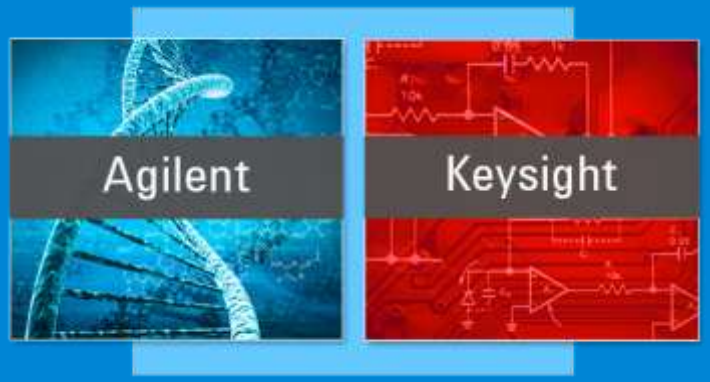
Power: Test modern DUTs faster and better



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DC Power Supplies

Programmable DC Power Supplies provide reliable and repeatable DC power to electronic devices, sub assemblies, circuits

- **Environments**
- Bench
- Design Validation
- Manufacturing / ATE
- **Industries**
- General Purpose Electronics
- Aerospace / Defense
- Wireless
- Medical

- **More than just a battery with a knob**
  - Built-in power consumption measurements
  - Fast speeds to simulate DC transients
  - Dynamic ranges to characterize sleep to peak currents
  - Built-in safety protection
  - Different form factors

Agenda

- **Introduction** **15 min**
  - Modern power supply basics and trends
- **Power supply test challenges with labs** **90 min**
  - Basic power up and measuring current drain
  - Simulating power waveforms
  - Battery drain analysis
  - Device characterization
- **Conclusion** **15 min**

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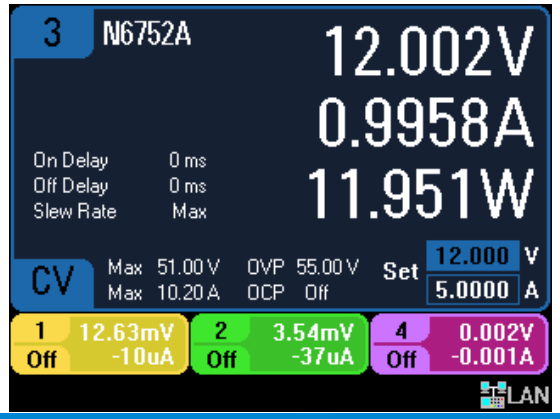
Intro: DC Power Supply Categories

KEYSIGHT TECHNOLOGIES

- **Basic Supplies**
  - Manual or programmable
  - Used for setting bias, powering circuits, etc.
- **Performance Supplies**
  - Faster, more accurate, higher power
  - Typically used in system applications
- **Modular Supplies**
  - Compact, flexible, mix-and-match
  - Easily interconnected
- **Specialty Supplies**
  - Battery simulation
  - Source/Measure Units

Basics: Output Measurements

- Many power supplies have a built-in voltmeter and ammeter to measure their own output
- The measurements can be displayed on the front panel or queried by a computer connected to the interface
- These measurements are particularly useful in computer controlled systems
- Measurement (or readback) accuracy is specified as a percent of reading plus an offset



Trends: Down Programming

- **Capacitors discharge slowly under light loads**
  - -Static voltage source: no problem
  - -Varying voltage levels: slow tests

- **Down programming**
  - -Rapidly reduce the output voltage
  - -Shorten discharge times by hundreds of milliseconds

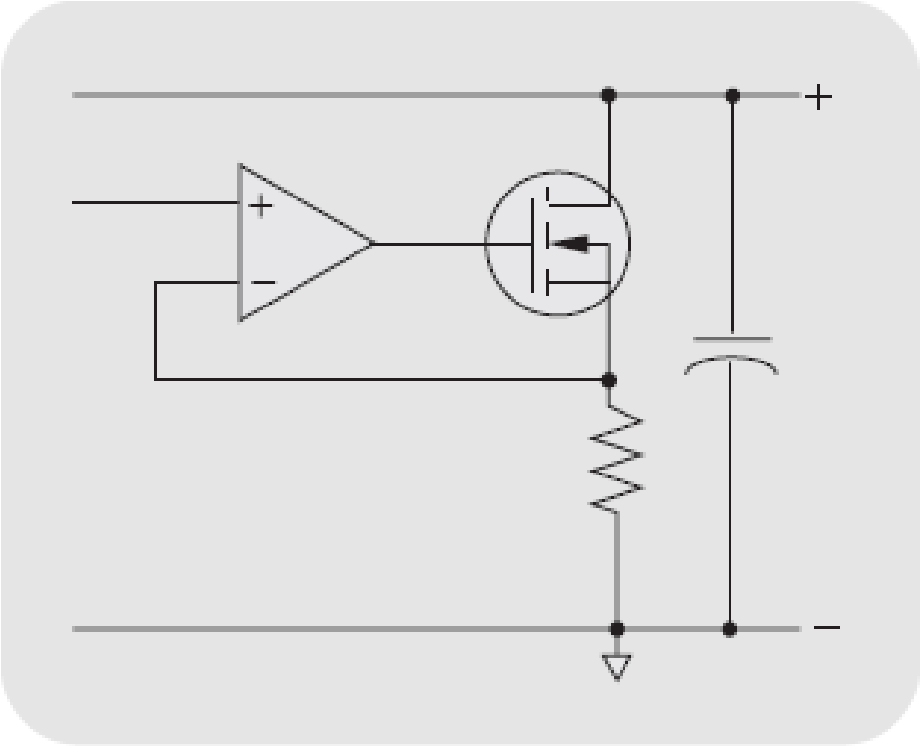
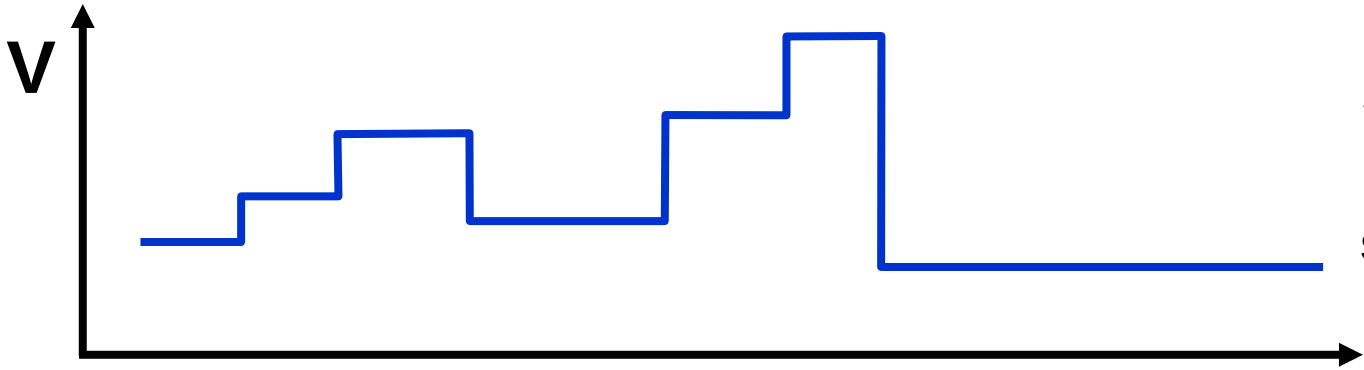


Figure 1: A down programming circuit with an FET across the output terminals

Trends: Arbitrary Waveforms/List Mode

- Advanced feature available in Agilent N6700 and 66000 only*
- LIST mode allows power supply to output a waveform like an Arbitrary Waveform Generator (ARB)
    - Slower than an ARB, but MUCH more power than an ARB
- For each point, you program a V, I, and step time
- LIST mode can change the output faster than a PC can send commands
- Example: LIST mode rapidly steps through test conditions for fast throughput



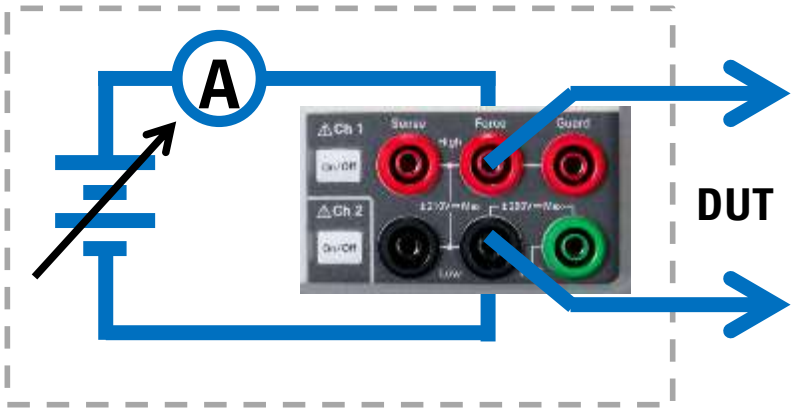
*** Also available in specialized products: AC Source, DC Loads**

What is a Source/Measure Unit (SMU)?

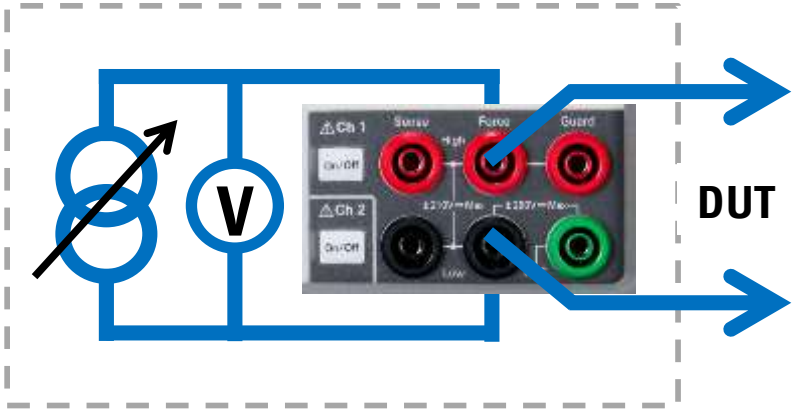
An SMU integrates the following capabilities into <u>each</u> <u>channel</u>:

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

Here are the two most common modes of operation:



VFIM (Force voltage & measure current)



IFVM (Force current & measure voltage)

BenchVue: Power Supplies

Supported Functionality

- Output Visualization
- Instrument configuration
- Exporting
  - Data
- Save/recall instrument state
- BenchVue Mobile

Supported Instruments:

- E3631A, E3632A, E3633A, E3634A, E3640A, E3641A, E3642A, E3643A, E3644A, E3645A, E3646A, E3647A, E3648A, E3649A, N6700A/B, N6701A, N6702A, N6705B

Agenda

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  - Battery drain analysis
  - Device characterization

- **Conclusion** 15 min

In 3 labs, we use the N6705 DC Power Analyzer

Boosts the productivity of the R&D Engineer

Integrates multiple instrument functions into a single box

- 1 to 4 advanced power supplies
- Digital voltmeter and ammeter
- Arbitrary waveform generator
- Oscilloscope
- Datalogger

- All functions and measurements are available from the front panel

Gain insights into your DUT's power consumption
— in minutes, not hours —
without writing a single line of code!

DC Power Analyzer has sourcing and measurement capability

Sourcing functions

- Simple DC bias
- Sequencing outputs
- Arbitrary waveform generator-like functions

Measurement functions

- DC measurements
- Oscilloscope-like functions
- Data logger function

Your lab setup contains 1 of each module type

N6705B DC Power Analyzer, 600W

- Holds up to 4 modules, below, in any combination

50 W DC Power Modules (6 models up to 100 V or 10 A)

100 W DC Power Modules (6 models up to 100 V or 20 A)

300 W DC Power Modules (5 modules up to 150 V or 15 A)

- For basic DUT or fixture power

High-Performance, Autoranging DC Power Modules

50, 100, 300, and 500 W (6 models up to 60 V or 50 A)

- For ATE systems where power supply plays key role as source and measurement instrument

Precision DC Power Modules

50, 100, 300, and 500 W (6 models up to 60 V or 50 A)

- For semiconductor testing and applications requiring precision in the mA & µA region

Source/Measure Units (SMU) & Application-Specific Modules

20 W (3 SMUs up to ±20 V or ±3 A; 2 app-specific up to 8 V, ±3 A)

- SMUs for high-precision sourcing & measurement applications, such as battery drain analysis; application-specific modules for battery-powered device manufacturing

APPLICATION & LAB #1

Basic DC power up and current drain

#1: Measuring Current Drain

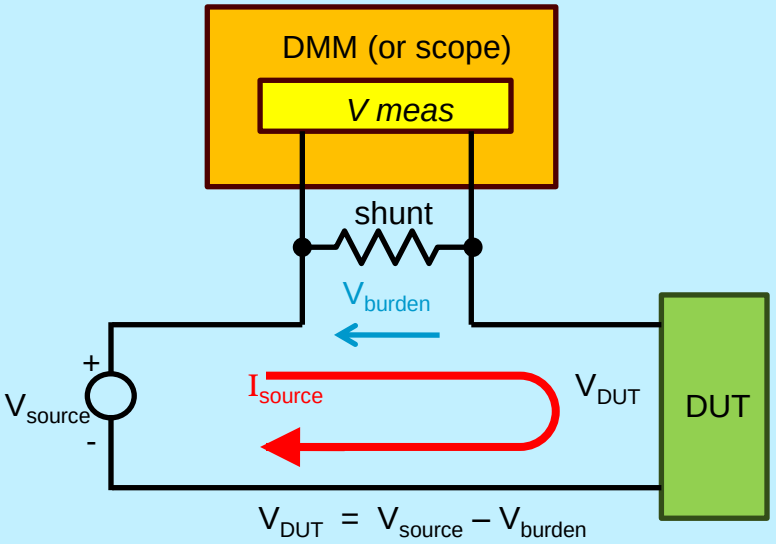
Example applications

- Battery drain analysis (on cell phones, tablets, laptops, GPS, portable tools)
- Embedded DC/DC converter power consumption (in consumer electronics, test instrumentation)

Current measurement test challenges

- Measurement errors (accuracy, self-heating effects, thermal EMF, mis-calibration)
- Current limitations (DMMs, current shunts have limited range)
- Solution implementation (must break circuit to measure current)
- Voltage burden (DMMs, current shunts produce unwanted voltage drop)

