MNC Standard Operating Procedure
Equipment Name: CVIV system

Badger Name:	KA3 CVIV Testing	**Revision Number:**	5
Model:	HP4145A & HP4280A	**Creator:**	TonyWhipple
Location:	Keller Area 2	**Revisionist:**	TonyWhipple
Date:	9 April 2020		

1 Description

This document covers the use of the capacitance-voltage (CV) and current voltage (IV) measurement systems located in Area 3 of the MNC. The mercury probe, when used with the HP4280A capacitance meter and a simple program, provides a quick, non-destructive C-V measurement, but it must be performed on a sample with a minimum radius of 2 cm to prevent mercury leakage. Used with the Signatone probing station the HP4280A provides the ability to measure the capacitance of a structure at the wafer level. The HP4145A Parameter Analyzer and Signatone probe station are set up to carry out the computer controlled measurement of the I-V characteristics of a BJT, FET, or diode.

2 Safety

The main safety concern beyond the normal electrical hazards associated with an electrical system is to be mindful of the chuck as it can be heated to 250 degrees C.
The mercury probe does have a small amount of mercury that it uses, so do not handle the mercury if it is out of the container. Contact MNC personnel about any such problems.

3 Restrictions/Requirements

Must be a qualified user on the CVIV

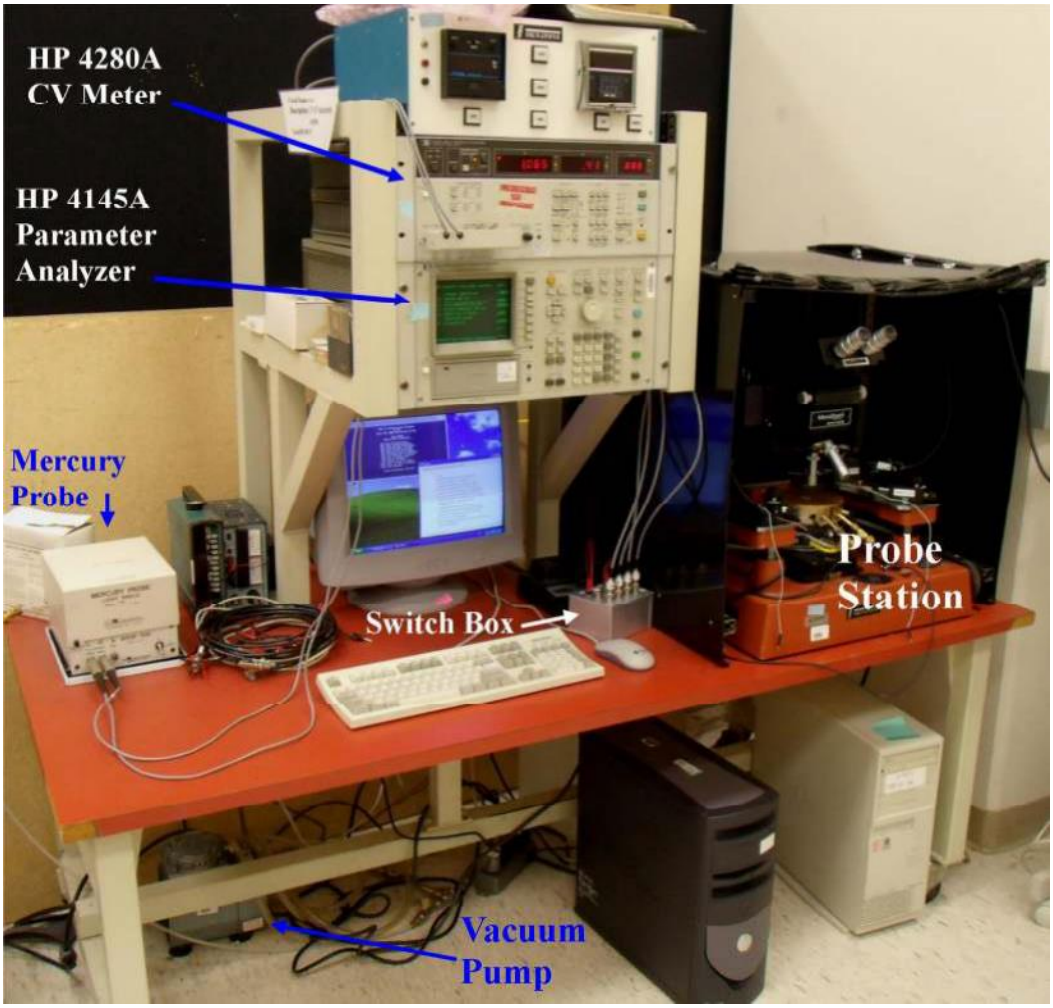
4 Required Facilities

None, as the system has a separate vacuum pump and water cooling for itself.

5 Definitions

- The CV measurement system is the HP4280A that is on the top of the instrument rack.
- The IV measurement system is the HP4145A that is on the bottom of the instrument rack.
- The Mercury Probe is the white box to the left of the computer monitor.
- The Mercury Probe vacuum pump is located under the desk to the left of the computer tower.
- The Switch box is the silver box to the right of the computer monitor.
- The Probe Station is the orange apparatus to the right of the computer monitor.

See picture below for any clarifications.



Picture 1: The labeled components of the CVIV system

6 Setup

No special setup required.

7 Operating Instructions

CVMEASUREMENTUSINGMERCURY PROBE

1.Turn on the computer and the monitor. Log in as MNC user. Click the desktop shortcut for CV-IV DOS program (the icon should be the classic MS-DOS logo).


Picture 2: CV-IV DOS program icon

2. Turn on the HP 4280A.

3. From the ten options presented in the CV-IV DOS program select SETPARAMETERS using F1.

4. Answer the questions about your measurement parameters as they appear on the screen. To select the defaults, simply press enter when prompted for each question.

5. Turn on the vacuum pump. Make sure the Hg pressure is properly adjusted. This can be done by placing a glass slide over the Hg contact and turning on the Hg contact switch. Hg should fill the contact holes, but not come out. The pressure should be set at the lowest setting available (Dial all the way counterclockwise). If you need to, only change the pressure by a small amount. Too much mercury will overflow the contacts, decreasing reliability, and spilling Hg into the vacuum lines. Turn off the Hg switch.

6. Place your sample on the chuck, front side down, with the area to be measured over the mercury contact and lower the backside ground plate lever. If there is an oxide on the back of the wafer, a diamond tip scribe may be used to make better contact by scratching the backside of the wafer.

7. Turn on the vacuum to hold the substrate securely.

8. Ensure that the Mercury Probe is attached to the device using the grey coaxial cables with the large metal ends. The cable marked with “H” should be connected to the small Hg contact connector on the probe that is also marked “H”. The cable marked “L” can either be connected to the disk or large Hg contact connector on the probe depending on where the user desires the measurement to take place. Choosing the disk option will measure from the small bubble of mercury to the backside ground plate using substrate backside contact. If this is to be done the user must ensure that no dielectric in present on the backside of the wafer. Choosing the large Hg contact will measure between the small and large Hg dots conducting a surface only test.

