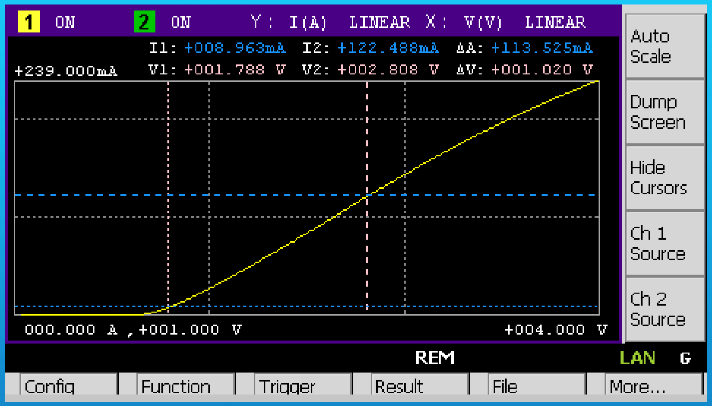
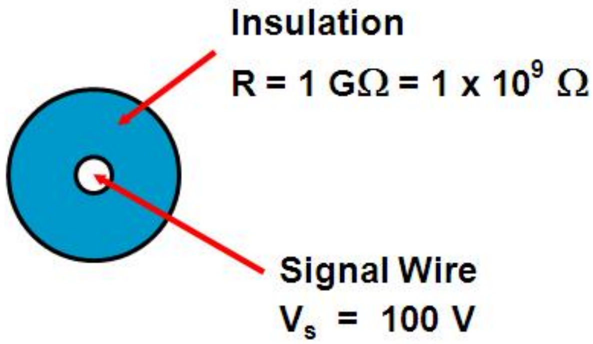
The Fundamentals of IV (Current/Voltage) Measurement of SMU



Agilent Technologies

Why Are Triaxial Cables Needed for Low-Current?

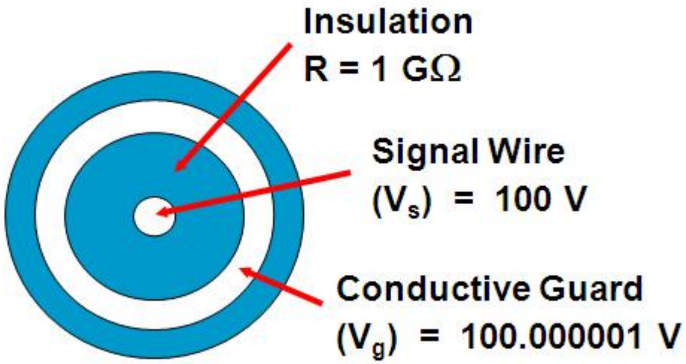
BNC (Coaxial) Cable:



Leakage Current:

$$\frac{100\,V}{1\times10^{9}\Omega} = 100\,nA$$

Triaxial Cable:

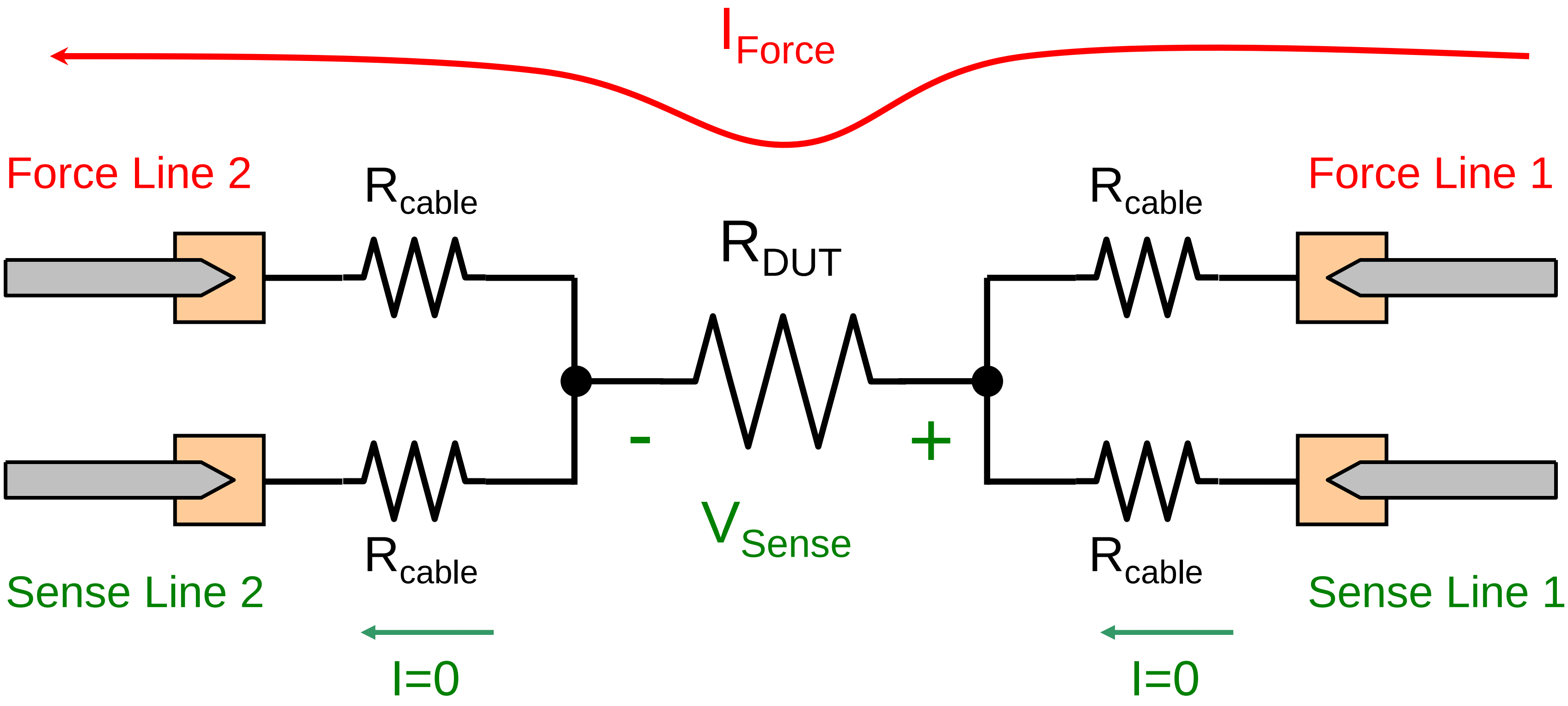


Leakage Current:

$$\frac{(100.000001\,V - 100\,V)}{1\times10^{9}\Omega} = 1\,fA$$

Triaxial cable reduces leakage current by a factor of 100,000,000.

What is a 4-Wire (Kelvin) Measurement?

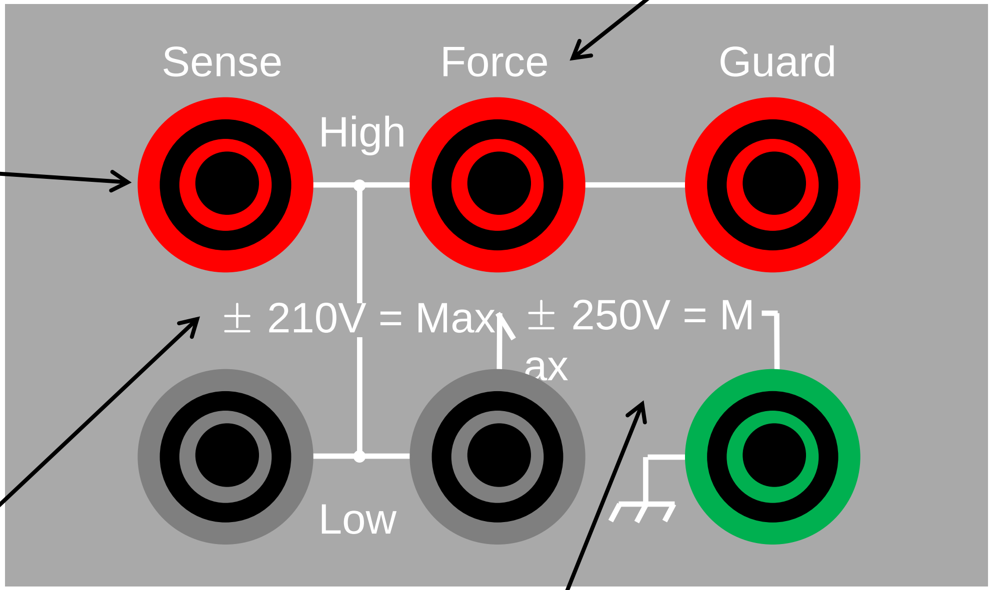


→ Eliminate cable resistance from the measurement

Example Instrument Outputs (Banana Jack)

When making a basic 2-wire measurement you should us e the **<u>Force</u>** outputs.