Past solution



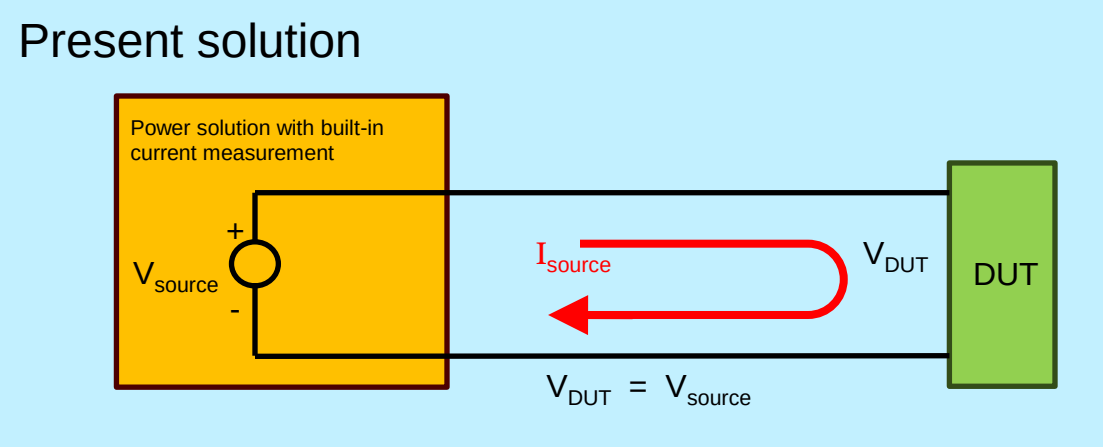
DMM with external current shunt

- Unspecified accuracy
- Must break circuit
- Shunt current limitations
- Unwanted burden voltage

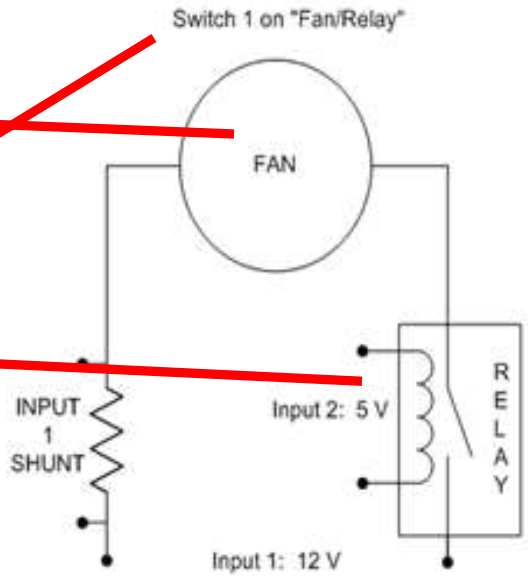
#1: Measuring Current Drain Today

Power solution with built-in current measurement

- Fully specified accuracy
- Easy implementation (no need to break circuit or add connections)
- Current measurement range matches current sourcing capabilities
- No voltage burden



Lab #1: Black Box Demo Kit – Fan/Relay Setup



Fan/Relay: Inputs 1 & 2

General Lab Instructions and Hints

- The screen on the DC Power Analyzer is not a touch screen
- Labs are meant to be exploratory
  - There are various ways to accomplish the same task
  - Follow instructions on slide or explore on your own
- Try pressing a button twice
  - Meter View button toggles between multi- and single- meter views 

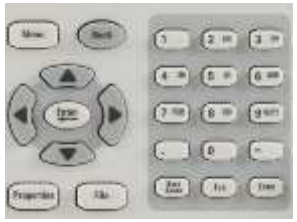
  - Scope View button toggles scope markers on and off 

- Some knobs are push-button knobs

Lab #1: Basic Power Up for a Fan and Relay

Basic power up and static measurements

1. Connect the black box demo kit wire sets 1 and 2 to the N6705 front panel Output 1 and 2 output terminals
   - Wire set 1 on the demo kit is connected to a 12 V fan (through a series relay)
   - Wire set 2 on the demo kit is connected to a 5 V relay coil (relay goes to fan)
   - Make sure demo kit switch is set to Fan/Relay
2. Use the arrow keys and number pad to set the following voltages and current limits
   - Output 1: 12 V, 1 A
   - Output 2: 5 V, 1A



3. Turn on Outputs 1 and 2

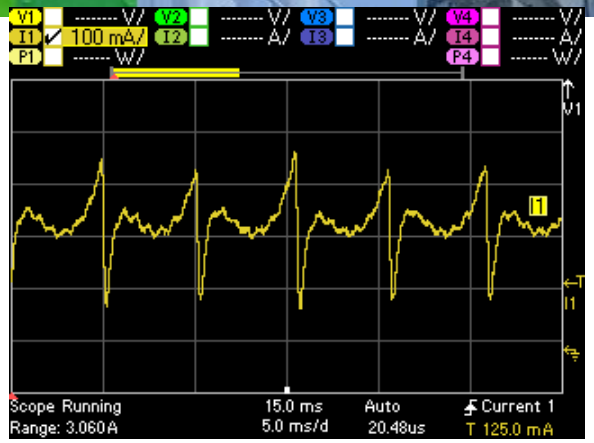
4. Press 

to toggle between views
5. Press 

to explore advanced settings

Lab #1: Measuring Current Drain

Measuring dynamic current



1. Press 

2. Press 

3. Using the arrow pad, enter key, and colored output buttons under “Select Output”, select the checkbox next to Output 1 current (I1) and deselect all other checkboxes
4. Set the Trigger source to be “Current 1 Level” with a level of 0.1 A
5. Press 

(if 

is not illuminated, press it)
6. Using the knobs under the display, change the vertical gain to “100 mA/” and center the waveform; set time scale to 5 ms/d

Lab #1: Questions

Can you see voltage and current waveforms with Meter View?

Can you make power measurements?

What is the easiest way to select the traces?

How else could you measure the dynamic current of the fan without a DC Power Analyzer?

APPLICATION & LAB #2

Simulating power waveforms

#2: Simulating Power Waveforms

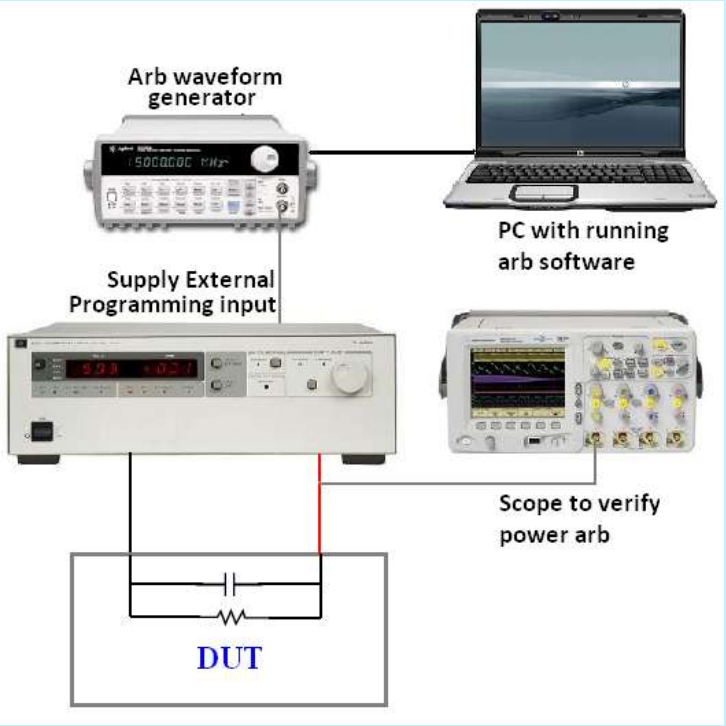
Example applications

- Power surge, spike simulation, dropout/brown-outs
- Interrupt simulation
- ISO standards, crank profiles
- Devices tested: consumer electronics, cell phones, tablets, laptops, automotive electronics, test instrumentation

Power waveform simulation challenges

- Need software to create waveform
- Must provide sufficient voltage, current, power
- Must provide power waveform verification (V, I, and P measurements)
- Solution implementation

Past solution



Creating power arbs

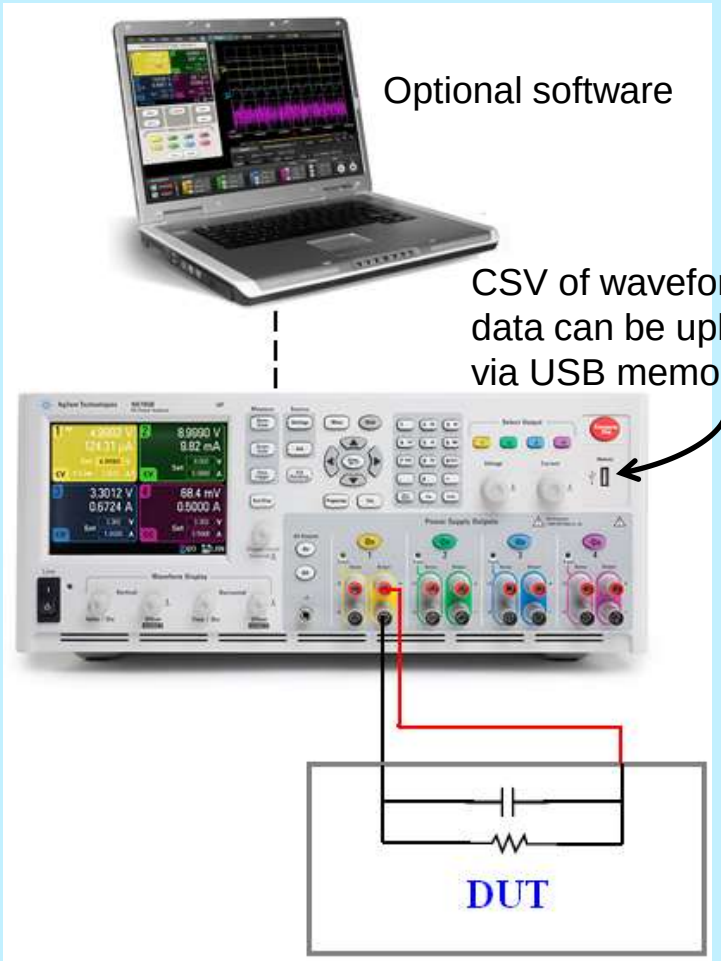
- **PC** programs waveform
- **Arb** generates waveform
- **Power supply** amplifies waveform
- **Scope** verifies waveform
- Would need shunt or current probe to measure current

#2: Simulating Power Waveforms Today

Power solution with built-in arbitrary waveform generator

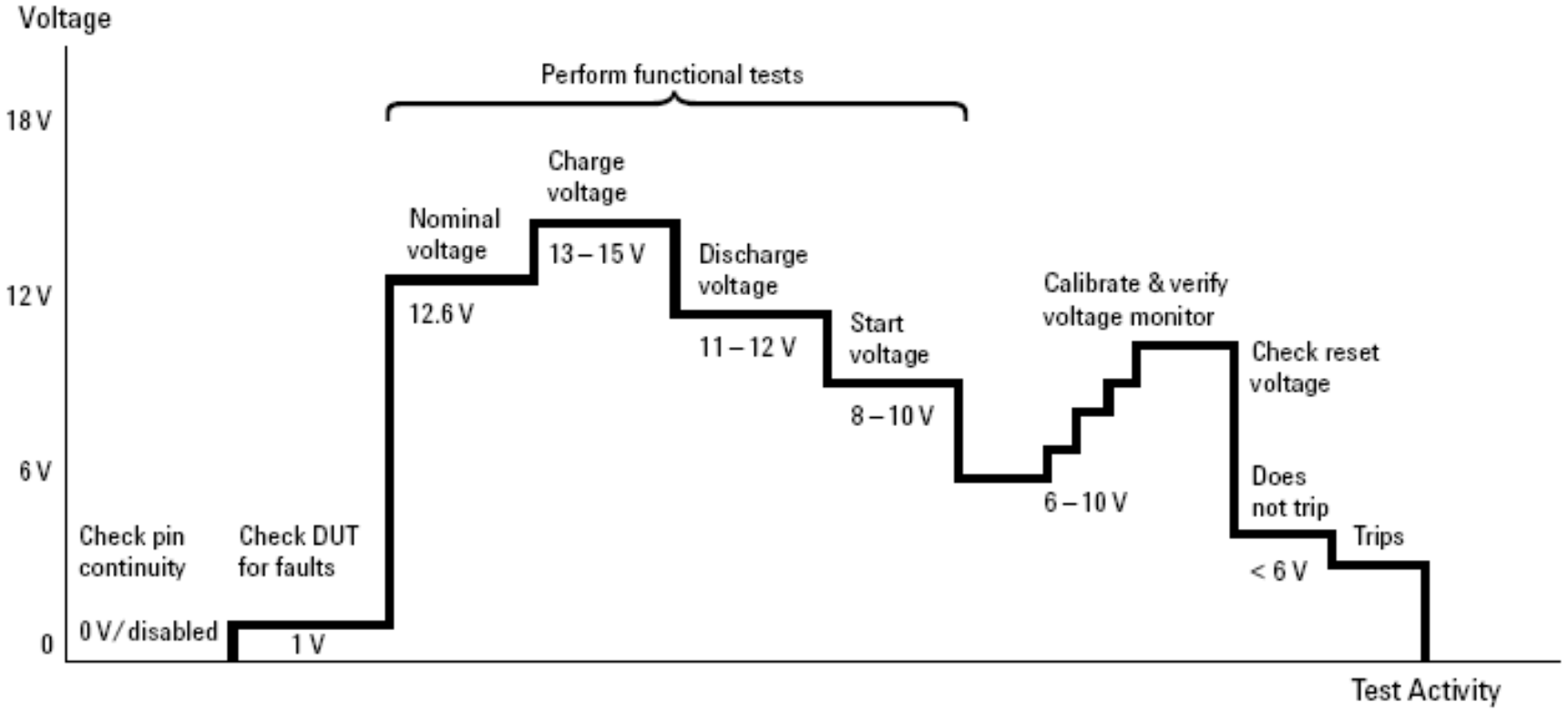
- Simple arbs available from front panel or waveform editing software is available
- Power solution provides full voltage, current, and power
- Built-in voltage, current, power measurement verifies waveforms
- Simplified configuration means no extra simulation or measurement connections needed

Present solution



#2: Specific Example of High Speed Margin Test:

