MatLab Data Manipulation program

The program made by Oleksandr Synhaivsky and explained in more detail in his report, albeit useful to collect the data from the HP4194 and HP4156A, doesn't allow for data manipulation e.g. calculate the transconductance from gain measurements. Therefore, the program explained here has the objective of reading the .text file received from Oleksandr's LabVIEW program and analyze it.

Requirements:

1- MatLab version 2013A installed. This program has not been tested with other MatLab versions, but it should work with newer ones. If it doesn't work you can send me an email: antoniosnl@hotmail.com .

Features:

1- Reading the .text file collected from the HP4159A Precision Semiconductor Parameter Analyzer and plotting the I-V curve (**saving the data in an excel file is not supported**).

2- Reading the Gain-Phase data measured with the HP4194 Impedance/Gain-Phase Analyzer using the Gain – Phase function in the Tch/Rch (db) – θ mode. It will plot the Gain, Phase and transconductance or conductance depending on the function that was chosen. It saves the raw and calculated data in an excel file. It also opens a second window where the peaks can be manually selected (it is possible to do it automatically, but it is not reliable).

3- Reading the Capacitance and Conductance obtained with the HP4194 Impedance/Gain-Phase Analyzer in the Impedance measurement mode (the $C - G$ mode). The user can then choose to use a Schottky or MOS equivalent circuit to obtain G_p and $G_p(\omega)/\omega$ data. During the measurement the user will also have to option to consider R_s and C_{ox}. The program will plot the measured conductance and gain as well as the $G_p(\omega)$ as a function of ω and $G_p(\omega)/\omega$ as a function of ω. All data, both measured and calculated, will be saved in an excel file. Finally, a second window can be opened where the peaks can be manually selected (it is possible to do it automatically, it is not reliable).

4- R_s and C_{ox} can also be calculated from a capacitance and conductance measurement made by the HP4194 Impedance/Gain-Phase Analyzer in the Impedance measurement mode (the $C - G$ mode). They will be plotted as a function of ω and the data will be saved in an excel file.

Observations:

1- If any modification must be made in the functions (such as the equivalent circuit), rather than changing the current functions simply add another function to the program. This is covered in the end of this report. Of course, if something in the function does not work, then change it.

2- Avoid changing the core structure of the code. This doesn't mean that new functionalities should not be added (not only functions, but also a code to save a plot in Origin (instead of Excel) for example, which can be added in the end of the program next to the function that saves in excel format).

Reading an I-V file from the HP4159A in sweep mode

Open MatLab and launch the main.m function. The following panel will open (Figure 1):

