Chapter 8.2

EVERBEING EB-8 ANALYTICAL PROBE STATION

(probe-eb8) ***(SDH 380)***

1.0 Equipment Purpose

1.1 The Everbeing EB-8 is an analytical probe station used to measure I-V characteristics of electronic devices. It consists of a microscope, four micro-manipulators with probe tips, a thermal wafer vacuum chuck and a host of ancillary measurement equipment including a

1.1.1 HP4145B semiconductor parameter analyzer,

1.1.2 Agilent 4284A LCR meter

1.1.3 Keithley SMU (source meter) 2635

1.1.4 other various power supplies, ammeters, voltmeters etc.

1.2 This manual covers the materials used, process, operation and safety procedures for this tool.

2.0 Material Controls & Compatibility

2.1 Probe-eb8 accepts wafers up to 200mm in diameter and chips of oblong shape.

2.2 The probe tips are user replaceable, and can be checked out from the NanoLab office. The probe tips just pull straight out from the end of the probe mount, and new ones are just pressed back in - make sure to push all the way in - and be careful, as they are sharp!

2.3 Note: Wafers that go through the mercury probe are mercury contaminated after measurement. This is not considered a health hazard. It is a cross-contamination hazard and wafers may not proceed to most etch equipment after this test.

3.0 Training Procedure & Applicable Documents

3.1 Basic Tool -this tool requires enabling and a formal qualification session, but does not have an online test.

3.1.1 Timeline (estimated time to completion: 1-2 days)

3.1.1.1 Get trained by any qualified member.

3.1.1.2 Arrange a qualification session with a superuser to show competency on the tool.

3.2 Superusers and staff qualify members on this tool.

3.3 Everbeing EB-8 Operation Manual. A copy is in the Nanolab Office.

3.4 Everbeing HT-100 Operation Manual. A copy is in the Nanolab Office.

3.5 HP 4145B Operation Manual. A copy is in the Nanolab Office and near the tool. Do not remove it.

3.6 Agilent 4284A Operation Manual. A copy is in the Nanolab Office and near the tool. Do not remove it.

4.0 Definitions & Process Terminology

4.1 **PVT:** PV temperature – the actual temperature measured on the chuck surface

4.2 **SVT:** SV temperature – the pre-set temperature on the chuck surface specified by the user

5.0 Safety

5.1 Follow general safety guidelines for the lab; the safety rules outlined in Chapter 1.01 - Marvell NanoLab Chemical Hygiene Plan and the following:

5.2 The heated chuck can burn you. Please pay special attention to make sure that, either the power to the thermal chuck is off, or, if you are using the thermal chuck, you do not touch it and burn yourself.

5.3 The probe tips are very sharp. Pay particular attention when you have your hands or fingers near them.

5.4 If you break probe tips, please replace it for next person. Be sure to dispose of any removed tips in the Sharps Bin.

5.5 **Pinch Hazard:** Probe-eb8 is enclosed in a cabinet with two doors. Please watch to make sure your clothes or fingers do not get caught in the door.

5.6 The Model 802B mercury probe available within probe-eb8 contains a sealed mercury system. Inspect the mercury probe prior to using it. If you see any metallic spheres, discontinue use and contact staff.

5.6.1 A mercury spill cleanup kit is available at probe-eb8. Members who wish to use the mercury probe must be familiar with the cleanup kit's location.

6.0 Process Data

6.1 This tool is not regularly monitored by staff

7.0 Available Processes, Gases, Process Notes

7.1 To be added when available

8.0 Equipment Operation

8.1 Enable *probe-eb8* on Mercury client. This controls the light source for the microscope, and it should be on...if not, check the on/off switch on the right side of the light housing (on the microscope).

For the rest of the operational procedures, refer to Figure 1

8.2 Lower the chuck with its front-mounted control lever, so that the probe tips do not touch your wafer

8.3 Put your wafer on the chuck and turn on the vacuum with the chuck vacuum control switches, located on the right side of the microscope base. Each switch is labeled, and applies vacuum to a progressively larger area of the chuck.

8.4 Raise the chuck (control lever) and focus the microscope on the desired test area. If necessary, use the locks to hold the stage in place.

8.5 Lower the chuck.

8.6 Release the magnetic clamp switch located on the bottom back of the micro-manipulator to move it to the desired position. Make sure to re-engage the magnetic switch after you put the

manipulator in place.

8.7 Use the coarse adjustment on the manipulator to raise the probe tip, making sure it is not touching your wafer.

8.8 If you want to change probe tips, this is a good time to do it. Pull out the old one, and place it in a safe place. You will be putting it back when you are done. Insert the new tip. It is held in by pressure between the holder and tip (a press fit - insert it all the way in).

8.9 Guide the probe head over your general measurement area by moving the micro-manipulator.

8.10 Slowly raise the chuck, but make sure you never touch your sample with the probe tips – even in the full up position.

8.11 Refine the position of the probe head over your measurement area with the microscope.

8.12 Use the coarse adjustment to lower the probe tip down until it almost touches your wafer.

8.13 Concurrently, as the probe tip comes into focus, use the x, y verniers on the micro-manipulator to position the tip over the desired point. Next, use the z vernier to lower the probe tip onto your desired contact point. When the probe tip contacts your substrate, it should deflect a bit (change from a vertical motion to a horizontal motion). There should be slight movement in a different direction (Figure 2).

8.14 To change measurement position, first use the z vernier to raise the probe tip off of your substrate surface. Afterwards either move the x, y verniers for nearby points or the micro-manipulator for distant points. Use the z vernier to lower the probe tip to make contact with your substrate as before.

8.15 The micro-manipulators are connected through a feed-thru to the various measurement equipment (Figure 3).The HP4145B has a dedicated feed-thru.

For heated chuck operation, refer to Figure 4

8.16 Turn on the main power switch of the hot chuck control panel (Figure 4).

8.17 Select the sideways arrow button to choose the decimal place to change for the desired set point.

8.18 Use the up and down arrow buttons to select the desired digit.

8.19 Go to the next decimal place and repeat the procedure for all setpoint digit values.

8.20 Once all of the set point digit values are selected, push the set button to enable the set point temperature.

8.21 Turn on the heat toggle switch. Power is now going to the chuck and you should see the actual temperature increase to the set point temperature.

8.22 When you are finished with your hot chuck measurements, turn off the heat toggle and main power switches. Put the sign up on the front of the door that states the chuck is/was hot, so the next person won't burn themselves. The sign is located on the right inner side of the cabinet. It has Velcro backing.

Sometimes a picture is worth a thousand words so we've tried to made a ***VIDEO*** for ease of use.

8.23 ***Automatic Measurement with Metrics Software and HP4145B***

8.23.1 Start computer, there is no password, so press Enter to continue through login stage.

8.23.2 Open Metrics ICS and Keysight IO.

8.23.3 Check in Keysight IO that HP 4145B has a green check mark next to it in the interface.

8.23.4 Then go to Metrics ICS and Click File, and then New Project.

8.23.5 Click “Select Instrument” and then highlight the instrument to be added. (In this case HP4145) And then Click “Connect”.

8.23.6 Once HP4145 is highlighted under “Selected”, click the “Config” button and then click poll. Then click OK button to close the configuration window and click OK again to close the instruments window.

8.23.7 At this point set up the configuration of the test in the EB Probe and attach them to the ports that correspond to HP4145B. The rightmost column of ports, when looking from the inside of probe EB8 correlate to the four ports that can be used for this device.

8.23.8 To measure a resistor or MOSFET, use a sweep measurement across a range of voltages to characterize the device.

8.23.9 Follow the directions below from the ICS manual to set up a sweep measurement for a resistor/MOSFET,

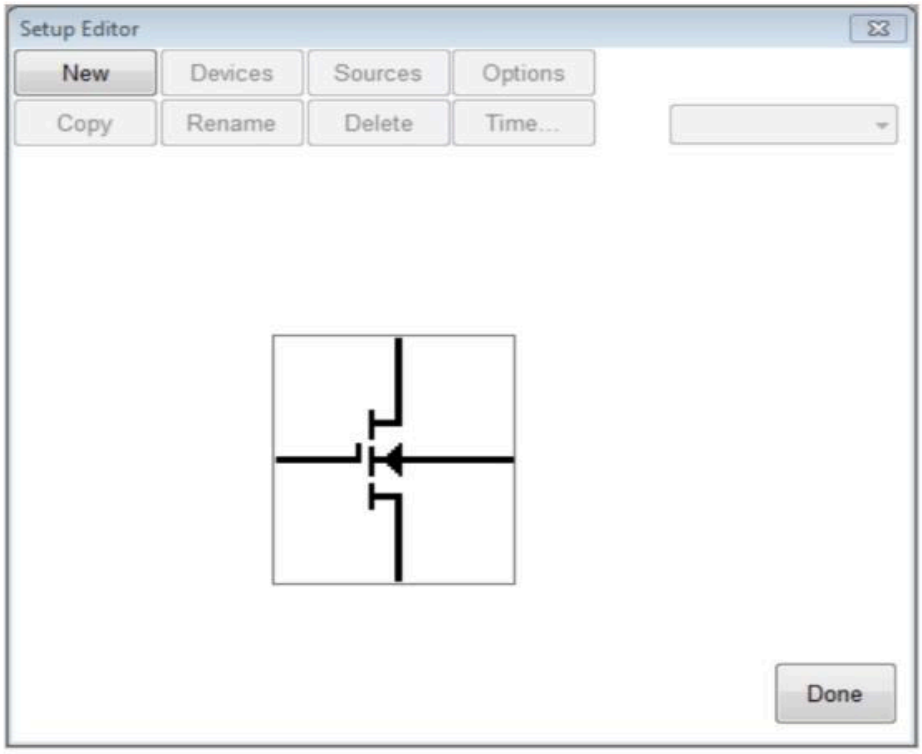
Create a Sweep Measurement

The following example demonstrates how to create a sweep measurement using ICS. This example uses the demonstration driver within ICS.