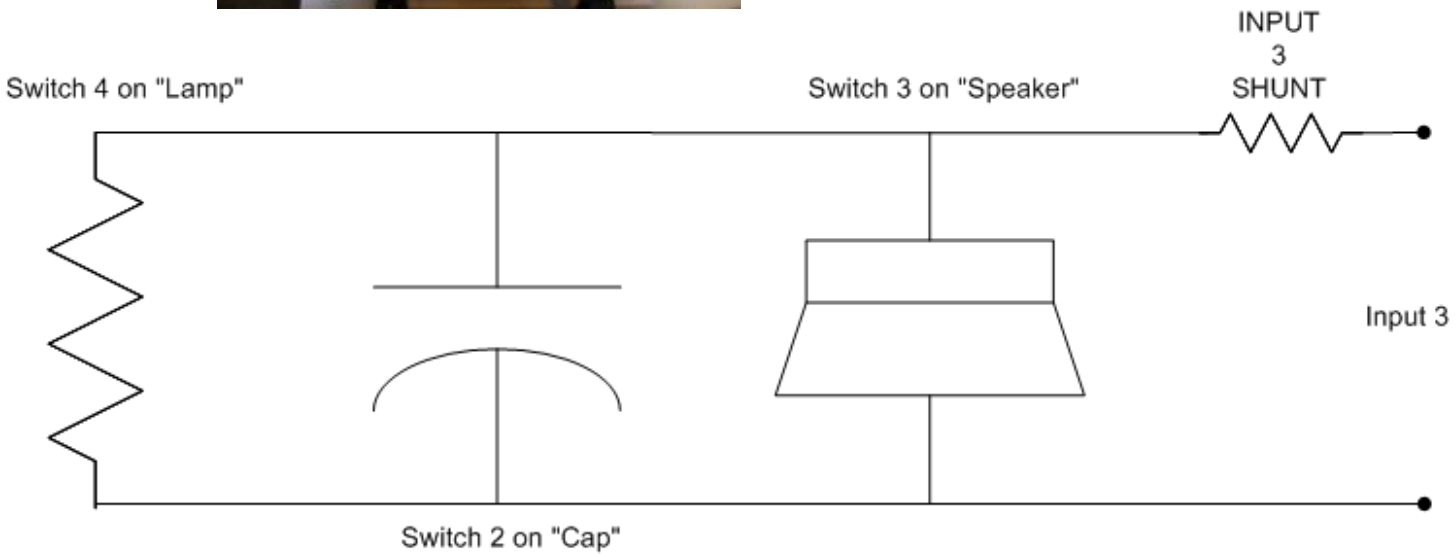
Automotive Engine Control Unit



Lab #2: Black Box Demo Kit – Speaker Setup

Set switches:

- Cap: Off
- Speaker: On
- Lamp: Off



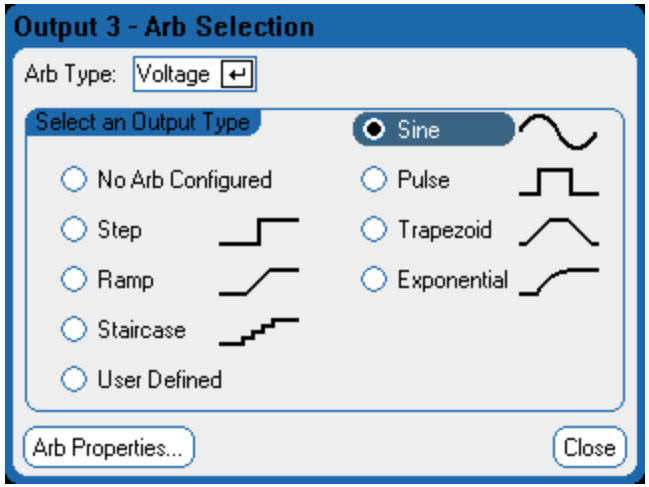
Capacitor, Speaker, & Light: Input 3

Lab #2: Simulating Power Waveforms

Setting up a Waveform

1. Connect wire set 3 from the demo box to the N6705 front panel Output 3 output terminals
2. Ensure the demo box is switched to “Speaker” (Cap & Lamp Off)
3. Set Output 3 current limit to 1 A
4. Press 

twice
5. Select “Sine”

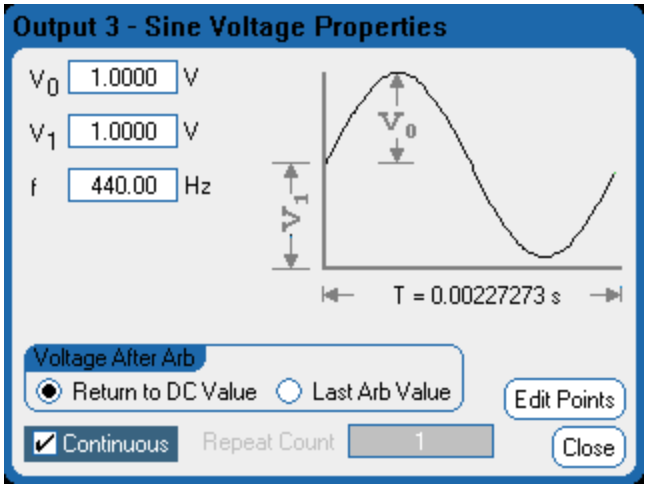


Lab #2: Simulating Power Waveforms

Configuring the sine wave

7. Press 

and configure the following parameters:
   - V_0 = 1 V
   - V_1 = 1 V
   - f = 440 Hz
   - Continuous waveform
8. Turn on Output 3
9. Press 



Extra Credit: What is 440 Hz musically?

More Extra Credit: Harmonize with your neighbor's sinewave

Lab #2: Questions

What other waveforms could you create with the DC Power Analyzer? (check with Output 1 waveforms to view full list)

Can you create voltage and current waveforms?

What is a Constant Dwell (CD) waveform?

How could you recreate this test without a DC Power Analyzer and what are its limitations?

APPLICATION & LAB #3

Battery drain analysis

#3: Battery Drain Analysis

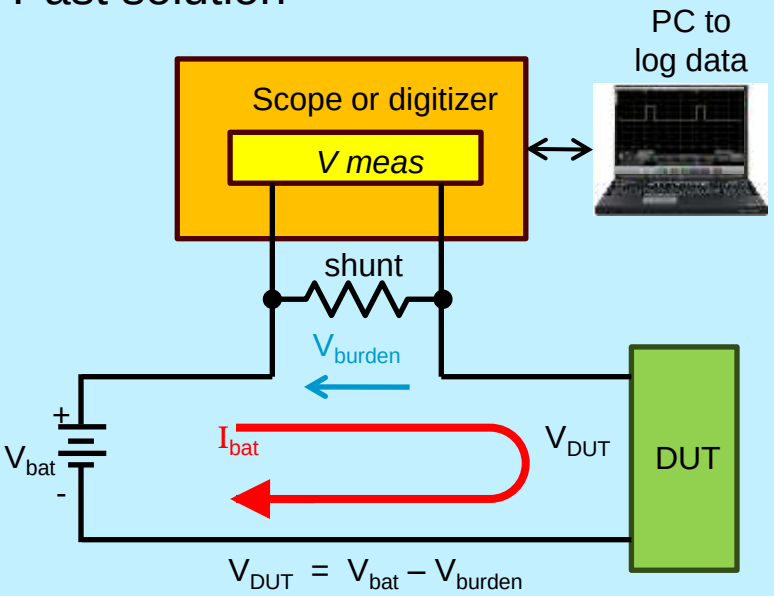
Example applications

- Hardware development: optimize energy efficiency
- Software development: validate new code builds to minimize current draw
- Design validation: battery run-down test
- Devices tested: cell phones, medical implants, police radios, tablets, laptops, GPS

Battery drain analysis challenges

- Wide dynamic current range (need multiple shunts)
- Voltage burden (current shunts produce unwanted voltage drop)
- Long data log times required to capture large variations in current drain (hours)
- Solution implementation (wiring, programming)

Past solution



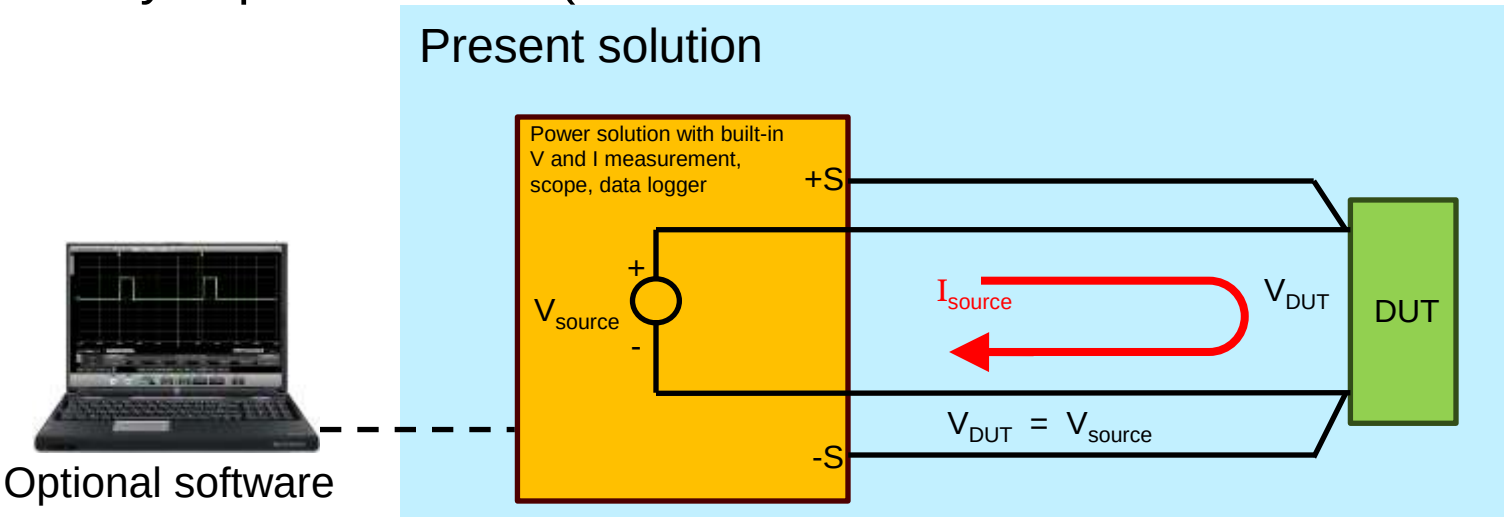
Scope or digitizer with external current shunt

- Dynamic range limitations
- Unwanted burden voltage
- Must develop software
- Must break circuit

#3: Battery Drain Analysis Today

Power solution with voltage and current measurement using scope or data logger

- Wide dynamic current measurement range (µA to several A)
- No voltage burden
- Built-in scope and data logging
- Easy implementation (no need to break circuit or add connections)



#3: Mobile Phone Example

Mobile phone standby current drain spans a wide dynamic range reflecting a composite of a wide range of activities

- Sleep activity: ~100 µA to mA level (lowest)
- Idle activity: ~20 to 50 mA level
- Receive activity: ~100 to 300 mA pulses
- Transmit activity: ~1 to 2.5 A pulses (highest)
- Overall standby average battery drain: ~ 0.5 to 5 mA
- Standby activities vary over time (~ hour timeframe)

Dictates having a 2.5 A measurement range ideally with:

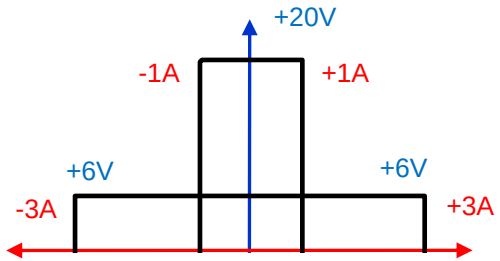
- ~25 µA offset accuracy (0.001% or 10 PPM) = 5% error for 0.5 mA signal!
- Able to log current drain at a high rate for an hour or more

#3: In the lab, we'll be using app-specific modules

N6781A 2-Quadrant Source/Measure Units

Specialized DC power supply module for battery drain testing:

- For use in the N6705 mainframe
- Settable battery emulation characteristics
- Fast transient response for pulsed loads
- Auxiliary DVM input port for battery run-down testing
- Up to 200 kSa/sec digitizing rate
- Voltage Source, Current Source, Electronic Load



N6781A for Battery Drain Analysis

N6782A for Functional Test

Innovation:

Seamless measurement ranging for accurate measurement of battery drain spanning wide dynamic ranges

#3: Key Feature: Seamless Measurement Ranging

Voltage				
Range	**20 V**	**6 V**	**1 V**	**100 mV**
Programming Accuracy	±(0.025% + 1.8 mV)	±(0.025% + 600 µV)		
Measurement Accuracy	±(0.025% + 1.2 mV)		±(0.025% + 75 µV)	±(0.025% + 50 µV)

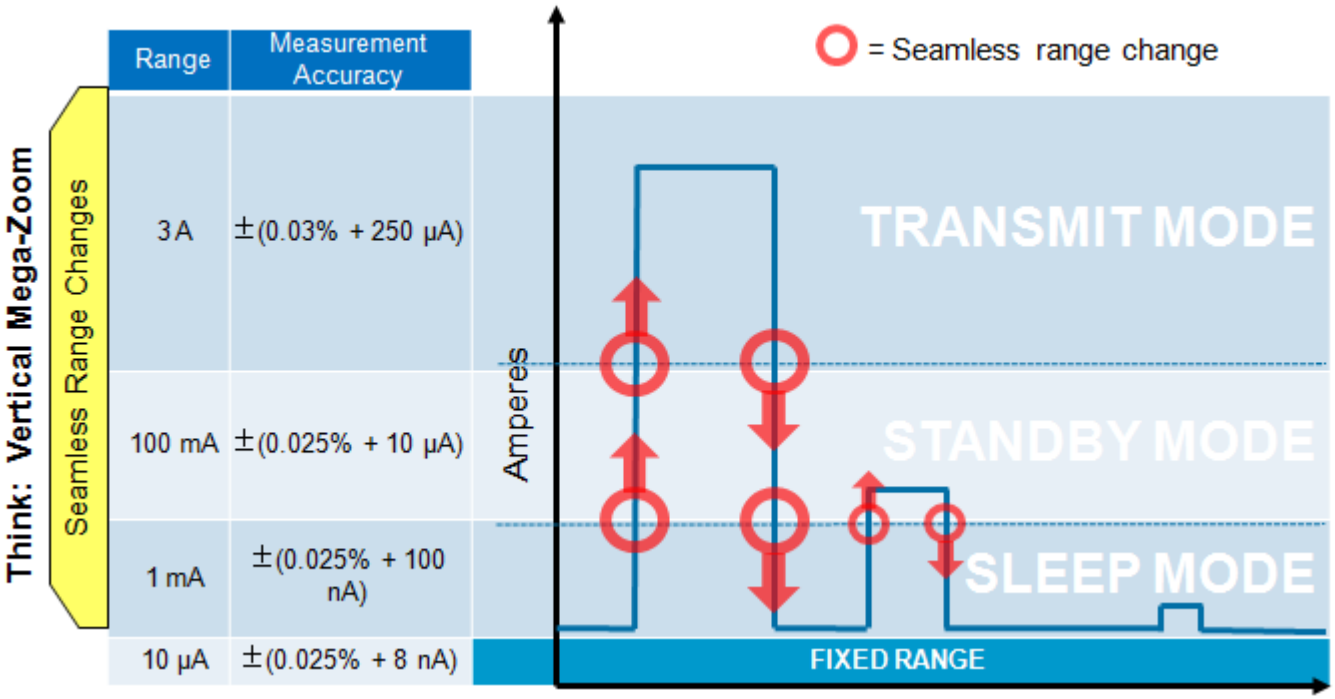
Seamless measurement between these 3 ranges