4-wire measurements requir e the use of the Sense lines in addition to the Force lines .



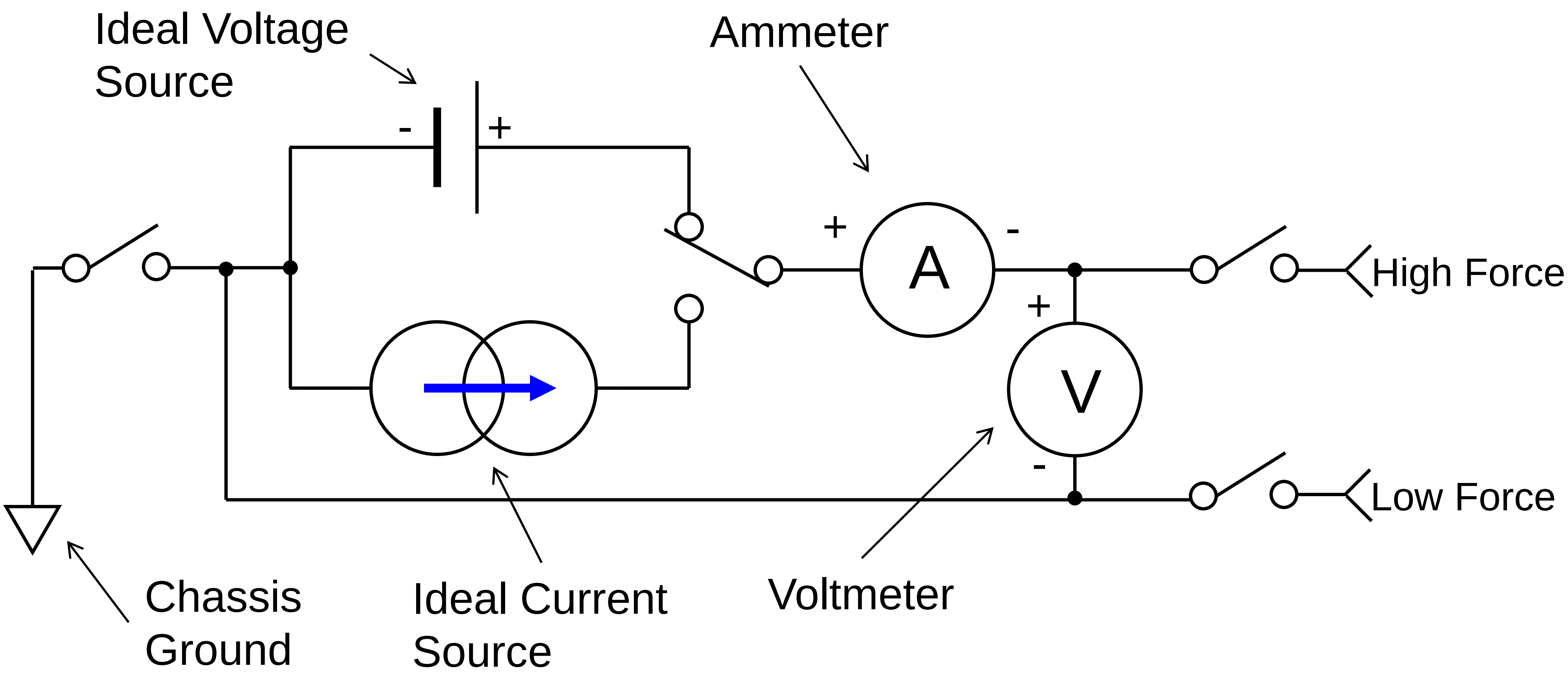
This tells you the maximum allowable voltage (210 V in this case) between the high and low inputs.

By default the low outputs are tied to chassis groun d, but in this case they can be floated up to 250 V above or below chassis ground if desired.

Source/Measure Unit (SMU) Introduction

What is a Source/Measure Unit (SMU)?

Simplified equivalent circuit (2-wire measurements):



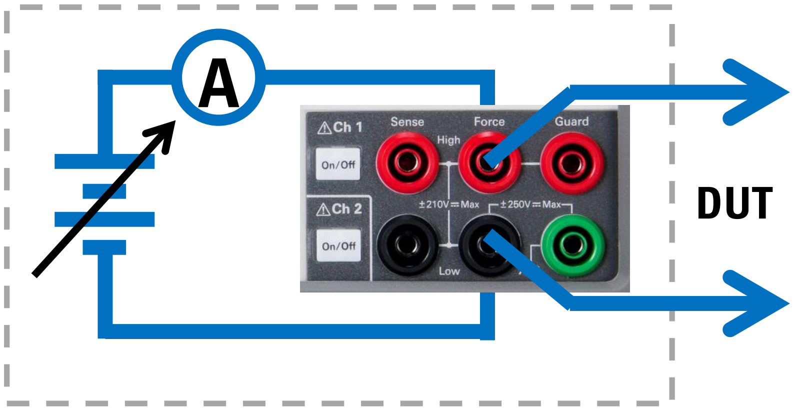
Note: The tight integration of these measurement resources yields better accuracy and faster measurement than would an equivalent collection of separate instruments.

Why Would You Use an SMU for IV Measurements?

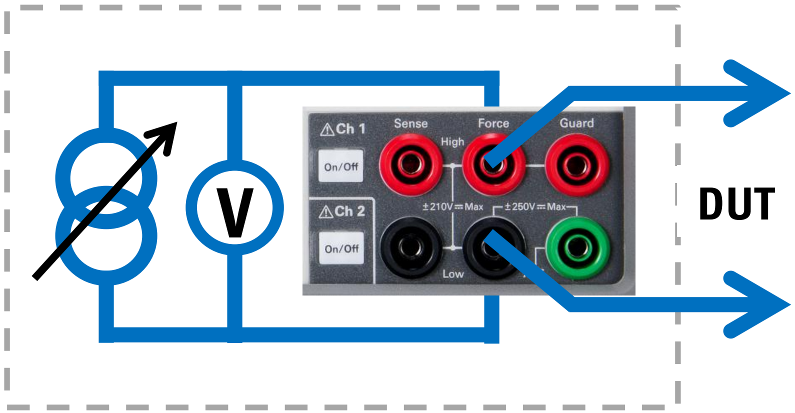
An SMU integrates the following capabilities into <u>each</u> <u>channel</u>:

- Four-quadrant voltage source
- Four-quadrant current source
- Voltage meter
- Current meter

Here are the two most common modes of operation:



VFIM (Force voltage & measure current)