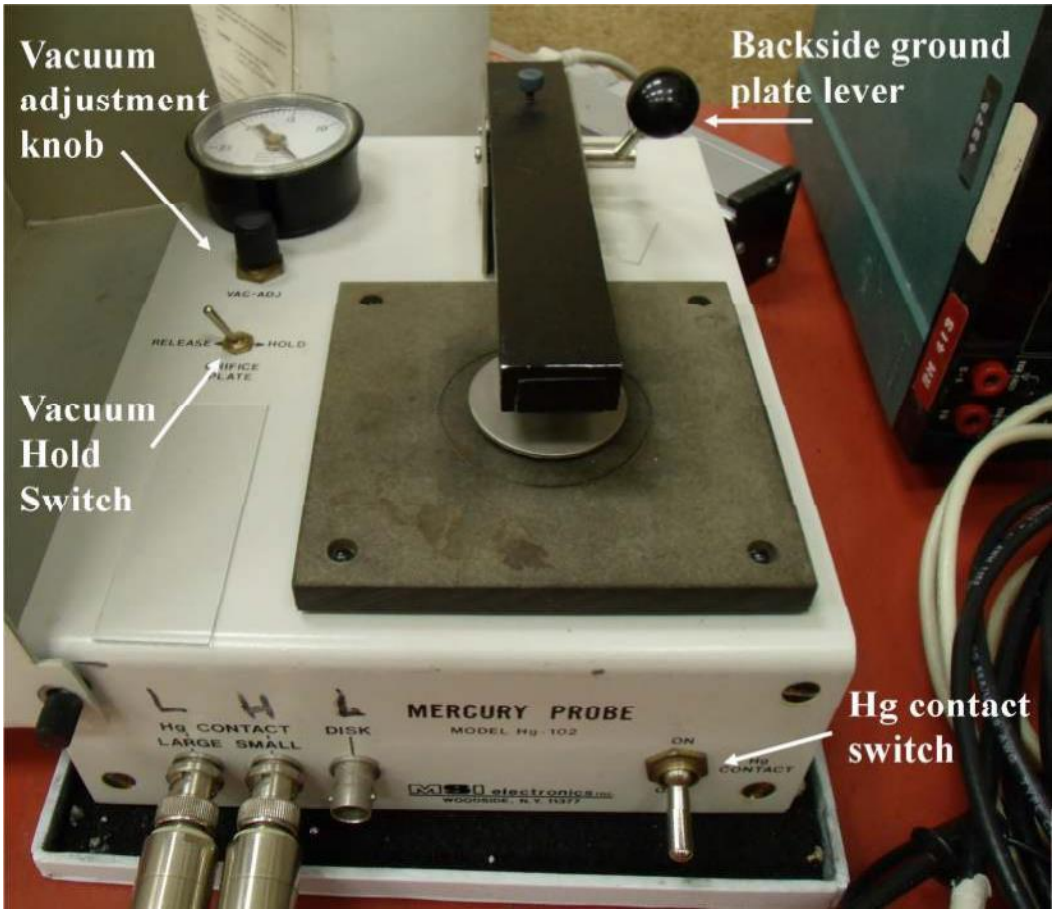


Photo 3: Closer view of the Mercury probe with the lid open.

9. Select option TAKEMEASUREMENTS using F2 in the CV-IV program. Make sure the Hg contact is switched off before continuing. Press enter to allow the program to calibrate the meter. Watch for the HP4280 display LEDs to blink as this happens. Then switch on the Hg contact when the computer program prompt says to. Wait approximately 10 – 15 seconds, while the mercury is making contact with the surface and then press enter. The computer will then conduct the measurements.

10. To see a preliminary plot of the data taken, select Detailed Plot using option F6 in the CV-IV program and answer a few questions to get the type of plot and parameters desired. This can be useful to check if the desired data was collected before more detailed plotting. For instructions on how to plot the data in Excel for printing or exporting see the Excel tutorial.

11. Once the user has collected the desired data it is important to save. Select SAVEDATA TODISK using F4 to save the data to the "C:\cvoutput" folder in ASCII format. The file has a list of Voltage and Capacitance values. The file name entered must conform to the following rules: eight characters or less, may not contain special characters, and must end with a 3 character file extension. EX: "TEST123.DAT"

If the data is to be read back into the CV-IV program for preliminary plotting having the file extension ".DAT" seems to work best. The data can be used with other database type of programs like Excel. See the Excel plotting tutorial for further information on this.

12. Make sure to shut off the vacuum pump, unload your sample and turn off the HP4280A. The computer may stay powered on.

CVMEASUREMENTUSINGTHE PROBING STATION

1. Follow steps 1 – 4 of the CV Measurement Using the Mercury Probe procedure.

2. Remove all connections to the Switch Box. Remove the coaxial cable connections from the mercury probe and attach them to two of the Switch Box coaxial inputs. Place the Probing Station leads into the holes in the Switch Box adjacent to the coaxial cables you just plugged in from the HP 4280A. Take note of what connection is marked "H" and "L" and the corresponding probe you have just connected each one to.

3. The connection marked "L" for Low should correspond to the probe connected to the larger sized structure on the wafer,which would be the ground plate, or substrate. The connection marked "H" for high should correspond to the smaller sized feature on the wafer. This connection should not be made just yet however. Simply leave it hovering just above the desired area for now.

4. Select option TAKEMEASUREMENTS using F2 in the CV-IV program. Ensure that the "H" or High probe is off of the wafer before continuing. Press enter and allow the program to calibrate the HP 4280A. When prompted place the "H" or High probe on the wafer and press enter. The program will now conduct the desired measurement.

5. Follow steps 10 and 11 of the CV Measurement Using the Mercury Probe procedure.

6. After using the Probing Station please reconnect the cables as they were before to the Mercury Probe.

IVMEASUREMENT

1. The IV measurement system consists of a HP 4145A semiconductor analyzer and a Signatone probe station. It is used to measure the IV curves of diodes, FETs and BJTs.

2. To begin taking a measurement, open the IV Data Collection program by clicking the icon in the shape of an IC on the desktop and make sure the HP 4145A parameter analyzer is powered on.

Photo 4: IV Data Collection program icon

3. Select the tab in the program corresponding to the type of measurement you would like to take.

4. Input the parameters you would like to use for your measurement or begin with the defaults by selecting “Use Defaults”. Scientific notation is acceptable when inputting parameters (for example 10E-6 is a valid input).

5. Connect the triaxial cables marked SMU 1-4 coming from the HP 4145A to the switch box. Place the leads coming from the probing station in the corresponding holes for the correct SMU as defined at the bottom of the IV program. Once you have connected the probe tips to the HP 4145A through the switch box you may place the tips on the area of the sample to be tested.

