APPLICATION NOTE

Bipolar Transistor Characterization Using the B2900B/BL Series of SMUs

KEYSIGHT

Introduction

The Keysight B2900B/BL Precision Source/Measure Unit is a compact and cost-effective bench-top Source/Measure Unit (SMU) with the capability to output and measure both voltage and current. They cover currents from minimum 10 fA to maximum 3 A (DC)/10.5 A (pulse) and voltages from minimum 100 nV to maximum 210 V, which enables you to make a wide range of current versus voltage (IV) measurements more accurately and quickly than ever before. In addition, the B2900B/BL Series of SMUs comes with an intuitive graphical user interface (GUI) and multiple software control options that make it easy for you to begin making productive measurements immediately, allowing you to choose the solution that best fits your particular application. These features make the B2900B/BL Series of SMUs the best solution for accurate characterization of a wide variety of devices such as bipolar transistors (BJTs).

What is the B2900B/BL Series of SMUs?

An SMU combines the capabilities of a current source, a voltage source, a current meter and a voltage meter along with the capability to switch easily between these various functions into a single instrument. This gives it the ability to evaluate the IV characteristics of devices across all four measurement quadrants without the need for any additional equipment. Besides being able to output and measure voltage or current very accurately, SMUs also possess a compliance feature that allows a limit to be placed on the voltage or current output to prevent device damage. The members of the B2900B/BL Series of SMUs are single or dual channel SMU units that offer a wide range of IV measurement capability for a variety of two-terminal and three-terminal devices. They cover currents from minimum

10 fA to maximum 3 A (DC)/10.5 A (pulse) and voltages from minimum 100 nV to maximum 210 V. In addition to their DC operation mode, the B2900B Series of SMUs also has the ability to perform pulsed measurements in order to prevent device self-heating from distorting the measurement results.

In general, BJT characterization requires applying different voltages and currents under either constant or the swept conditions to the transistor terminals.

The B2902B and B2912B have two SMU channels, with each channel possessing accurate IV measurement capabilities as well as the ability to supply either constant or swept voltage/current. This makes the B2902B and B2912B excellent choices for accurate IV characterization of BJTs. Figure 1 illustrates the connections necessary to measure the common emitter output characteristics of a BJT using the B2902B and B2912B.

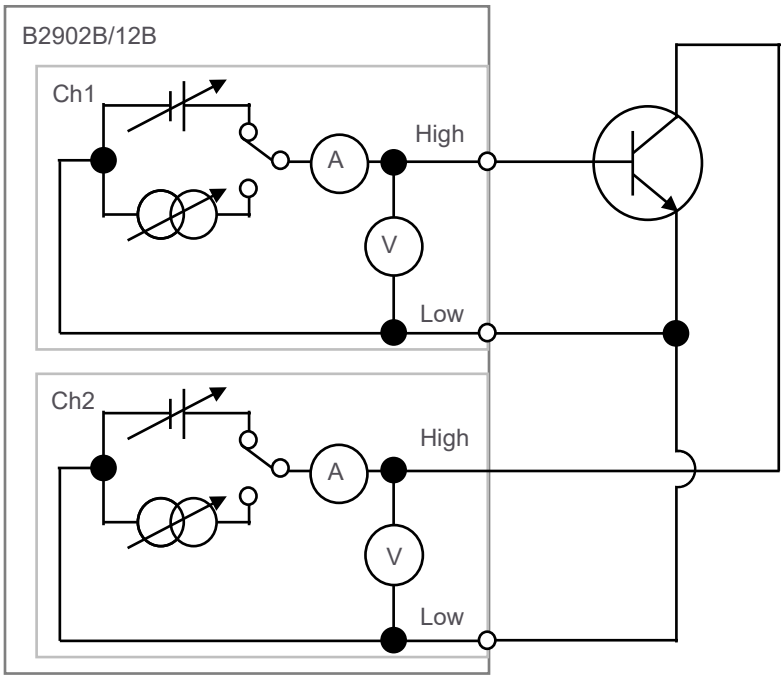


Figure 1. Using the B2902B/12B to characterize a BJT

Quick and Easy IV Characterization

During routine device evaluation it is often desirable to make a quick measurement from the instrument's front panel without having to go through the time and trouble of writing a test program. To meet this need, the B2900B/BL Series of SMUs has a resident GUI that makes it easy to perform a variety of tests and save measurement data without having to write any code.

The wide QVGA LCD display of the B2900B/BL Series of SMUs supports an easy-to-use GUI that provides easy instrument control from the front panel. The GUI of the B2900B/BL Series of SMUs has the following multiple viewing modes: Single View, Dual View, Graph View and Roll View (for viewing time domain measurements). Single View mode allows you to easily set up not only constant voltage and current measurements but also swept voltage and current measurements for a single SMU channel. Dual View can perform similar functions for both channels simultaneously (for B2902B and B2912B). After measurement completion you can use the front panel GUI to graphically view measurement results such as IV curves using Graph View, and display a list of the measurement data using the Measure Result dialog window (please see Figure 2).

The B2900B/BL Series of SMUs has a USB interface on the front panel so that a USB flash memory device can be used with the B2900B/BL Series of SMUs to save and load measurement setups as well as to save measurement results. In addition, Graph View supports a Screen Dump function that enables you to save screen images (such as IV curves) to any attached USB flash memory device as JPEG files, making it easy to include graphical results in reports and presentations (please see Figure 3 on following page).

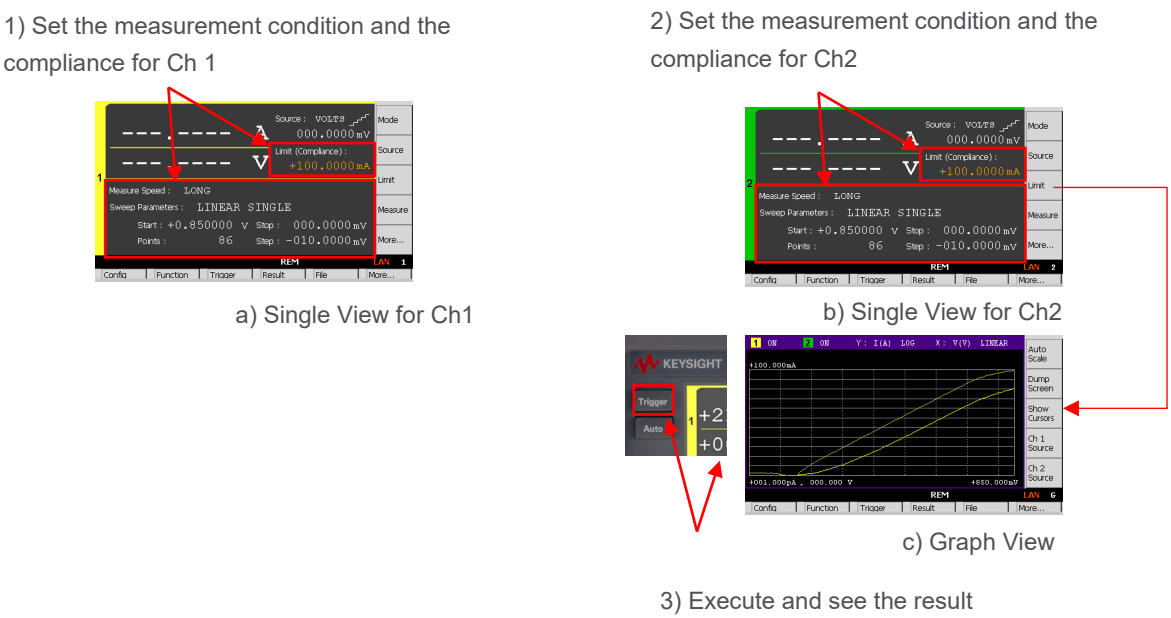


Figure 2. The GUI of the B2900B/BL Series of SMUs makes it easy to take a quick measurement and display the results