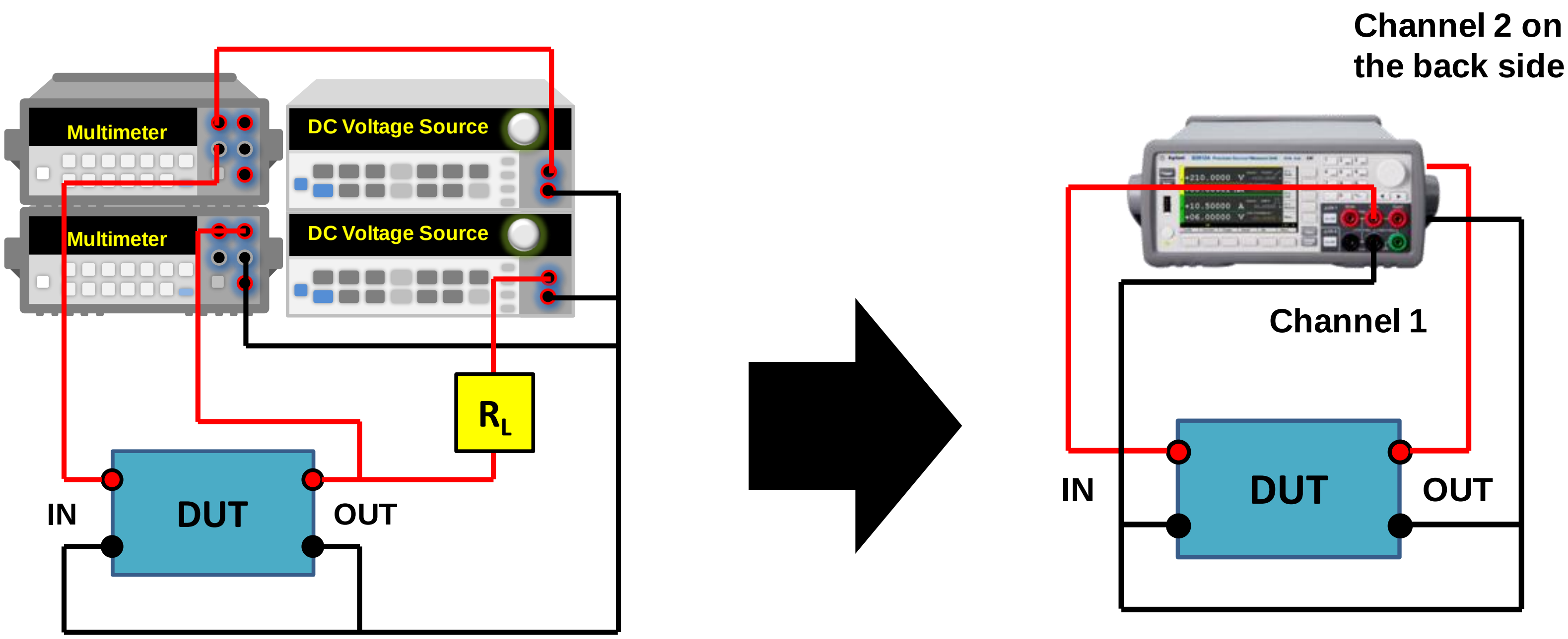


IFVM (Force current & measure voltage)

Why Use a Benchtop SMU for IV Measurements?

Problem: Limited bench-top space for single-function instruments.

Solution: A benchtop SMU reduces the number of instruments and reduces messy wiring.