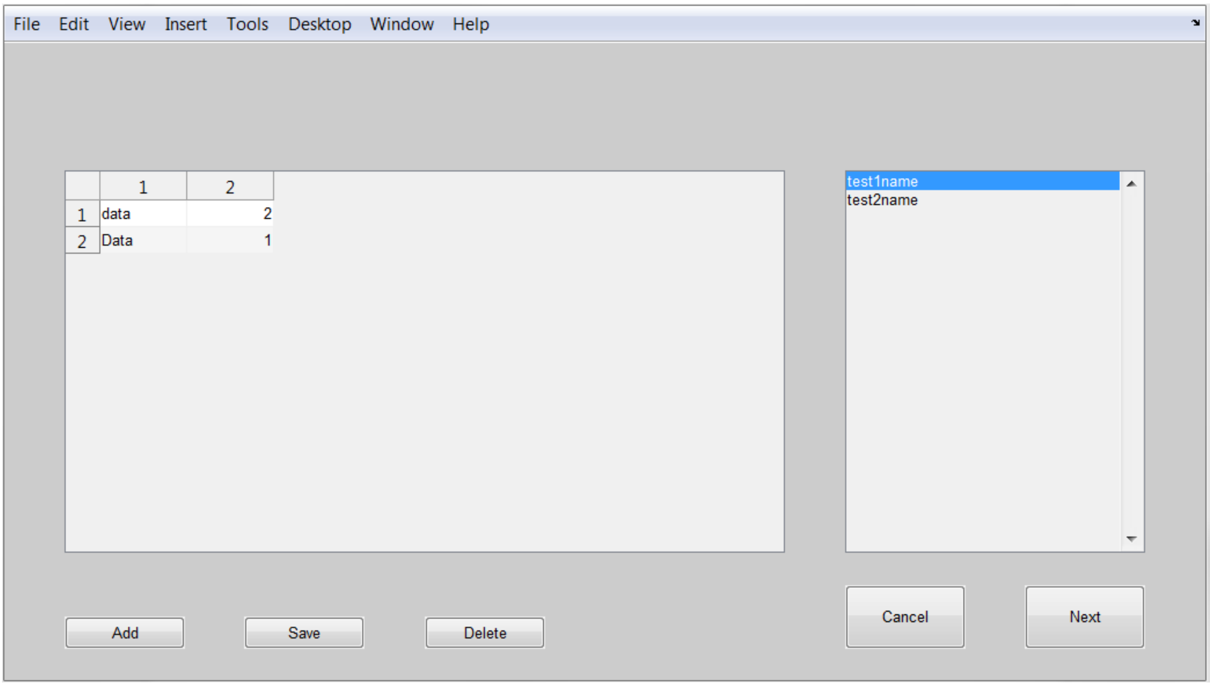


Figure 1

Press the Add button and choose I-V from the Add data panel that will pop-up (Figure 2). Once selected, click on the Select button. A pop-up will open and the user can selected the .text file to consider. **This function only allows for one .text file to be treated at the time**. Once the file is selected, the number in the left side of the Add data panel can be changed, it represents the number of variables that will be put in the legend of the figure, e.g. selected 2 if you plot something and want the legend to indicate both temperature and V_{bias}. This is not that useful here, but it might be for the other functions.

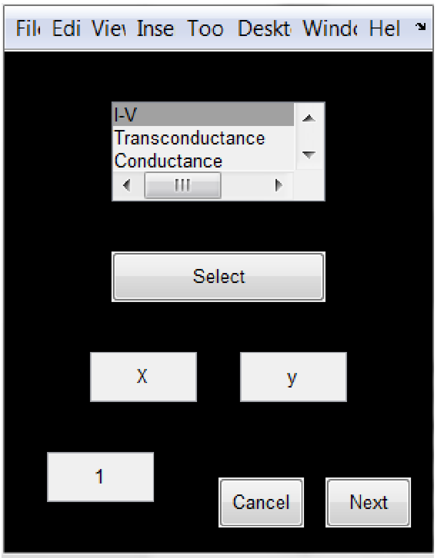
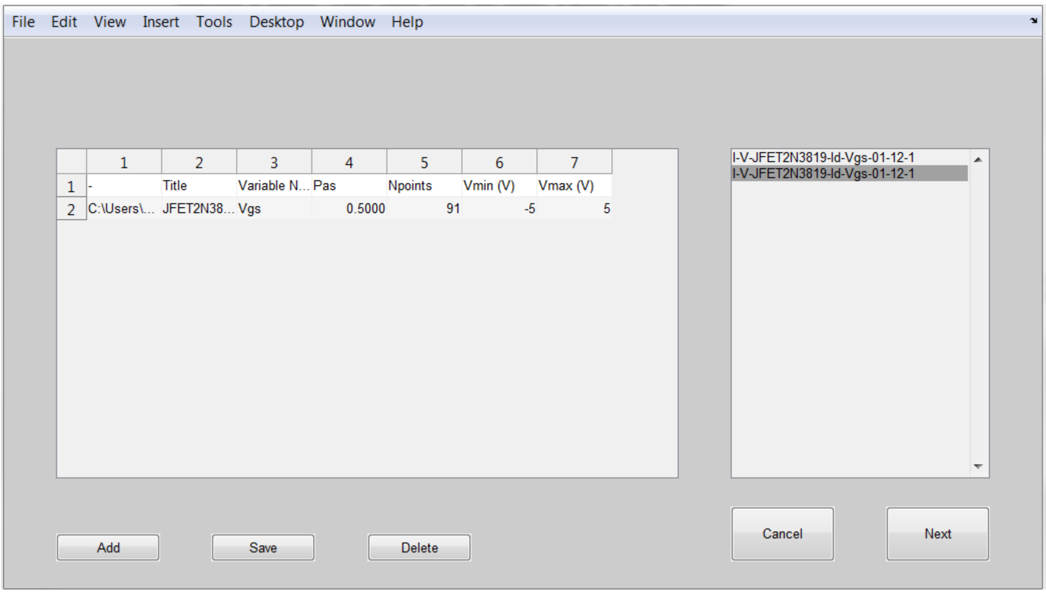