To Create a Sweep:

1. Open the setup editor.

The Setup Editor is the dialog in Metrics ICS where the measurement is configured. It can be opened by clicking the Setup Editor button.



2. Click "New" to create a new setup

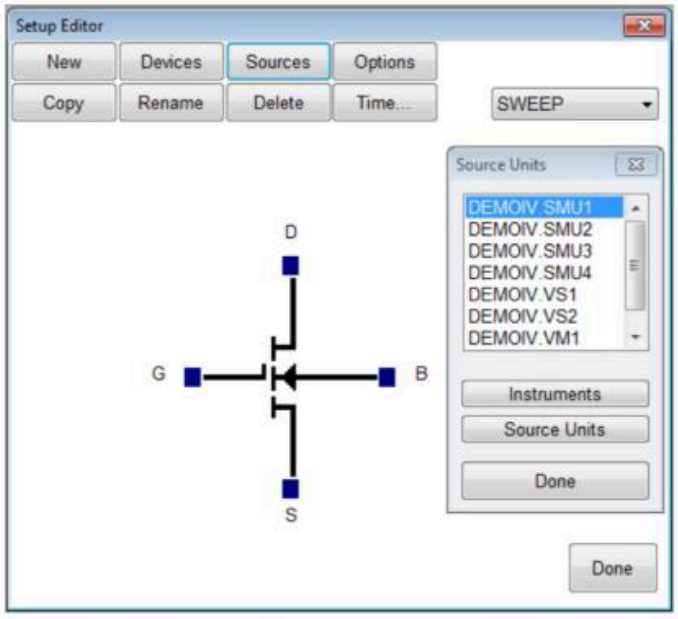
3. Name the Measurement Setup.

Each measurement must have a unique name. Before the measurement can be created, it must be given a name. To name the measurement:

a. Click the **OK** button after entering the name.

4. **Select Source Units.**

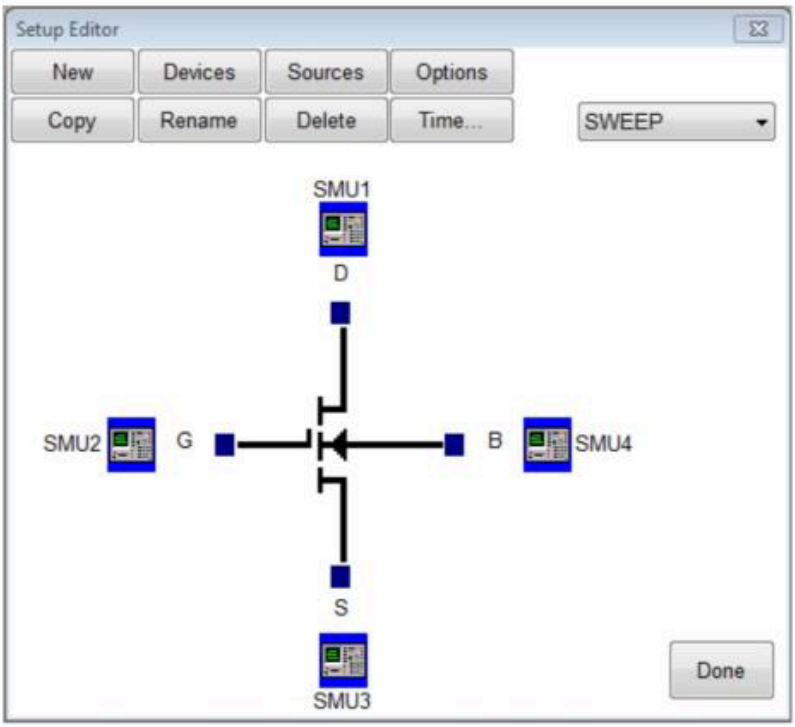
The source units correspond to the outputs of the instrument you are using. Metrics ICS provides a graphical way to document the connections for later reference. To add a source unit:



a. Click on the **Sources** button to open the Source Units window.
b. Highlight the specific unit.
c. Click the blue box beside the device lead in the Setup Editor.

To remove a source unit:

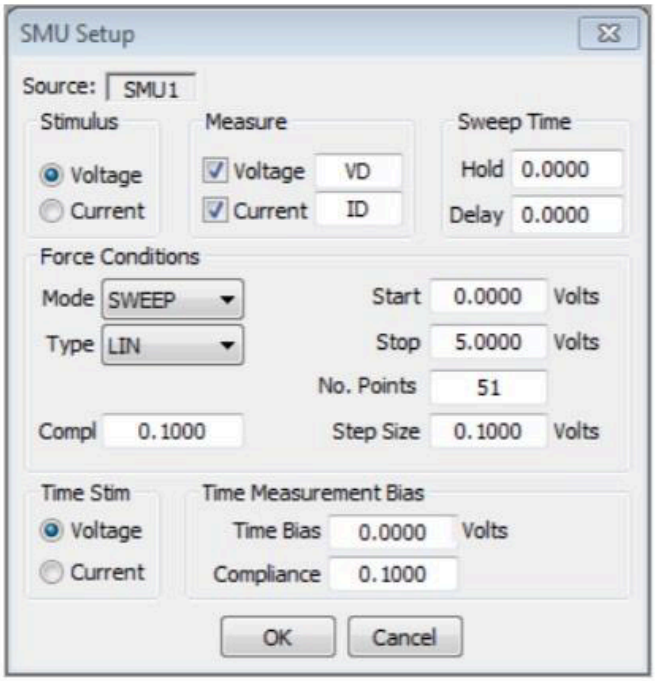
a. Highlight the attached unit.
b. Click the blue box beside the device lead in the Setup Editor.
c. Click the **Yes** button when asked if "Do you really want to remove the source".



Note: The graphic is merely a representation of the device. The software does not expect behaviors from the data. Thus, the pin-out does not have to exactly match, rather it is only for reference.

5. **Configure Source Units.**

In this example we are creating a sweep source, so we must configure the source unit properly. To setup a sweep source:



a. Select the stimulus type.
b. Select the values to be measured (see note below).
c. Click the blue box beside the device lead in the Setup Editor.
d. Select the sweep timing (see note below).
e. Select the Source Mode. In this case we want it to be Sweep.

Setup the sweep parameters.

Note: Most SMU's can only measure the signal that is not being sourced. Therefore in this case we have selected the Stimulus to be Voltage resulting in the Current being measured. The values returned for Voltage in this case would be the calculated voltage steps. The opposite is true when the Stimulus mode is set to Current. The Sweep Time parameters are to control the rate of the sweep. Please note that these inputs vary for different instruments.

Once the measurement is set up, use the directions below to execute the measurement.

Executing the Measurement

The measurement mode is **Standard** by default. Thus all of the previous measurement types (sweep and single point) did not need this value changed.

To access the Measurement Remote control click on the **Measure** button on the ICS toolbar.

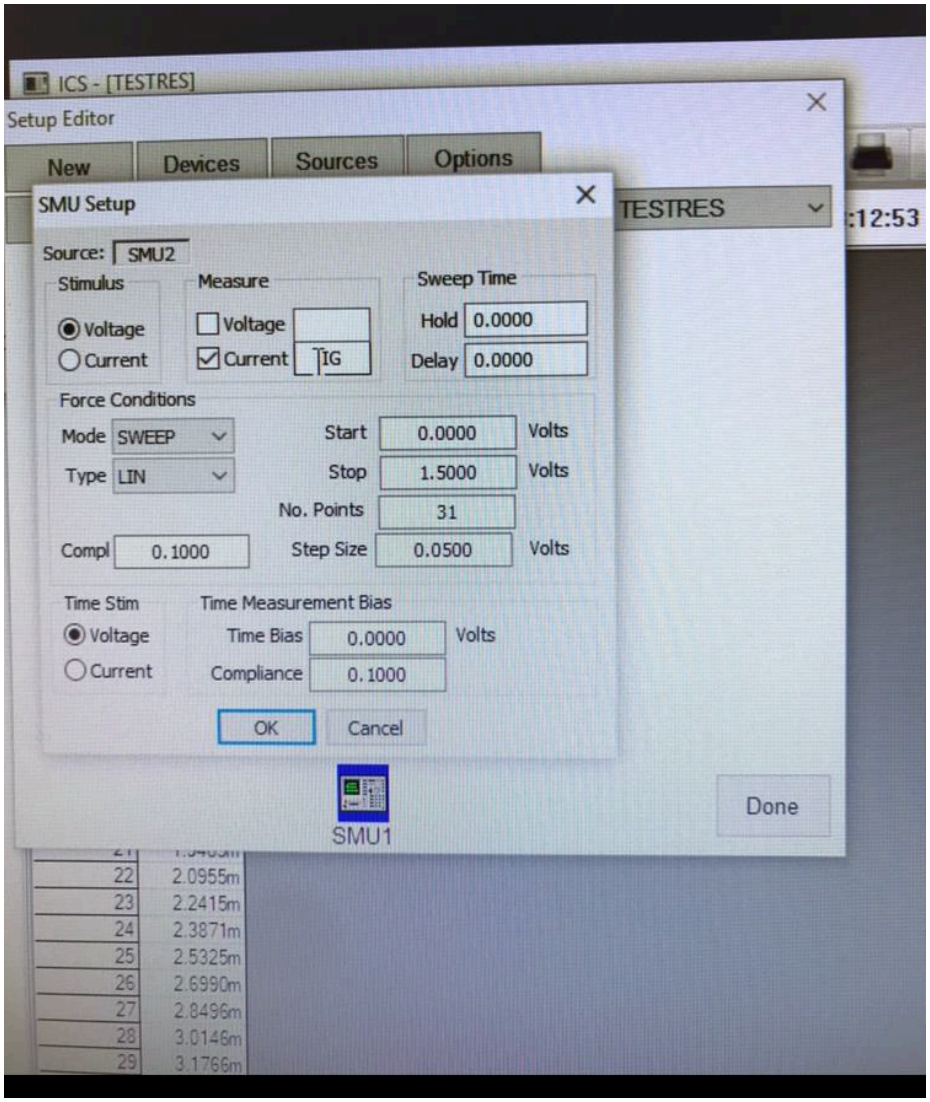
To Execute a Measurement:

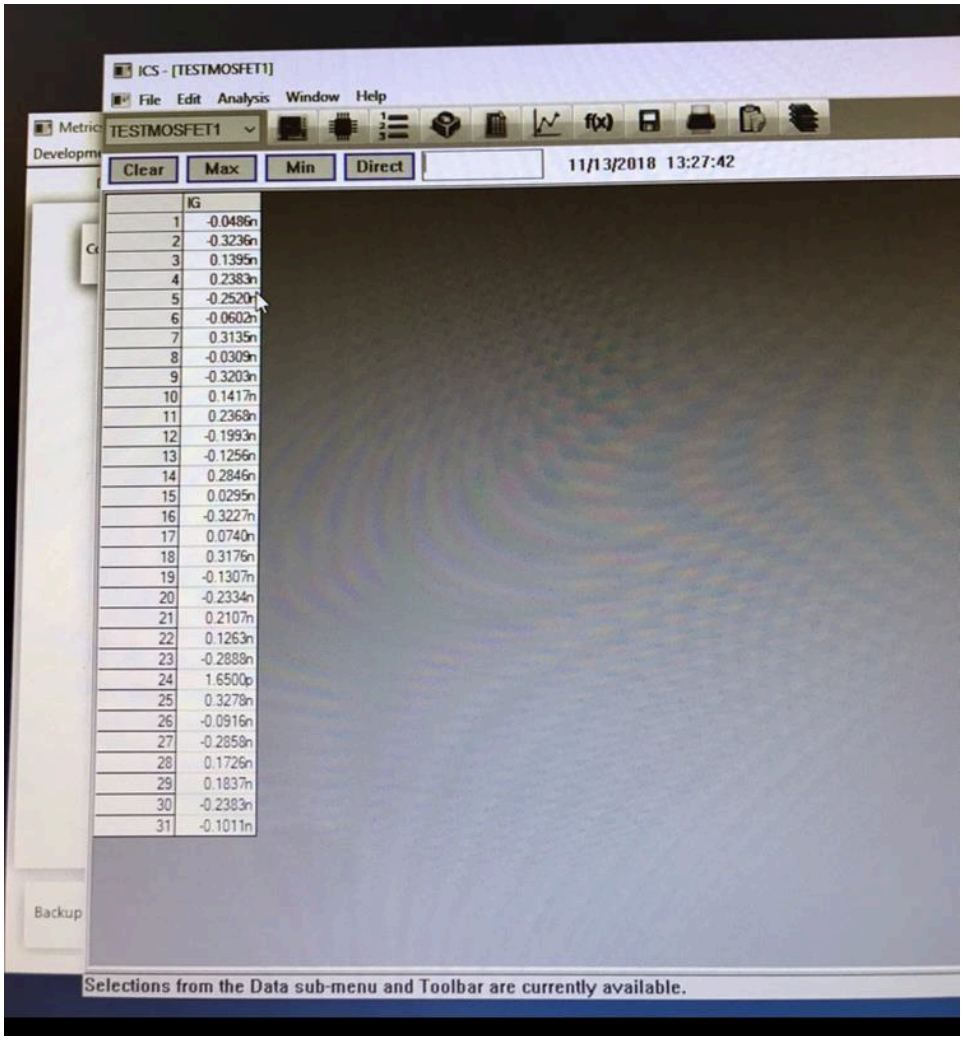
1. Make sure the measurement name is displayed in this box.
2. Use the pull down menu to select the **Standard** mode.
3. Click the **Single** button to execute the measurement.

This toolbar contains buttons to begin the measurement as well as menus to select the measurement and mode.

At this point the software will communicate with the instrument and execute the measurement.

If the measurement does not run, one must restart HP4145B by turning the machine off then on again.Configuration and data output attached below for a sample MOSFET. The other parameters used were, SMU1 was source (ground, constant 0V). SMU3 was drain (constant 1V).


ICS - [TESTRES]
Setup Editor
New
Devices
Sources
Options
TESTRES
:12:53
SMU Setup
Source: SMU2
Stimulus
Voltage
Current
Measure
Voltage
Current
IG
Sweep Time
Hold 0.0000
Delay 0.0000
Force Conditions
Mode SWEEP
Type LIN
Start 0.0000 Volts
Stop 1.5000 Volts
No. Points 31
Compl 0.1000
Step Size 0.0500 Volts
Time Stim
Voltage
Current
Time Measurement Bias
Time Bias 0.0000 Volts
Compliance 0.1000
OK
Cancel
SMU1
Done
22 2.0955m
23 2.2415m
24 2.3871m
25 2.5325m
26 2.6990m
27 2.8496m
28 3.0146m
29 3.1766m



8.24 ***Automatic Measurement with Metrics Software and HP4284A***

HP4284A with Metrics ICS

1. Start computer, there is no password, so press Enter to continue through login stage.

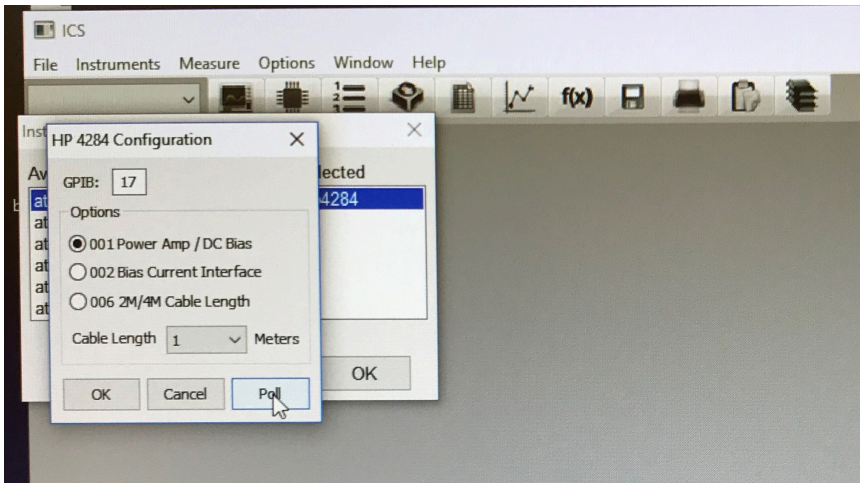
2. Open Metrics ICS and Keysight IO.

3. In Keysight IO check that HP 4284A has a green check mark next to in the interface. This means the device can be connected to Metrics ICS.

4. Then go to Metrics ICS and Click File, and then New Project.

5. Click “Select Instrument” and then highlight the instrument to be added. (In this case HP4284) And then Click “Connect”.

6. Once HP4284 is highlighted under “Selected”, click the “Config” button and then click poll. This ensures that the software is reading the GPIB port to be 17. Leave everything else as is, it should look like the image shown below. Click the OK button to close the configuration window and click OK again to close the instruments window.



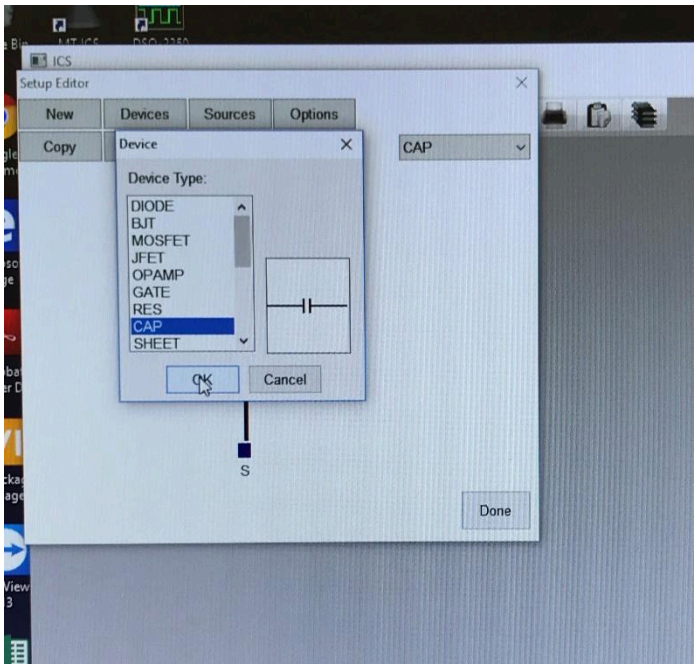
7. At this point set up the configuration of the test in the EB Probe but do not press probes to the substrate and attach the cables to the ports that correspond to HP4284A. This is the leftmost column of ports, when looking from the inside of probe EB8 correlate to the four ports that can be used for this device. There will probably be two ports used based on experimental configuration which are labeled H and L in the software.