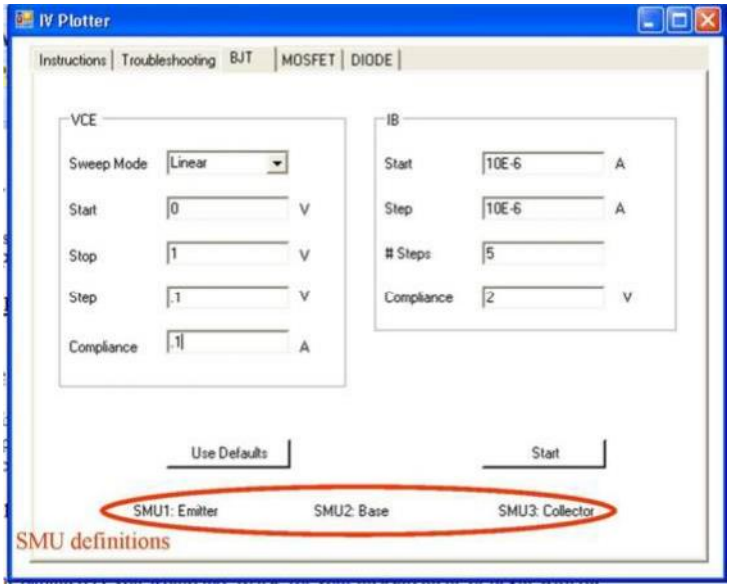


Photo5: Screen capture of the IV program pointing out the SMU definitions

6. Once everything is set up at the probing station, select “Start” in the IV program to begin measurement.

7. A new window will appear containing the program that controls the parameter analyzer. This program will move though the steps of setting up the machine and collecting the data. It will then pause and prompt you for your output filename. The file will be saved to “C:\IVoutput\<your file name here>.txt”. The file name you input should not contain special characters, spaces, or a file extension. If your output file is not seen in the IVoutput folder when the program exits please try a simpler filename such as “output”.
WARNING: Selecting the same file name as a pre –existing file will overwrite it!

8. After you have input the file name press enter and patiently wait for the program to collect your measured data. This will take several minutes depending on the data size. When the program is done collecting the data it will close itself.

9. To obtain a preliminary plot of your data select the “AUTO SCALE” softkey on the HP 4145A and view the plot on the screen. This is useful to determine if the correct parameters were used and the desired data was collected. To create a more presentable and savable plot consult the Excel plotting tutorial.

10. Make sure to save your data to a removable device for safe keeping, unload your sample and turn off the HP44145A. The computer may stay powered on.

11. Hints

- Consult the HP 4145 Operators manual Section 3 for more information about taking measurements.

- Be careful in placing the probe tips onto the pads. Excessive force will ruin the tips.

-If the control program hangs, ensure that the selected parameters are within the range of the device. The defaults are a good place to start.

-Data not appearing? Double check the connections at the switchbox and probing station. If they are too loose try adding a piece of tin foil to create a tighter fit.

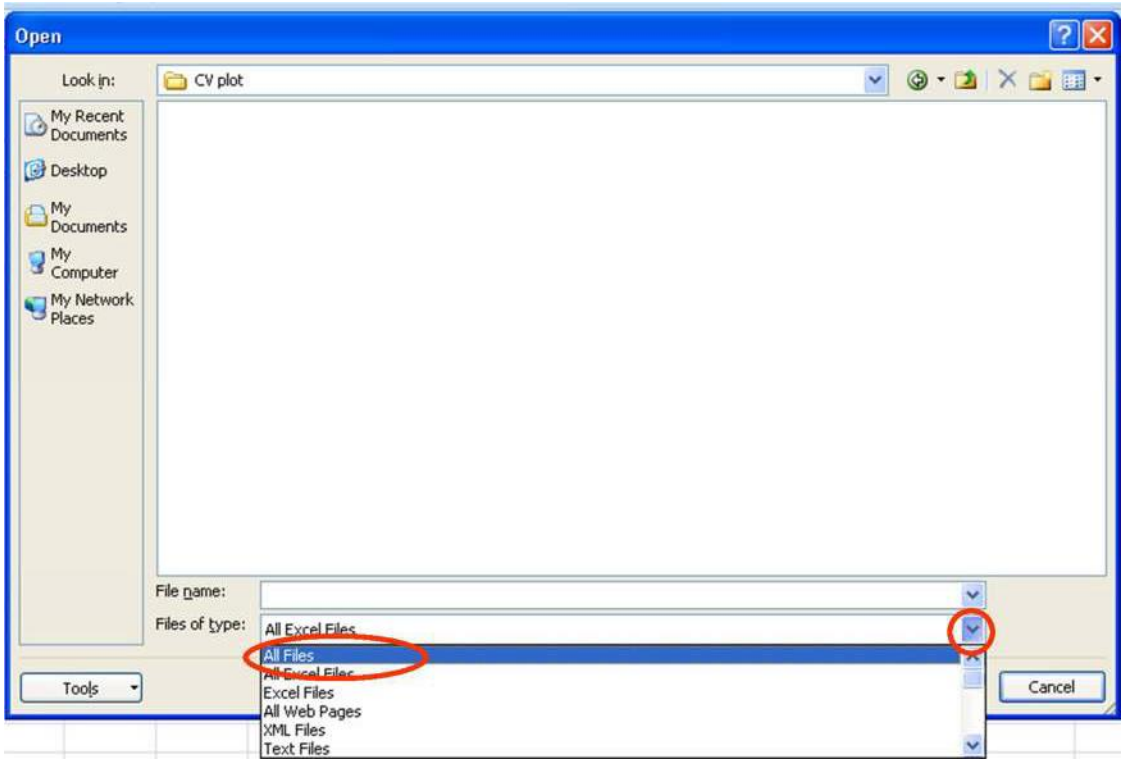
-If your data is there but looks incorrect check to ensure that the probes are connected to the 4145A correctly by double checking the SMU definitions on the computer and tracing back the wires from the switch box to the probes.

-You cannot get good grounding if you are using the wafer chuck as a substrate ground if there is still oxide or other films on the backside of the wafer. Even having a bare Si backside on the wafer most likely will not be good enough to give a backside ground for the device. This is solved by removing a layer of film from the backside and then putting on a layer of Ti and Au.