Figure 2

By pressing next the function will be added to the list and Figure 2 will close. Before proceeding remember to deleted both test1name and test2name. This should only be done after the first function is added. Once these steps are made, Figure 1 will become:



If one looks at the list on the right, it is possible to notice that there is more than one I-V function. Indeed, it is possible to press Add multiple times and select multiple .text files to plot multiple I-V curves. Before pressing next, the table on the right must be filled for each function in the list on the right. By clicking once in the name of the function its corresponding table will appear. The data in the table for the I-V function corresponds to:

1- **Position (1, 1)** – Title: corresponds to the title of the figure. Replace title by the desired name.
2- **(2, 1)** – it is the path to the selected .text file
3- **(2, 2)** – the name of the selected .text file
4- **(3, 2) and (3, 1)** – the name of the variable. Replace both of them with the name of the variable that will show up in the legend of the figure. For example, when plotting $I_{ds}(V_{ds})$ for multiple constant V_{gs}, replace (3, 2) and (3, 1) by V_{gs}.
5- **(4, 2);(6, 2) and (7, 2)** – If $V_{ds}(V_{ds})$ was measured for multiple constant V_{gs} going from $V_{min} = -2V$ and $V_{max} = +2V$ with a step of 1V, replace (4, 2) by 1V, (6, 2) by -2V and (7, 2) by 2V.
6- **(5, 2)** – Considering the previous example, the number of I_{ds} points taken for one constant V_{gs}, e.g. 91, must be written in (5, 2).

Once the table is filled, **press Save**, otherwise all data will be lost if another function is selected. Moreover, **if Save** is not pressed or the table not properly filled, the software will crash when Next is pressed.

Once everything is saved and all the data in the table filled, you can press Next. The I-V plot will then appear.

Reading the Gain-Phase data measured with the HP4194 Impedance/Gain-Phase Analyzer gain function in the? mode.

Open the MatLab and run the main.m function. The panel in Figure 1 will open. Then:

1- Press the add button. This will open the pop-up shown in Figure 2.
2- Select either the transconductance or conductance function depending on what you want to plot. This can be done by selecting either of those two functions in the list.
3- Press the Select button. A pop up will open and ask the user which .text files he wants to load. **Multiple .text file selection is allowed**.
4- If plotting in function of multiple variables, e.g. temperature and V_{ds}, change the number on the left of the panel shown in Figure 2 to the number of variables, e.g. 2.
5- Press Next and the function will be added to the list shown in the right side of Figure 3