Current						
Range	**3 A**	**1 A**	**300 mA**	**100 mA**	**1 mA**	**10 µA**
Programming Accuracy	±(0.04%+ 300µA)	±(0.04%+300µA)	±(0.03%+150µA)			
Measurement Accuracy	±(0.03% + 250 µA)			±(0.025% + 10µA)	±(0.025% + 100 nA)	±(0.025% + 8 nA)

Seamless measurement between these 3 ranges

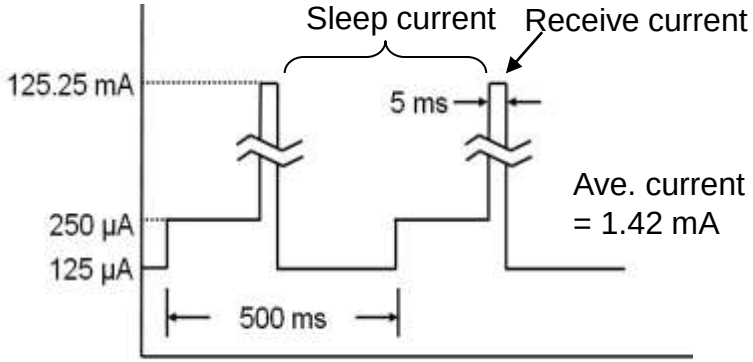
- Seamless ranging continually changes ranges without glitches or losing readings
- 200 kHz, 18-bit digitizer, with seamless ranging, acts likes single range of ~28-bits
- 3 A range with an effective offset error as low as 100 nA (0.03 PPM) Accurate measurements from Amps to µA during a single scope sweep or data-log

#3: Seamless Measurement Ranging Example



- Seamless ranging is optimized for this current waveform measurement:
  - Measurement is never over-ranged providing a uninterrupted stream of accurate, valid readings
  - As an SMU, measurement and sourcing are totally decoupled assuring glitchless output performance

Lab #3: Battery Drain Demo Set Up

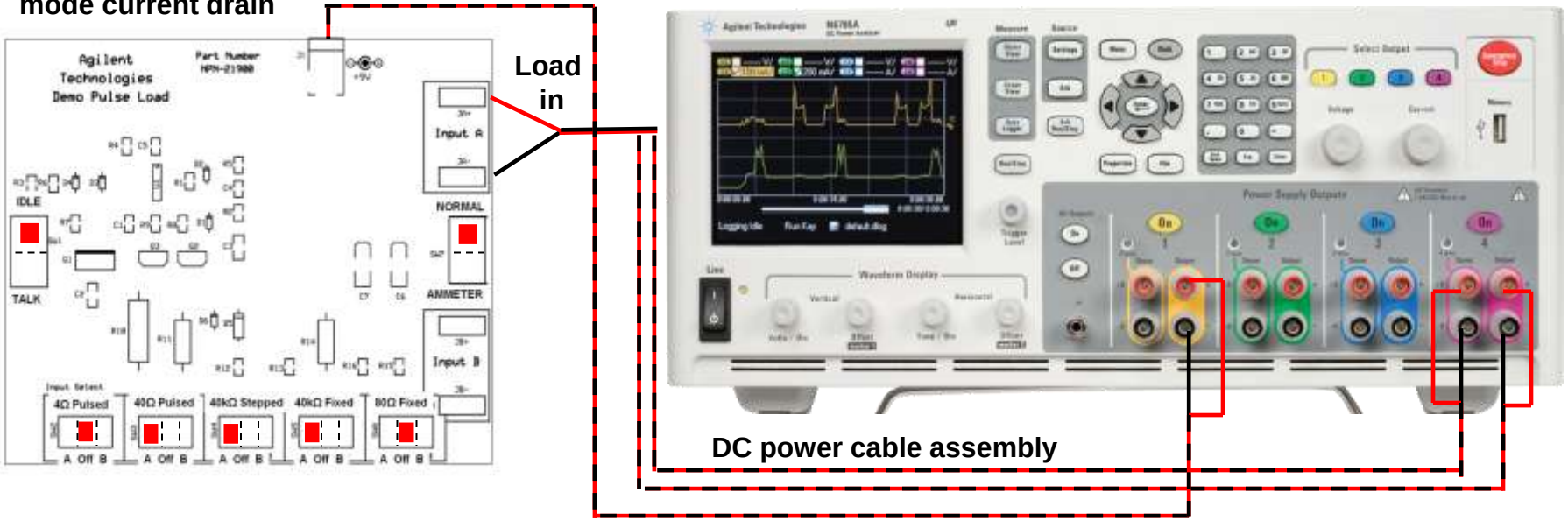


Pulsed demo load simulates mobile phone standby mode current drain

9V DC in

Load in

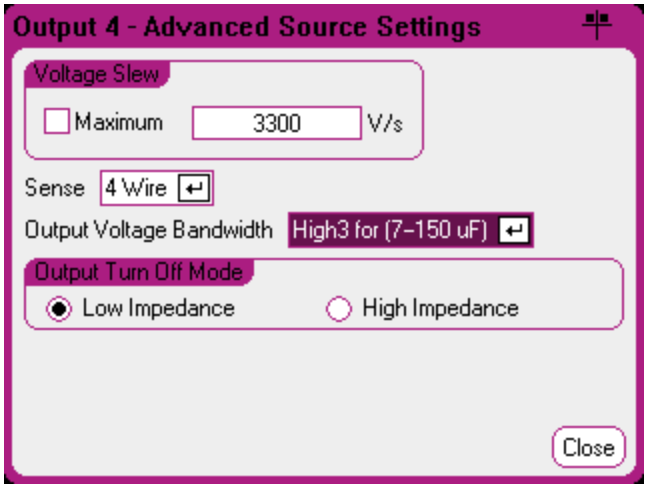
N6705B DC Power Analyzer with N6781A Source Measure Module



Lab #3: Battery Drain Analysis

Configure the power outputs

1. Press File and navigate to Reset / Recall / Power-On State...
   Select Reset to Defaults (*RST) to reset the unit (don't forget: press Enter)
2. Set Output 1 to 9 V (current setting can be left at low value)
3. Select Output 4 and press Settings
4. Set Output 4 to have the following characteristics:
   a) Voltage: 5 V (leave other settings at defaults)
   b) Go to Advanced... and set:
      i. Sense: 4 Wire
      ii. Output Voltage Bandwidth: High3
5. Turn on Outputs 1 and 4



Lab #3: Battery Drain Analysis

Measurement without Seamless Meas. Ranging

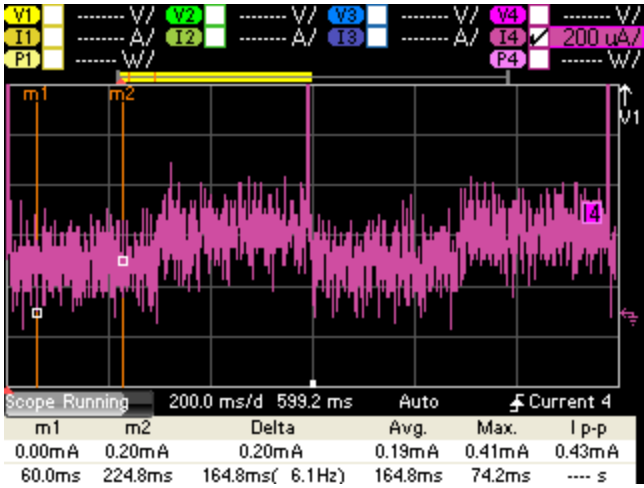
6. Press 

and select only the I4 trace to display
7. Press 

8. Set Trigger Source to Current 4 Level and Trigger Level to 0.001 A
9. Press 

and change the horizontal Time/Div to show 3 current spikes (~200 ms/d)
10. Use the vertical gain and offset knobs to zoom in on the valley (~200 µA/d)
    - HINT: Center ground in the middle of the screen while adjusting A/div
11. Press 

to view marker view and move m1 and m2 to the lowest step



Lab #3: Battery Drain Analysis

Measurement with Seamless Measurement Ranging

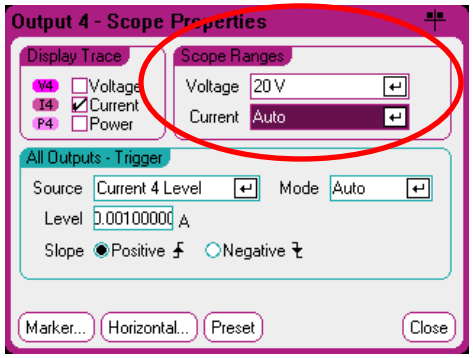
12. Press 

13. Change Scope Ranges for Current to “Auto”

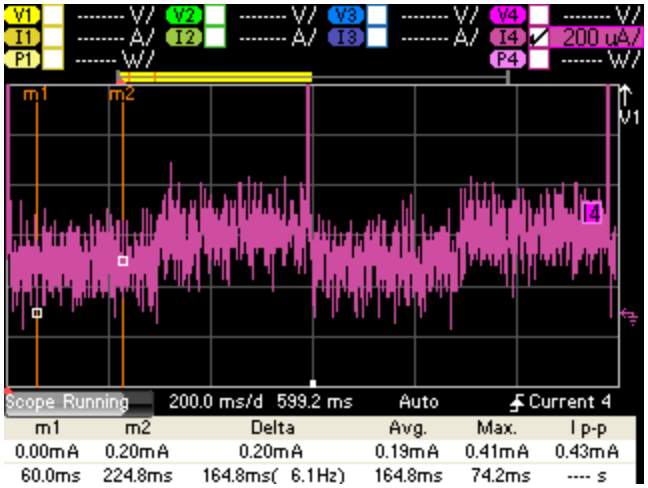
14. Press 

15. Press 

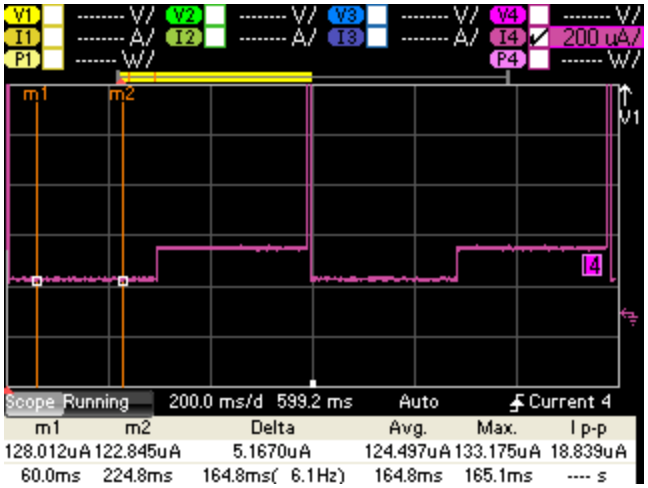
twice to stop then rerun the scope



Seamless measurement ranging!!!



Fixed 3 A measurement range



Seamless measurement ranging on

Lab #3: Questions

Seamless measurement ranging!!!

What I_{pk-pk} did you see with the Auto current measurement range and how does that compare to the current you measured while in the 3 A current measurement range?

What are the benefits of seamless measurement ranging?

What other operating modes does the N6781A module have?