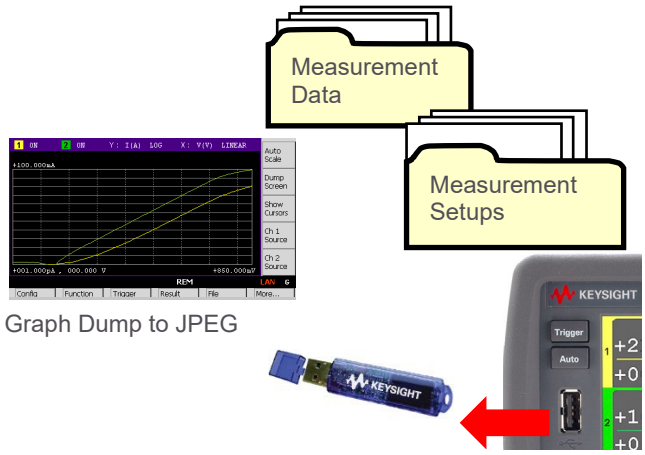


Figure 3. Measurement results and measurement setups can be saved to any attached USB flash memory device

A Range of Software Control Options

In addition to its powerful and easy-to-use GUI, if you prefer PC-based instrument control, then the B2900B/BL Series of SMUs comes with a range of software control options to facilitate program development, allowing you to choose the solution that best fits your particular application.

PathWave BenchVue

The Keysight PathWave BenchVue software for the PC reinvents your bench testing by making it simple to connect and record results with your instruments without the need for programming. You can quickly and easily obtain results by viewing, logging and exporting measurement data and screen images with just a few mouse clicks. PathWave BenchVue provides a wide array of capabilities, depending on the chosen instrument application. These capabilities will vary according to the functionality of the instrument types and models, including the B2900B/BL Series of SMUs, that are connected to the PC that is running the PathWave BenchVue software. See http://www.keysight.com/find/benchvue for more details.

Graphical Web Interface

The Keysight B2900B/BL Graphical Web Interface provides functionality to allow access to the B2900B/BL Series of SMUs over a LAN connection. The B2900B/BL Series of SMUs is fully compliant with the LXI class C specification and contains a web server that provides a webpage with an interface to support the basic measurement functions of the B2900B/BL. You can quickly and easily make measurements using a standard web browser by simply connecting the B2900B/BL Series of SMUs to a PC using a LAN cable.

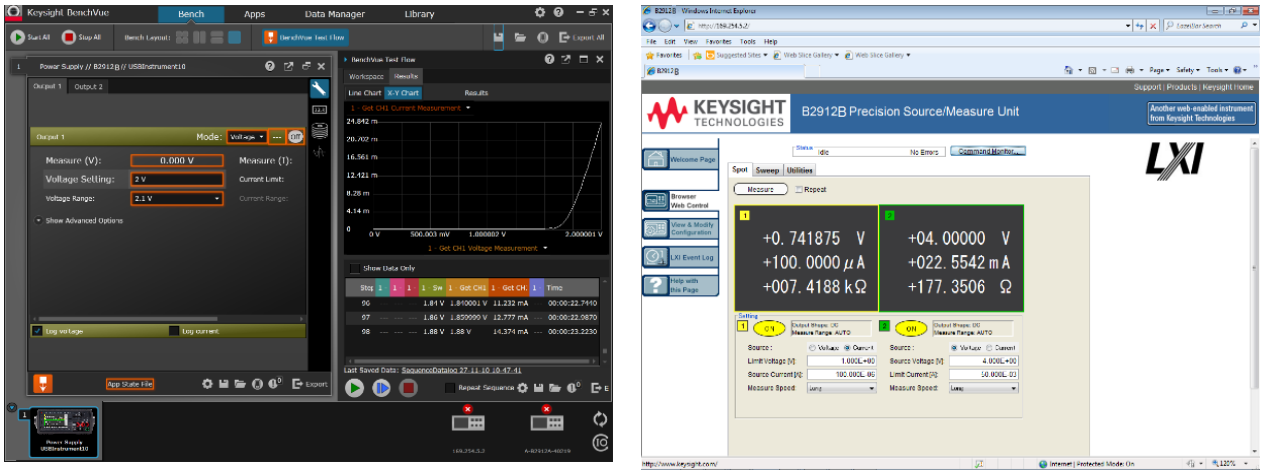


Figure 4. PathWave BenchVue and Graphical Web Interface

PW9251A PathWave IV Curve Software

The PW9251A PathWave IV Curve is a ready-made GUI software to perform a variety of synchronous current-voltage (IV) measurements without programming. Various analysis function on graphs and tables allow users to review test results immediately after the measurement. Export functions of graphs with markers and tables support efficient reporting. In addition, the test result files contains all the settings, allowing users to accurately review and repeat the test. The PW9251A PathWave IV Curve accelerates your research, development and design verification with increasing productivity, enabling more accurate and reliable data acquisition, and more efficient use of the equipment.

