NPLC	0.1 NPLC	0.01 NPLC	0.001 NPLC	0.00048 NPLC
Non-Keithley 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

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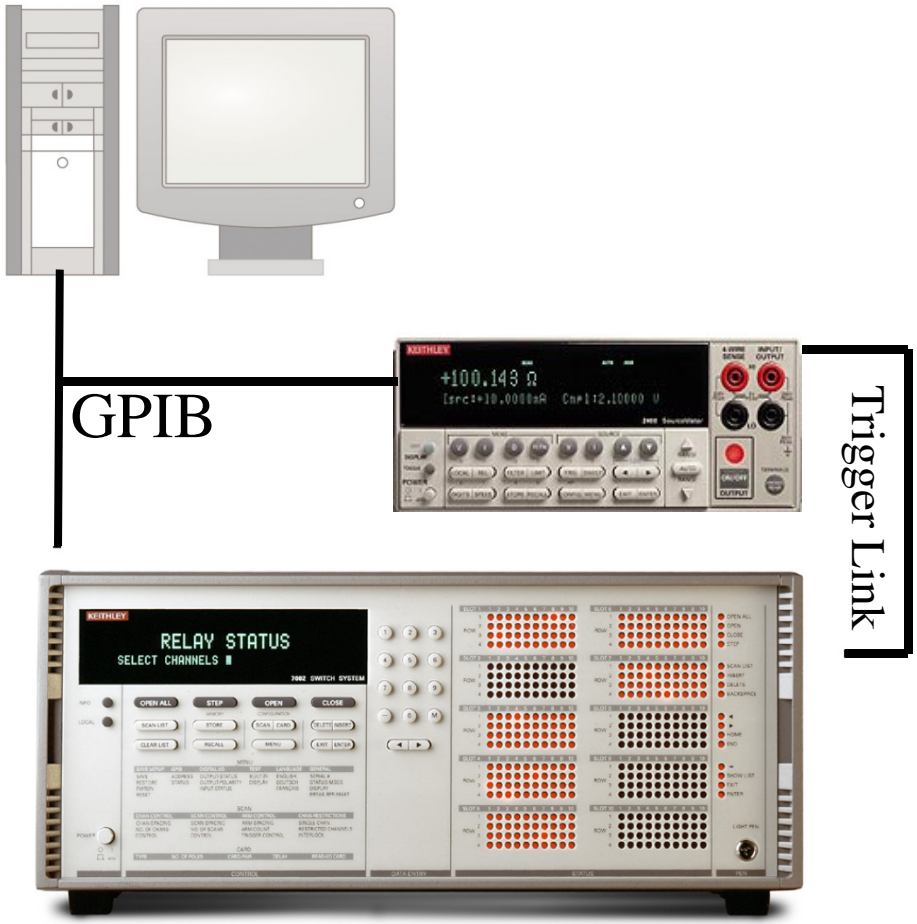
Keithley TSP® Technology

- **It is now…**



Configure Trigger Model of 2410

```
Send 2410 ("ARM:COUN 1")                ' Scan once per initialization
Send 2410 ("ARM:SOUR IMM")              ' Immediately proceed to Trig Layer
Send 2410 ("ARM:DIR ACC")               ' Wait for Arm source (IMM)
Send 2410 ("TRIG:COUN 7")               ' Seven measurements per scan
Send 2410 ("TRIG:SOUR TLINK")           ' Wait for Trig source (Trigger Link)
Send 2410 ("TRIG:DIR ACC")              ' Don't skip first trigger
Send 2410 ("TRIG:OLIN 1")               ' Define output trigger line
Send 2410 ("TRIG:ILIN 2")               ' Define input trigger line
Send 2410 ("TRIG:OUTP SENS")            ' Output trigger after measurement
Send 2410 ("TRIG:DEL 0")                ' Set trigger delay
```