#3: 14565B Device Characterization Software

PC Control of the N6705B with extra capabilities

- Simultaneously control & display up to 4 N6705Bs / 16 outputs
- Large PC monitor enhances viewing details
- Data log direct to PC hard drive, limited only by available space
- Doubles scope mode memory space (512K vs. 256K)
- Adds histogram & CCDF (Complementary Cumulative Distribution Function) for N6781A SMU module
- Adds pre-configured Arb waveforms, formula-based arbs
- Record and playback
- Formula-based traces for re-scaling and unit conversion

Some limiting considerations

- External app
- Limits data-logging maximum speed (10 Ksps vs. 50 Ksps for the N6705B mainframe directly)

Scope Mode

Data Log Mode

Statistics Mode

#3: Lab with 14565B Software

Fixed Range Measurement

With fixed ranging we are limited to the DC offset accuracy and noise floor of the 3A range

Seamless Ranging Measurement

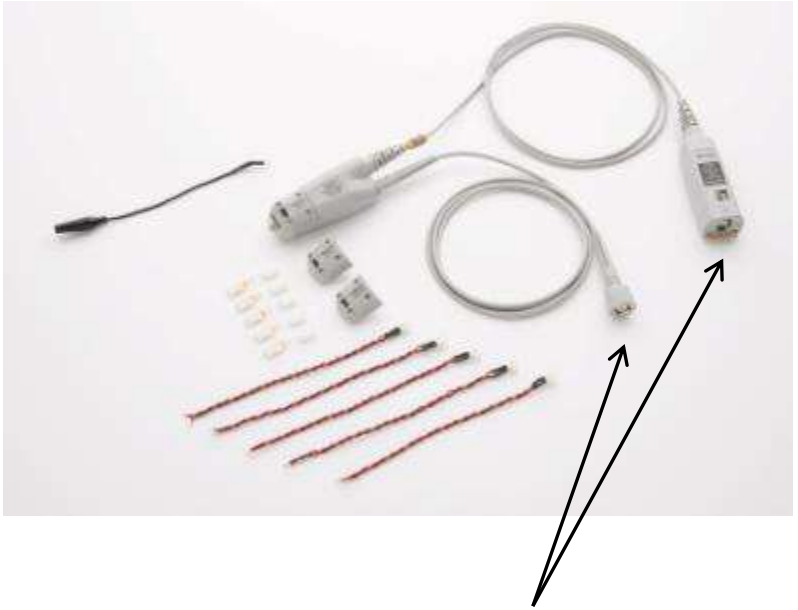
With seamless ranging we can measure up to 3A while having the DC offset accuracy and noise floor of the 1 mA range

#3: High-Sensitivity/Wide Dynamic Range Current Probe for Scopes

- **See the details without losing sight of the big picture**

N2820A Overview

- Measure currents as low as 50 uA
- Measure current as high as 5 A
- Measure AC *and* DC currents
- Compatible with:
  - InfiniiVision 3000X/4000X
  - Infiniium 9000A/H
  - 90000X/Q (with N5449A)



Two inputs to oscilloscope:

1. High sensitivity input
2. Wide dynamic range input

APPLICATION & LAB #4

Device characterization

#4: Device Characterization

- **Application:**
- Low-level IV characterization of components, devices and materials

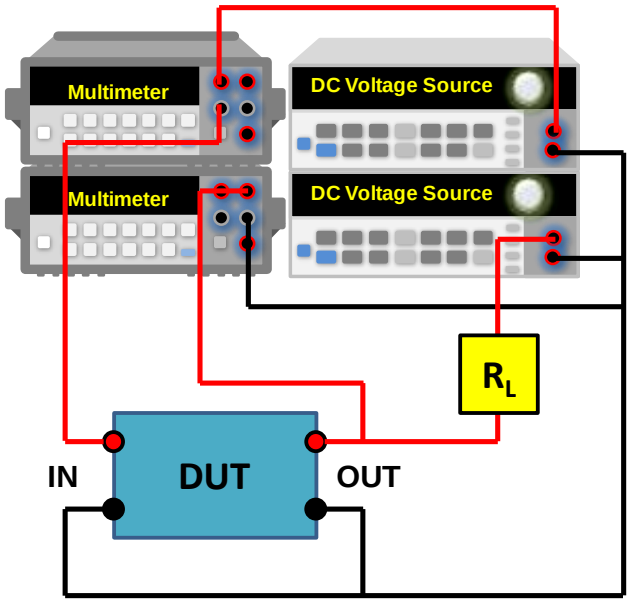
- **Example devices:**
- Active components: Semiconductors, diodes, transistors, ICs
- Passive components: resistors, capacitors, transducers
- Solar cells


Cell

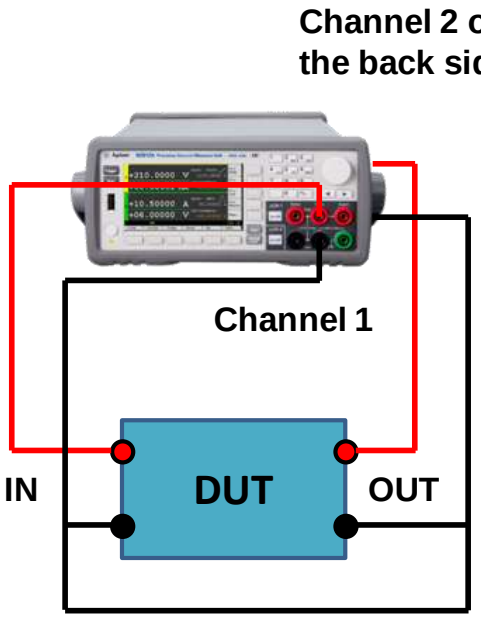
Need: Improved Bench-Top Measurement Efficiency

Test Challenge: Limited bench-top space for single-function instruments.

Solution: The B2900A series reduces the number of instruments and reduces messy wiring.



Bench-top setup example for 4-terminal DUT

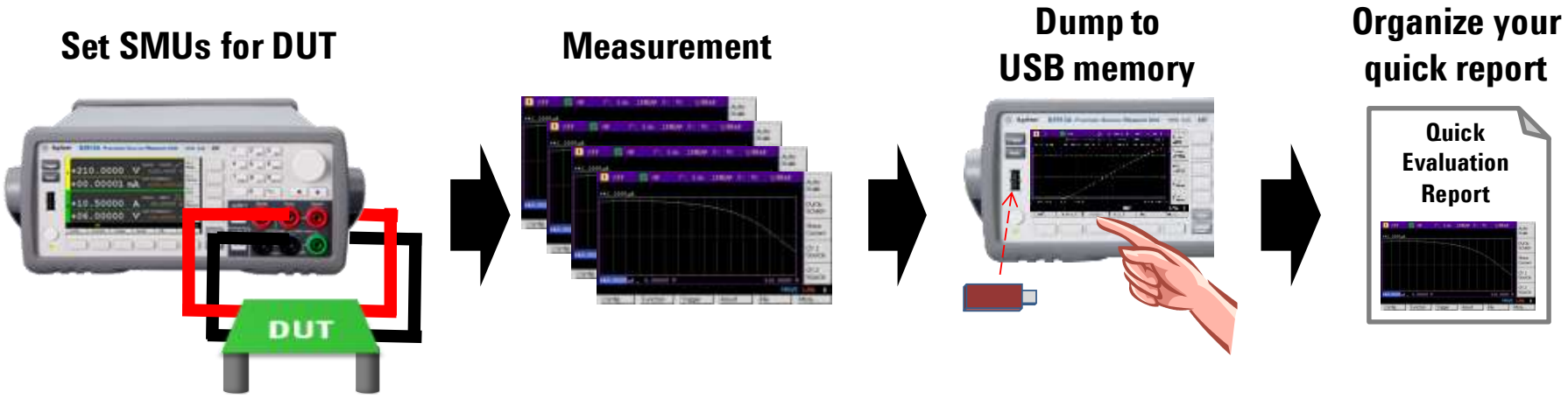


B2900A setup example for 4-terminal DUT

Need: Eliminate PC Control on the Bench

Test Challenge: Many bench-top instruments require a PC to graphically display data and to make measurements.

Solution: The B2900A series' graphical user interface supports real-time IV curve monitoring directly on the instrument.



Application Summary

❑ B2900A series of Source/Measure Units (SMUs)

Only Agilent SMUs can display two I-V curves (2-channels) on their screen!

Applications

- Diode & LED Testing
- Optical devices (laser diodes, photo diodes)
- DC to DC converter evaluation
- Component devices
- Industry R&D
- Research & Education

❑ B2960A series of Low Noise Power Source

A power source with a 10 μV rms noise floor at a very low cost!

Applications

- AD/DA converter Component vendor
- Oscillator, VCO
- Sensor devices
- Research & Education

B2900A Series Common Features

B2901A/B2902A/B2911A/B2912A
Source/Measure Units (SMUs)

B2961A/B2962A
Low-Noise Sources

B2900A Family Key Common 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. Source resolution of 10 fA and 100 nV enables precise characterization of devices and materials
3. Interactive 4.3” front panel GUI for quick bench-top testing, debug and characterization

The B2900A Series Key Differentiators

B2900A SMUs :

Superior Source & Measurement Capability

Source Function	Measure Function
Sourcing resolution of 100 nV / 10 fA (*1)	Measuring resolution of 100 nV / 10 fA (*1)
Sweep waveform generation function	I/V-t plotting
2,500 sweep points	Sweep measurement & I-V plotting
	Measurement auto-range

*1) 100 nV / 100 fA for B2901A/02A

B2961A/B2962A Sources :

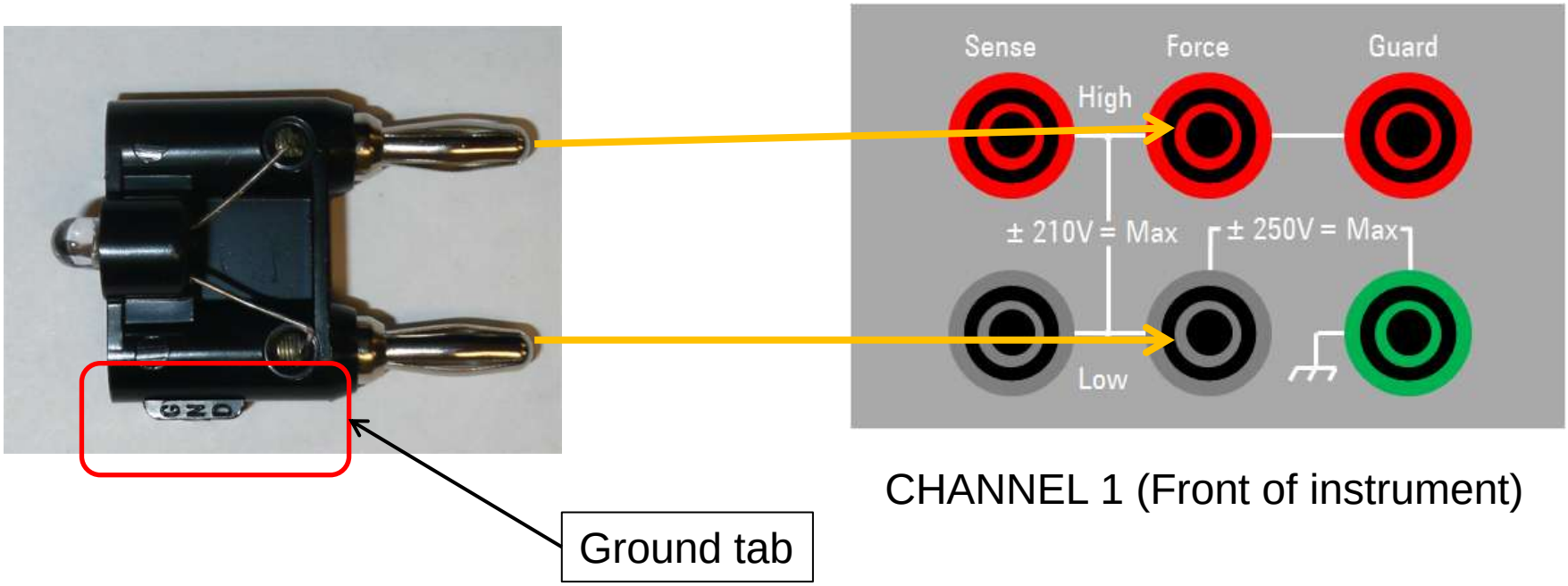
Low Noise & Excellent Sourcing Capability

Source Function	Measure Function
Sourcing resolution of 100 nV / 10 fA	Measuring resolution of 10 µV / 10 pA
Sweep waveform generation function	I/V-t plotting
100,000 sweep points	
10 µV(rms) output noise Performance (*2)	
Built-in waveform generation function	
I/V characteristic emulation function	

*2) with ULNF option

Lab 1: Making Diode Spot & Sweep Measurements

If the diode is not already inserted into channel one, please plug it into the Force High and Force Low inputs as shown below.



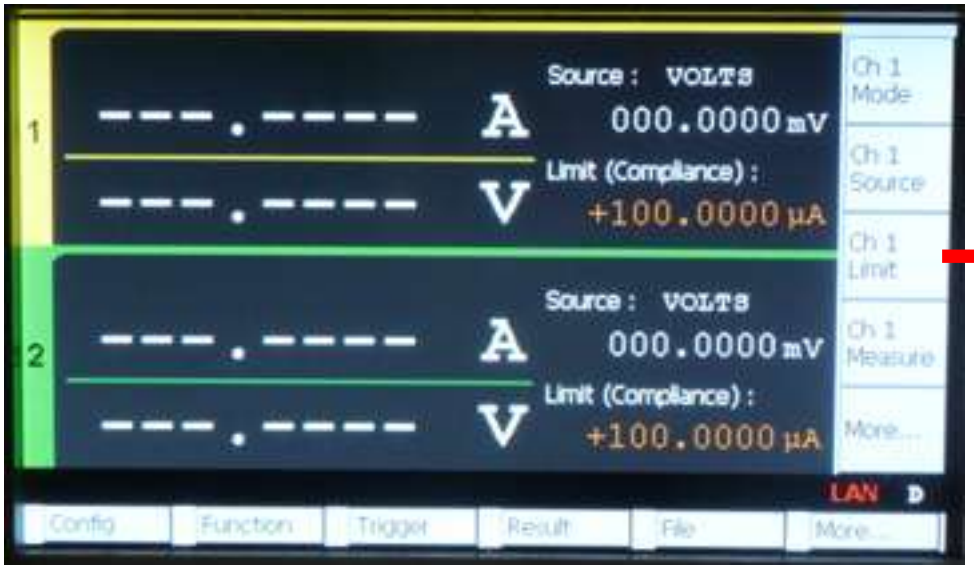
CHANNEL 1 (Front of instrument)