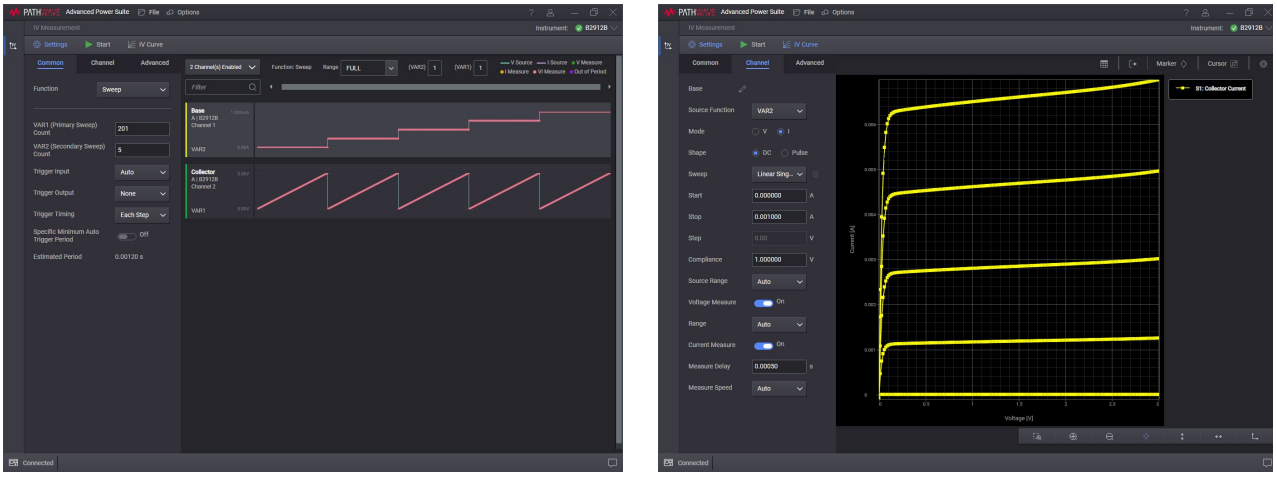


Figure 5. It is easy to make a quick measurement on a PC using the PW9251A PathWave IV Curve Software

EasyEXPERT group+

The EasyEXPERT group+ software is the more powerful solution for detailed characterization and analysis of devices, circuits and materials. It supports efficient and repeatable characterization across the entire characterization process from measurement setup and execution to analysis and data management. EasyEXPERT group+ makes it easy to perform complex characterization with ready-to-use furnished measurements (application tests), and gives you the option of automatically storing every test condition and piece of measurement data in a unique built-in database (workspace), ensuring that valuable information is not lost and that measurements can be repeated at a later date. See http://www.keysight.com/find/easyexpert for more details.

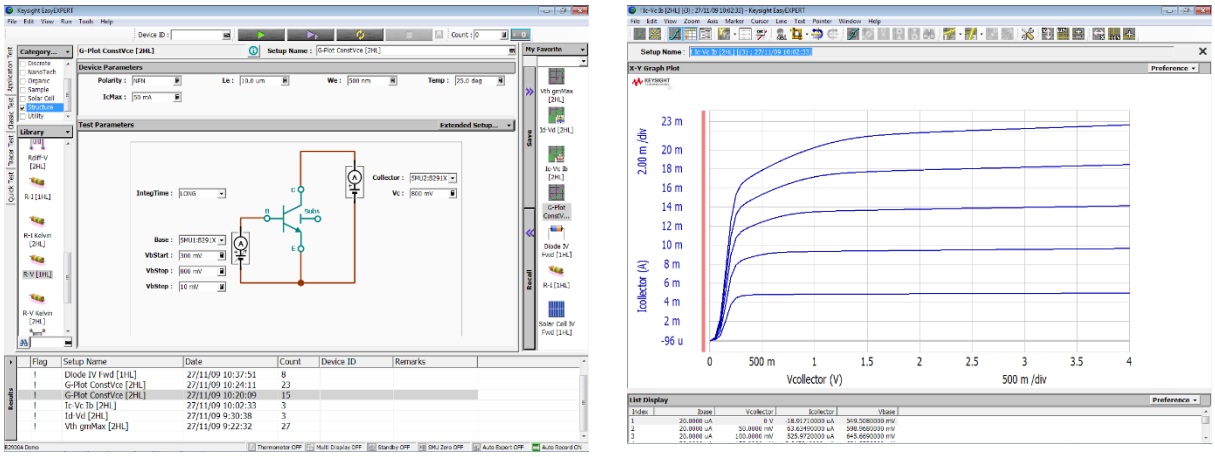


Figure 6. EasyEXPERT group+ is a powerful solution for detailed characterization and analysis of devices, circuits and materials

Lab Exercises

This lab exercise gives you extensive hands-on experience to make the BJT characterization using a B2900B/BL.

Required instrument and accessories

All of the accessories required to perform the demos described in this demonstration guide are provided as a low current demo kit that is included with some of Keysight B2900B/BL demo units.

B2902B/12B 2Ch SMU

N1295A Test Fixture

N1297A Banana-to-Triax Adapter x2

16494A-001 Triax cable x4

Bipolar Transistor

Measurement concept

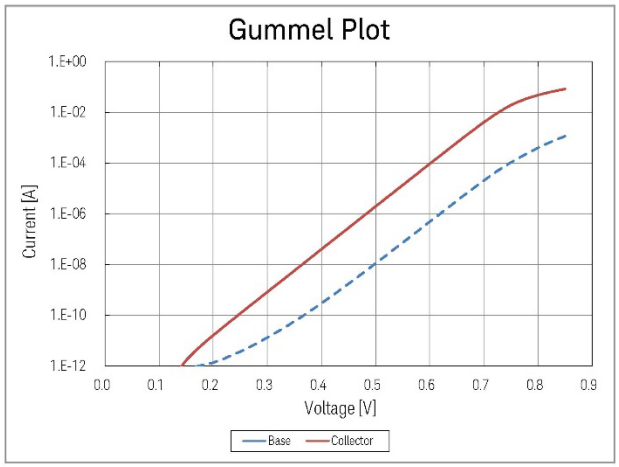


Figure 7. Gummel Plot

An IV characteristics measurement of a BJT (Gummel Plot) is made based on the following:

- Sourcing a voltage from two channels to activate a transistor.
- The two channels work simultaneously to make measurements.
- The limit value feature prevents the instrument from sourcing too much even if the Source value is increased.
- Stepping voltages from start voltage to stop voltage to make current measurements at each voltage step.
- Voltage steps are sourced from internal voltage sources.
- Current measurements are made by internal current meters.
- Complicated measurements can be easily configured using the Intuitive Graphical User Interface (GUI).
- The current-voltage curve can be easily seen by changing View mode.

Setup

1. Put the device on the device socket in the fixture (The BJT Emitter, Base and Collector are connected to 1, 2 and 3 respectively).
2. Put the N1297A on the Ch 1 output terminals of the B2900B/BL SMU.
3. Put the N1297A on the Ch 2 output terminals of the B2900B/BL SMU.
4. Connect the N1297A Ch 1 Low terminal to the fixture terminal 1 with a triaxial cable.
5. Connect the N1297A Ch 1 High terminal to the fixture terminal 2 with a triaxial cable.
6. Connect the N1297A Ch 2 Low terminal to the fixture terminal 4 with a triaxial cable.
7. Connect the N1297A Ch 2 High terminal to the fixture terminal 3 with a triaxial cable.
8. Connect terminals 1 to 4 on the fixture with a black Pin-Plug Cable.
9. Close the fixture cover.