Configure Trigger Model of 7002

```
Send 7002 ("ARM:LAY2:COUN 1")           ' Scan once per initialization
Send 7002 ("ARM:LAY2:SOUR IMM")         ' Immediately proceed to Trig Layer
Send 7002 ("ARM:LAY2:TCON:DIR ACC")     ' Wait for Arm source (IMM)
Send 7002 ("TRIG:COUN 7")               ' Seven measurements per scan
Send 7002 ("TRIG:SOUR TLINK")           ' Wait for Trig source (Trigger Link)
Send 7002 ("TRIG:TCON:PROT ASYN")       ' Allow asynchronous triggering
Send 7002 ("TRIG:TCON:DIR SOUR")        ' Skip first trigger to start scan
Send 7002 ("TRIG:TCON:ASYN:OLIN 2")     ' Define output trigger line
Send 7002 ("TRIG:TCON:ASYN:ILIN 1")     ' Define input trigger line
Send 7002 ("TRIG:DEL 0")                ' Set trigger delay
```

Configure scan list

```
Send 7002 ("ABORT;OPEN ALL")            ' Abort operation and open all relays
Send 7002 ("ROUT:CLOSE (@1!1,2!1)")     ' Close channels for 1st bridgewire test
Send 7002 ("MEM:SAVE M1")               ' Save channels in 1st memory location
Send 7002 ("OPEN ALL")                  ' Open all relays
Send 7002 ("ROUT:CLOSE (@1!3,2!3)")     ' Close channels for 2nd bridgewire test
Send 7002 ("MEM:SAVE M2")               ' Save channels in 2nd memory location
Send 7002 ("OPEN ALL")                  ' Open all relays
Send 7002 ("ROUT:CLOSE (@1!2,2!2)")     ' Close channels to test housing contact
Send 7002 ("MEM:SAVE M3")               ' Save channels in 3rd memory location
Send 7002 ("OPEN ALL")                  ' Open all relays
Send 7002 ("ROUT:CLOSE (@1!1,2!1)")     ' Close channels for 1st shunt bar test
Send 7002 ("MEM:SAVE M4")               ' Save channels in 4th memory location
Send 7002 ("OPEN ALL")                  ' Open all relays
Send 7002 ("ROUT:CLOSE (@1!3,2!3)")     ' Close channels for 2nd shunt bar test
Send 7002 ("MEM:SAVE M5")               ' Save channels in 5th memory location
Send 7002 ("OPEN ALL")                  ' Open all relays
Send 7002 ("ROUT:CLOSE (@1!1,2!2,3!2)") ' Close channels for 1st insulation test
Send 7002 ("MEM:SAVE M6")               ' Save channels in 6th memory location
Send 7002 ("OPEN ALL")                  ' Open all relays
Send 7002 ("ROUT:CLOSE (@1!2,2!3,3!1)") ' Close channels for 2nd insulation test
Send 7002 ("MEM:SAVE M7")               ' Save channels in 7th memory location
Send 7002 ("OPEN ALL")                  ' Open all relays

Send 7002 ("ROUT:SCAN (@M1,M2,M3,M4,M5,M6,M7)")   ' Scan through memory locations
```

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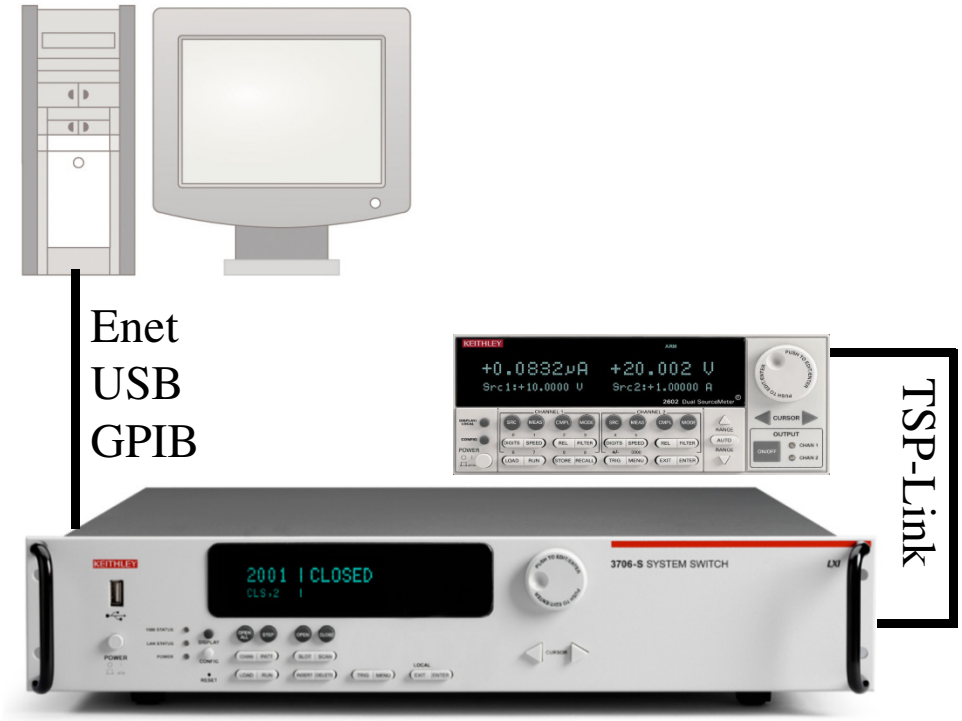
- **As to be !!**




```
90 tsplink.reset()
91
92 smua = node[2].smua          --2602 set to node 2
93
94 mem_pattern1 = {"1031,1914,1924","1032,1914,1924","1033,1914,1924","1034,1914,1924","1035,1914,1924","1036,1914,1924"}
95
96 smua.source.output = smua.OUTPUT_ON --Enable source
97
98 for i = 1, 6 do
99
100    channel.exclusiveclose(mem_pattern1[i])
101
102    LEDTest()
103    ReturnData()
104
105 end
106
107 smua.source.output = smua.OUTPUT_OFF
108
```