Set the Ch 1 Source Mode to Volts

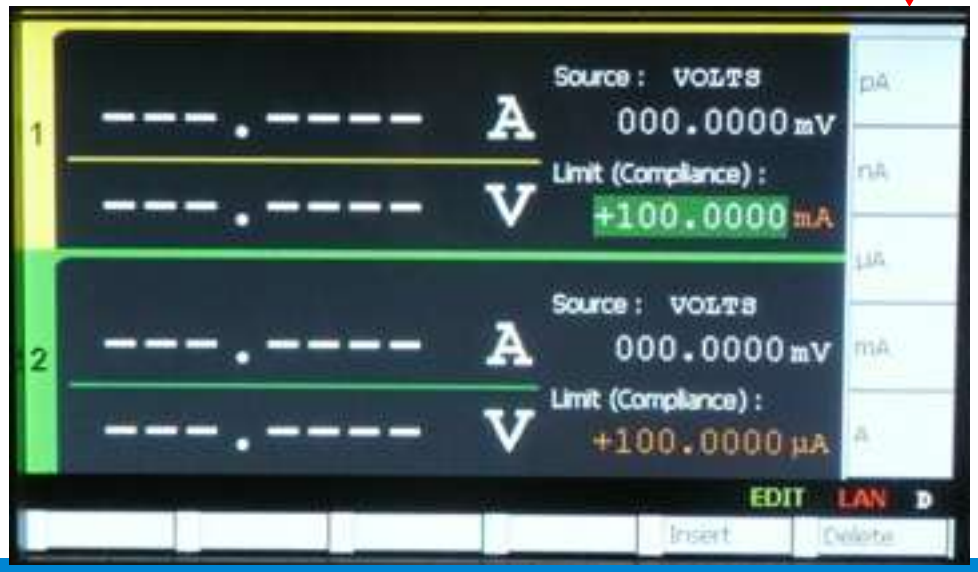
Select “Ch 1 Mode” softkey

Select “Volts” softkey

Set the Ch 1 Limit Value

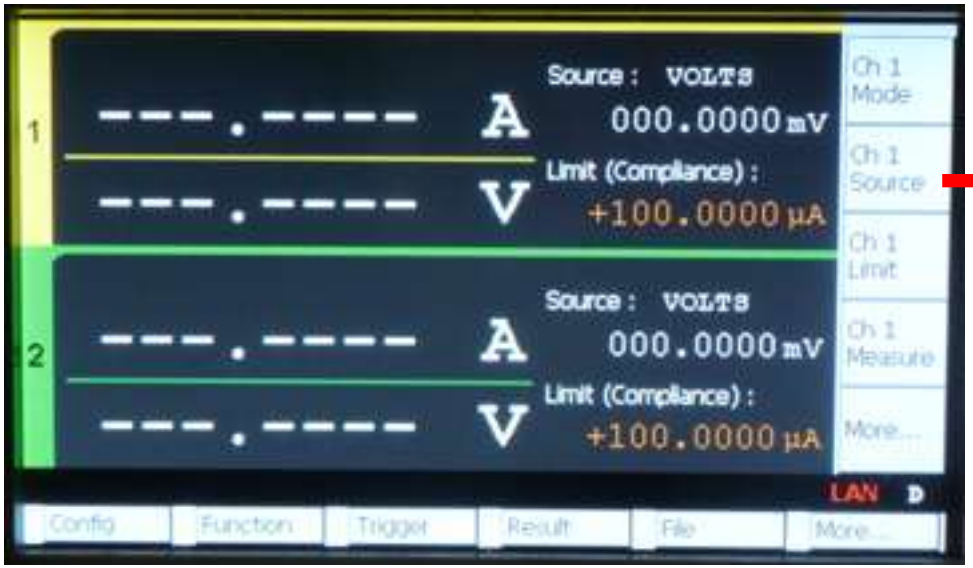


Select “Ch 1 Limit” softkey

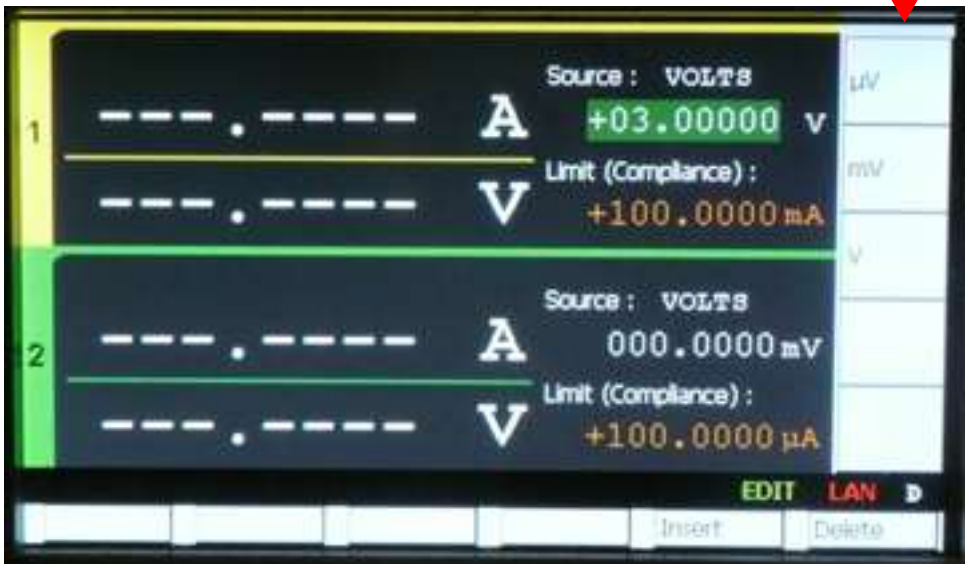


Set limit value to 100 mA

Set the Ch 1 Source Value



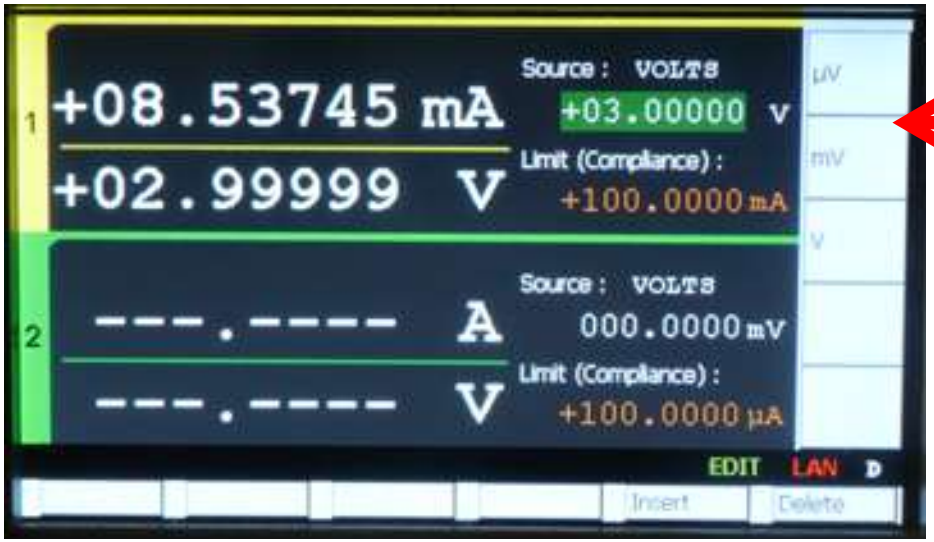
Select “Ch 1 Source” softkey

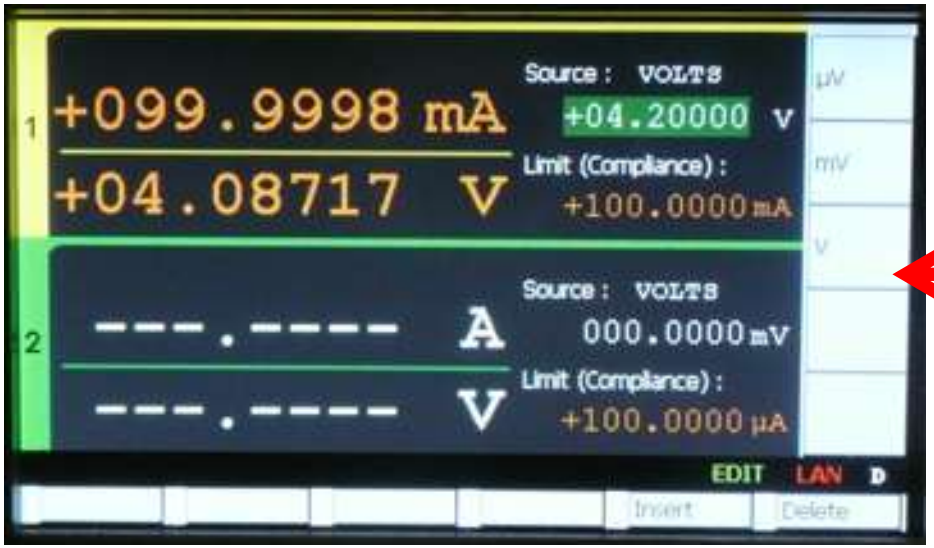


Set source value to 3 V

After setting the source value, turn on channel 1 by pressing the “On/Off” button next to the SMU inputs.

Turn on Channel 1





You should see a display similar to the one at the left. You should also see the diode light up.

Use the wheel to move the marker over the source value (3.00000 V). Push the wheel and turn the knob. Note that you can change the voltage on-the-fly using the wheel.

As you increase the voltage you will eventually see a screen similar to that on the left.
What is happening?
Why are the applied and measured voltages not equal?

Go to Channel 1 View and Show Sweep Setup

Turn off channel 1.

Press the dark gray “View” button at the lower right corner of the screen once to get into Channel 1 view.

Set the source value back to 0 V.

Press the “More…” softkey and then the “Show Sweep” softkey as indicated to the left.

Set up a Linear Single Sweep - 1

Use the rotary knob or the arrow keys under the knob to move the cursor to the “Sweep Parameters” menu as shown.

Press the knob and change the sweep type to “LINEAR SINGLE”

Note that an icon appears in the upper right corner of the screen to tell you which sweep mode you are in.

Set up a Linear Single Sweep - 2

Use the rotary knob or the arrow keys under the knob to move the cursor. Change the “Stop” value to 3 V, and the number of points to 61. Note that the “Step” size automatically changes.

Next, press the dark gray “View” button twice to get to the graphical display window. Make sure channel 1 is turned on, and press the dark gray “Trigger” button in the upper left corner. What happens?

Viewing and Modifying the Graphical Display

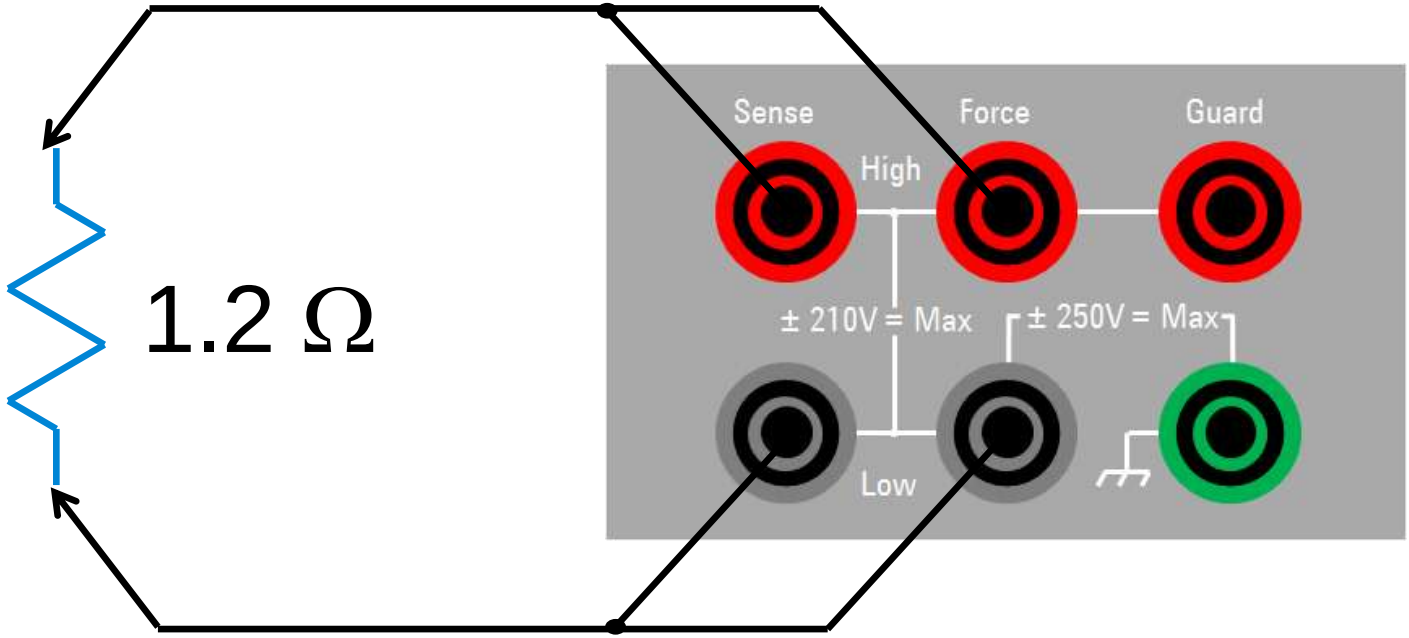
Press the “Auto Scale” softkey to get the graph shown on the left.

Now, move the marker using the knob until you have highlighted the “LINEAR” label at the top of the graph. Push the knob and change the scale to “LOG”. You should see the graph to the left.

If you have time, press the “Show Cursors” softkey and try playing with the cursors.

Lab 2: Making a Low-Value Resistance Measurement

If the 4-wire cable is not already inserted into channel two, please plug it into inputs as shown below. Place the 1.2 Ohm resistor between the clips as shown.