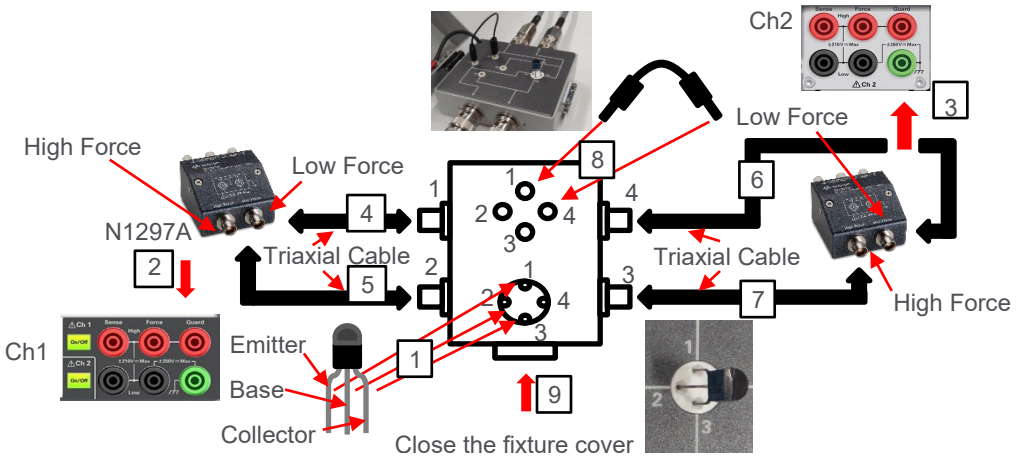
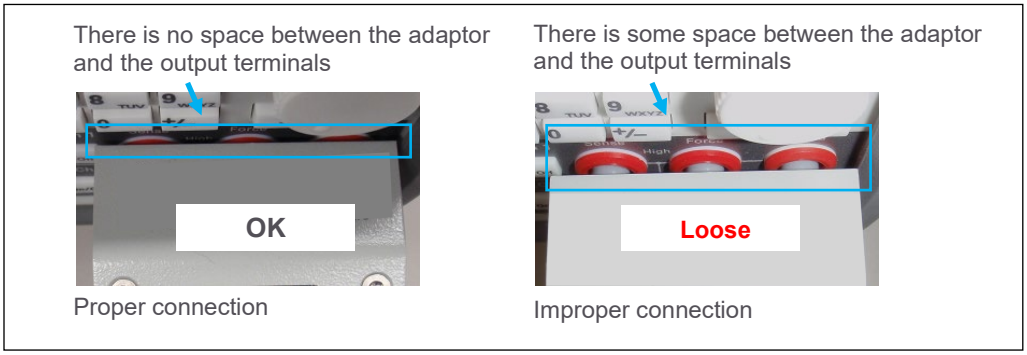


Figure 8. Connection diagram

Make sure that the connection between the output terminals and the N1297A Banana to Triax Adaptor is secure, because a loose connection can affect the measurement results.



LAB: Make BJT Characterization using SMU

Objective

This demo explains how to make a voltage sweep measurement simultaneously using 2 channels to make a BJT IV characterization.

Procedure

1. Change the View mode to the Channel 1 Single View.
2. Configure the Channel 1 condition to source and measure.
3. Change the View mode to the Channel 2 Single View.
4. Configure the Channel 2 condition to source and measure.
5. Change the View mode to Graph View.
6. Perform the measurement.
7. View the measurement result graph
8. View the list of measurement results
9. Store the measurement data to a USB flash memory device
10. Copy the Graph View screen dump to a USB flash memory device.

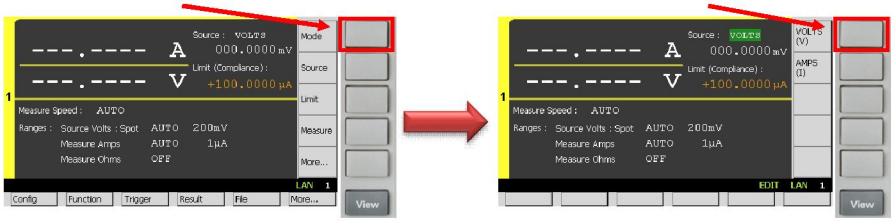
Demonstration

1. Change the View mode to the Channel 1 Single View

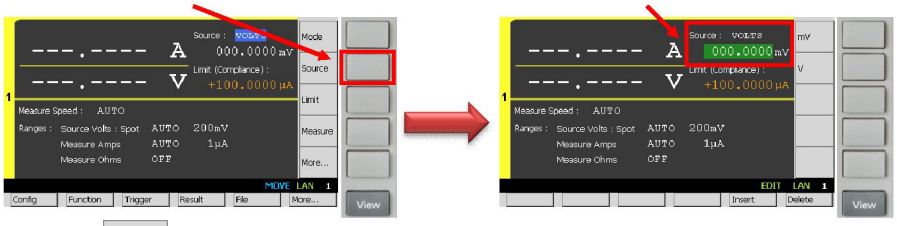
1) Press View repeatedly until the Channel 1 Single View is displayed.

2. Configure the Channel 1 condition to source and measure

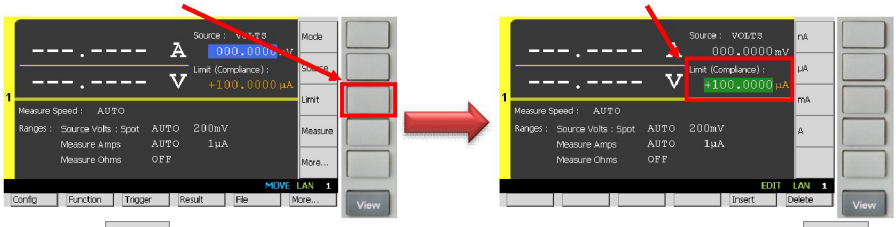
1) Press Mode to edit the Source function, and then select VOLTS (V) to set the Source function to Voltage source.



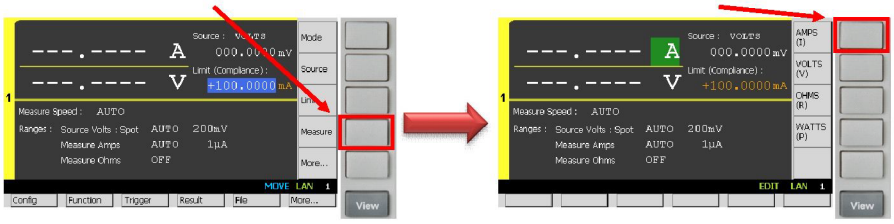
2) Press Source to edit the Source value then enter 0 V to set the Source value to 0 V.



3) Press Limit to edit the Limit value then enter 100 mA to set the Limit value to 100 mA.

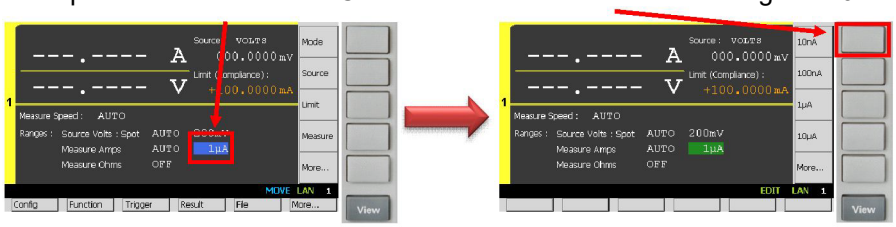


4) Press Measure to configure the Measurement parameter then select AMPS (I) to set the Measurement parameter to Current.

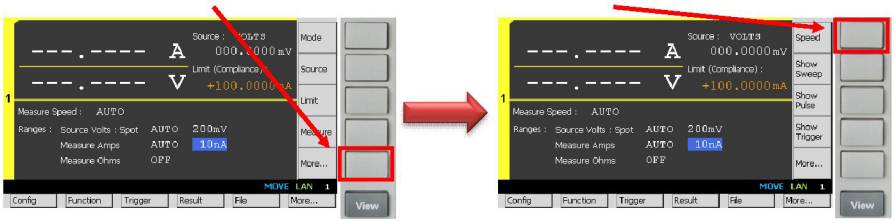


5) Rotate to select the Current minimum measurement range and press to edit it.

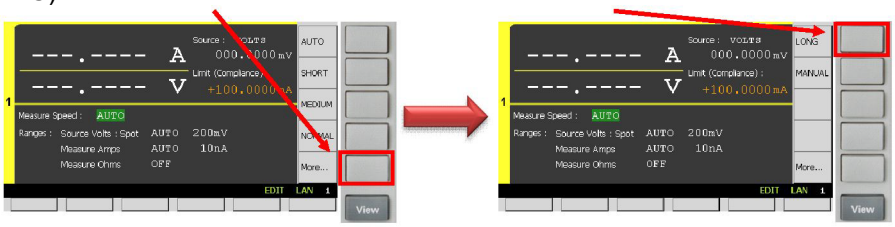
Then press 10nA to set the Current minimum measurement range to 10 nA.



6) Press More... to change the keys shown in Assist keys then press Speed to set the Measurement Speed Parameter.

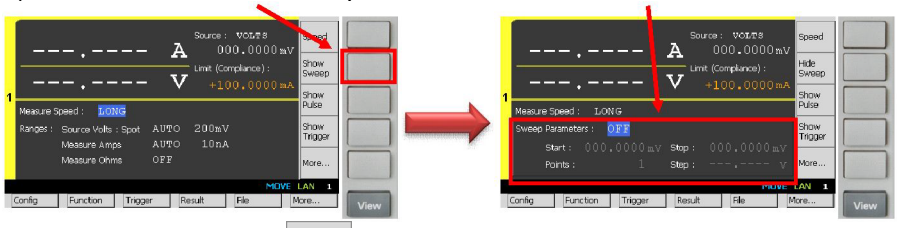


7) Press More... then press LONG to set the Measurement Speed to LONG (10 PLC).

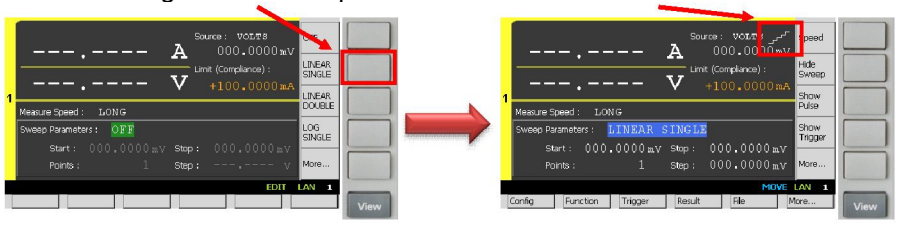


If you do not want to make the sub-nA current measurement, “AUTO” Measure Speed should be selected. It makes the measurement much faster.

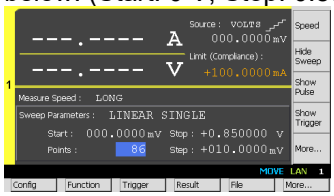
8) Press Show Sweep to show Sweep Sub-Panel.



9) Press , then press LINEAR SINGLE to turn on the Single Linear Sweep Mode. After turning on the Single Linear Sweep Mode, you can see the Source Shape which shows the single linear sweep mode.



10) Rotate to select the Channel 1 Sweep Parameters and set them up as below. (Start: 0 V, Stop: 0.85 V, Points: 86, Step: 10 mV)

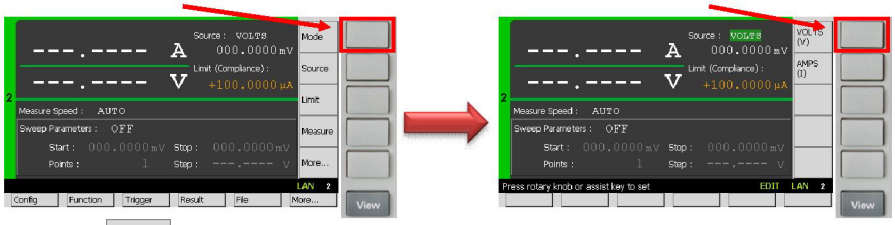


3. Change the View mode to the Channel 2 Single View

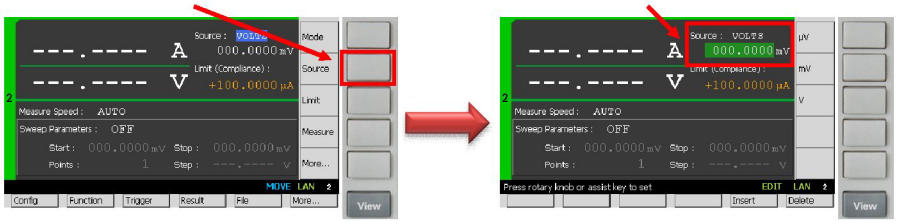
1) Press View repeatedly until the Channel 2
Single View is displayed.

4. Configure the Channel 2 condition to source and measure

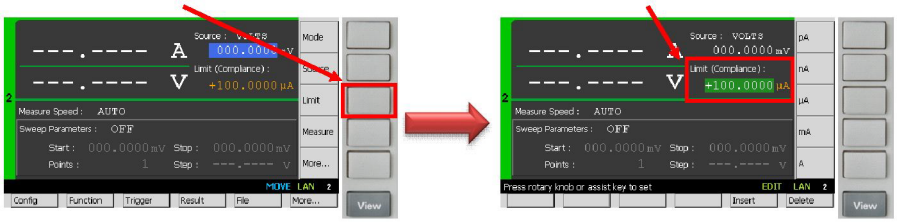
1) Press Mode to edit the Source function then select VOLTS (V) to set the Source function to Voltage source.