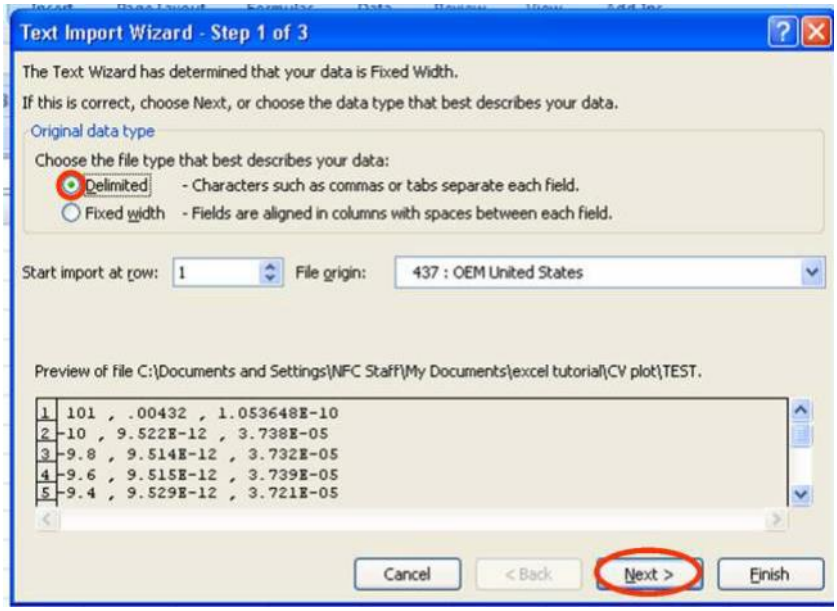
MNC Standard Operating Procedure Appendix 1:
Procedure for Plotting CV data obtained from CVIV system in Excel
Equipment Name: CVIV system

Badger Name:	CVIV	Revision Number:	1
Model:	HP4145A & HP4280A	Creator:	Benjamin Brueske
Location:	Area 3		
Date	4 May 2012		

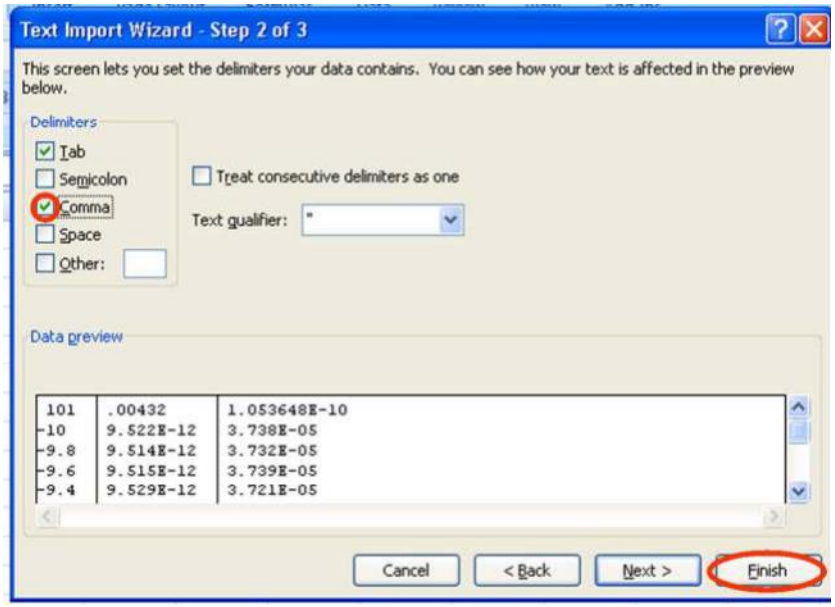
1. Gather the desired data using CV Plotter.
2. Find saved data on computer in the "C:\cvoutput" folder.
3. Open Excel.
4. Hit Ctrl+O in Excel to get the open file dialogue.
5. On the "Files of type" line use the down arrow button to select "All Files".



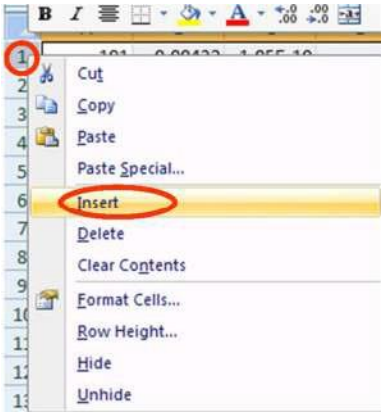
6. Navigate to and open your data.
7. Excel will warn you that there is potential data corruption as it doesn't recognize the file type. Simply select yes to continue.
8. When the import data wizard appears select the bubble for "Delimited" under "Original data type" and click next.



9. For the next step of the data import process simply check the box next to comma and select finish.

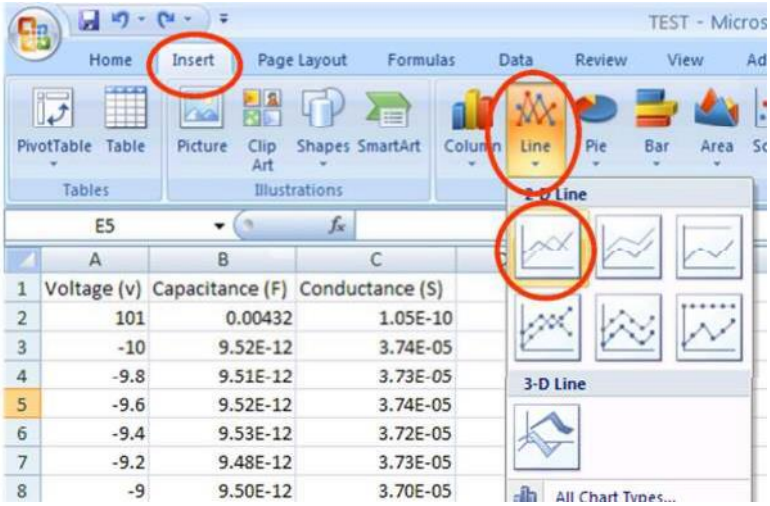


10. You will notice that there are no labels on the columns of data; you will also notice that there are two distinct sets of data in the file. The set of data at the beginning of the file is the C/V data and is organized as such: Voltage (V), Capacitance (F), and Conductance (S) for columns one, two and three respectively. The set towards the end of the data file is the Nd/Xd data and is organized as such: Nd, Xd for columns one and two respectively. To label these in you Excel data one can insert a new line above the data by right clicking on the row number of the row containing the first data points and selecting insert.



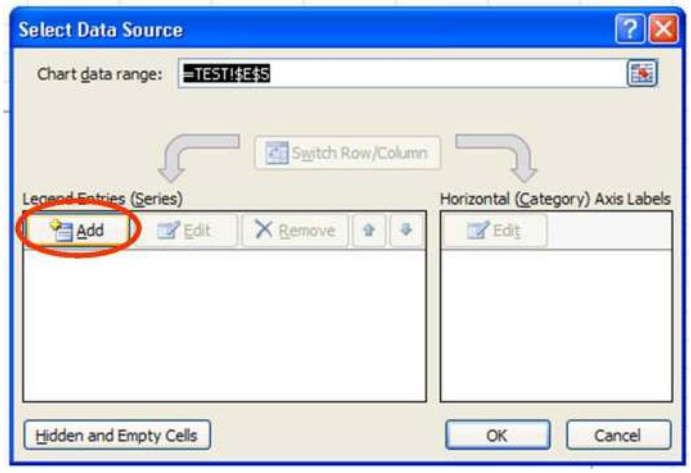
Labels can then be added in the new empty row.