8.) To run a sweep measurement click on the Setup Editor which is the second from the left on the bar of different graphics in Metrics ICS. It resembles a chip with pins emanating from all sides. Then click new to create a new setup.

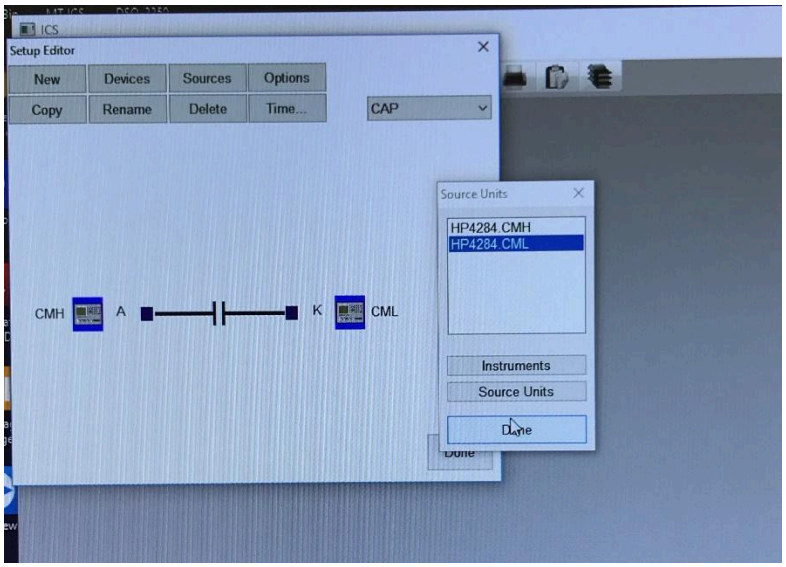
*Please note the following steps are designed to work for a CV curve of a capacitor.

9.) Then name the setup and click OK to continue to the Setup Editor.

10.) Select the device that will be tested, in this case a capacitor was used.



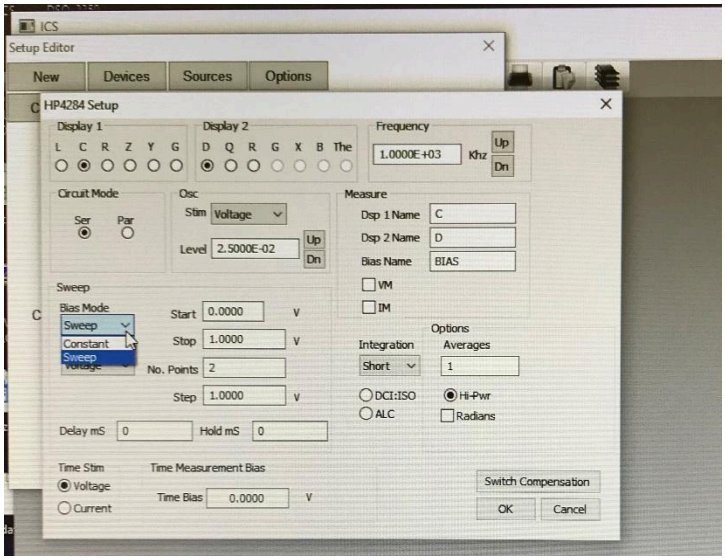
11.) Select Sources and first click on the source name in the menu and then click on the black square where it should go for the measurement as shown below. Click Done when setup is complete.



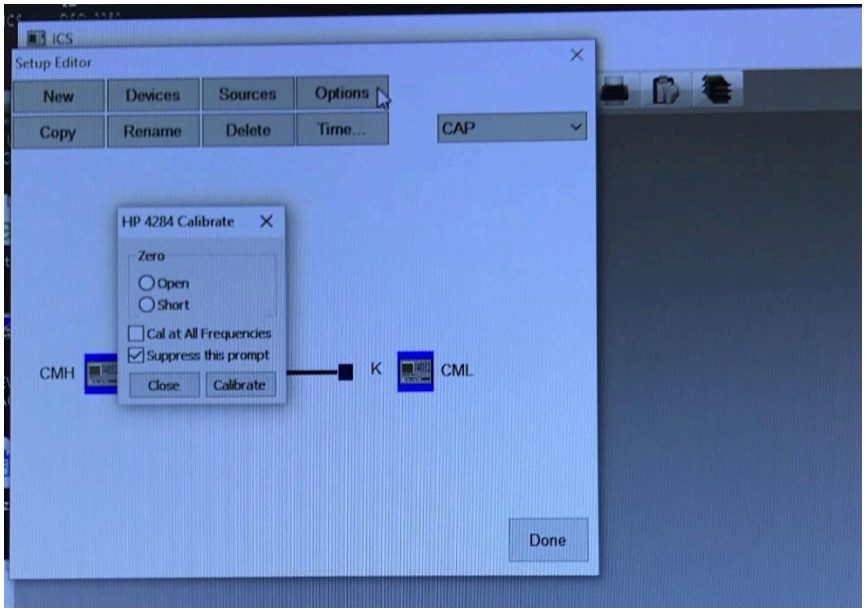
12.) Two calibration measurements must be completed at every frequency that will be tested. First, set the frequency by clicking on the blue square representing the CMH and set the frequency and test measurements as shown below. One will need to change the Bias mode from Constant to Sweep and select the parameters to be measured and the frequency at which the measurement should occur. Set the circuit mode using the guidelines below. Click OK when finished.

You may also calibrate OPEN and SHORT for "all frequencies" at the same time, however since our tool set up works best with lower frequency (1kHz - 100kHz) measurements you may get the error "UNBAL" for higher frequencies depending on your set up.

Circuit Mode:
Cp = use this mode when small capacitance is expected. This is because small C leads to large X, so the Rs can be neglected but Rp can not. Rule of thumb - if the impedance of the capacitor >10kΩ use Cp
Cs = use this mode if C is large , X is small and Rs becomes more significant than Rp. If the Impedance of the capacitor is <10Ω use Cs
Example: 20uF capacitor at 1kHz - Z=8Ω use Cs



13.) Click Options to open the menu shown below. Corrections for Stray Capacitance in the cabling should be performed -OPEN to correct for high impedance measurements <10pF or >1MΩ
SHORT to correct for low impedance measurement >10nF or <1MΩ. One can also perform a LOAD correction. However due to the test terminals being extended with long non-standard cables, measurements at high frequencies (>300kHz) might become unbalanced due to the large phase shift. Setup the probe tips such that neither are touching the substrate and click calibrate to run the calibration for Open. This must be done first. Check the screen on the HP4284A to ensure that the calibration runs. Then setup the probe tips such that they are shorted directly, connected by a good conductor and click calibrate to run the calibration for Short. Click Close when these calibrations are finished and Click Done to close the setup editor.



Once all parameters are set for the measurement use the directions below to execute the measurement.

Executing the Measurement

The measurement mode is **Standard** by default. Thus all of the previous measurement types (sweep and single point) did not need this value changed.

To access the Measurement Remote control click on the **Measure** button on the ICS toolbar.

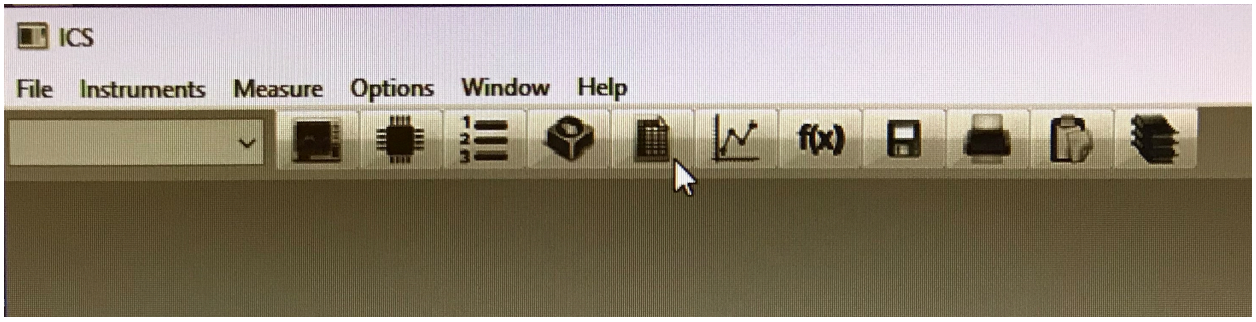
To Execute a Measurement:

1. Make sure the measurement name is displayed in this box.
2. Use the pull down menu to select the **Standard** mode.
3. Click the **Single** button to execute the measurement.

This toolbar contains buttons to begin the measurement as well as menus to select the measurement and mode.

At this point the software will communicate with the instrument and execute the measurement.

15.) Once the data is collected, one can graph using the Data View option shown in the image below.



Troubleshooting Section:
If any problems arise it is best to reset the connection between the HP4284A and Metrics ICS by turning off both the computer and the HP4284A and then turning them back on. If this does not work contact staff about the problem.

8.25 ***Using the EXTECH 380193 LCR Meter for Measurements at 120Hz and 1kHz***

8.25.1 The EXTECH 380193 LCR meter is designed to measure inductance, capacitance or resistance at 120Hz and 1kHz and display the results graphically, by text or exported to EXCEL or similar programs.

8.25.2 Connect cables from the device under test in the probe station to the EXTECH LCR meter located on the upper right-hand side of the electronics rack (see Figure 7).

8.25.3 Open the EXTECH 380193 LCR meter software on the computer as shown in Figure 8. There is also a pdf Help file icon named 380193-SW-... if you have problems. It should be located right below the LCR meter software icon.