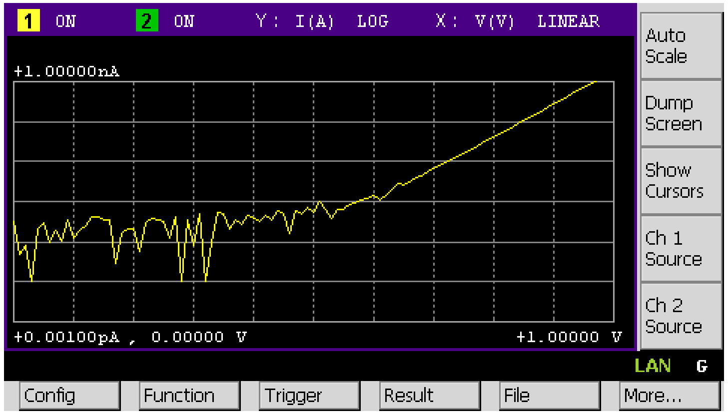


Non-SMU setup example for 4-terminal device

SMU setup example for 4-terminal device

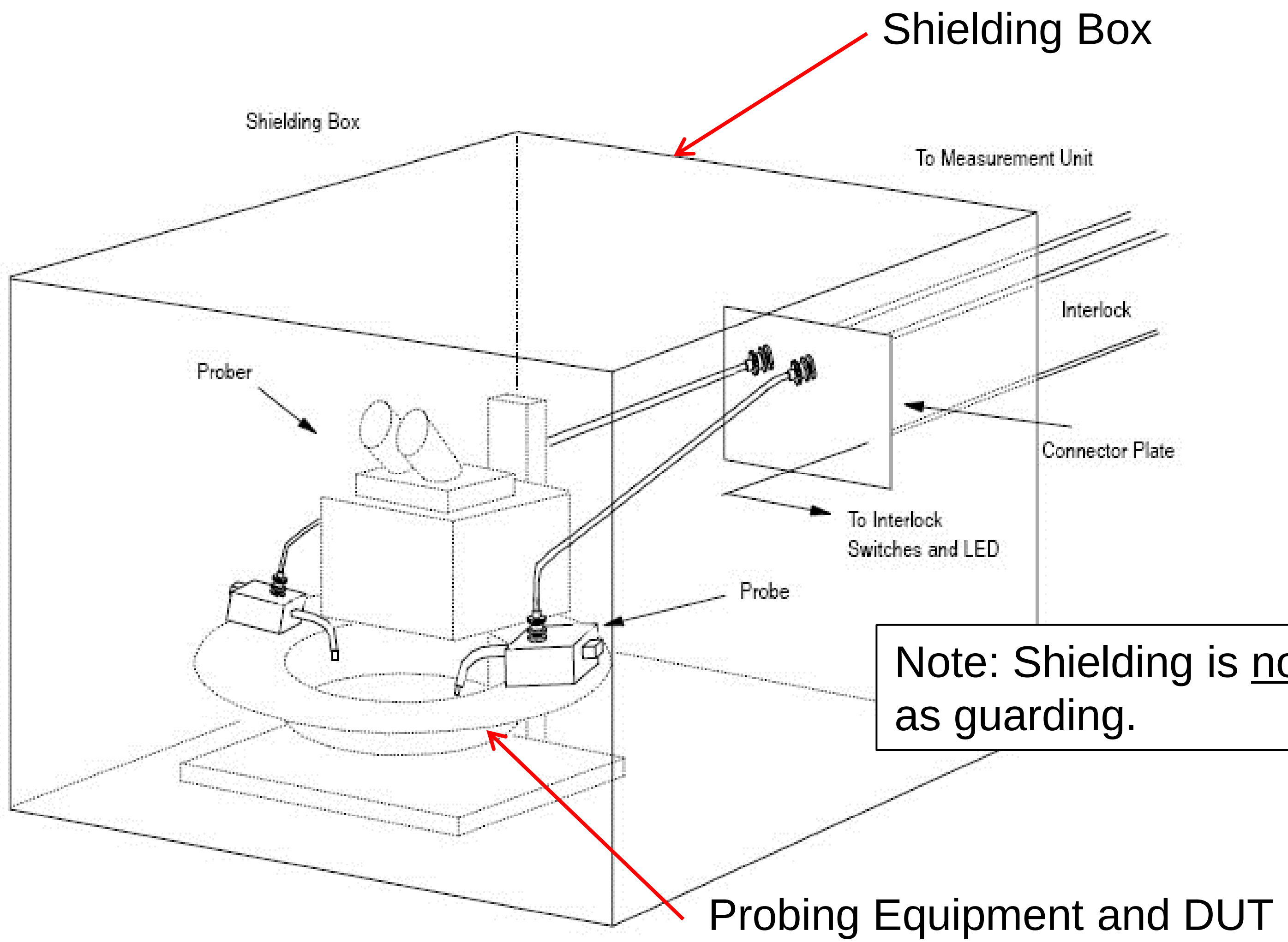
Low current measurement TECHNIQUES

Low-Current Measurement Challenges



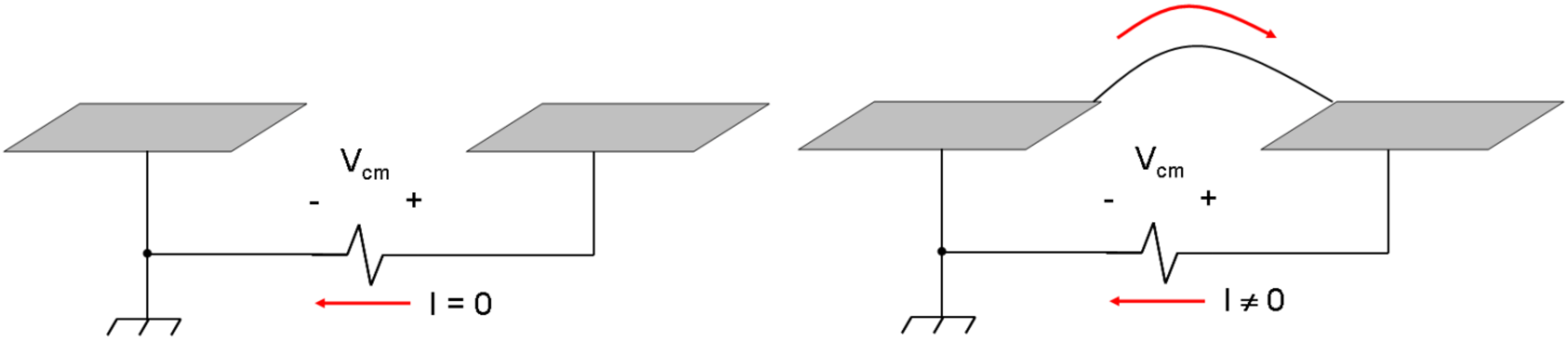
- How do I eliminate electromagnetic interference?
- How do I avoid creating ground loops?
- What is measurement ranging and how do I optimize it?
- Why is integration time important in eliminating noise?
- How do I eliminate voltage and current transients?

Use Shielding to Avoid Electromagnetic Interference



Note: Shielding is not the same as guarding.

Avoiding Ground Loops

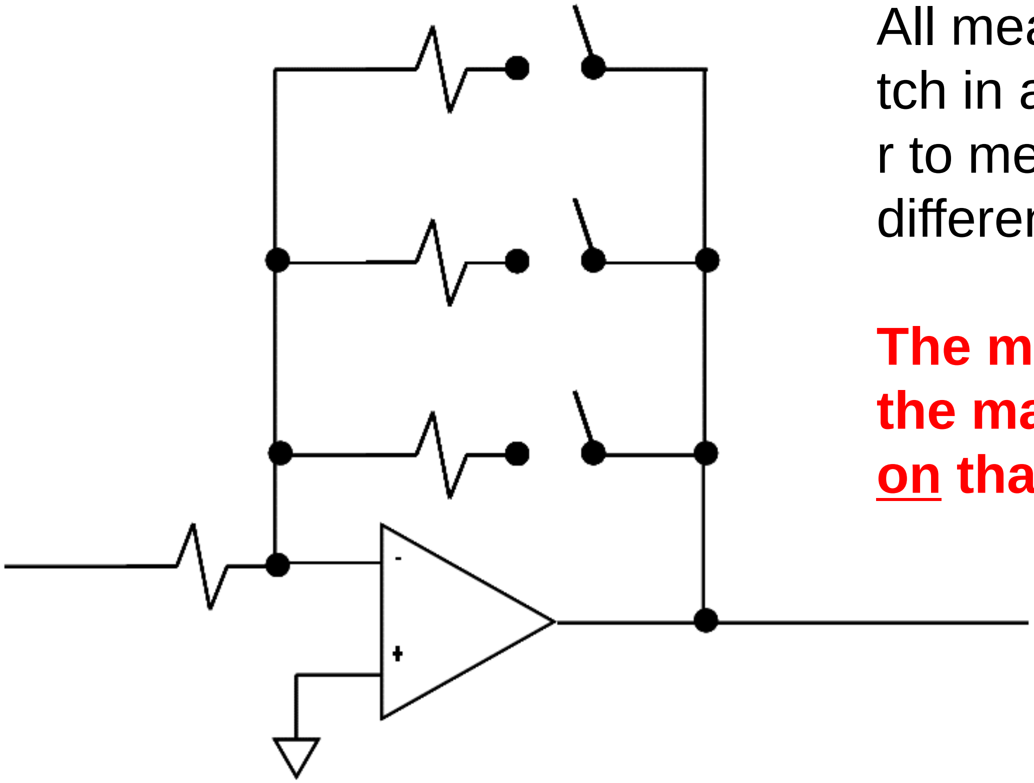


Conductive planes tied together at only one point cannot have any current flowing between them.

Conductive planes tied together at multiple points creates a loop for current (a condition to be avoided).

→ Do not connect up equipment to ground at more than one point!

Understanding Measurement Ranging - 1

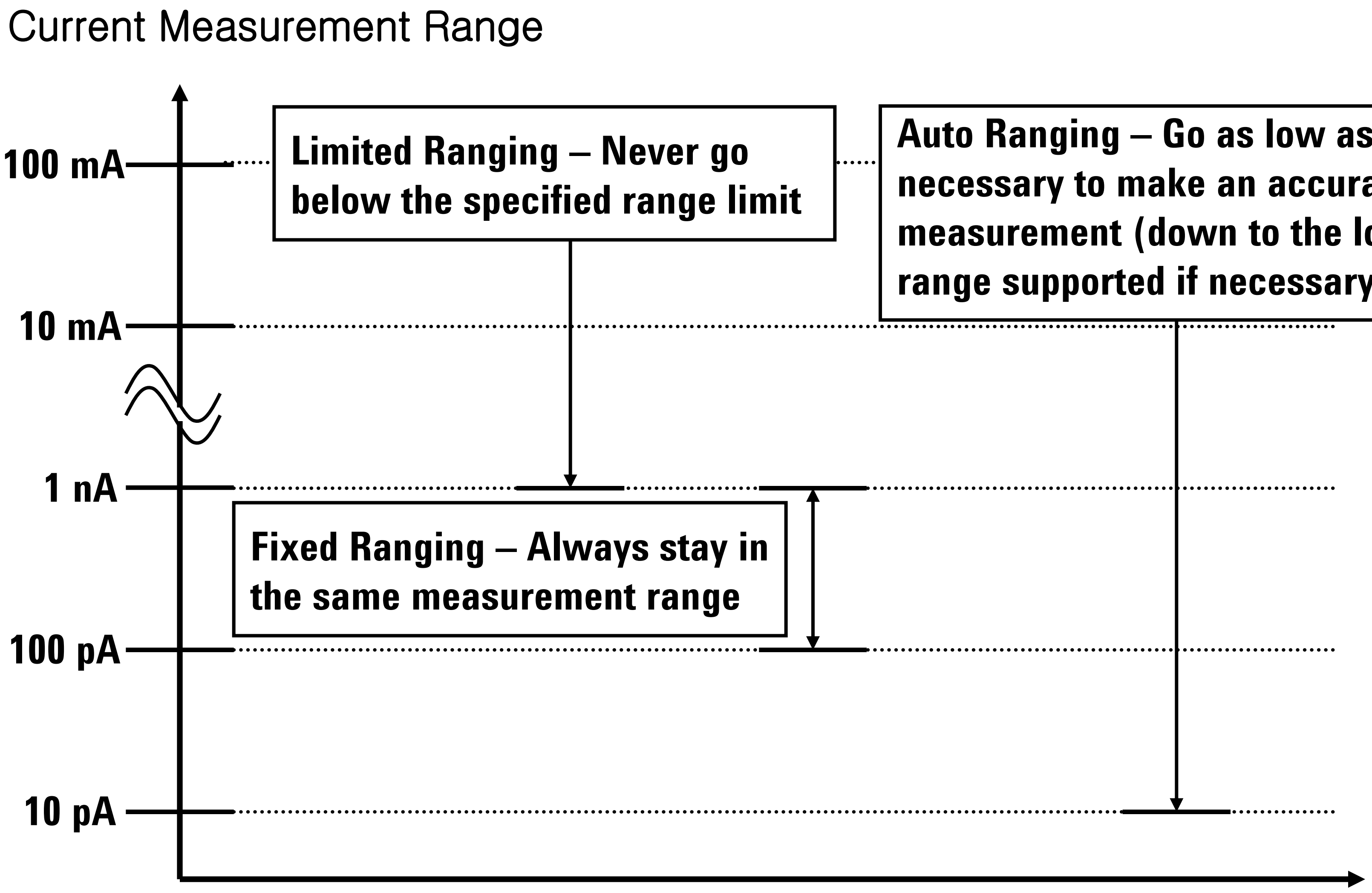


All measurement circuitry needs to swi tch in and out various resistors in orde r to measure currents and voltages at different levels.