11. Data should now be in a plot-able format. If a more advanced plotting software is desired one can now save the reformatted data in a new file type to be imported into another program. This tutorial will continue on plotting in Excel. Be sure to save your data in an Excel format using the "save as" feature at this point if you are importing or continuing on creating the plots. Different types of data will require different plotting options. This guide will step you through the settings to plot the C/V and Nd/Xd data for a sample wafer.
12. Starting with the C/V plot, select Insert in the ribbon then select line in the charts section and then the upper left selection as shown below.



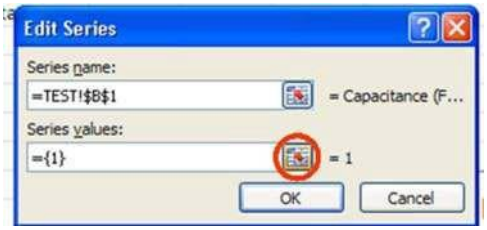
13. This will open a blank chart; we now need to select data for this chart. This can be done by using the select data option is the Chart tools->design ribbon. Excel has already automatically changed to this ribbon so simply select "Select data" as shown below.

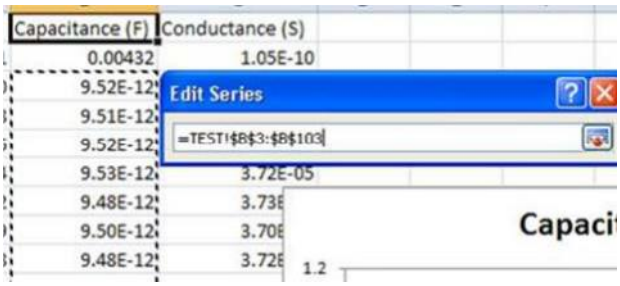
14. When the Select Data Source Dialogue box appears click Add under Legend entries (series) as shown below.



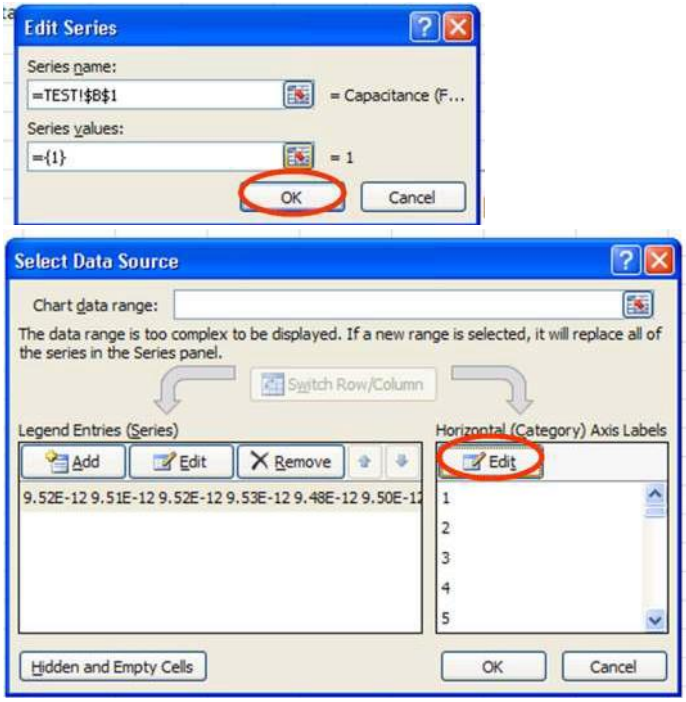
15. When the edit series dialogue box appears click the select range button next to the Series name box. This will give you the chance to select the header for your data. For this example we want to select the box in the chart containing “Capacitance (F)”. Once your header is highlighted in the black and white boarder hit the enter key to return to the edit series dialogue box.

16. Next click the select range button next to the Series values box. This time you will want to select all of the data that that is under the capacitance header until the break in the file that starts the Nd/Xd data. Once the data is highlighted by clicking and dragging over it, hit enter. (Note: this data started with an outliner that was omitted from the chart, you may want to see if your data has an outliner at the beginning or end of the data that you wish to omit.)

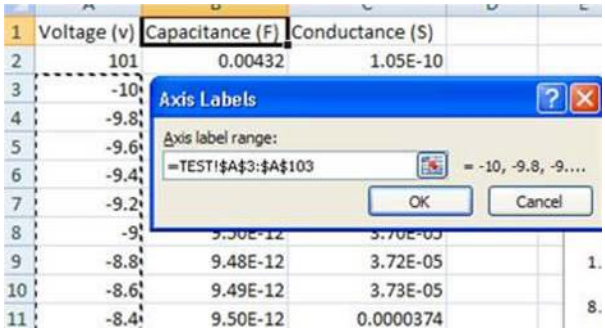




17. Select ok in the edit series dialogue box. Then select Edit under the Horizontal (category) axis labels when the Select Data Source dialogue box returns.

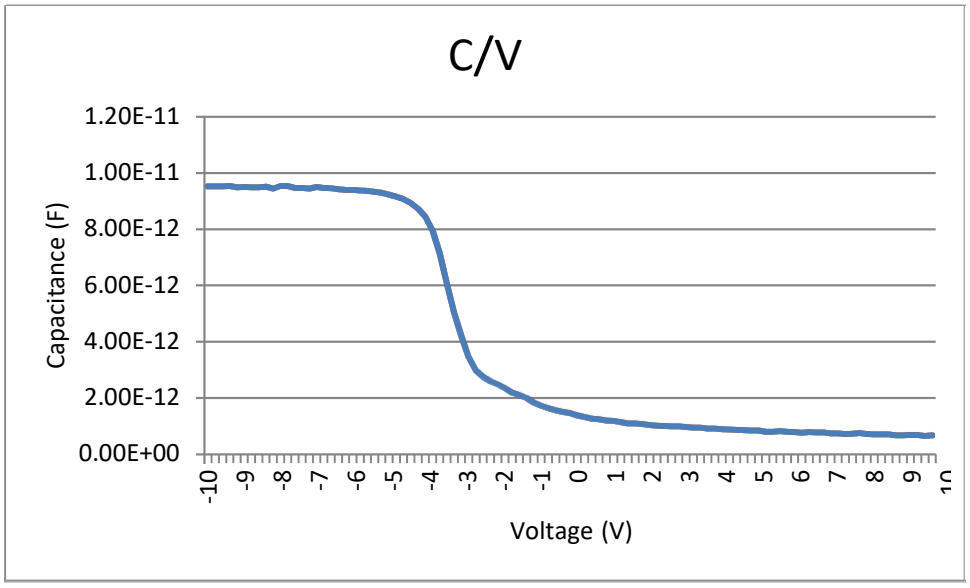


18. Highlight the voltage data next to the Capacitance data you have just selected. Once it is highlighted in the black and white boarder hit the enter key. You can then click “ok” in the Select Data Source dialogue box when it reappears.