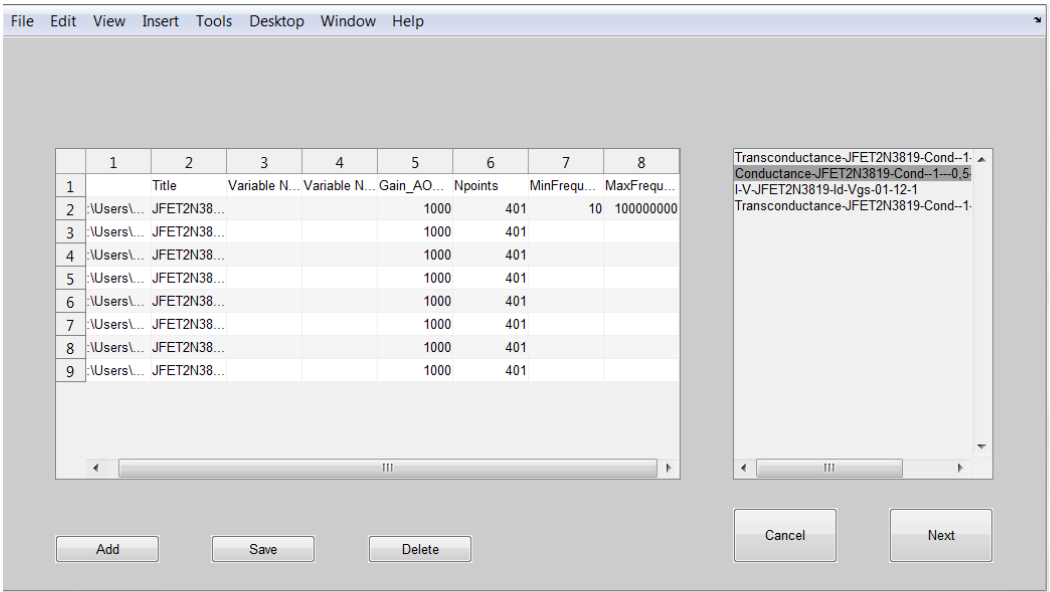


Figure 3

6- If needed, you can add multiple different functions, as it is shown in Figure 3. For this repeat steps 1 till 5.
7- Select a function to work with by clicking over its name in the list on the right. The table on the left will change to the one associated with the selected function.
8- Fill the table with all the data and SAVE it, otherwise when changing the function all the data will be erased or when pressing next the program will crash. For the Transconductance or conductance functions the data in the table correspond to :
    a. Position (2,1) – the title of the figure and the graph
    b. Position (1, 2:end) and (2, 2:end) - .text file path and name respectively for all selected files

c. (3, 1) and (4, 1) – variable name, e.g. following the example given earlier, if one wants to plot g_m in function of temperature and V_{ds}, one can replace (3, 1) by "Temperature" and (4, 1) by V_{ds}

d. (3, 2: end) and (4, 2: end) – following the example in c, the temperature corresponding to each .text value must be given in (3, 2: end) and the V_{ds}values in (4, 2: end). In this example the legend would then show Temperature = ?; V_{ds} = ?.

e. (5, 2:end) - The Gain used in the AOP when measuring the gain-phase. If no gain was used, set it to 1.

f. (6,2:end) – the number of measuring points for each .text file

g. (7, 2) – starting frequency , i.e. smallest measured frequency

h. (8, 2) – end frequency, i.e. biggest frequency

9- Press Save once all the data is filled

10- Go to the next function if there is one

11- Once everything is filled and saved, press Next. The following plot will be shown (only one variable, i.e. temperature, was chosen) :

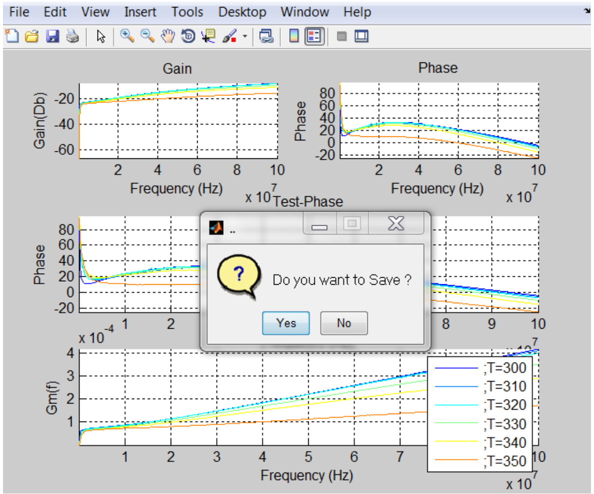


Figure 4

12- Press save if you want to create an Excel file containing both the measured data as well as the one calculate with the program. An example of the excel file and of the MatLab figure can be found with the source code file. The formulas used to recover the conductance and transconductance from the Gain is :

$$\frac{10^{\frac{G_{mesurée}}{20}}}{Gain_{I-V\ AOP}} = g_{DS,M} \tag{1}$$

For more information go to the final year project report, section "Gain-Phase measurement electrical setup".