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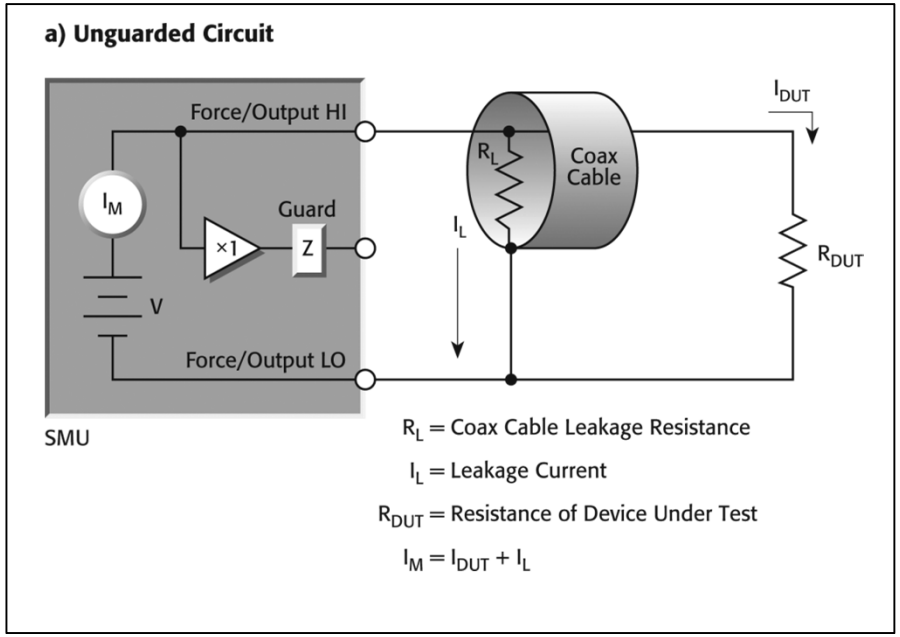
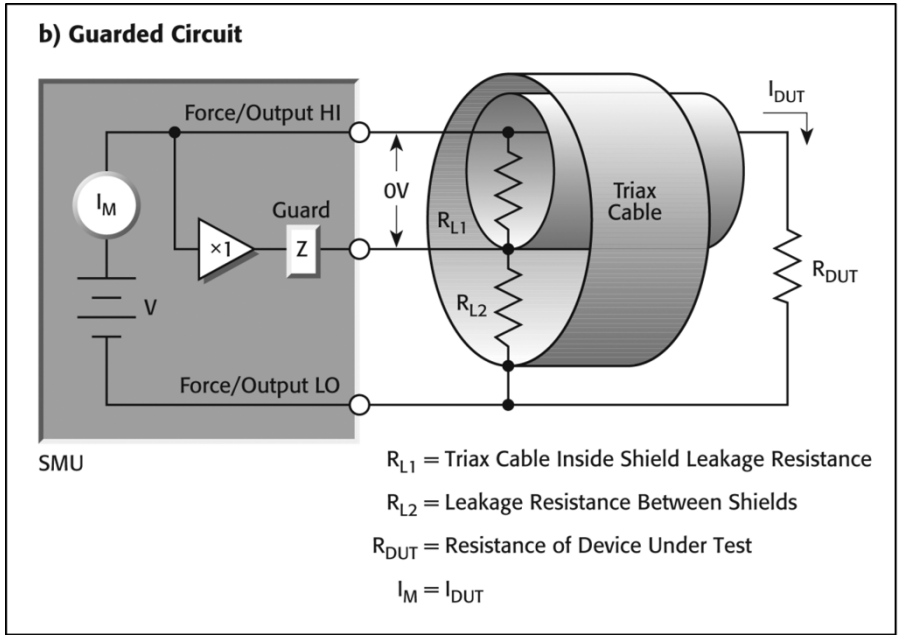
Cable and Connection Considerations