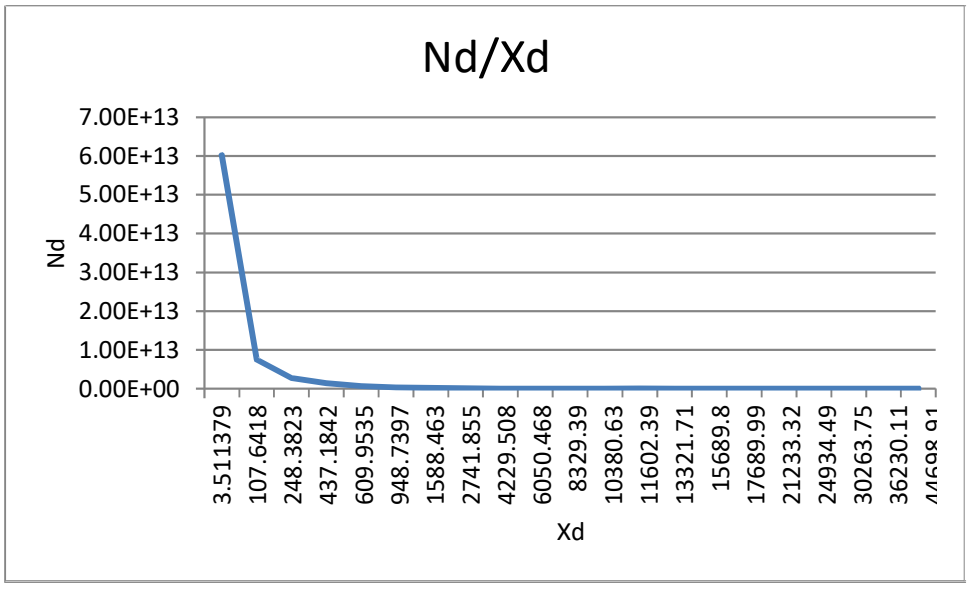


19. Your C/V graph should now be looking about right. Small changes you may want to do include renaming the chart by double clicking its header, eliminating the series label on the right side (select it and hit the delete key), removing the data markers (right clicking on the trace->format data series->marker options->none), and adding axis titles (click the

plot and go to chart tools->layout->Axis titles in the ribbon). The final result is shown below:



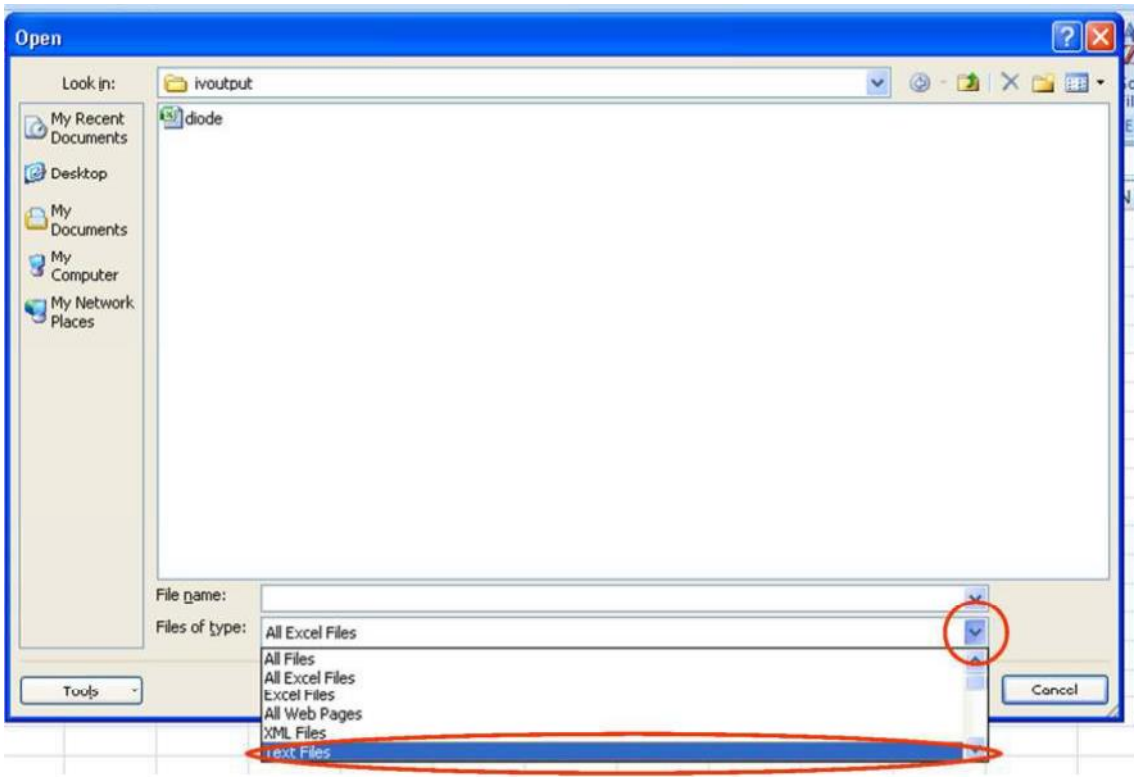
20. Next we will focus on the ND/Xd plot. To begin insert another plot as you did in step 12.
21. Follow steps 13 through 15 but on step 15 select the Nd header you created in step 10.
22. Now follow step 16 selecting the Nd data instead contained under the Nd header.
23. Follow steps 17 and 18 instead selecting the data under the Xd header.
24. You have now created your Nd/Xd plot. You may like to make some of the changes as noted in step 19 with the C/V plot. Final result is as shown:



MNC Standard Operating Procedure Appendix 2:
Procedure for Plotting IV data obtained from CVIV system in Excel
Equipment Name: CVIV system