13- Once the data has been saved, another pop-up will show. It asks if you want to continue If you press “continue” then another panel will open (Figure 5)

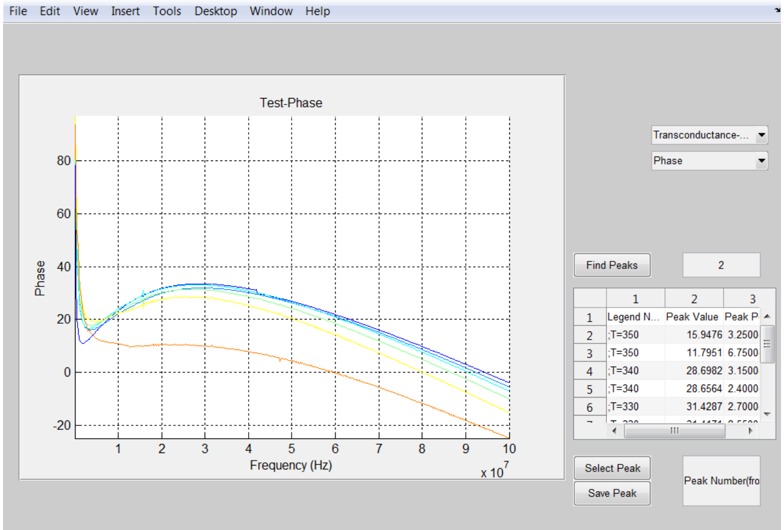


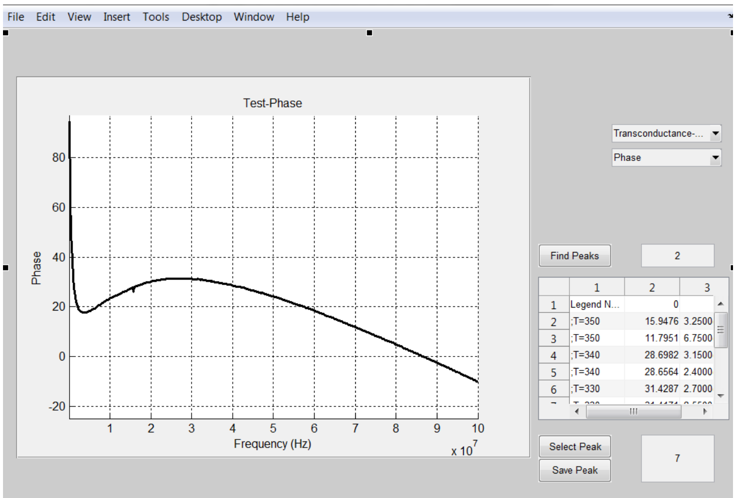
Figure 5

14- Here each plot is shown. Once it opens no image will be seen, you must first select a plot by using the drop boxes on the right. The number of peaks text box allows you to say how many peaks per plot there is and by pressing the find peaks button the program will find them (not reliable).

15- Once the find Peaks button has been pressed, the table will load and the Select Peak, Save Peak and Peak number objects will appear.

16- Replace Peak Number by the line of the table that you want to change (Peak Value and Peak Position).

17- Press Select peak, all the other curves inside the plot will be hidden and only the chosen will be shown.



18- Go to tools, then select data cursor. Place it in the peak, and then press Save peak. The peak value and peak position at the chosen line will be replaced by the position of the data cursor. Go to tools to zoom in, edit the plot etc. Once all the peaks have been chosen, you can copy the table.

Reading the Capacitance - Conductance data measured with the HP4194 Impedance/Gain-Phase Analyzer impedance function in the $C_p - G$ mode.