Coax Cable



Triax Cable



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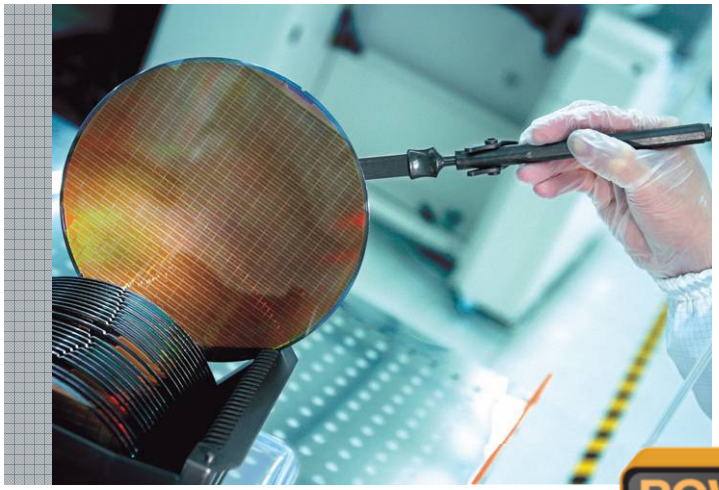
Applications



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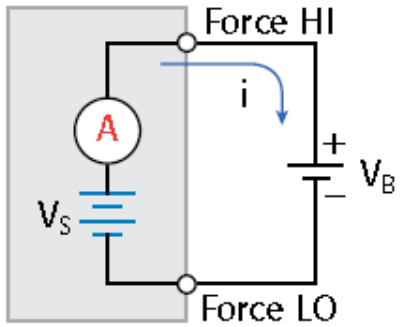
Application1 – Battery Discharge Test using 2450 SourceMeter