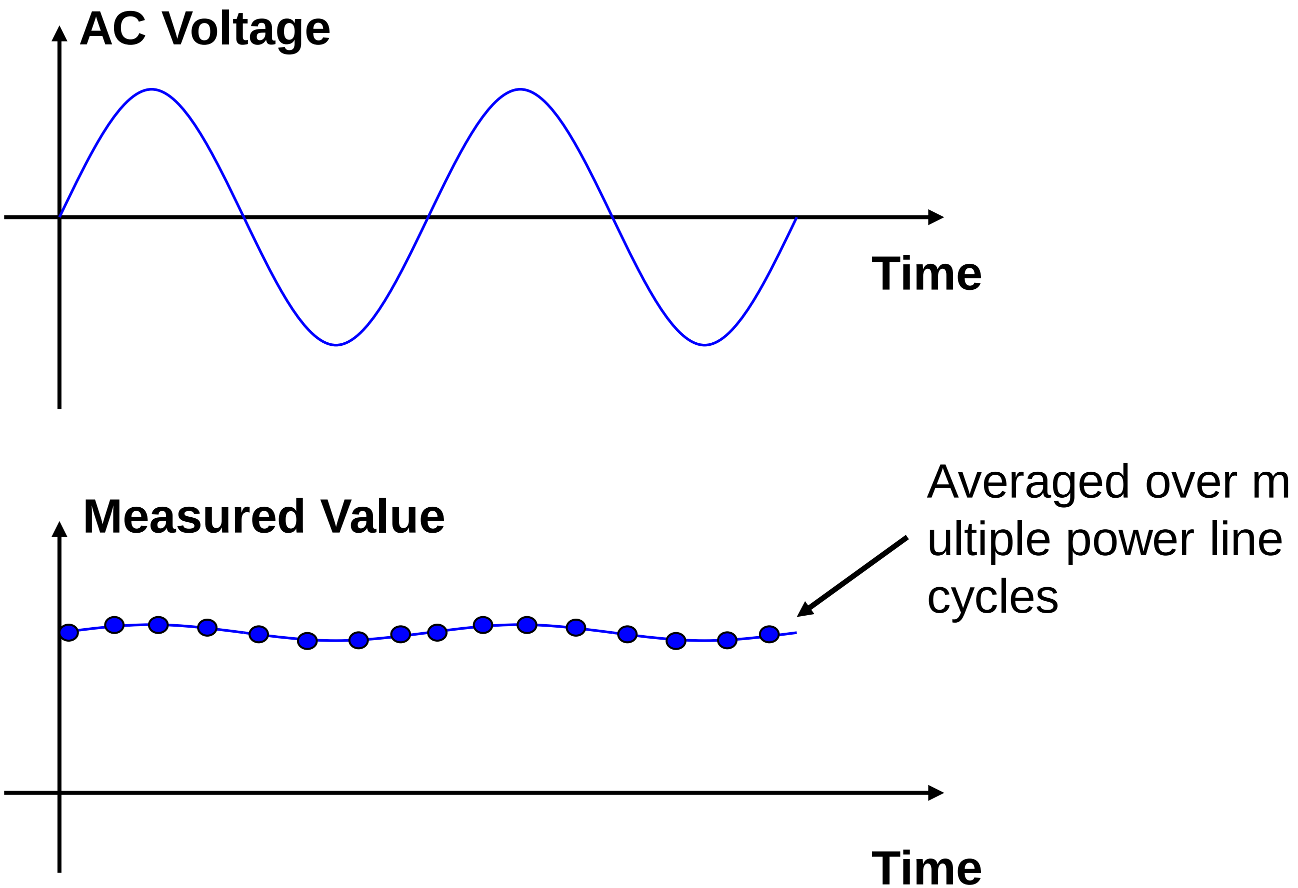
The measurement range determines the maximum measurement <u>resoluti on</u> that you can obtain*.

*Typically 5 decades below the measurement range.

Understanding Measurement Ranging - 2



Integration Time Eliminates Measurement Noise



Integration **DOES NOT** have any effect on the measurement resolution.

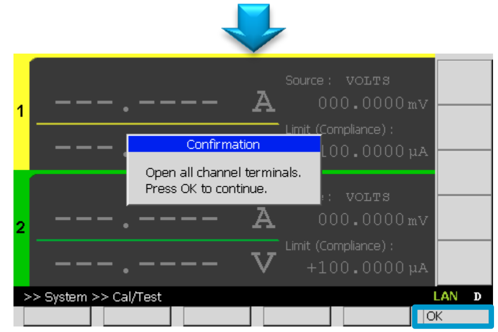
Step #1: Perform Self-calibration

Almost all instruments designed for low-current mea surement have some sort of self-calibration mechani sm. It is important that you DO THIS before attempt ing a low-current measurement.

Note: B2900A example shown

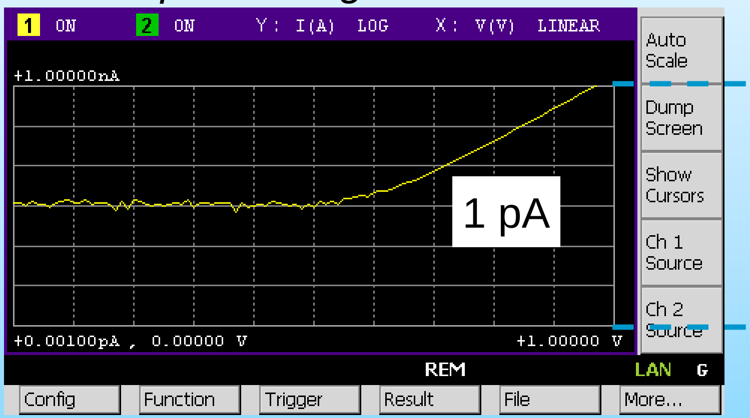
From the front panel:

Press the System > Cal/Test function keys

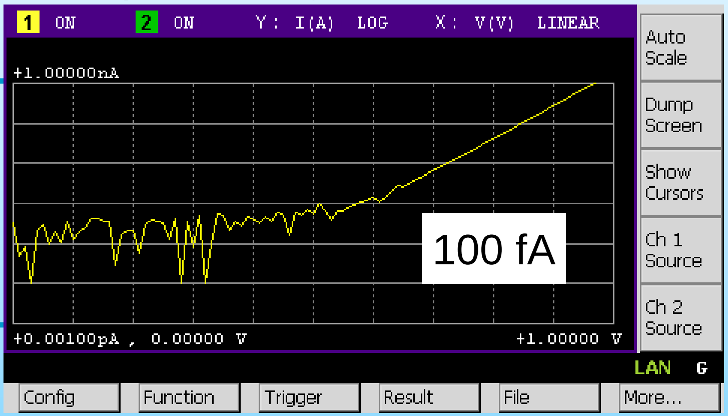


Press OK to perform Self-calibration

Before performing Self Calibration



After performing Self Calibration



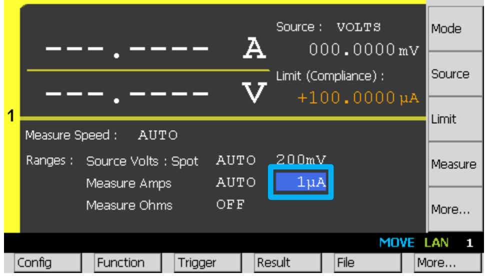
Step #2: Select the Correct Current Measurement Range

Most instruments DO NOT boot up in their lowest measurement range. In this example notice the improvement in measurement performance obtained by changing from the 1 mA current measurement range to the 10 nA current measurement range.