8.25.4 The software should open up to the Main measurement page as shown in Figure 9.

8.25.5 Open the Menu tab then Setup Initial. You will have to set up initial measurement tolerances.

8.25.6 To set the main tolerance level set the mode to Mode 1. To set the Hi and Lo Limit tolerances set the mode to Mode 2. To set the Hi and Lo Limits set the mode to Mode 3.

8.25.7 Click on the Range Tab (see Figure 10). The screen shows the current range and the group number (1 - 10) that the user can change. The Auto/Manual selection can calculate automatically or be changed by hand. When the left side value is greater than the right side value, the Wrong Range will light up. While the Wrong Range is lit, adjust the value or there will be an error.

8.25.8 Click on the Instrument Set Tab to set the LCR meter parameters, inductance, L (henries), capacitance, C (farads), or resistance, R (ohms) as well as the secondary parameters of quality, Q and dissipation, D. The parameters of frequency, parallel/serial and auto/menu may also be set. Once this is done, click on, Set Instrument, to put the parameter into the LCR meter.

8.25.9 Click on the menu tab and choose, Profile. There are four buttons, Auto Record - record data with one second sample rate; Record - manually record a data point; Clean - clear the recorded data table; Save Data - save recorded data to a text or EXCEL file. The Profile Tab displays the setup values including current value, maximum (Max), minimum (Min), average (Avg), total number (Total) and Reject Rate (see Figure 11).

8.25.10 The List Tab shows real time data in table form. Run Auto Record to collect a list of data.

8.25.11 The Frequency Distribution Tab shows real time data in histogram form. Each column is a range set up in the setup screen (see Figure 12).

8.25.12 To save recorded data, click on the Save Data button. The resultant screen allows you to change the save name and location, file type and gives the ability to add descriptive fields to the file.

8.25.13 To obtain a clear view of where the current value sits on the scale of ranges that were defined on the setup screen, click on the OPEN menu tab and choose Sorting.

8.26 ***Using the Computer Based Oscilloscope***

8.26.1 Turn on the oscilloscope software in the computer terminal by double clicking the DSO-225 USB icon in the upper left corner of the desktop screen.

8.26.2 The oscilloscope has three ports, CH1, CH2, and EXT, as shown in Figure 5.

8.26.3 To connect your probes to the oscilloscope use the BNC measurement cables located at the bottom of the electronic rack.

8.26.4 To measure different values on the oscilloscope, such as the voltage difference between two points, click the Cursor drop down menu and go to the Type folder. There are different measurement options to choose from. The values measured will appear near the bottom of the window. See Figure 6 for a typical voltage measurement.

8.27 Using the Mercury Probe

8.27.1 DO NOT ATTEMPT TO USE THE MERCURY PROBE UNLESS YOU HAVE BEEN SPECIFICALLY TRAINED ON IT'S USE BY A PROCESS ENGINEER!

8.27.2 The model 802B mercury probe on the right side of probe-eb8's enclosure is capable of making temporary contact to wafers for capacitance and breakdown measurements of thin films.

8.27.3 Always check your wafers under a particle lamp, and use the LED lamp in the probe station to check the mercury probe itself.

8.27.3.1 It is extremely important that all surfaces are clean of particles. Contaminated surfaces will lead to contamination of mercury on contact - this can result in mercury spilling out of the sides of the contact points and give both bad data and require time-intensive mercury cleanup efforts. A single severe contamination event can cause replacment of 2-3 mL of reagent grade mercury at the cost of 4-5 hours of staff time and 3+ days of downtime on the tool.

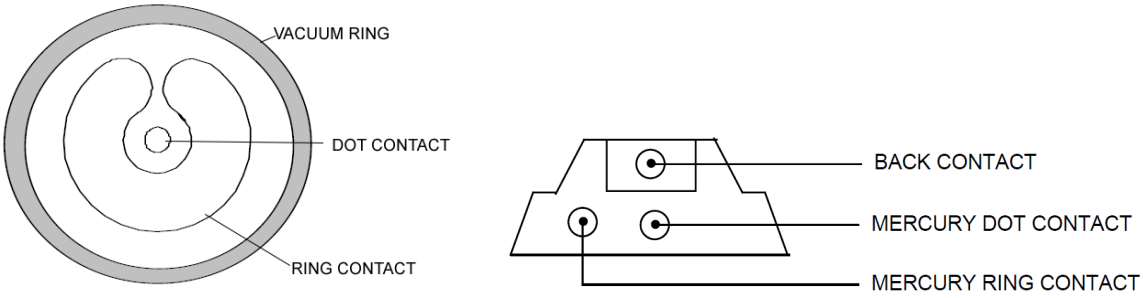
8.27.4 It is recommended that you always load a clean 1kA thermal oxide wafer into the mercury probe to calibrate your measurements. You should see a measurement between 100-150 pF depending on the mercury probe behavior that day, and can adjust your calculations to the dot size appropriately.

8.27.5 Hook up your instrumentation to the mercury probe rear BNC connectors. There are three contact points:

8.27.5.1 Backside substrate contact

8.27.5.2 Inner dot contact

8.27.5.3 Outer ring contact



Left: Mercury Probe front contact diagram. The Ring contact is ~50x the surface area of the dot contact.
Right: Rear BNC connection arrangement.

8.27.6 To use the mercury probe, place the wafer with the side you wish to measure facing down. Try to avoid scraping the surface of the wafer along the mercury probe stage.

8.27.7 Pull the lever to the purge position

8.27.8 Ensure the vacuum gauge on the pump assembly behind the mercury probe reads 4-5 psi.

8.27.9 Wait for 3 seconds.

8.27.10 Pull the lever down to engage the arm and contact the substrate.

8.27.11 Adjust the vacuum gauge to between 7 and 10 psi.

8.27.12 Take your measurement.

8.27.13 Push the lever to the purge position for 3 seconds.

8.27.14 Push the lever to the unload position and remove wafer

8.27.15 Note: Wafers that go through the mercury probe are mercury contaminated after measurement. This is not considered a health hazard. It is a cross-contamination hazard and wafers may not proceed to most etch equipment after this test.

9.0 Troubleshooting Guidelines

9.1 There are some important points to look out for, the chuck should be lowered and the probe tips should not be touching it. The microscope lamp should be on, as well as the general use lamp at the back of the probe cabinet (optional- switch is located on the lamp cable at the back of the isolation box). Remember to turn off the vacuum switches when you are done. Of course the most important point is that when you are finished with your hot chuck measurements, turn off the heat toggle switch and the main power switch, close the doors, and put the “Caution Hot Chuck” sign up on the front of the cabinet – remember “***CAUTION HOT CHUCK***” sign goes up on the front of the ***CLOSED DOOR***. If there is a problem with the tool, please report it on Mercury Client.