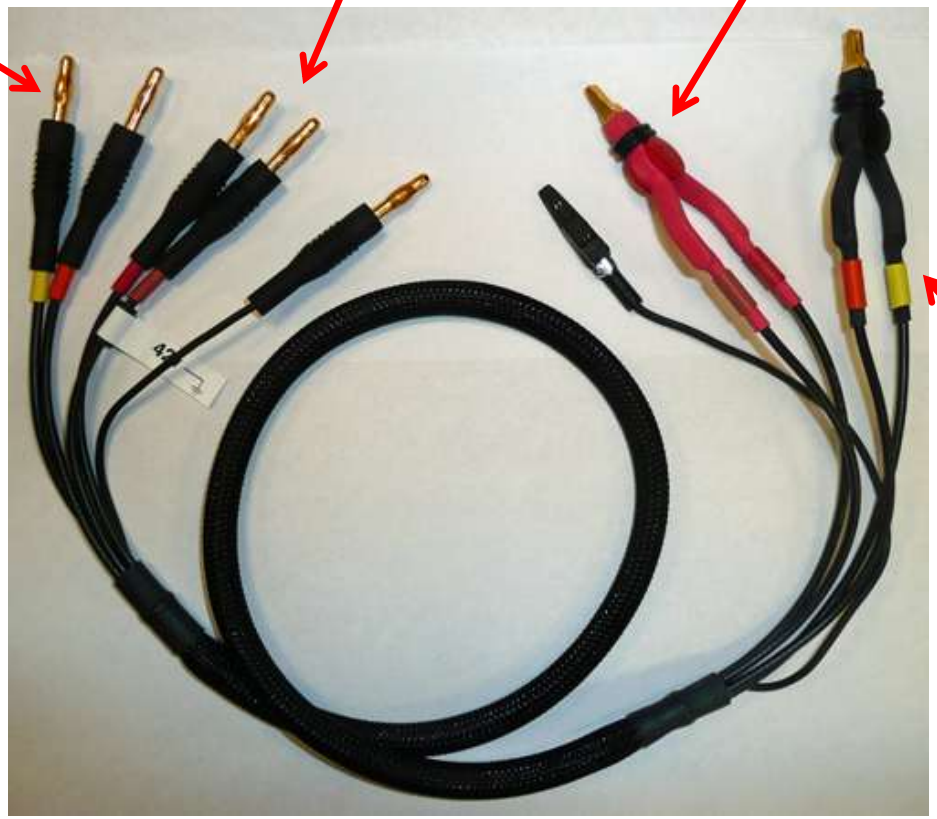
CHANNEL 2 (Rear of instrument)

The 4-Wire (Kelvin) Cable

Low Side Connectors (Yellow/Orange)

High Side Connectors (Red/Maroon)

High Side Clip (Red/Maroon)



Low Side Clip (Yellow/Orange)

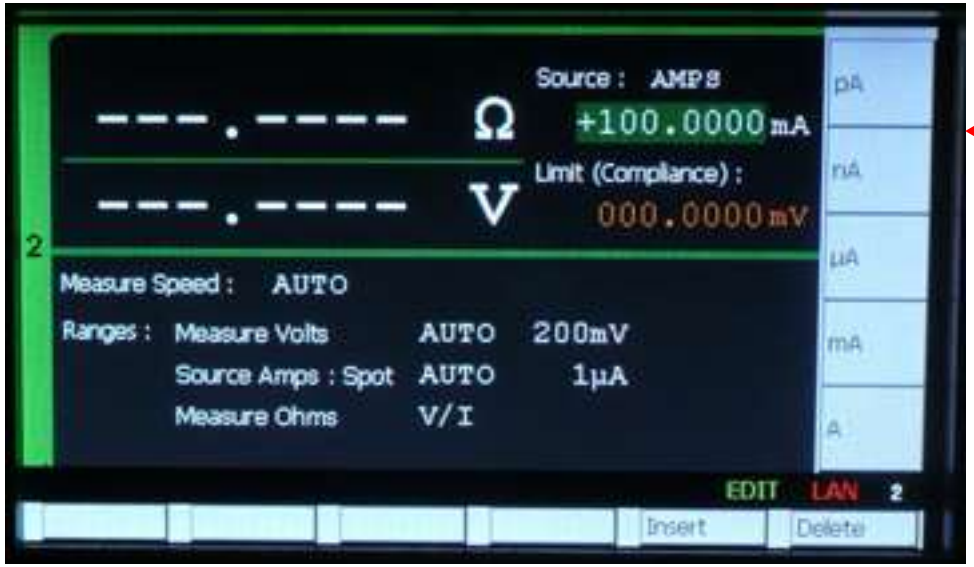
Select Channel 2 View & Enable R Measurement

Keep pushing the dark gray "View" button at the lower right of the screen until the Channel 2 view appears.

Use the knob to move the cursor onto the "OFF" value shown next to "Measure Ohms". Push the knob to select this item, and change it to "V/I" as shown.

Set Up R Measurement Parameters

Push the “Mode” softkey (or move the cursor to the “Source” field) and change the source mode to “AMPS”.



Move the cursor to the source value. Push the knob and change the value to 100 mA

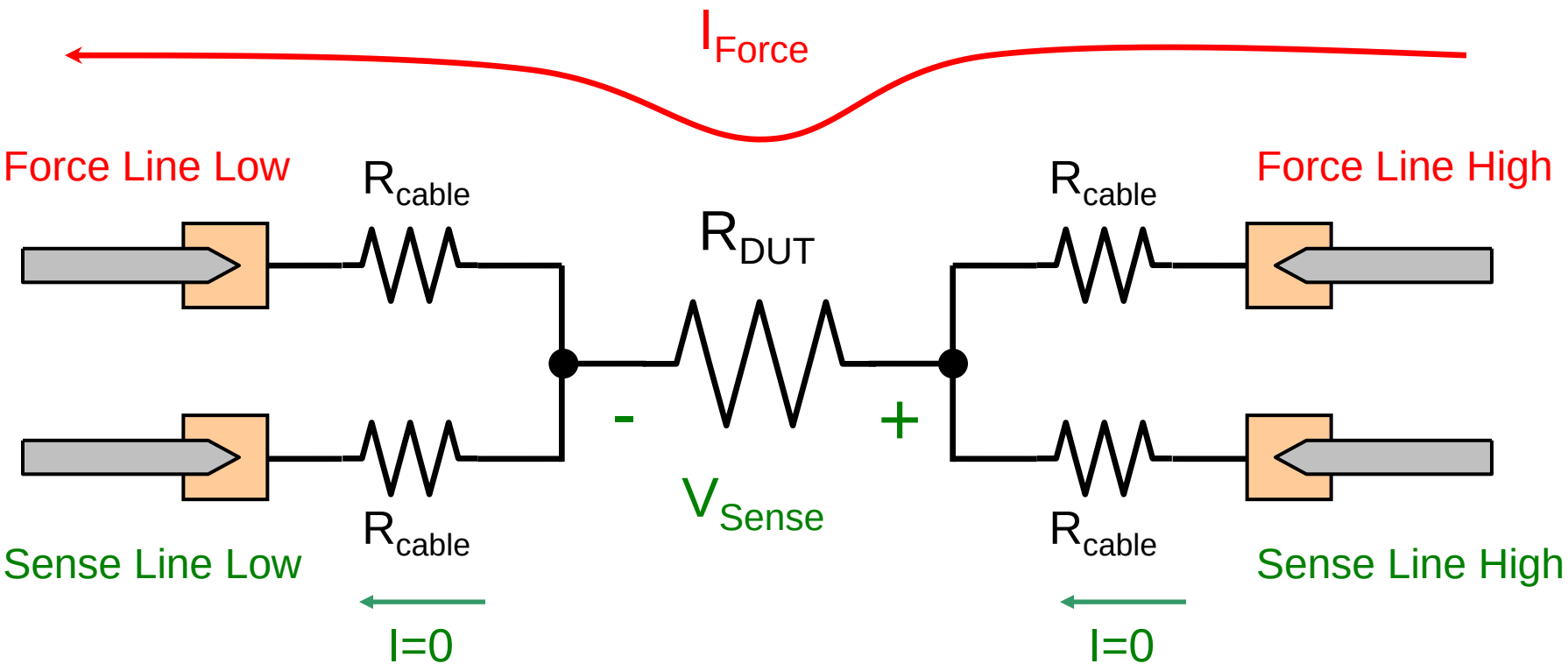
Set Up R Measurement Parameters

Move the cursor to the Limit (Compliance) value. Push the knob and change the value to 200 mV.

Turn on Channel 2. You should see a display similar to that shown on the left. The value of the resistor is supposed to be about 1.2 Ohms. Why is it not reading correctly?

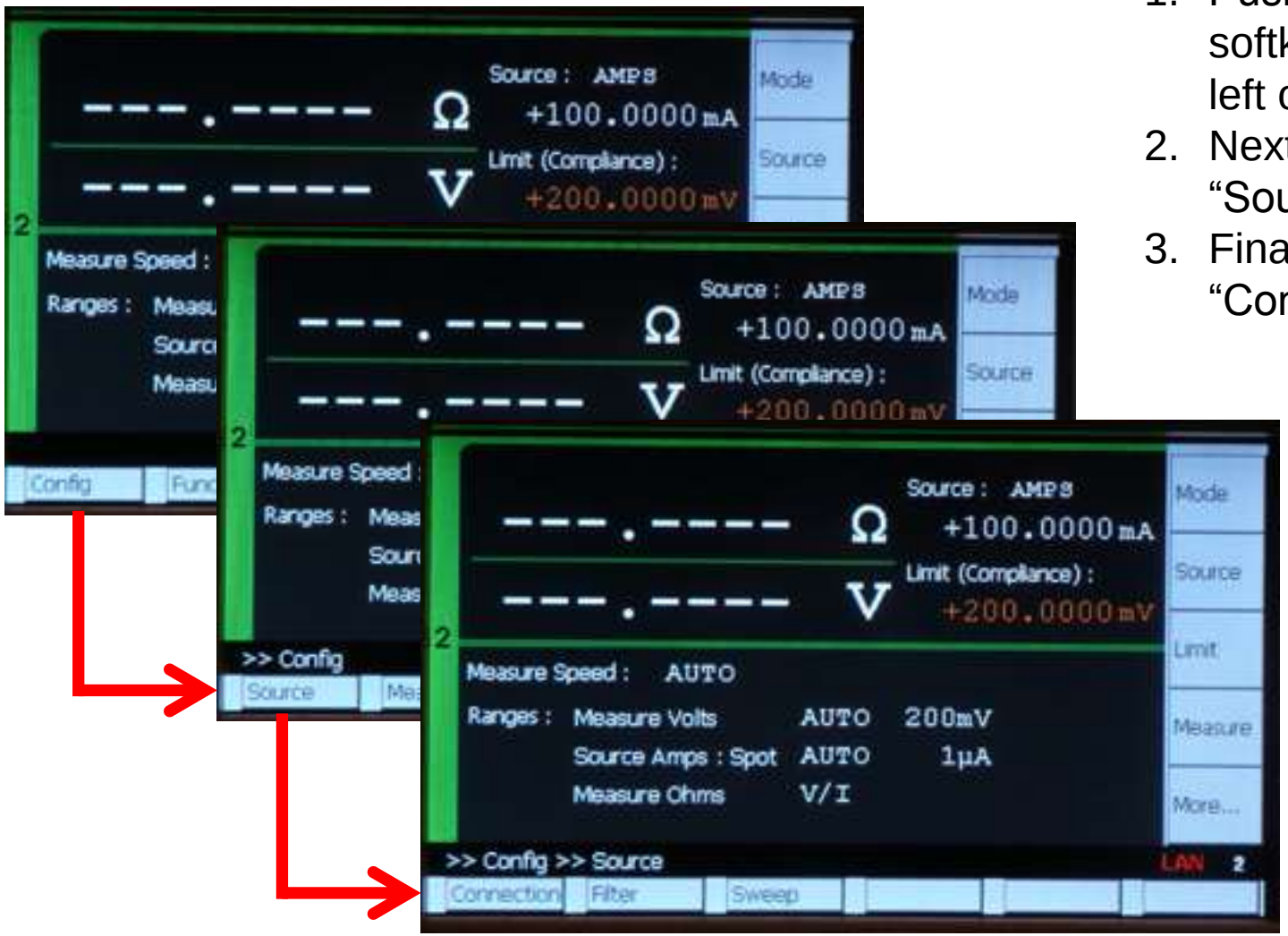
Turn off Channel 2 before proceeding.

To Measure Small Resistances We Need to Make a 4-Wire (Kelvin) Measurement



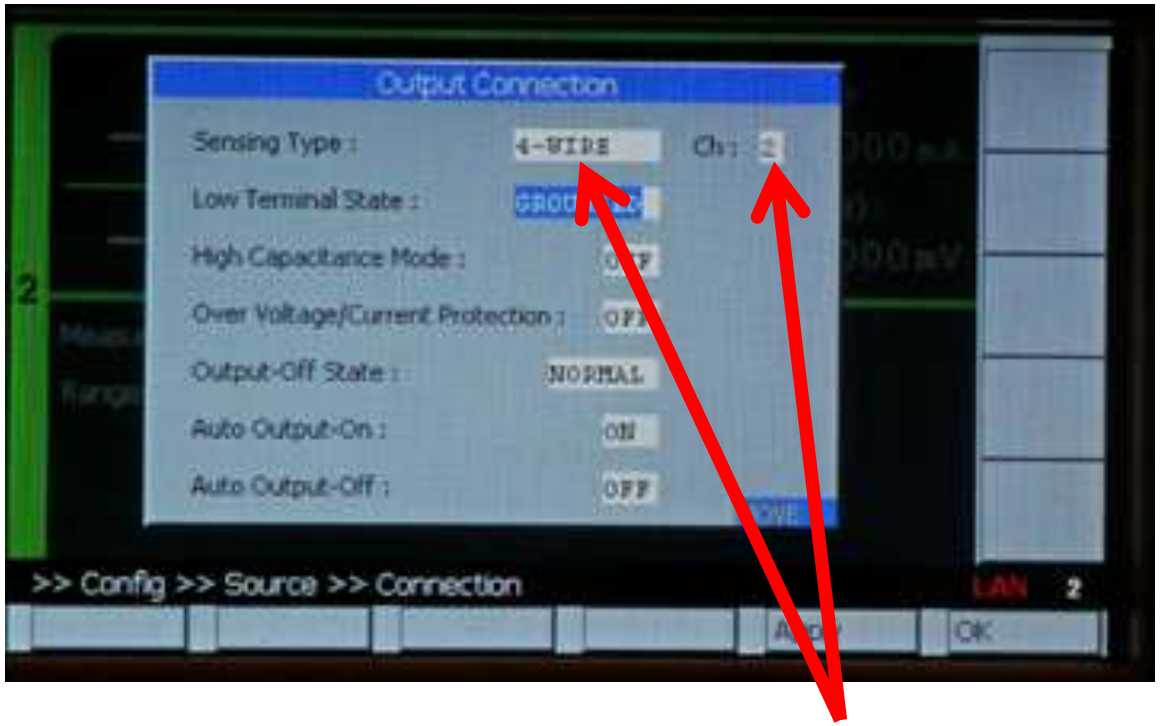
By measuring the voltage through the sense lines the cable resistance effects are eliminated.

Set Up a 4-Wire (Kelvin) Measurement - 1



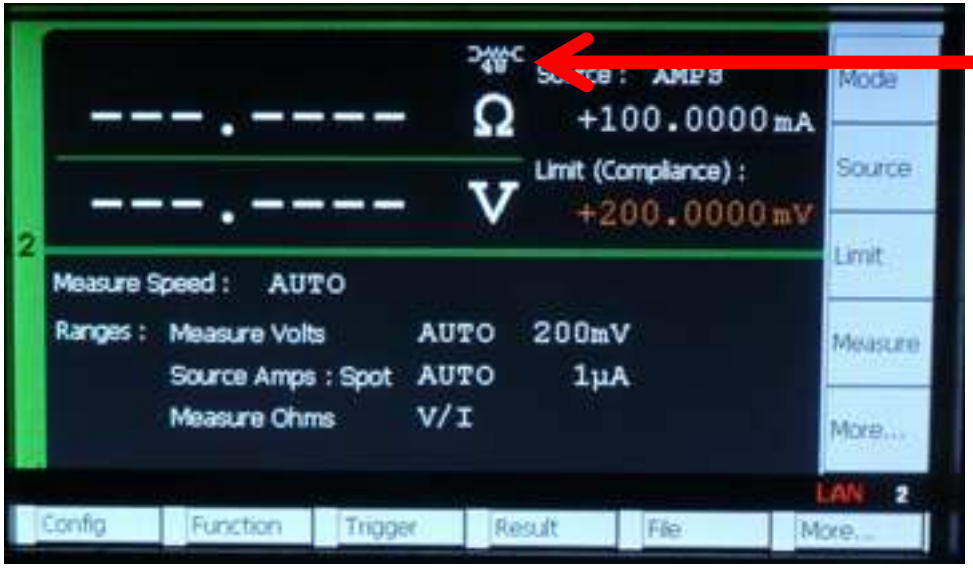
1. Push the “Config” softkey at the lower left of the screen.
2. Next, push the “Source” softkey.
3. Finally, push the “Connection” softkey.