Note: B2900A example shown

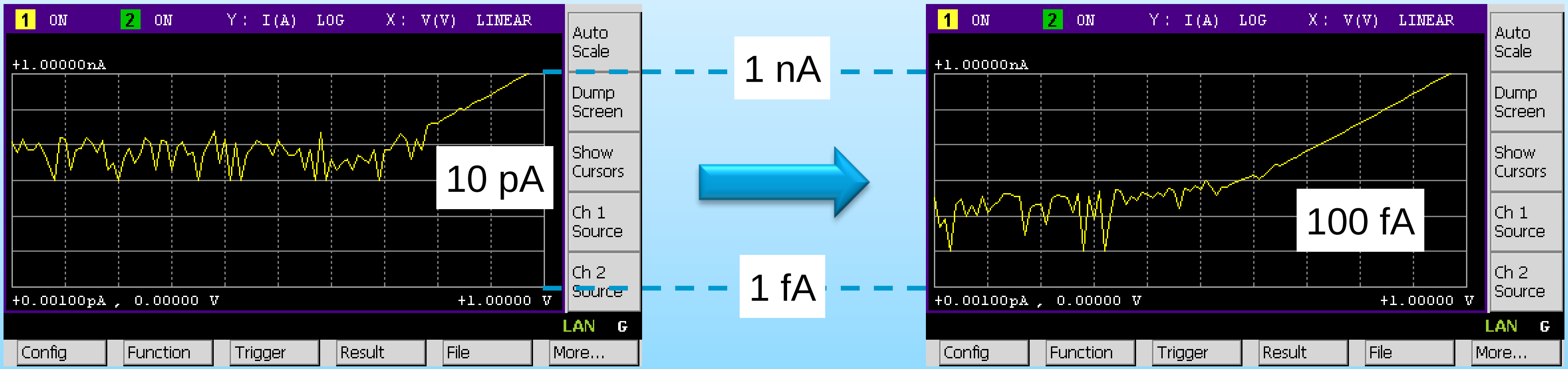
From the front panel:

In Single View mode you can specify the current measurement range.



Using 1 mA Current Measurement Range:

Using 10 nA Current Measurement Range:

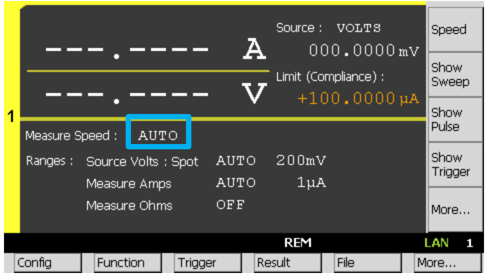


Step #3: Increase the Integration Time to Eliminate Measurement Noise

In general, low-current measurements need at least 1 power line cycle (PLC) of integration to obtain dec ent results (in this example NORMAL integration). E xtremely low currents and/or noisy environments ma y require LONG integration (16 PLCs). You can use MANUAL integration to select PLC values between t hese two extremes.

From the front panel:

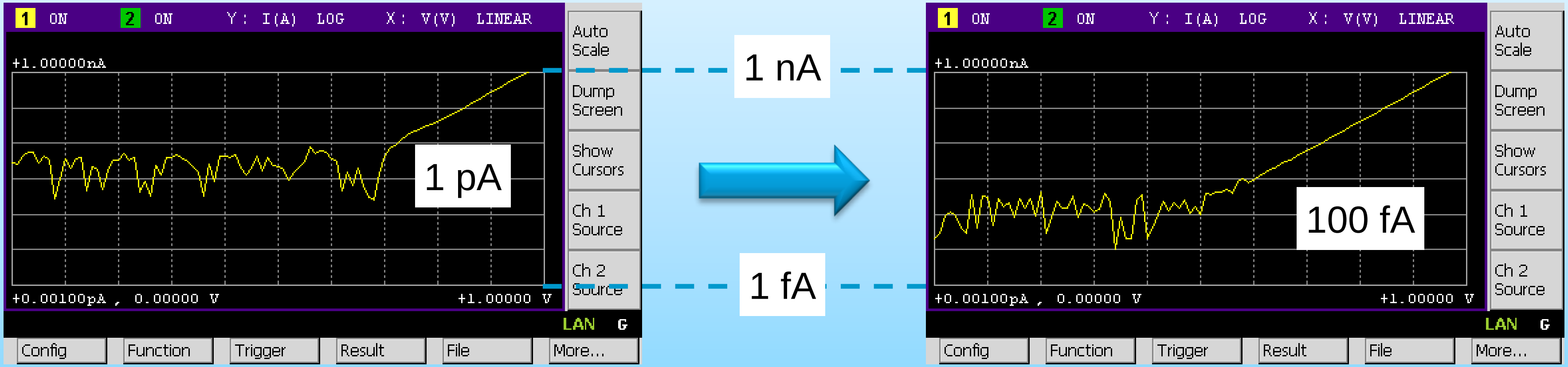
In Single View mode you can select the measure-ment speed (integration time)



Note: B2900A example shown

Using SHORT(0.01 PLC) integration time:

Using NORMAL (1 PLC) integration time:



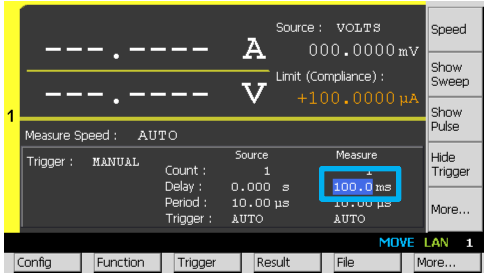
Step #4: Select an Appropriate Measurement Trigger Delay Time

The length of the wait time depends primarily on the size of the voltage step; larger voltage steps require longer wait times. However, the magnitude of the c apacitance being driven also impacts the wait time (l arger C → longer wait times).

Note: B2900A example shown

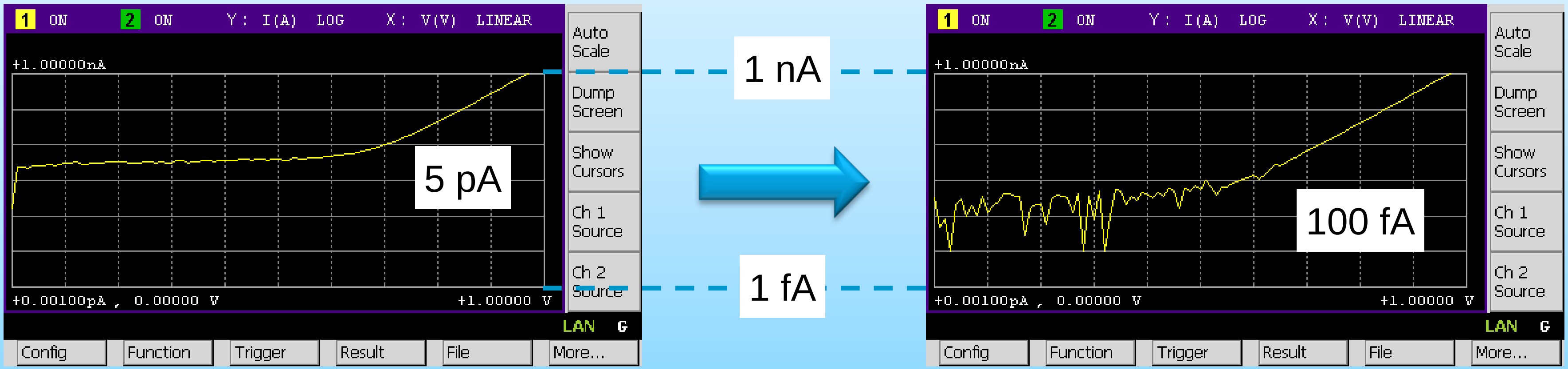
From the front panel:

In Single View mode you can select the measure-ment delay time



Using a Trigger Delay Time of 0 ms

Using a Trigger Delay Time of 200 ms



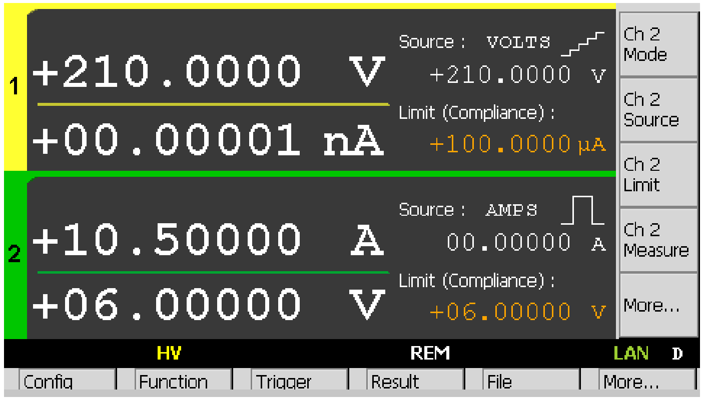
B2900A SMU series features & benefits

B2900A Series of Precision Source/Measure Units

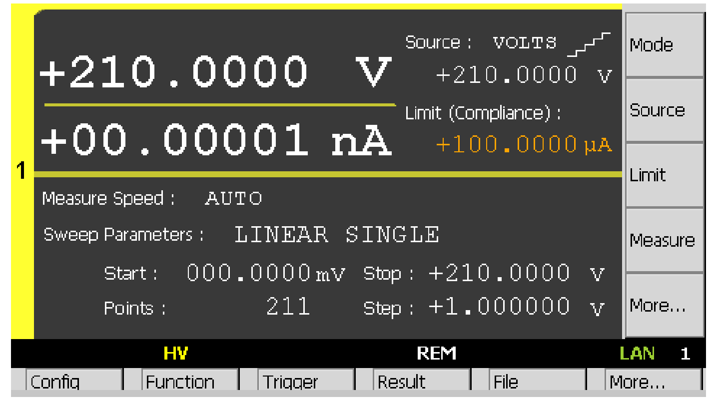
B2900A Key Features:

1. Range of up to ±210 V and ±3 A (DC) / ±10.5 A (pulsed) provides wider coverage for testing a variety of devices
2. Measurement resolution of 10 fA and 100 nV offers better source and measurement performance
3. GUI for quick bench-top testing, debug and characterization

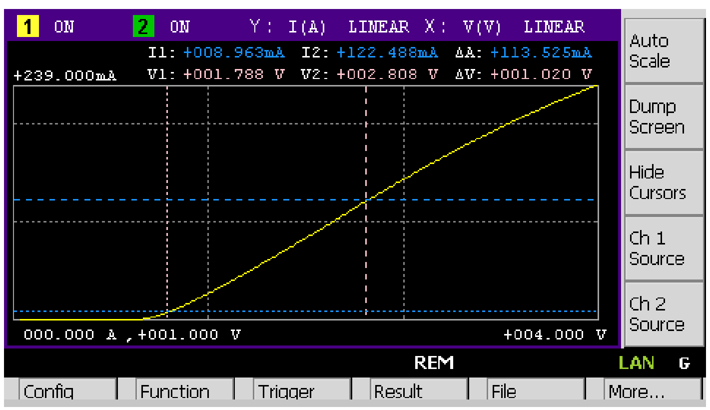
Interactive Device Evaluation Can be Performed Entirely from the Front Panel (4 Viewing Modes):



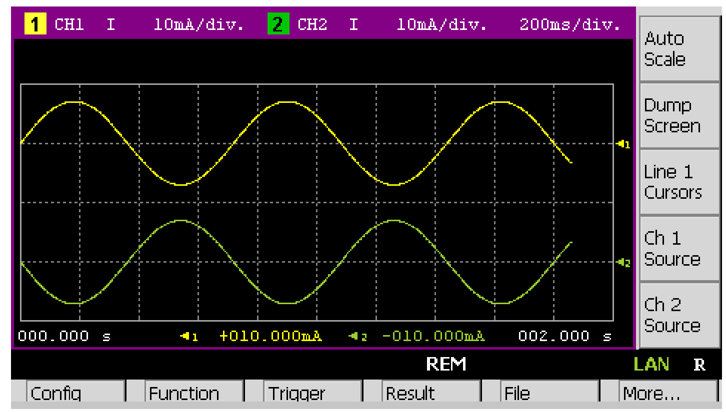
Dual Channel View (2-ch Units Only)



Single Channel View

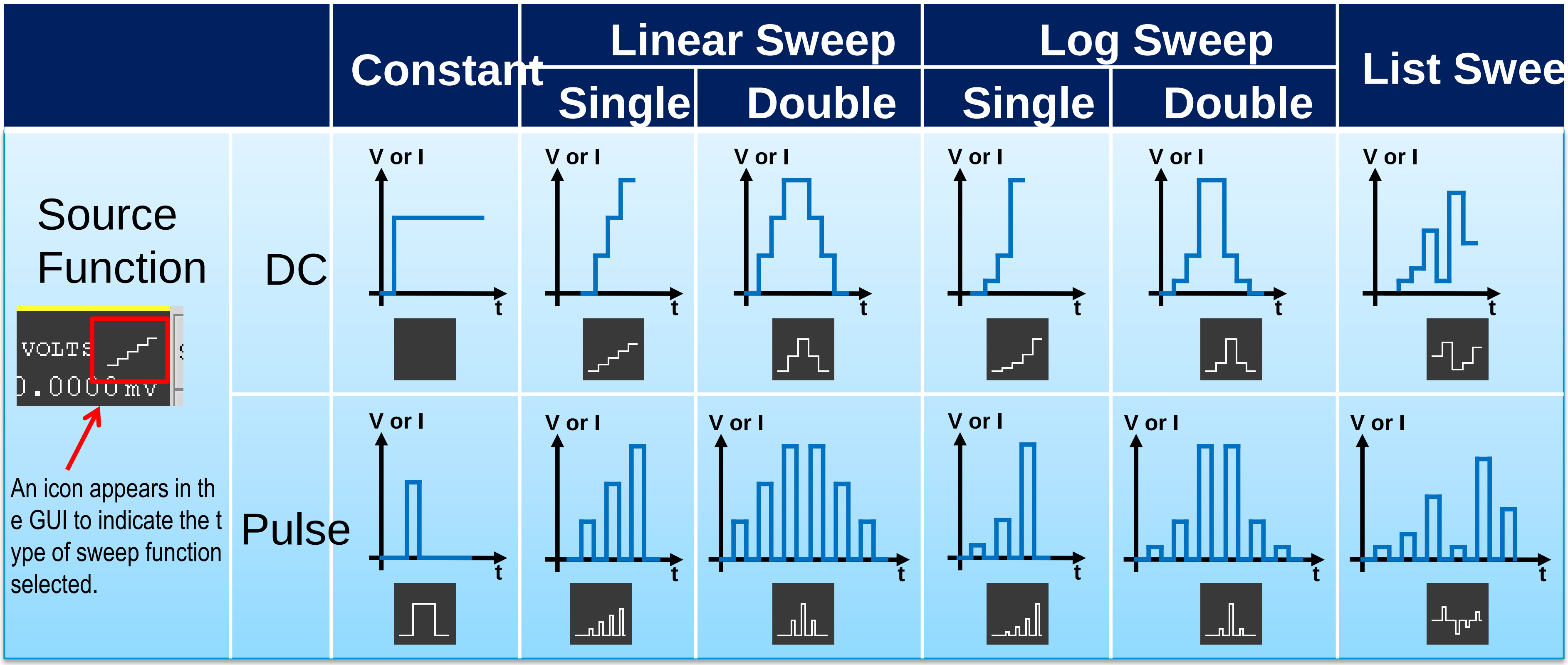


Graph View (I-V, I-t, and V-t plots)



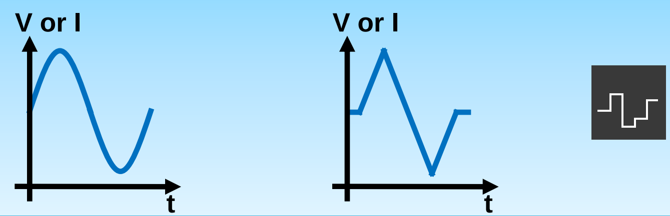
Roll View (similar to strip chart)

B2900A Series Sourcing Capabilities



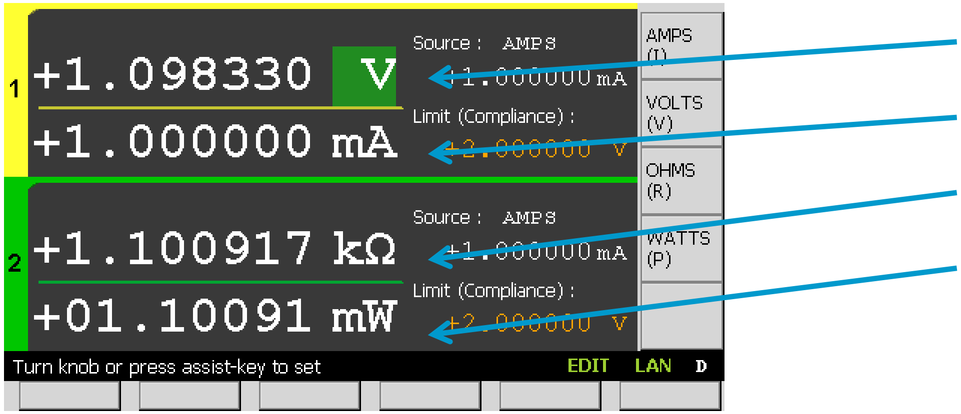
Arbitrary Waveform Generation

The List Sweep function allows you to create arbitrary waveforms wi th up to 2500 steps. The timing resolution varies by B2900A model (20ms for B2901/02A, 10ms for B2911/12A).