10.0 Study Guide

10.1 What is probe-eb8 used for?

10.2 What is the largest wafer diameter that can be used in the tool?

10.3 Does the tool have a heated vacuum chuck?

10.4 Demonstration and safety are the keys here, so we’ll ask you to show us how to use the probe.

11.0 Appendices, Figures & Schematics

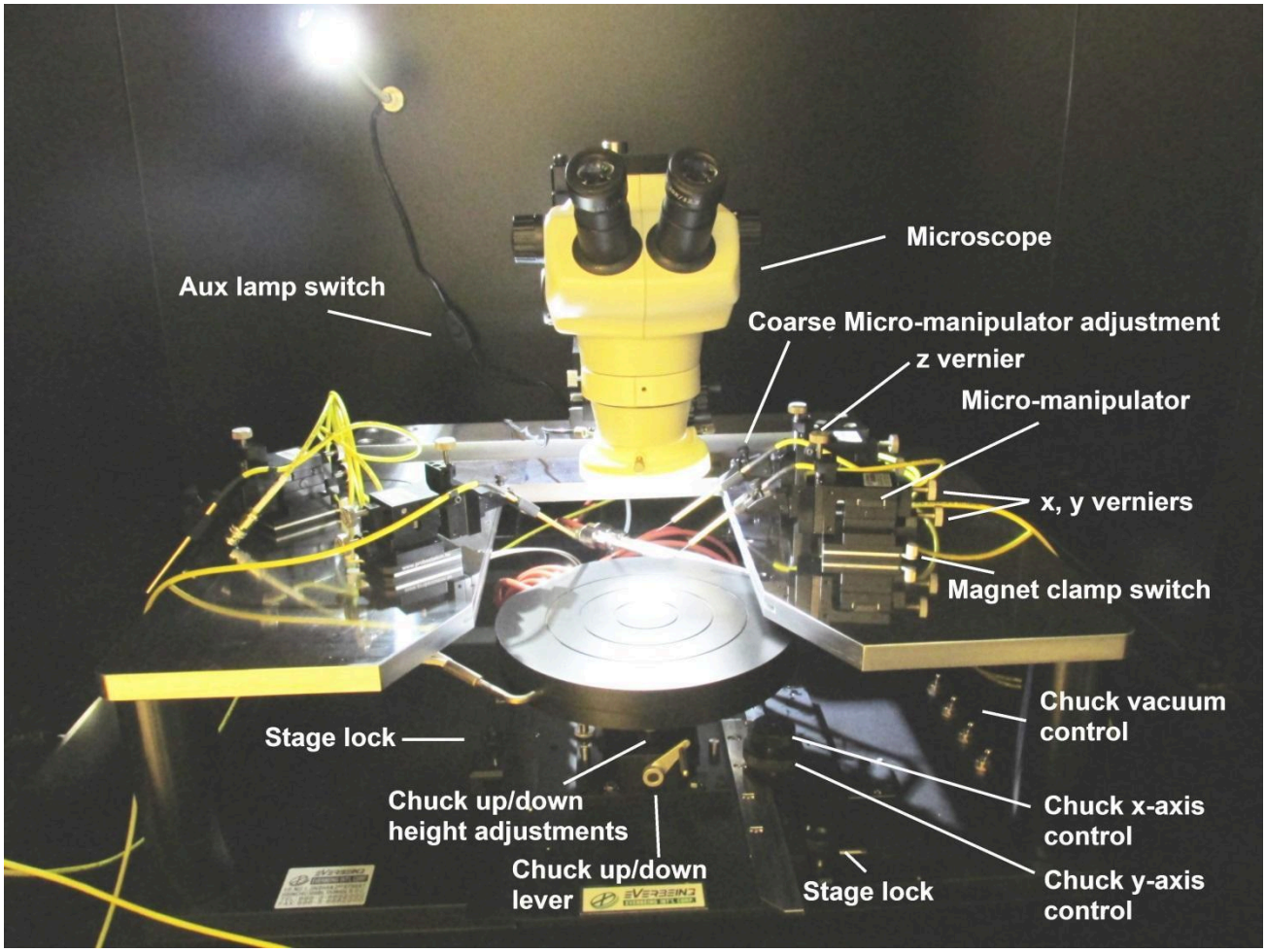


Figure 1, Probe Station Definitions

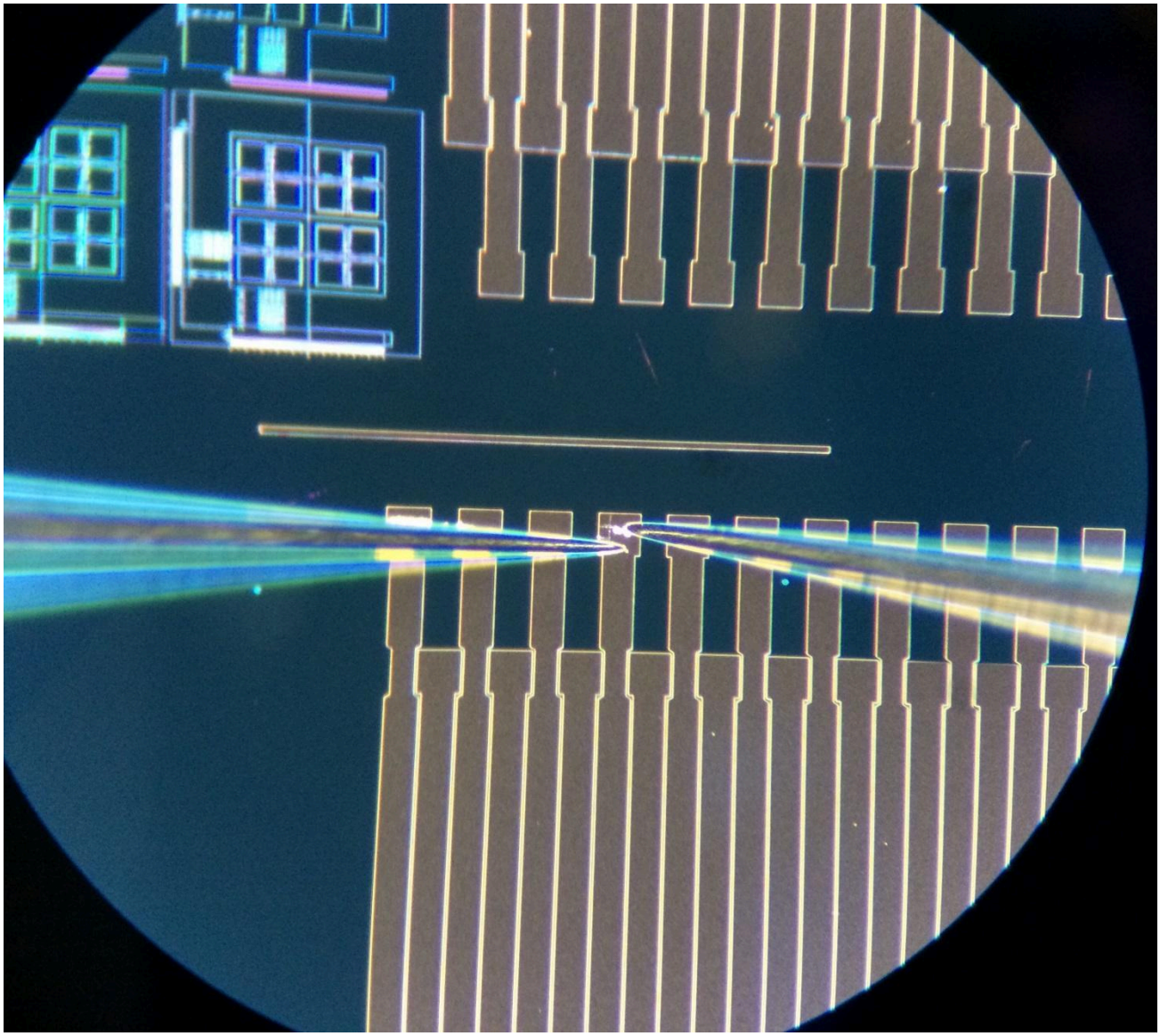


Figure 2, Microscope view of probe tips touching substrate

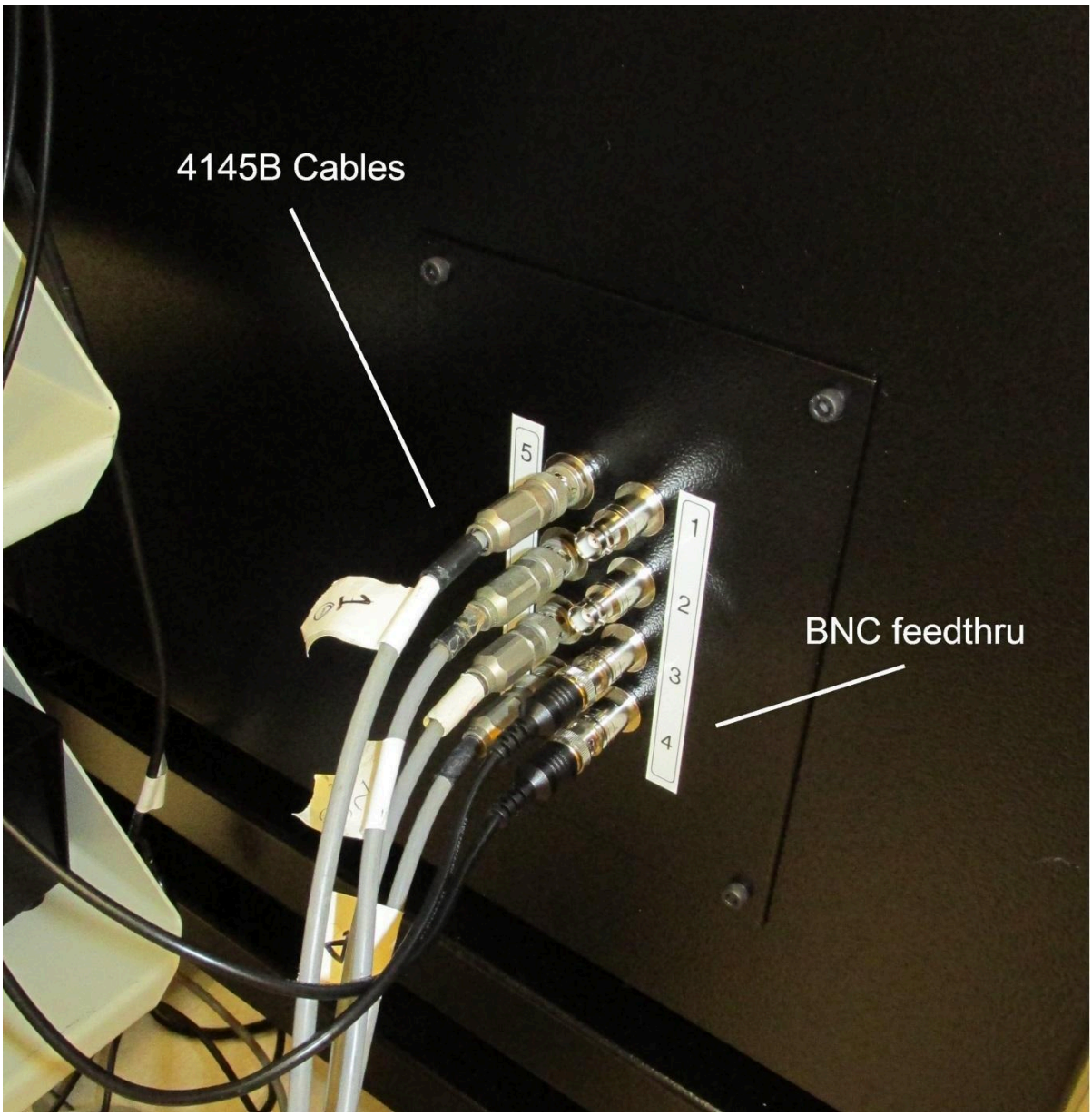


Figure 3, Probe Station Feedthru