Open the MatLab and run the main.m function. The panel in Figure 1 will open. Then:

1- Press the add button. This will open the pop-up shown in Figure 2.
2- Select either Dynamic Conductance Schottky (DCS), Dynamic Conductance MOS (DCM) or Calculate R_s and C_{ox} (CRC).

   a. DCS: find G_p using the equivalent circuit shown in Figure 17 – a from the final year project report (version "G v6"). The only modification is that C_{ox} is removed. Therefore the program considers $G_p = G_m$ and $C_p = C_m$. There is also the option to consider R_s, in this case the circuit in Figure 17-d without G_t nor C_{ox} is taken, therefore equations (10-a), (10-b) and (11) are used, G_p is considered equal to G_c and $C_p = C_c$. R_s can either be calculated from an accumulation - $C_p - G$ measurement or given as a constant value. C_{ox} can also be considered and calculated from a $C_p - G$ measurement made in accumulation using equation (2 – from this report) found in reference [1]. The G_p is then calculated using equation (7) if no R_s is used or (9) if R_s is used. Deducing C_{ox} from the accumulation measurement might not be the best technique, since it was only found in reference [1].

$$C_{ox} = C_{ma}[1 + \left(\frac{G_{ma}}{\omega C_{ma}}\right)^2] \tag{2}$$

   b. DCM: find G_p using the equivalent circuit shown if Figure 17 – a from the final year project report. Therefore equation (7) is used to find G_p. There is also the option to consider R_s, in this case the circuit in Figure 17-d without G_t is taken, therefore equations (10-a), (10-b) and (11) are used, G_p calculated from (9). R_s can either be calculated from an accumulation - $C_p - G$ measurement or given as a constant value. C_{ox} can also be calculated from the accumulation $C_p - G$ measurement by using formula (2 – from this report). Deducing C_{ox} from the accumulation measurement might not be the best technique, as it was only found in reference [1].

   c. CRC: From a $C_p - G$ measurement made with the device polarized in accumulation the R_s is recovered using equation (11) from the final year project report (version "G v6"). Moreover, from reference [1] formula (1 – from this report) is used to find C_{ox}. Deducing C_{ox} from the accumulation measurement might not be the best technique, as it was only found in reference [1].

3- Press the Select button. A pop up will open and ask the user which .text files he wants to load. Multiple .text file selection is allowed for all functions.

4- If plotting in function of multiple variables, e.g. temperature and V_{bias}, change the number on the left of the panel shown in Figure 2 to the number of variables, e.g. 2.

5- Press Next and the function will be added to the list shown in the right side of Figure 6

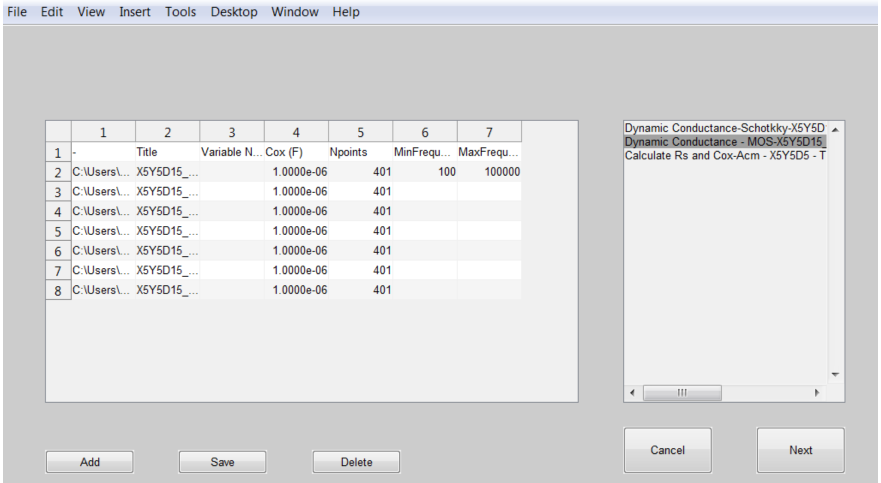


Figure 6

6- If needed, you can add multiple different functions, as it is shown in Figure 6. For this repeat steps 1 till 5.

7- Select a function to work with by clicking over its name in the list on the right. The table on the left will change to the one associated with the selected function.