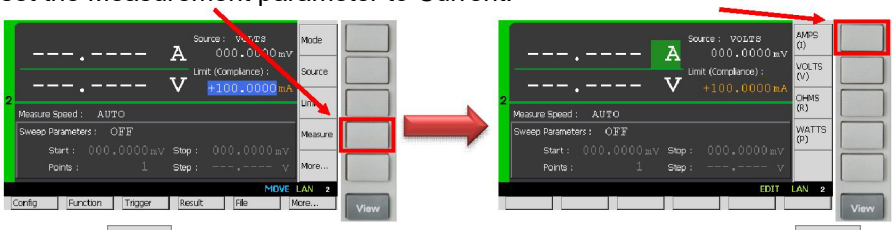
2) Press Source to edit the Source value then enter 0 V to set the Source value to 0 V.



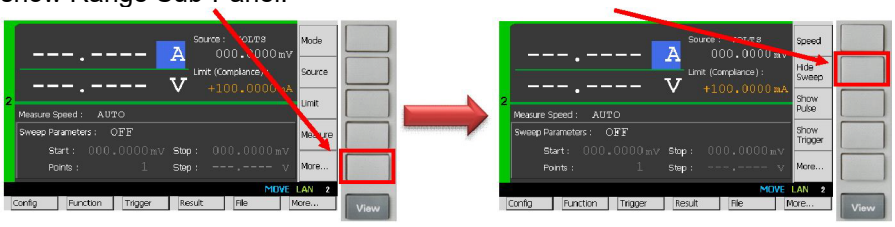
3) Press Limit to edit the Limit value then enter 100 mA to set the Limit value to 100 mA.



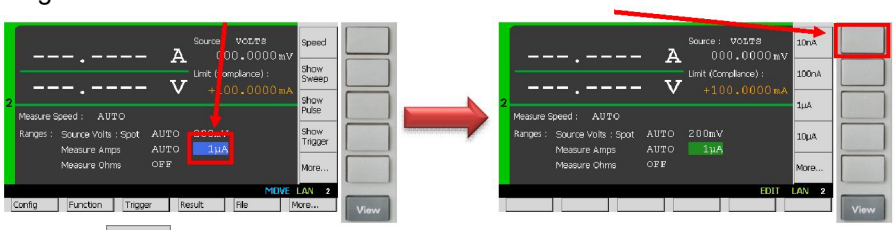
4) Press Measure to configure the Measurement parameter then select AMPS (I) to set the Measurement parameter to Current.



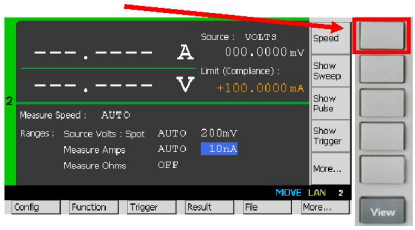
5) Press More... to change the keys shown in Assist keys then press Hide Sweep to show Range Sub-Panel.



6) Rotate to select the Current minimum measurement range and press to edit it. Then press 10nA to set the Current minimum measurement range to 10 nA.

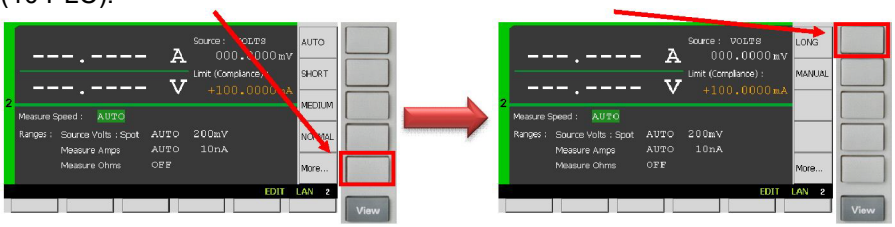


7) Press Speed to set the Measurement Speed Parameter.

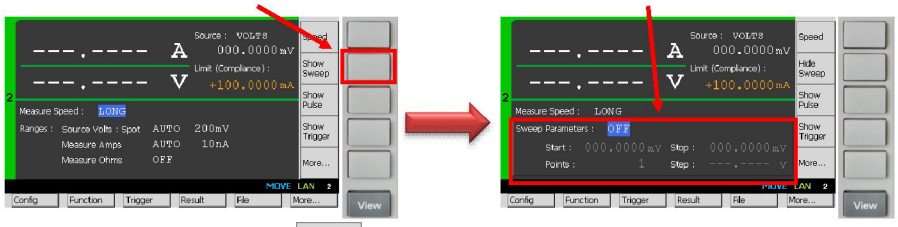


If you do not want to make the sub-nA current measurement, “AUTO” Measure Speed should be selected. It makes the measurement much faster.

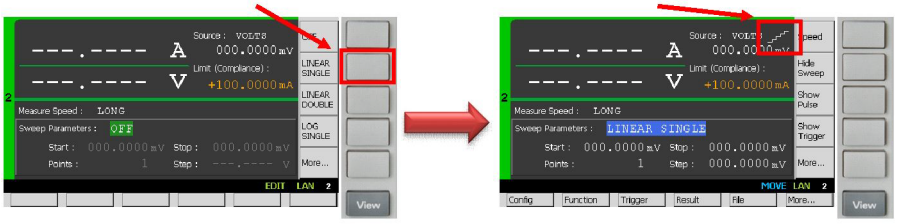
8) Press More... then press LONG to set the Measurement Speed to LONG (10 PLC).



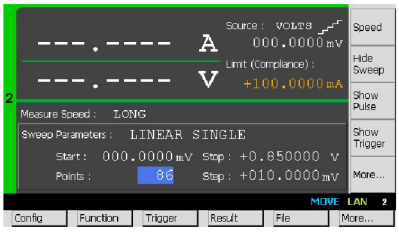
9) Press Show Sweep to show Sweep Sub-Panel.



10) Press , then press LINEAR SINGLE to turn on the Single Linear Sweep Mode. After turning on the Single Linear Sweep Mode, you can see the Source Shape which shows the single linear sweep mode.

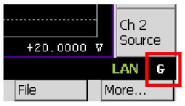


11) Rotate to select the Channel 2 Sweep Parameters and set them up as below. (Start: 0 V, Stop: 0.85 V, Points: 86, Step: 10 mV)



5. Change the View mode to Graph View

1) Press View repeatedly until Graph View is displayed.

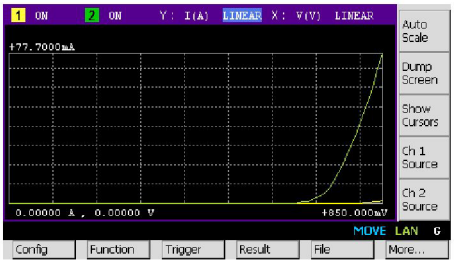


6. Perform the measurement

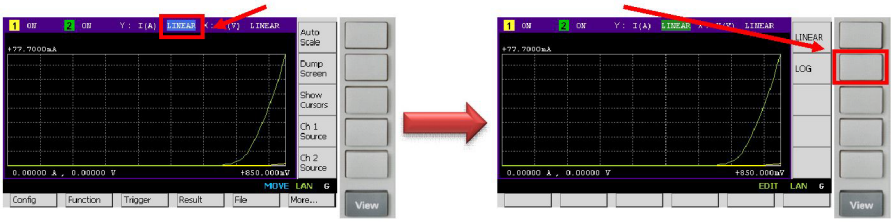
1) Press Ch1 and Ch2 On/Off to turn on both Channel Output relays.
2) Press Trigger to perform a sweep measurement.
(The status information will show ARM during the measurement.)