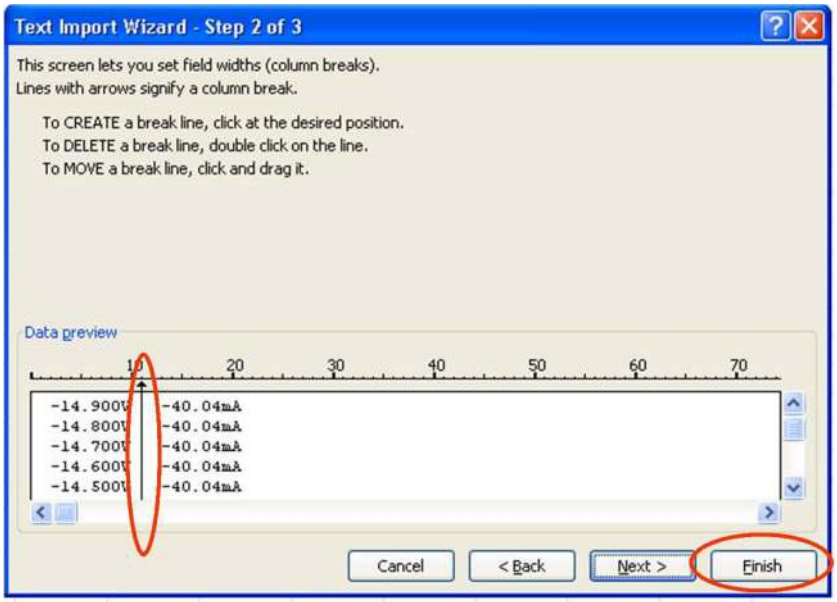
Badger	CVIV	Revision Number:	1
Name:	HP4145A & HP4280A	Creator:	Benjamin Brueske
Model:	Area 3		
Location:	4 May 2012		

1. Gather the desired data using IV Data Collection program.
2. Find your saved .txt data generally located in the "C:\ivoutput" folder.
3. Open Excel.
4. Hit Ctrl+O in Excel to get the open file dialogue.
5. On the "Files of type" line use the down arrow button to select "text files".



6. Navigate to and open your data.
7. When the import data wizard appears, select the bubble for "Fixed data width" under "Original data type" and click next

8. For step two of the import data wizard Scroll down the preview window until you have passed the header and are down to the recorded data columns. Ensure that there is a separator between each column of data in your file. Simply click to add a separator, click and drag to move them or double click to remove them. Excel should do a decent job at guessing for you on this step. Select finish when this step is complete.



9. When saving data it is suggested that the Save As-> Excel Workbook is used to both protect original data and keep Excel formatting if anything needs to be edited. It is suggested to do this early on as not to forget.
10. The next step will be to replace the SI prefixes with scientific notation.
    a. Highlight the data columns of your file, this will ensure not to destroy your header any more than it already is.
    b. Hit Ctrl+F to bring up the find dialogue box

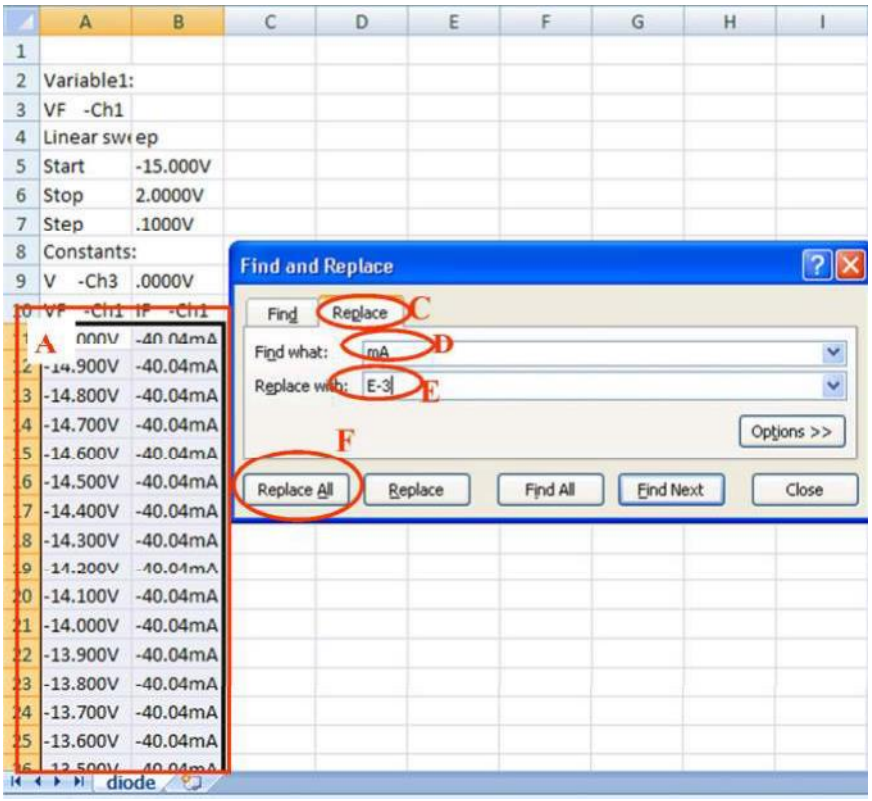
c. Select the replace tab
d. Under “Find what:” type an SI prefix
e. Under “Replace with:” type the corresponding scientific notation
f. Select “Replace all”
g. Repeat for all SI prefixes occurring in your file.

Note: Numbers should now be in “number format” in the spreadsheet

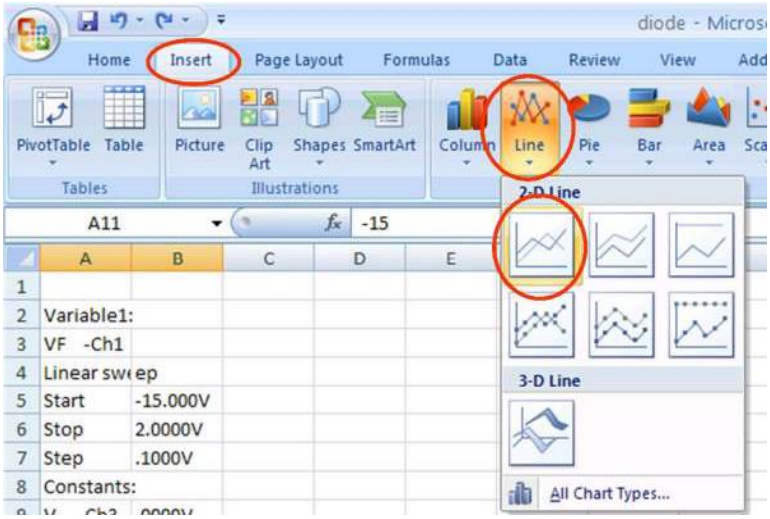
The base unit also needs to be removed ex: “V” -> “” or replace v with nothing

Replacement table (omit quotes)	
Find what:	Replace with:
“GV”, “GA”	“E9”
“MV”, “MA”	“E6”
“KV”, “KA”	“E3”
“V”, “A”	“”
“mV” , ”mA”	“E-3”
“uV” , ”uA”	“E-6”
“nV” , “ nA”	“E-9”
“pV” , ”pA”	“E-12”

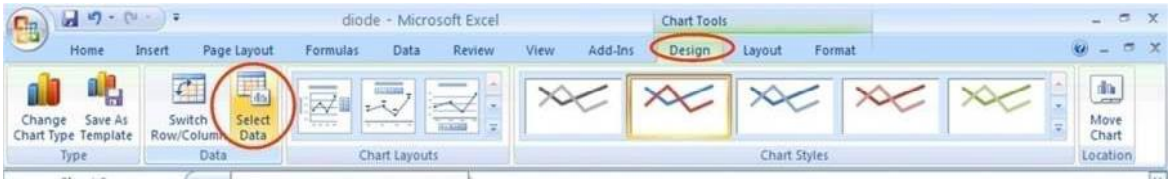
Below is an example replacing “mA” with “E-3”