8- Fill the table with all the data and SAVE it, otherwise when changing the function all the data will be erased or when pressing next the program will crash. For the Dynamic Conductance - MOS function the data in the table correspond to :

a. Position (2,1) – the title of the figure and the graph

b. Position (1, 2:end) and (2, 2:end) - .text file path and name respectively for all selected files

c. (3, 1) – Variable name. For example, if one wants to plot $G_p(\omega)/\omega$ in function of temperature, one can replace (3, 1) by "Temperature". If two different variables were chosen, such as temperature and V_{bias}, then a second "Variable Name" cell would appear at position (4,1) and everything after it would be shifted of one position, e.g. C_{ox} would be at (5,1) instead of (4,1).

a. (3, 2: end) – following the example in c, the temperature corresponding to each .text value must be given in (3, 2: end). In this example the legend would then show Temperature = ?. If two variables were chosen, then, following the example above, V_{bias} values would have to be written in (4, 2:end) and the legend would then show Temperature = ?; V_{bias} = ?.

d. (4, 2:end) - The C_{ox} used in the equivalent circuit.

e. (5,2:end) – the number of measuring points for each .text file

f. (6, 2) – starting frequency , i.e. smallest measured frequency

g. (7, 2) – end frequency, i.e. maximum frequency

Obs: For the Dynamic Conductance – Schottky function and the Calculate R_s and C_{ox} function the column asking for the C_{ox} do not exist.

9- Press Save once all the data is filled

10- Go to the next function if there is one

11- Once everything is filled and saved, press Next. For DCS and DCM a pop-up will ask if you want to consider R_s or C_{ox} :

   a. For DCS, if you press yes, then another one will ask if it is a file. If no then you will be asked to type a constant value that will be considered as R_s. Otherwise you will be asked to select a .text file (only one) with a dynamic conductance measurement made in the accumulation regime. At that point, C_{ox} can only be calculated from a .text file, if you want to consider a constant C_{ox} select the DCM function instead of DCS. Once the R_s or the file has been selected, you will be asked again if R_s and C_{ox} must be considered.

   b. FOR DCM only one .text file can be chosen. It should contain the data from a dynamic conductance measurement realized in the accumulation regime. Once the file is chosen you will be asked if R_s and later if C_{ox} are to be considered. In the latter select no if you want to use the C_{ox} chosen in step 8. If yes is pressed, the program will use the accumulation measurement to find C_{ox} as explained before (a priori this should be avoided, the validity of this method has not yet been confirmed, i.e. you should just use the C_{ox} chosen in step 8).

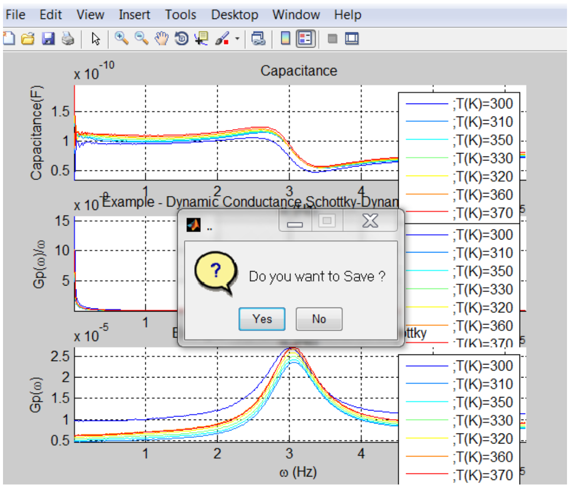


Figure 7

12- Press save if you want to create an Excel file containing both the raw measured data as well as the one calculate with the program. An example of the excel file and of the MatLab figure can be found with the source code. A description of how the program calculates $G_p(\omega)/\omega$ is given in step 2. For more information go the final year project report.