7. View the measurement result graph

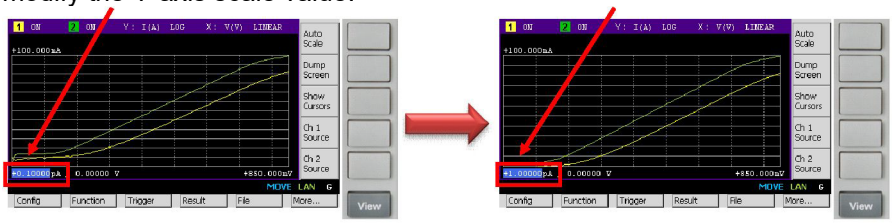
1) Press Auto Scale to adjust the scale of the graph after finishing the measurement. Now you can see the measurement result on the GUI of the B2900B/BL SMU as below.



2) To change the Graph scaling of the Y-axis from LINEAR to LOG, rotate and press to select the Y-axis scaling.



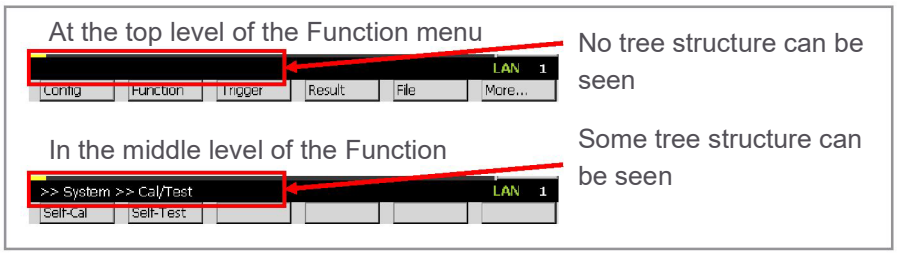
3) To change the Graph scale value of the Y-axis, rotate and press to modify the Y-axis scale value.



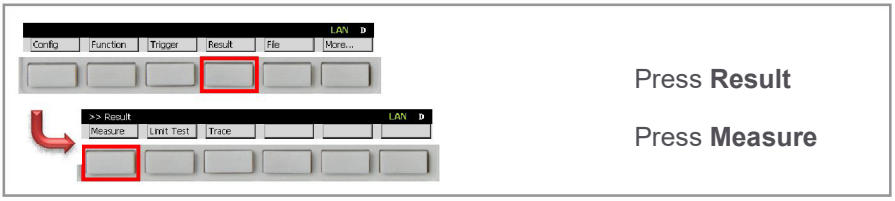
8. View the list of measurement results

The measurement results can be viewed by following the steps below:

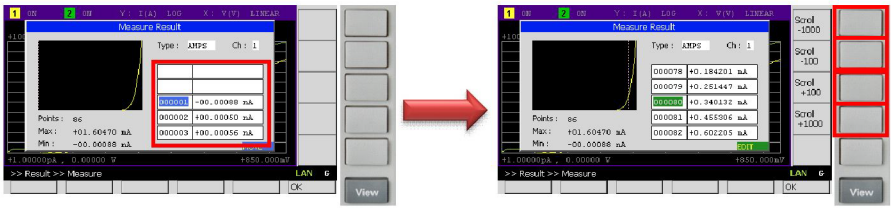
1) If you are not at the top of the Function menu, press Cancel Local repeatedly to return to the top level.



2) To view the List of measurement results, press Result, then press Measure to open the Measure Result dialogue.



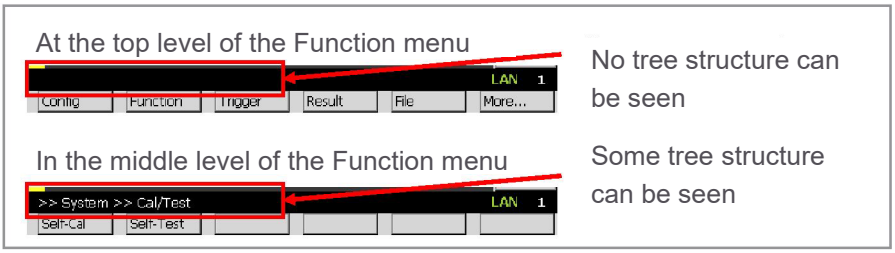
3) Rotate and press to select the Data field. Then rotate to scroll the Data list.



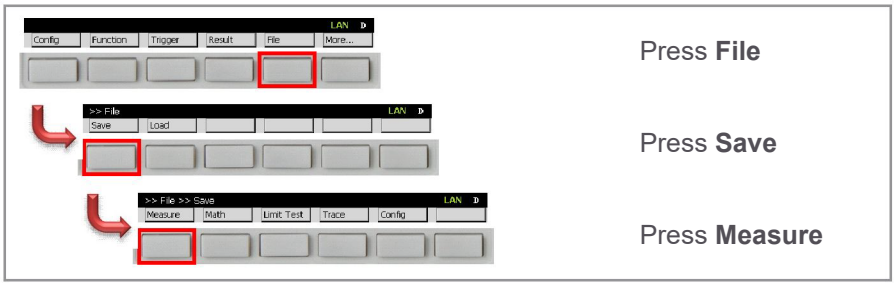
9. Store the measurement data to a USB flash memory device

Attach a USB flash memory device to the USB port on the front panel of the B2900B/BL SMU.

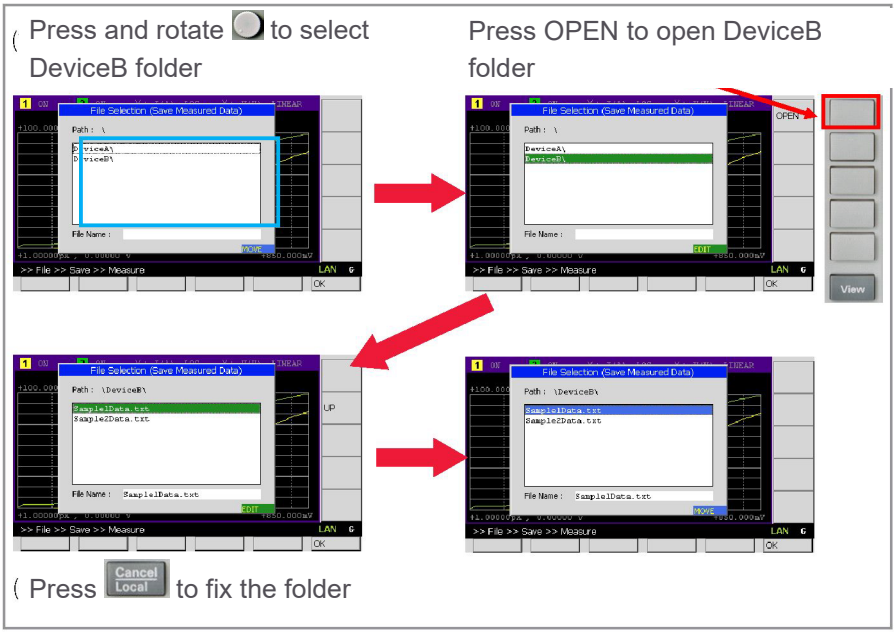
1) If you are not at the top of the Function menu, press Cancel Local repeatedly to return to the top level.