Simplified circuit diagram

Charge Cycle



2450 SourceMeter

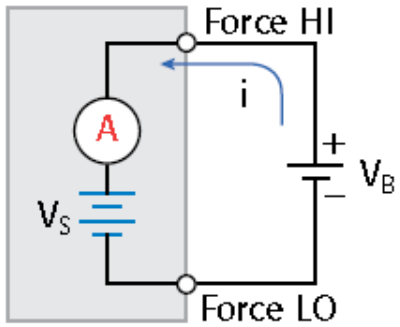
SourceMeter in Source Mode

$V_S > V_B$

SourceMeter functions
as Power Supply

Charge Current (i) is Positive

Discharge Cycle



2450 SourceMeter

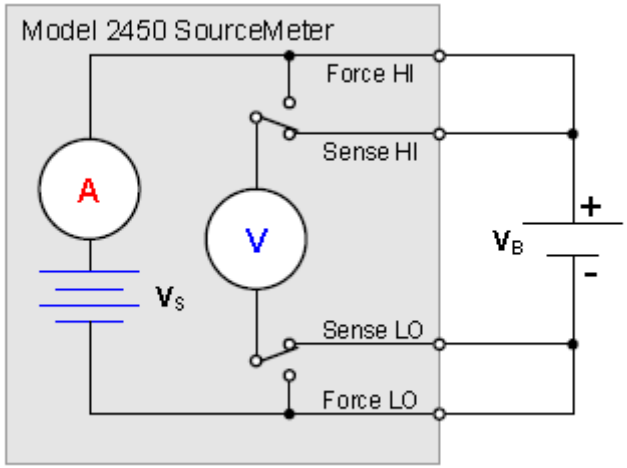
SourceMeter in Sink Mode

$V_S < V_B$

SourceMeter functions
as Electronic Load

Discharge Current (i) is Negative

Connections



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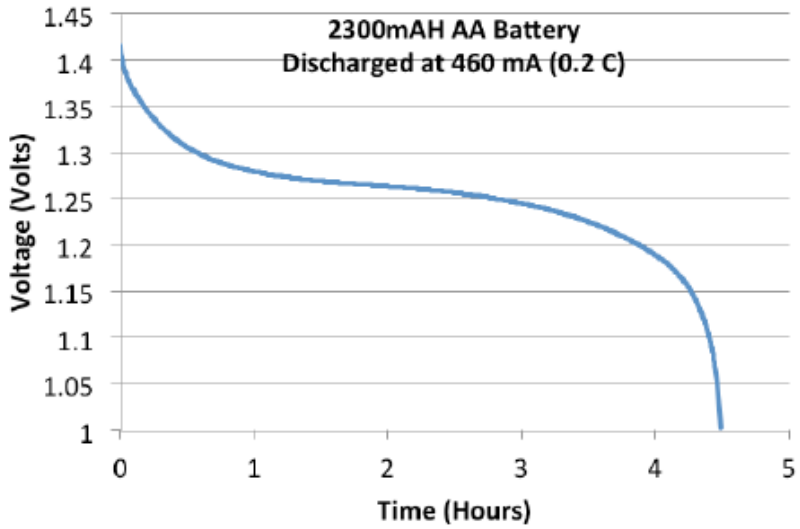
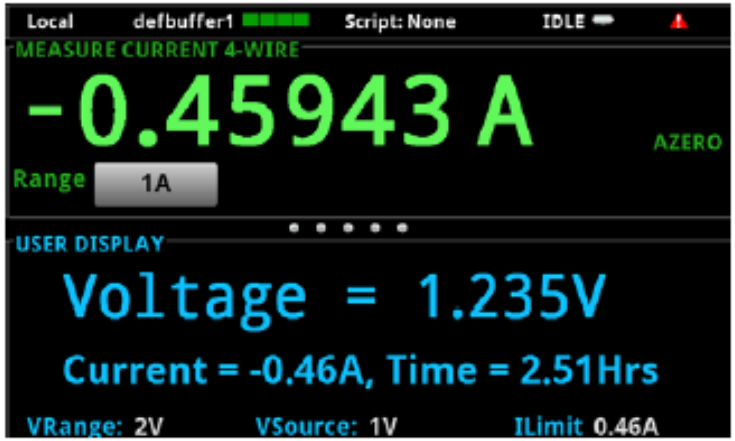
Application1 – Battery Discharge Test

Examples of Discharging an AA Battery



2450 Screen supports measured load
Current, battery voltage, elapsed
Time on screen etc.



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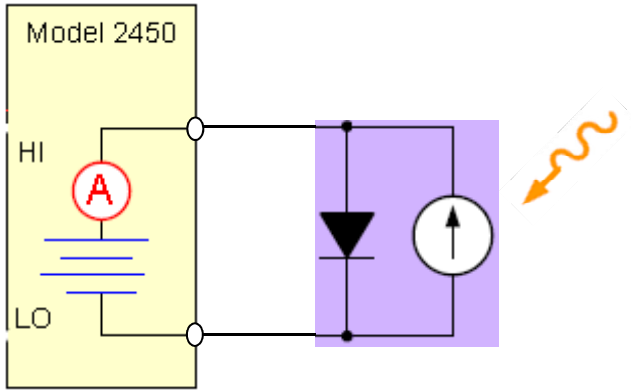
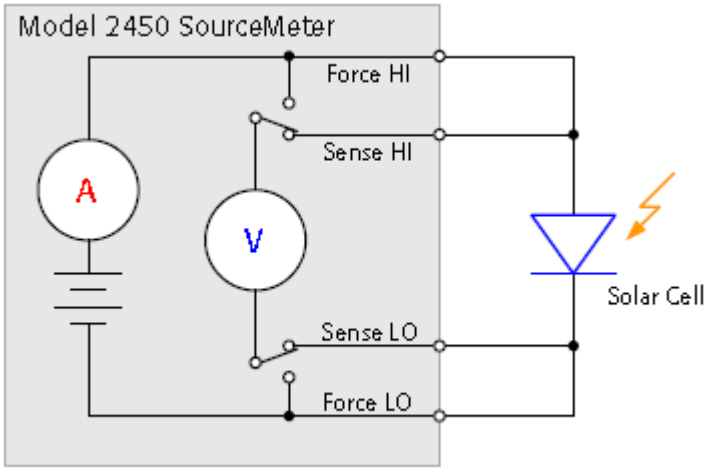
Application2 – Photovoltaic Test using 2450 SourceMeter