13- Once the data has been saved, another pop-up will be shown. It asks if you want to continue. If you press “continue” then another panel will open (Figure 8)

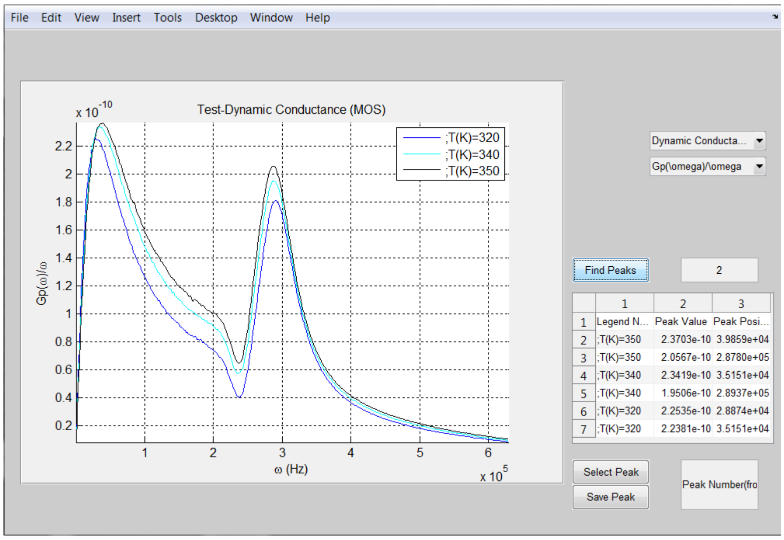


Figure 8

14- Here each plot is shown. Once it opens no image will be shown, you must first select a plot by using the drop boxes on the right. The number of peaks text box allows you to say how many peaks per plot there is and by pressing the find peaks button the program will attempt to find them (not reliable). If there is no legend, press the right button of your mouse and choose to show the legend.

15- Once the find Peaks button has been pressed, the table will load and the Select Peak, Save Peak and Peak number objects will appear.

16- Replace Peak Number by the line of the table that you want to change (you can only change Peak Value and Peak Position).

17- Press Select peak, all the other curves inside the plot will be hidden and only the chosen one will be shown (Figure 9).

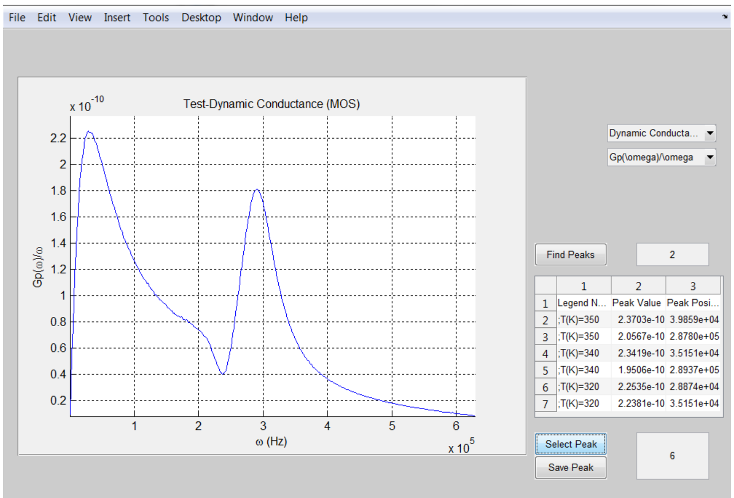


Figure 9

18- Go to tools, then select data cursor. Place it in the peak, and then press Save peak. The peak value and peak position at the chosen line will be replaced by the position of the data cursor. Go to tools to zoom in, edit the plot etc. Once all the peaks have been chosen, you can copy the table. I advise to change the panel shown in Figure 7 rather than the one shown in Figure 8 or Figure 9 since the latter are not permanent and the curve will be reset to the one shown in Figure 7 once the plot being shown in the panel in Figure 8 is changed. Modifying the plot in Figure 7 does it permanently (reselect the plot in panel Figure 8 so the changes made in Figure 7 are visible).

References

[1] N. Shiwakoti, A. Bobby, K. Asokan e B. Antony, "Temperature dependent dieletric studies of Ni/n-GaP Schottky diodes by capacitance and conductance measurements," *Materials Science in Semiconductor Processing* , vol. 42, pp. 378-382, 2016.