Set Up a 4-Wire (Kelvin) Measurement - 2



After pushing the “Connection” softkey you will see the menu shown above pop up on the screen. Use the rotary knob or arrow keys to move the marker around and change channel 2 to be 4-WIRE sensing. **Make sure that you change channel 2 and not channel 1.** After making this change press the “Apply” softkey in the lower right and then press “OK”.

Make a 4-Wire Resistance Measurement



Note that an icon now appears above the Ohm symbol to indicate that you are in 4-wire sensing mode.

Turn on channel 2. You should see the measured value of resistance shown at the left.

Can you see why 4-wire measurements are needed when measuring small resistances?

B2900A Labs Summary

- Very easy to set up interactive measurements.
- Graphical data can be viewed & examined right on the instrument.
- Measurement setups, test data and graphs can be saved to a USB flash drive.

Agenda

- **Introduction** **15 min**
  - Modern power supply basics and trends
- **Power supply test challenges with labs** **90 min**
  - Basic power up and measuring current drain
  - Simulating power waveforms
  - Battery drain analysis
  - Device characterization
- **Conclusion** **15 min**

Agilent's Power Products Offering: 200+ solutions

High Performance
1U Modular Power
System

AC Power
Supplies

High Power Basic ATE
DC Power Supplies

Bench
Power Supplies

N6705B DC
Power
Analyzer

High Performance
System DC Power
Supplies

Source/Measure Units

DC Electronic Loads

Power Supplies

Accuracy
Speed
Output Integrity

	Low	Medium	High
Integrated Source & Measure System (Source & Sink Operation, Advanced Measurement, Advanced Triggering, Seamless Ranging, Black Box Recorder Operation)			*Precision Power Supplies*
Source Measure (Seamless Measurement Ranging, Bipolar Operation, Source & Sink Capability, Fast Output Response)			
Analyze (Digitizer to measure V & I over time)		*Performance Power Supplies*	
Dynamic Sourcing (Fast Output Response to track load changes from mA to A)			
Measure (Voltage & Current Readback, Remote Sensing)	*Basic Power Supplies*		
Source (Single & Multiple Outputs, CV & CC Operation)			

Agilent Basic DC Power Supplies

Non-programmable (for Labs and Low-cost Manufacturing)



U8000A	E3620A	E3630A	U803xA
90 W, 150 W	*50 W*	*35 W*	*375 W*

$290 *Single output* 4 models *Multiple Output* $1000

Programmable (All have GPIB -- some include RS-232 or USB + LAN/LXI)




E3640A-45A	E3646A-49A	E3631A	E3632A-34A	N5700	N8700	N8900
Single Output	*Dual Output*	*Triple Output*	*Single Output*	*Single Output*	*Single Output*	*Single Output*
30 W - 80 W	*60 W - 100 W*	*80 W*	*120 W - 200 W*	*750 W, 1500 W*	*3200 W, 5100 W*	*5 kW, 10 kW, 15 kW*

$700 72 models $12,000

U8030 Triple-Output DC Power Supply

More reliability. Unrivalled performance.

The only triple-output non-programmable DC power supply in its class with **analog front panel programming** capability

Excellent load regulation
(CV: < 0.01% + 2 mV; CC: < 0.02% + 2 mA)
and **cleaner output noise** ≤ 1 m Vrms

Fast transient response < 50 µsec

- Dual display shows both voltage and current reading
- OVP/OCP

N5700 and N8700 System DC Power Supplies

Key Applications

- Basic DC Bias
- Burn-in
- Margin Testing

N5700

N8700

45 models with stable, single-output power, up to 1.5 kW in 1U or 5 kW in 2U

Models	#	$	Power	Max V	Max I
N5741A thru N5752A	12	$2500	750 W	600 V @ 1.25 A	90 A @ 8 V
N5761A thru N5772A	12	$2959	1500 W	600 V @ 2.5 A	180 A @ 8 V
N8731A thru N8742A	12	$4700	3300 W	600 V @ 5 A	400 A @ 8 V
N8754A thru N8762A	9	$6100	5000 W	600 V @ 8 A	250 A @ 20 V

The NEW N8900 High Power Autoranging Series

N8900 Series
Basic, Autoranging System DC Power Supplies

15 kW in 3U

- Basic power supplies with “just the right amount of performance”
- 5 kW, 10 kW, and 15 kW units
- Up to 1500 V, Up to 510 A
- Parallel master/slave up to 7 units for > 100 kW total output power
- The only DC supplies in this power range available worldwide with autoranging, offering greater flexibility as well as space and cost savings for the system user
- LAN (LXI Core), USB, GPIB and Analog programming all standard
- 5 kW single Φ AC input; 10 kW & 15 kW 3-Φ AC input

Agilent Performance DC Power Supplies

$4,000

N6700 Low-Profile
Modular Power System

$8,000

$20,000

N6705
DC Power Analyzer

$15,000

$6,000

$20,000

66000 Modular Power System
8 x 150 W, for legacy systems

Single Output DC, GPIB, Ideal for ATE, Accurate, Low Noise

6610
50 W

6630
100 W, 2Q

6640
200 W

6650
500 W

6670
2000 W

N6900
Advanced Power System
1000 W, 2000 W

6680
5000 W

6690
6600 W

$2,000

45 models

$8,000

The N6705 DC Power Analyzer
Boosts the productivity of the R&D Engineer

Integrates multiple instrument functions into a single box

- **1 to 4 advanced power supplies**
- **Digital voltmeter and ammeter**
- **Arbitrary waveform generator**
- **Oscilloscope**
- **Datalogger**

- **All functions and measurements are available from the front panel**

Gain insights into your DUT's power consumption
— in minutes, not hours —
without writing a single line of code!

How does the DC Power Analyzer compare to the alternatives available to the R&D Engineer today?

NATIONAL INSTRUMENTS LabVIEW 8.20

Datalogger / DMM

Scope

ARB

4 Power Supplies

To get the job done still requires cabling, transducers, integration, programming

N6705B
DC Power Analyzer

Works out of the box
Fully integrated
No programming required

Agilent N6700 Modular Power System

Key Applications for ATE

- Output Sequencing
- Margin Testing
- Characterization using waveforms

N6700B Low-Profile MPS Mainframe

N6700 DC Power Modules

Small, flexible, and fast multiple-output power supply for ATE

Mainframe Model	# of DC Power Modules	Maximum Power	$ for the mainframe only
N6700B	Up to 4	400 W	$2500
N6701A	Up to 4	600 W	$2800
N6702A	Up to 4	1200 W	$3650

Agilent Precision DC Power Supplies







U2722/3A USB Modular Source Measure Unit	B2900A Precision SMU	B2960A 6.5 Digit Low Noise Power Source	E5260A series High Speed Measurement	E5270A series High Precision Measurement	B1500A Semiconductor Device Analyzer	B1505A Power Device Analyzer / Curve Tracer
$2300-$4000	$6,000 4+2 models $13,000		$20,000-$110,000		$50,000-$150,000	$70,000-$250,000




$2,000	5 modules	$5,000	$2,000	5 modules	$5,000	$9,900	12 models	$12,900
N676xA Series Precision DC Power Modules *50 W, 100 W, 300 W, 500 W*			N678xA Series SMU and Application Specific Modules			N7900 Series Dynamic DC Power Supplies Advanced Power System *1000 W, 2000 W*		

B2900A Precision Source/Measure Unit (SMU) Series

NEW PRODUCT

B2900 Precision Source/Measure Unit Series

A revolutionary source/measure solution with easy-to-use GUI

Introduced May 2011

Key Features:

- Innovative GUI : I-V (current - voltage) measurement without PC programming
- High sourcing & measurement resolution : 10 fA / 100nV
- Wide application coverage : 210V, 3A DC / 10.5A pulsed
- Minimum digitizing interval : 10 µsec

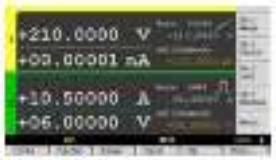
Options and accessories

Model	Option	Description
B2901A B2902A B2911A B2912A	A6J	ANSI Z540 compliant calibration
	UK6	Commercial calibration certificate with test data
	1CM	Rack mount kit
N1294A	001	Banana-triaxial adapter for 2-wire
	002	Banana-triaxial adapter for 4-wire
	031	GPIO-BNC Trigger adapter
N1295A		Device/component test fixture

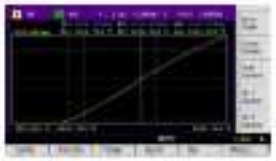
Which product to use:

- **Do you want to see I-V curves quickly on the bench? : B2900A series**
- **Do you need faster measurement for laser diode (LD) test? : Use B2902A**
- **Do you need low current measurement? : Use B2912A**

Single View



Dual View



Graph View

Model	No. of Ch	Max output		Source Resolution			Measurement Resolution			Minimum Digitizing Interval
		Voltage	Current	Digits	Voltage	Current	Digits	Voltage	Current	
B2901A	1	±210V	±3.03A (DC)	5½	1 µV	1 pA	6½	100 nV	100 fA	20 µsec
B2902A	2									
B2911A	1		±10.5A (Pulsed)	6½	100 nV	10 fA	6½	100 nV	10 fA	10 µsec
B2912A	2									

B2960A Low Noise Power Source Series

NEW PRODUCT

B2960 Low Noise Power Source Series

A revolutionary power supply for precision and low noise voltage/current sourcing

Key Features:

- Precision : 6.5 digit, 100nV/10fA sourcing resolution
- Low Noise : 10µVrms output noise with optional filter
- Innovative function : Wide output AWG function, Programmable output resistance
- Innovative GUI for easy-to-set, output and debugging

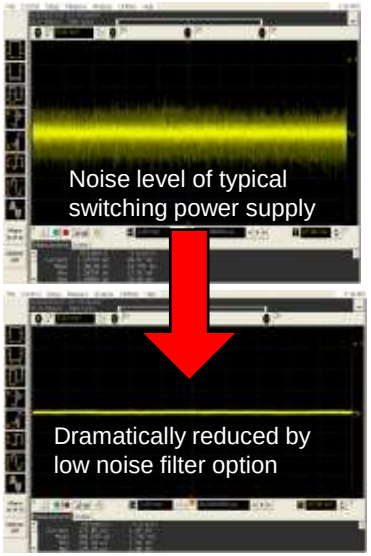
Introduced November 2012

Options and accessories

Model	Option	Description
B2961A B2962A	A6J	ANSI Z540 compliant calibration
	UK6	Commercial calibration certificate with test data
	1CM	Rack mount kit
N1294A	001	Banana-triaxial adapter for 2-wire
	002	Banana-triaxial adapter for 4-wire
	021	Ultra Low Noise Filter
	022	Low noise filter (210 V/3 A)
	031	GPIO-BNC Trigger adapter

Which product to use:

- **Do you need precise setting resolution?**: Use B2960A series
- **Do you need "ultra-low noise" output? :** Use B2960A with N1294A-021
- **Do you need both "low noise" and "wide output"? :** Use B2960A with N1294A-022



Model	Filter Option	Voltage Noise	Max output				Source resolution			ARB	
		10Hz to 20MHz	Power	Voltage	DC Current	Pulse Current	Digit	Voltage	Current	Memory	Built-In Functions
B2961A B2962A	---	3 mVrms	31.8 W	±210 V	±3.03 A	±10.5 A	6 ½	100 nV	0.01 pA	100 k points	Sine, Square, Trapezoid, Ramp, Triangle, Exponential User defined
	Low Noise	350 µVrms*	31.8 W	±210 V	±3.03 A	±3.03 A	6 ½	100 nV	10 pA		
	Ultra Low Noise	10 µVrms*	4.4 W	±42 V	±105 mA	±0.1 A	6 ½	100 nV	10 pA		

The NEW Agilent Advanced Power System

1000 W in 1U

2000 W in 2U

High performance ATE system dc power supplies

Agilent N6900 Series DC Power Supplies **1000 W and 2000 W**	N6950A 9V, 100A N6951A 20V, 50A N6952A 40V, 25A N6963A 60V, 16.5A N6954A 80V, 12.5A	N6970A 9V, 200A N6971A 20V, 100A N6972A 40V, 50A N6973A 60V, 33A N6974A 80V, 25A
Agilent N7900 Series Dynamic DC Power Supplies **1000 W and 2000 W**	N7950A 9V, 100A N7951A 20V, 50A N7952A 40V, 25A N7963A 60V, 16.5A N7954A 80V, 12.5A	N7970A 9V, 200A N7971A 20V, 100A N7972A 40V, 50A N7973A 60V, 33A N7974A 80V, 25A
Accessories	N7907A Rack Mount Kit N7908A Black Box Recorder N7909A 1000 W Power Dissipater Unit	

Agilent's power page:
www.agilent.com/find/power

Agilent's "Watt's Up" power blog:
http://powersupplyblog.tm.agilent.com

Summary

- **Today's power supplies**
  - Are used in many different applications
  - Offer a variety of features to address specific needs
- **Agilent's power supply offering**
  - Includes a wide range of power products
  - Has the right product to meet your needs

Thank You!

Unlocking Measurement Insights for 75 Years

Agenda

Time	Topic
9:00 – 9:30	Welcome , Introductions, Today's Test Challenges
9:30 -11:30	**Function Generator Lab**
11:30 -12:30	Lunch and visit product table
12:30 - 2:30	**Power Lab**
2:30 - 2:45	Break
2:45 - 4:45	**Oscilloscope Lab**
4:45 - 5:00	**BenchVue Software Demo**
5:00 – 5:15	Wrap-up (Channel Partner, Feedback Forms, Awards, Raffle)