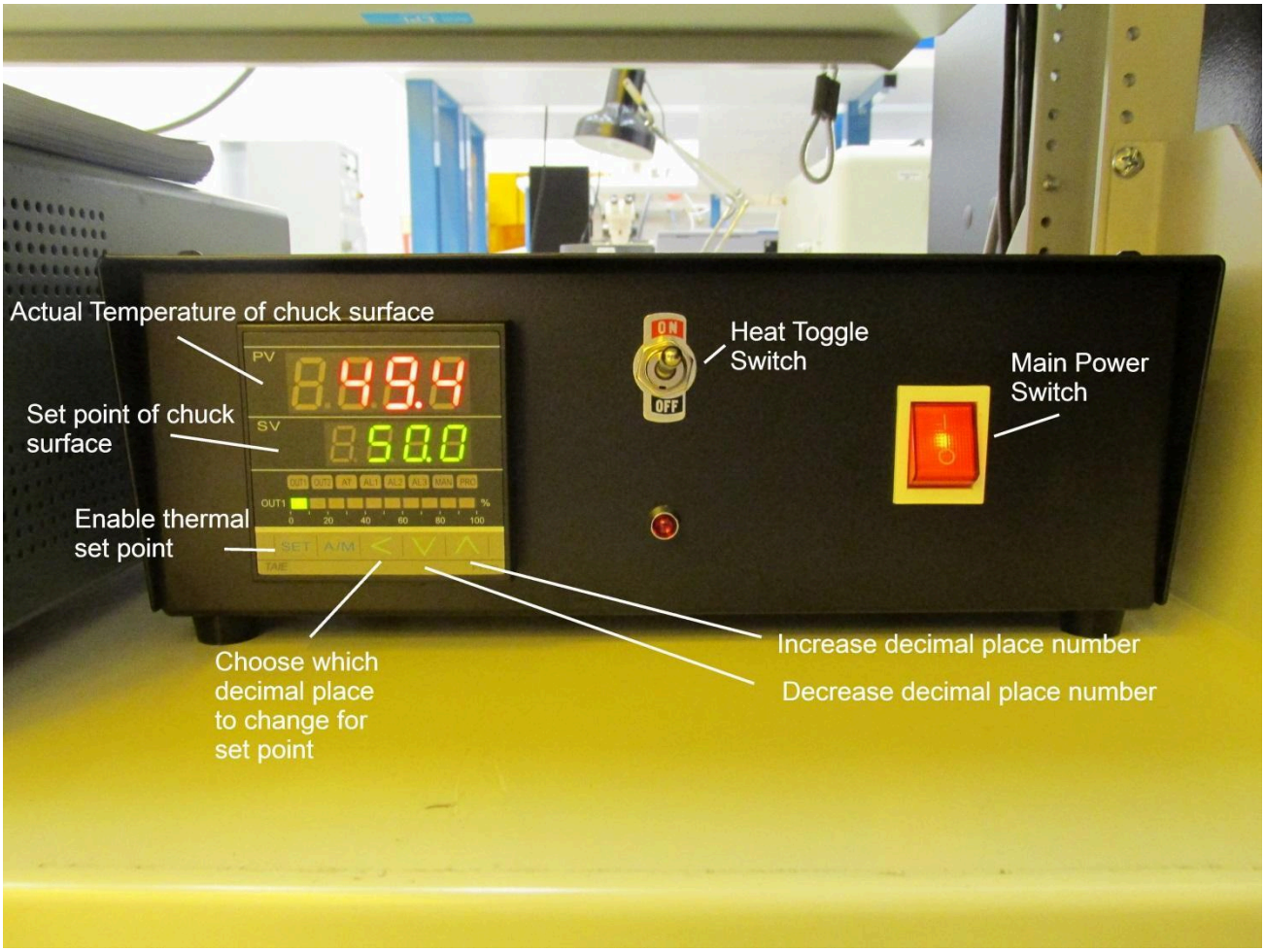


Figure 4, Hot chuck control panel

Figure 5, three ports of oscilloscope

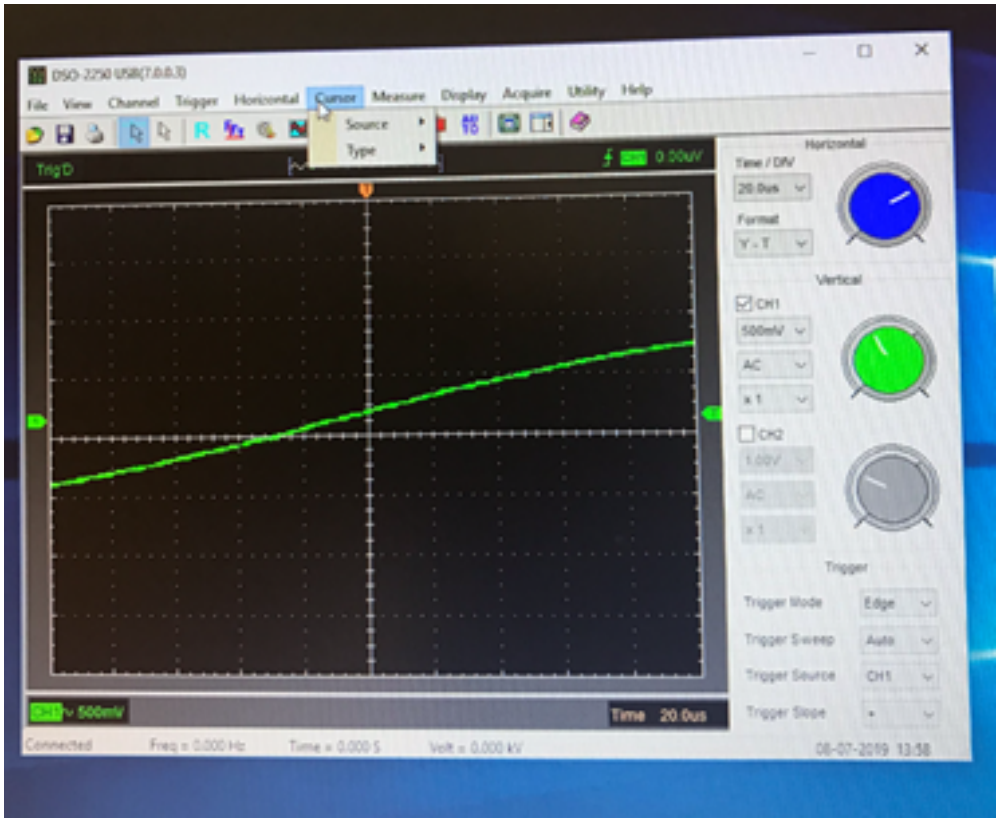


Figure 6, Typical Voltage measurement using DSO-2250 PC oscilloscope

Figure 7, EXTECH LCR Meter

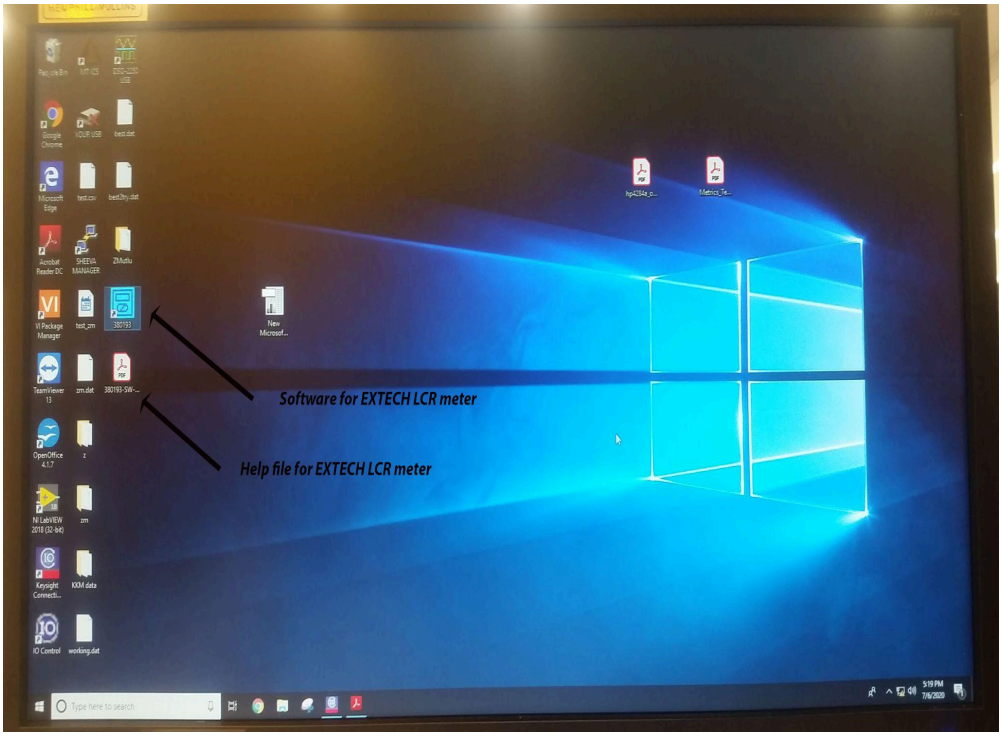


Figure 8, EXTECH LCR meter computer screen

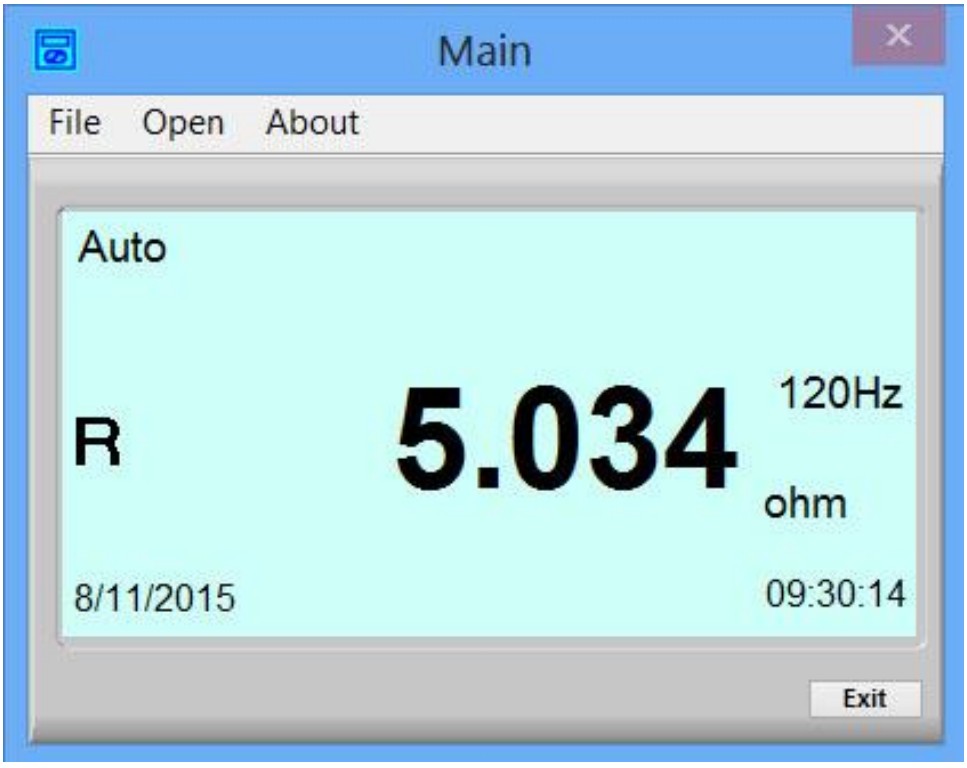


Figure 9, EXTECH LCR meter main page

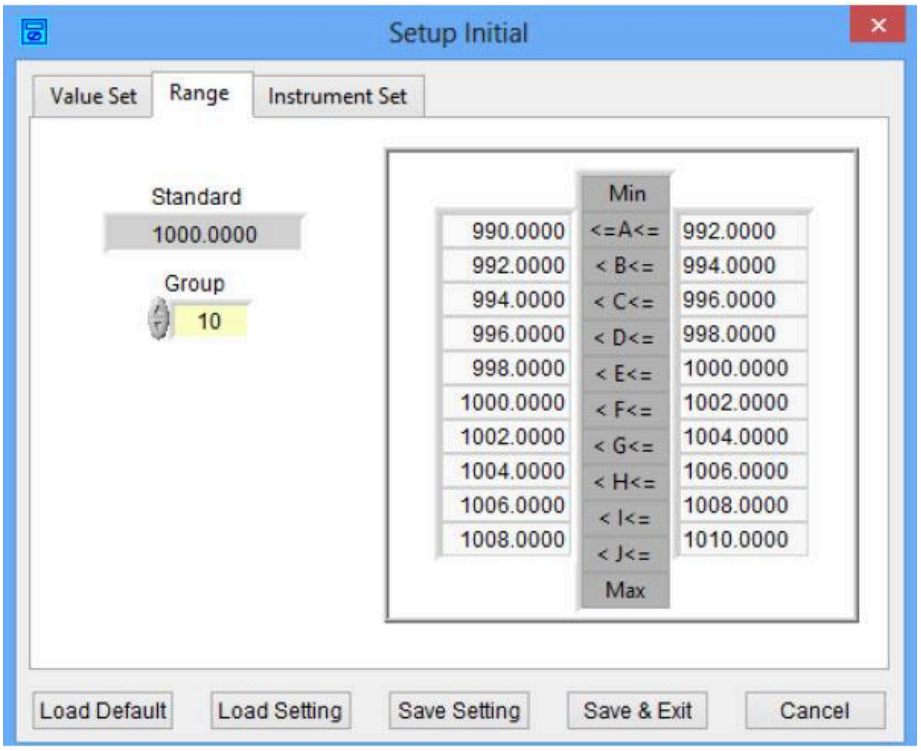


Figure 10, Range Tab

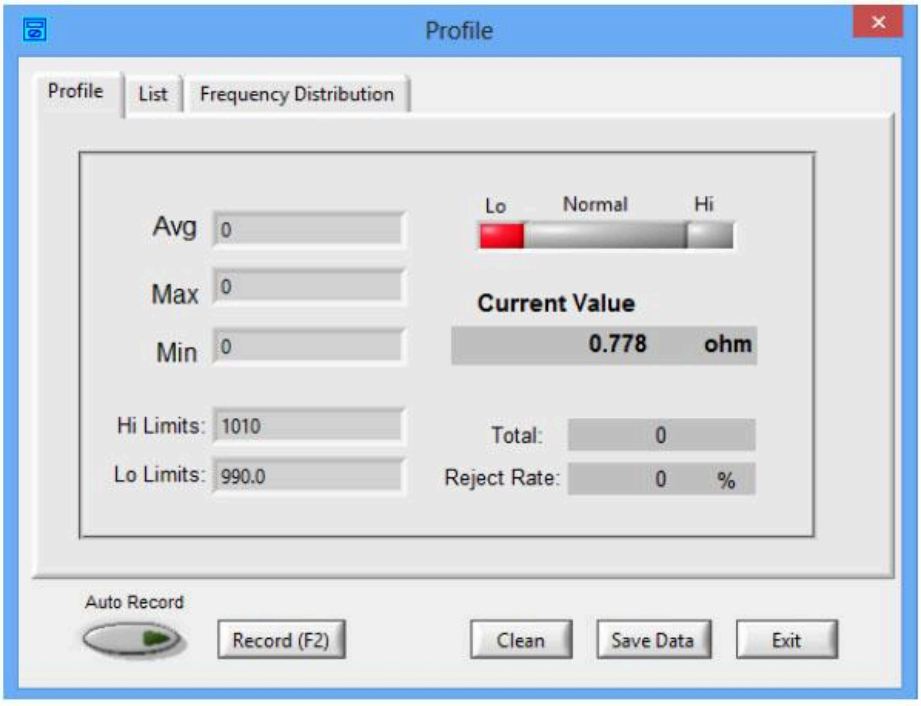


Figure 11, Profile

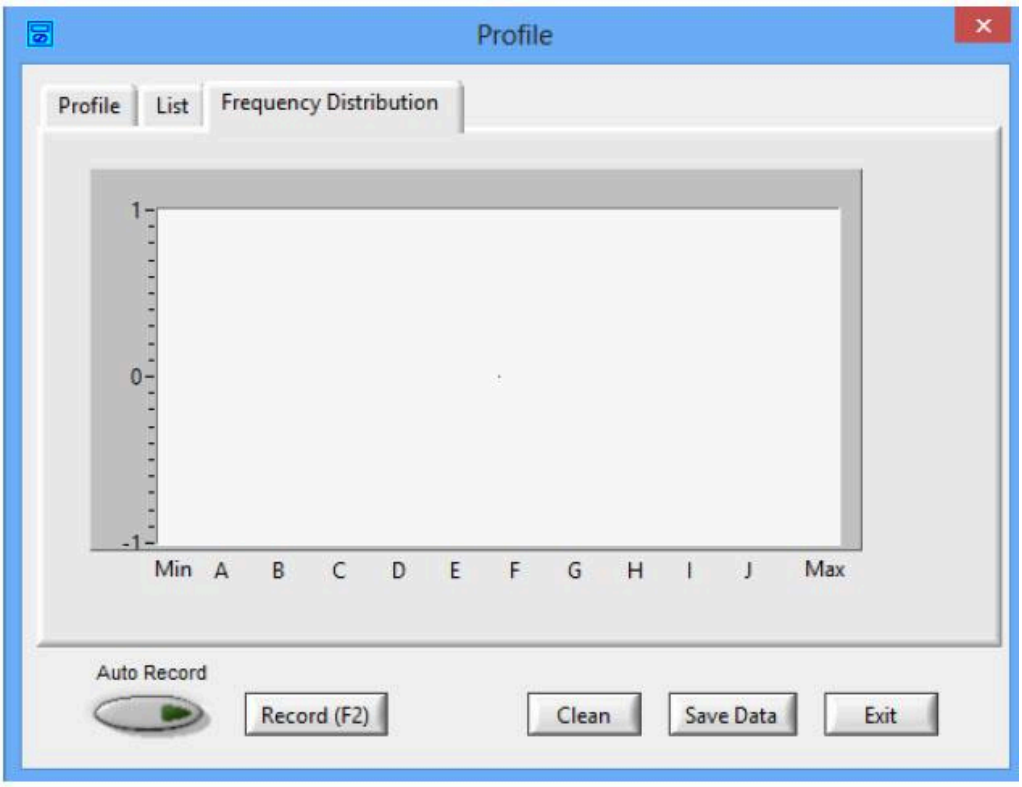


Figure 12, Frequency Distribution

<u>Appendices</u>

11.1 Quick operation notes for manual measurement of a two port system with the HP4145B

11.1.1 Make sure cables from HP4145B are connected to device through feedthrus

11.1.2 Turn on the HP4145B

11.1.3 Push Channel Definition Button

11.1.4 Choose V1 I1 Com Const

11.1.5 Choose V2 I2 V VAR1

11.1.6 No need to use the rest of the fields given

11.1.7 Choose Source Set Up

11.1.8 Choose Next

11.1.9 Choose MEA & DISP Mode

11.1.10 Choose Next

11.1.11 Choose MEASUREMENT

11.1.12 Choose SINGLE

11.1.13 Choose AUTO SCALE