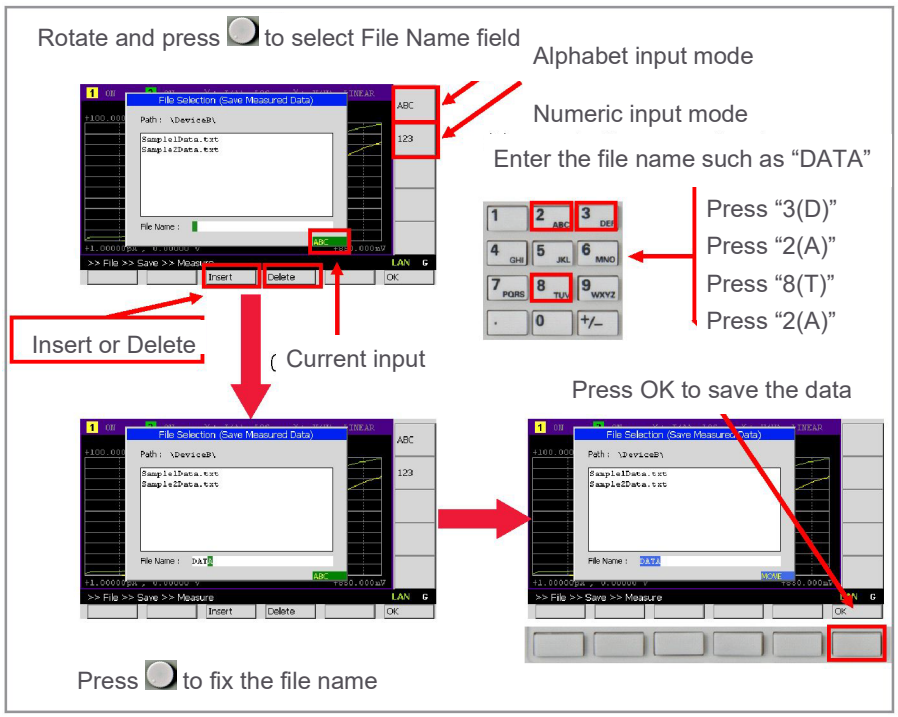
2) Press File, Save then press Measure to open File Selection dialogue.



3) Select the folder on USB flash memory device to which the data file should be saved. For example, select DeviceB folder.

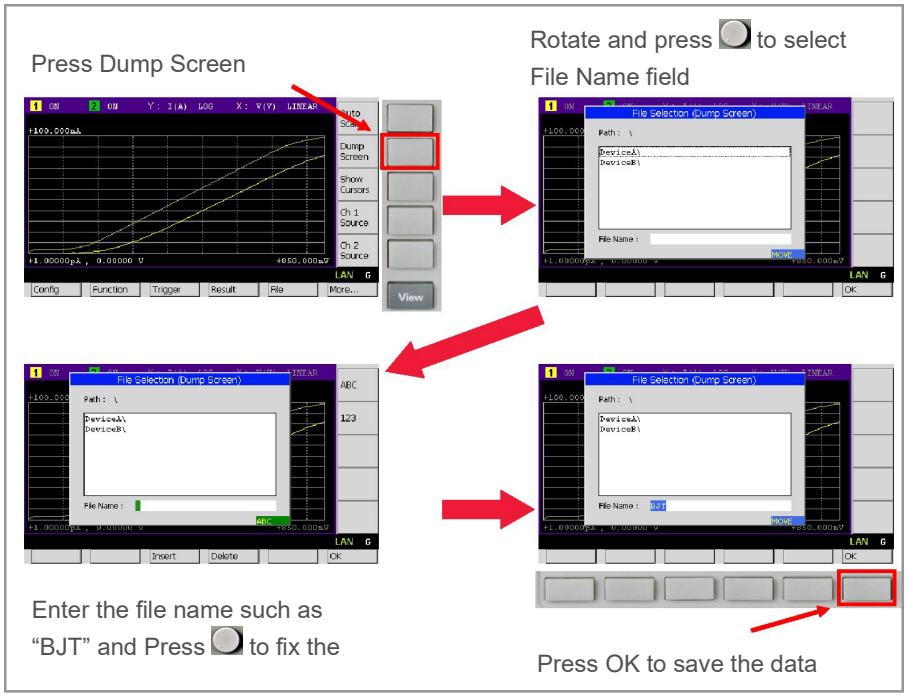


4) Specify the saved data file name.



10. Copy the Graph View screen dump to a USB flash memory device

1) If you connect any USB flash memory device to the B2900B/BL SMU, you can copy the Graph View screen dump to the USB flash memory device as a JPEG file. “.jpg” is added to the file name automatically.



Summary

The Keysight B2900B/BL Precision Source/Measure Unit is the best solution for IV characterization of BJTs and a variety of other devices. Its wide current and voltage measurement ranges (from minimum 10 fA/100 nV to maximum 10.5 A/210 V) provide superior measurement performance and allow you to characterize devices more accurately and easily than ever before. The easy-to-use GUI of the B2900B/BL Series of SMUs has a variety of capabilities and features that make it easy to take measurements quickly and to save both the measurement setup conditions and data to USB-based flash memory devices.

In addition to being able to control the B2900B/BL Series of SMUs remotely over GPIB, USB and LAN interfaces, Keysight offers multiple software control options to facilitate program development if you prefer PC-based instrument control, allowing you to choose the solution that best fits your particular application.

For more detailed information on the various models of the B2900B/BL Series of SMUs, please refer to the data sheet of the B2900B/BL Series of SMUs.

The B2900B/BL Series of SMUs enables you to quickly debug and accurately characterize a wide variety of devices using only a single bench-top SMU.

B2900 Precision Instrument Family

The B2900 family contains products that perform both precision sourcing and precision measurement.

Keysight enables innovators to push the boundaries of engineering by quickly solving design, emulation, and test challenges to create the best product experiences. Start your innovation journey at www.keysight.com.

KEYSIGHT

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