B2900A Series Measurement Capabilities

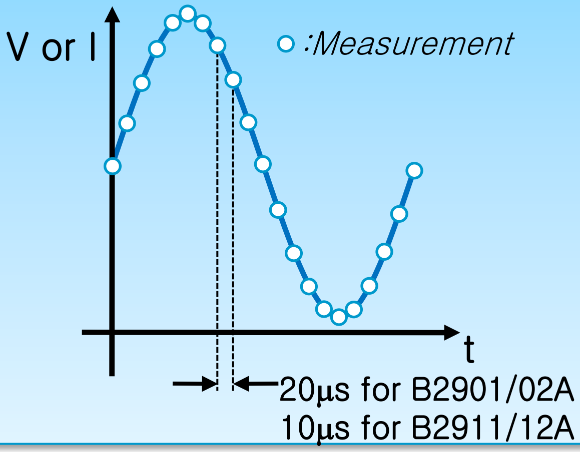
The B2900A Series has four measurement functions that can be selected for either channel using its front-panel GUI or SCPI commands.



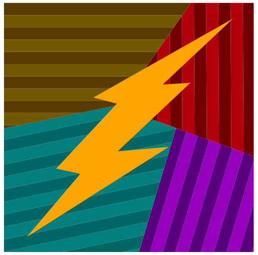
Note: The Power Measurement function cannot be specified when using remote control

High Speed Digitizing Capability

In addition to its intrinsic measurement functions, t he B2900A Series has an advanced trigger design that enables high speed digitizing measurements (20µs for B2901/02A, 10µs for B2911/12A).



B2900A Maximum Voltage and Current Output



	Maximum Voltage	Maximum Current
DC or Pulsed	210 V	0.105 A
	21 V	1.515 A[2]
	6 V	3.03 A[2]
Pulsed only[1]	200 V	1.515 A
	6 V	10.5 A

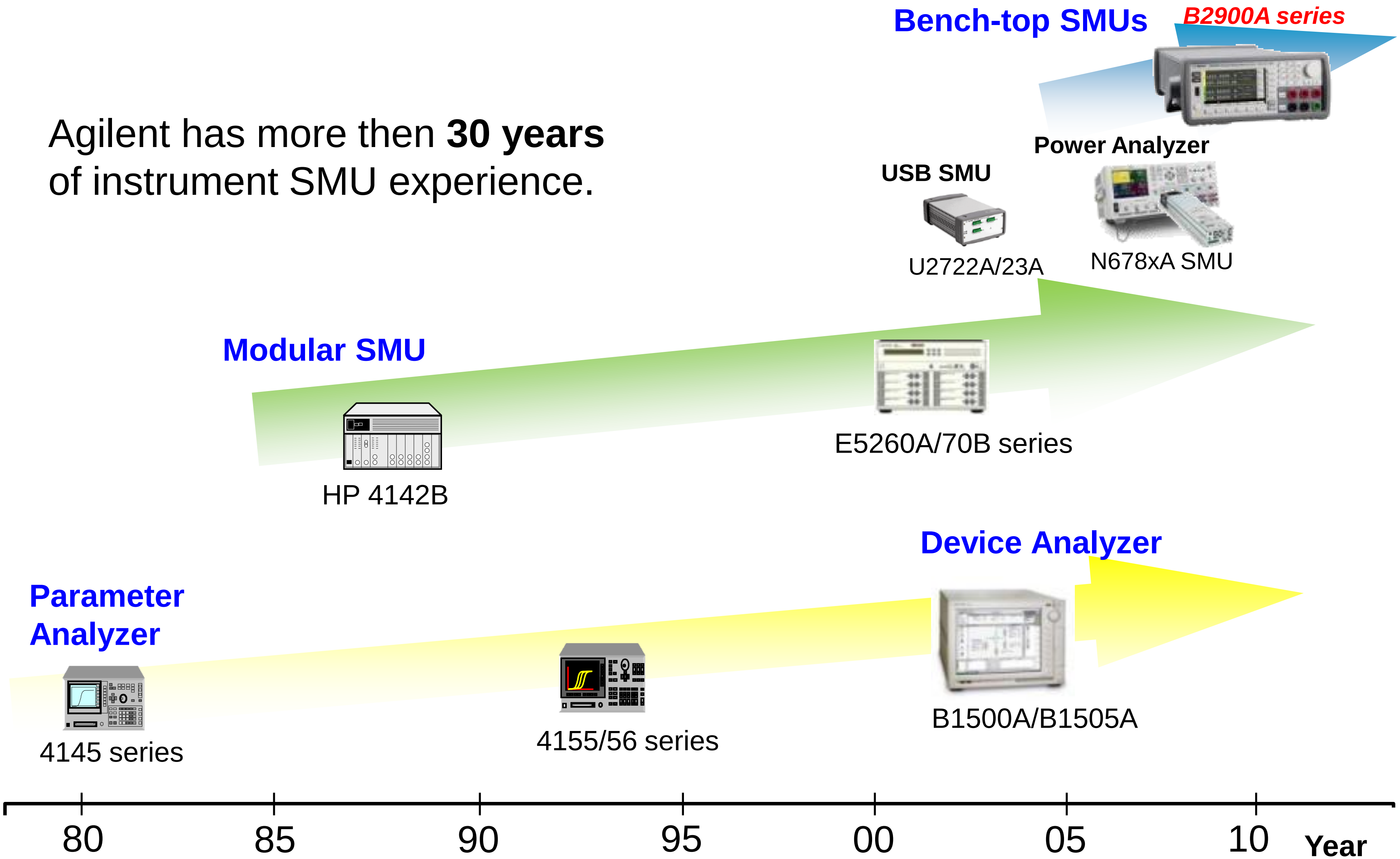
1. Maximum duty cycle is 2.5%
2. On 2-channel units some additional restrictions apply on the combined current outp ut of both channels (please refer to data sheet)

Agilent Has Free "Quick I/V" Software for Customers Wanting PC-Based Instrument Control

FINAL REMARKS

Additional Agilent SMU Instrument Products

Agilent has more then **30 years** of instrument SMU experience.



Comparison of the B1500A & B1505A

B1500A

Modules
- MPSMU
- HRSMU
- ASU
- HV-SPGU
- WGFMU

Accessories
- SCUU
- GSWU

Max I/V - 1 A, 200 V

Meas. Res. - 0.1 fA, 0.5 mV

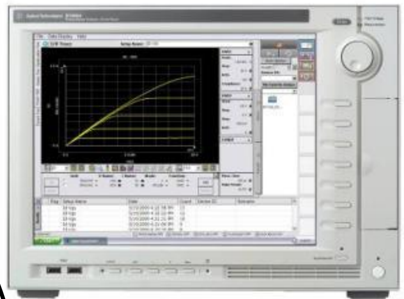
Common to both

Software

EasyEXPERT
- Tracer Test
- Classic Test
- Application Test
- Quick Test

Modules
- HPSMU
- MFCMU

B1505A



Modules
- HCSMU
- HVSMU

Accessories
- HV Bias-T
- Module Select or Unit

Max I/V - 40 A, 3000 V

Meas. Res. - 10 fA, 2 mV

Thank you