Simplified circuit diagram



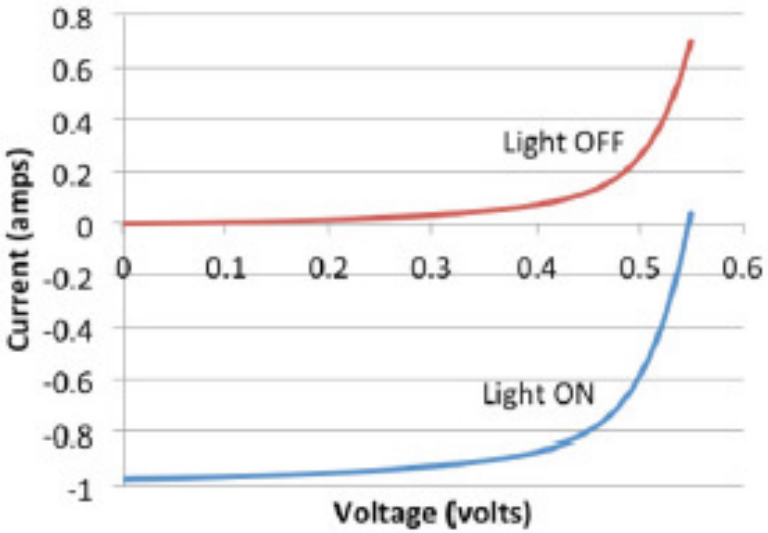
Connections



An illuminated solar cell will cause a current to flow when a load is connected to its terminals.

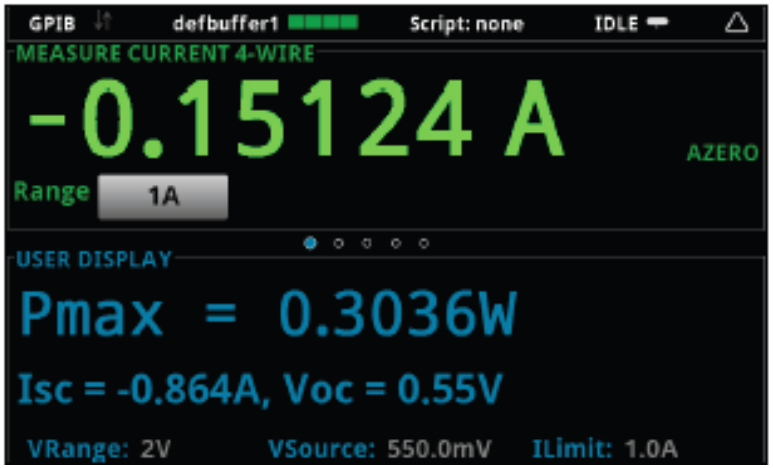
Application2 – Photovoltaic Test using 2450 SourceMeter

Examples of test output



Condition
- Voltage sweep from 0V to 0.55V in 56 steps

2450 Screen supports circuit current,
Maximum power, open circuit voltage
Etc.



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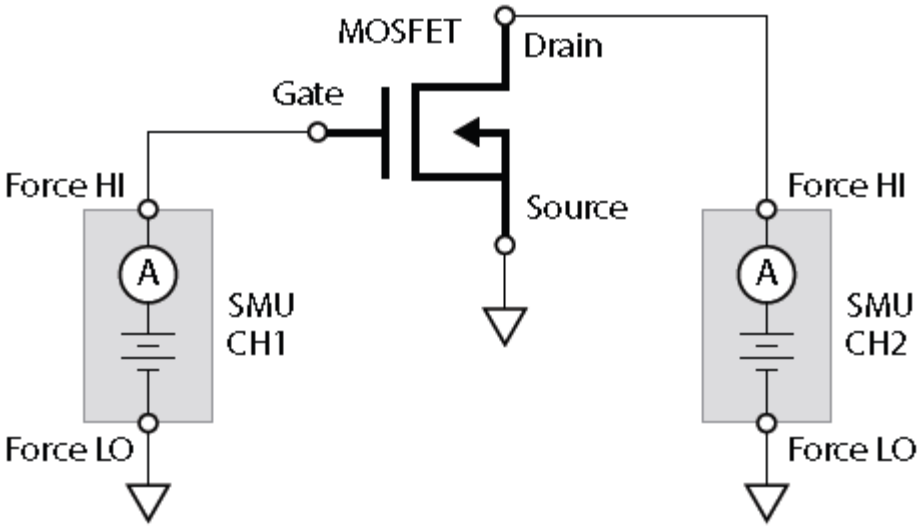
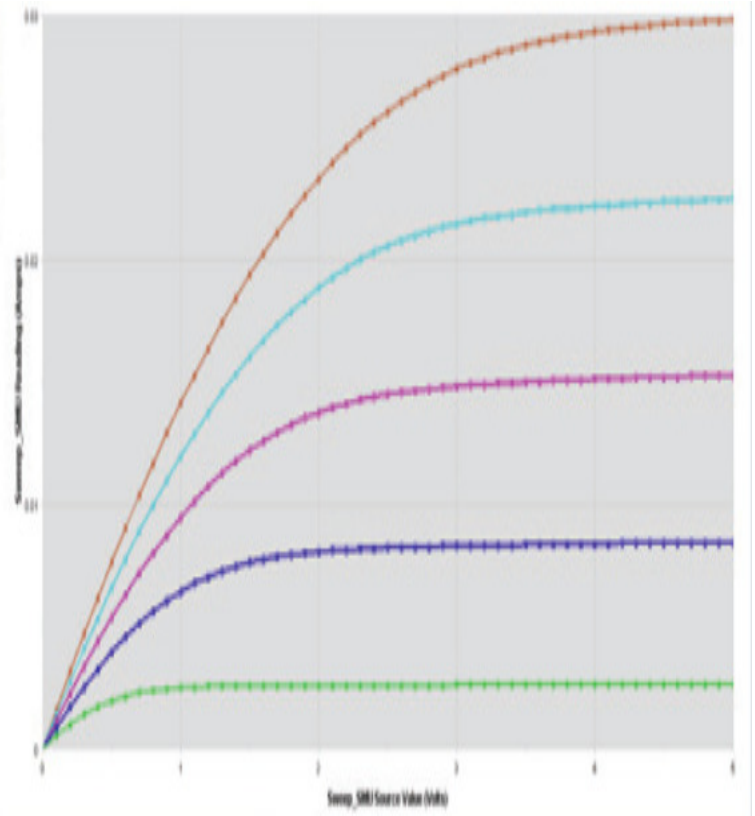
Application3 – MOSFET Test



- Using 2 SMUs to Gate and Drain
- Measuring drain current curves (Vds-Id)
- SMU CH1 steps gate voltage
- SMU CH2 sweeps drain voltage and measure current



Drain curves

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- Numerous industry awards, including *R&D*100, Test of Time, Best in Test, Best Electronic Design, and more
- Thousands and thousands of customers
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www.keithley.com/knowledgecenter

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

www.keithley.com/events/semconfs/webseminars

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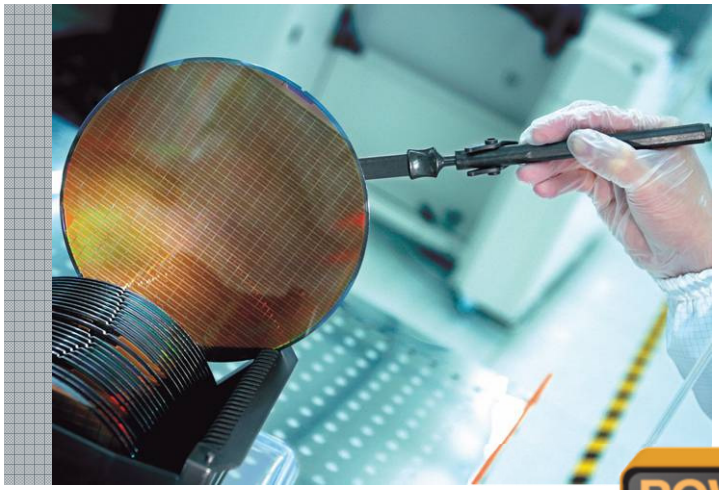
Thank You!



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