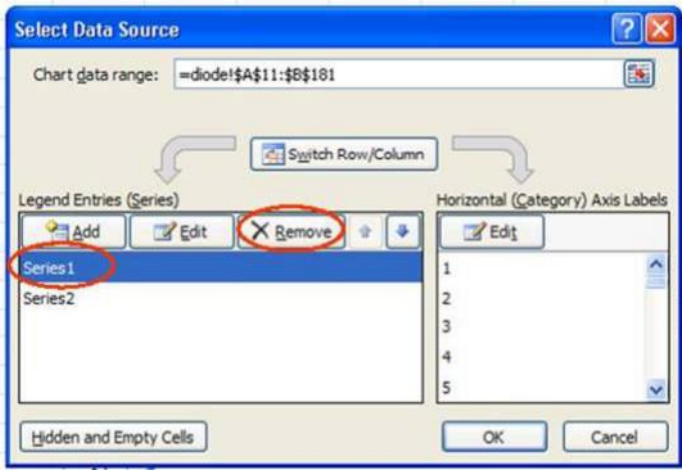
11. Data should now be in a plot-able format. If a more advanced plotting software is desired, one can now save the reformatted data in a new file type to be imported into another program. This tutorial will continue on plotting in Excel. Different types of data will require different plotting options. This guide will step you through the settings to plot the IV curve of a Zenner Diode.
    a. With data still selected select insert->charts->line->line



    b. This plot will not look as desired, some adjustments are needed. Select Chart tools->design->Select data

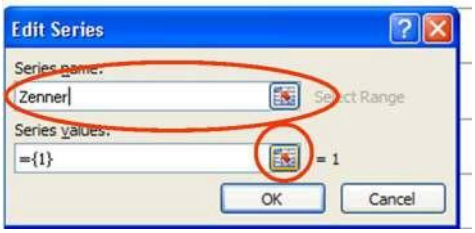


    c. Select each series in the Legend Entries box and then hit remove until the Legend Entries box is empty:

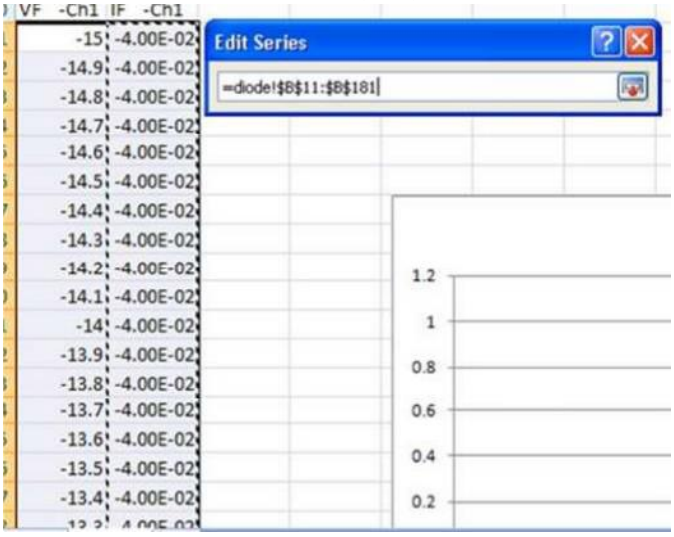


    d. Click add under Legend Entries

e. When the edit series dialogue box appears, enter a series name and select the icon next to the series values box. This will allow you to select your current data to be plotted.

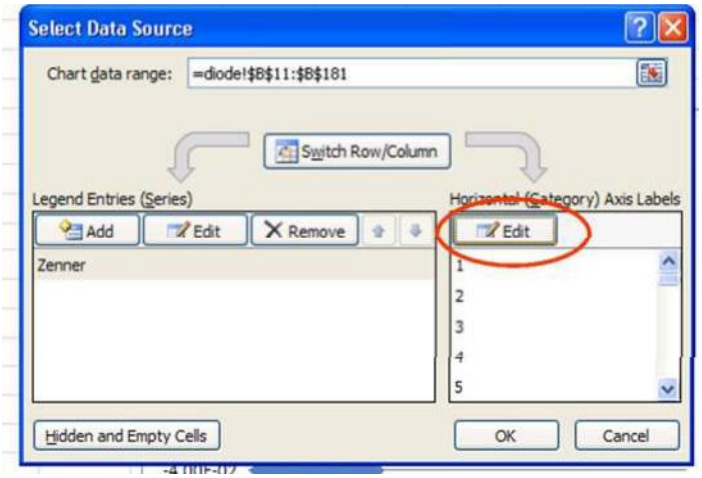


f. Take the cross cursor and highlight your current column with the dashed outline.

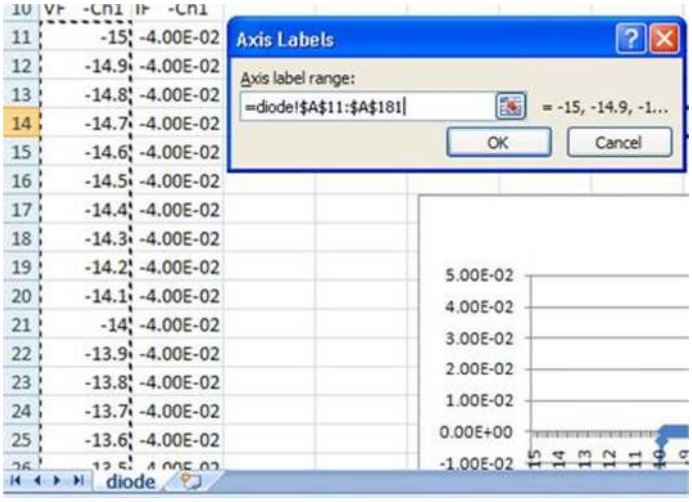


g. Press enter, then select ok in the Edit Series dialogue box to return to the Select Data Source dialogue box.

h. Select the Edit button under Horizontal Axis Labels



i. Highlight your voltage column with the dashed outline as you did for the current column.



j. Click ok to return to the Select Data Source dialogue box.

k. To add more traces for bjt or fet repeat steps d through j ensuring that you have the correct series highlighted before selecting edit in step h and are only selecting one sweep for each data series.

l. Click ok to exit the Select Data Source dialogue box.

m. The plot should be looking about right. Further formatting that may be desired includes removing data markers (right click on trace->Format Data Series->Marker Options-> None), labeling axis (Chart tools->Layout->Labels->Axis Titles), and moving the X axis to the bottom or top of the plot (right click on Y-axis labels->format axis ->Horizontal axis crosses-> Axis Value:-> input the lowest current value on your plot).

End result of example: