The procedure for using the parameter analyzer to measure NMOS characteristics is nearly identical to the BJT measurements done earlier.

There are several different types of measurements that can be done. We will do two measurements: a set of $i_D - v_{DS}$ characteristics that are the standard way of representing the behavior of an NMOS and the i_D-v_{GS} characteristic that can be used to extract two of the basic parameters of the NMOS. The analyzer has canned programs for doing both of these measurements, although we will set up the second measurement manually, since it is very easy to do.

T1he source of the NMOS will be the ground connection (SMU 1 in the canned programs). The drain voltage is controlled using SMU 2 and the gate voltage is controlled with SMU 3.

Since we have used the analyzer previously, we won't describe each step in detail. As with the BJT, there are 5 basic steps: 1) physically connect the device to the analyzer, 2) define the function of the SMUs (channel definition page), 3) set up the voltages and currents to be used (sweep setup page), 4) set up the axes for the graph (display setup page), and 5) perform the measurement and observe the results (graph/list page).

I_D-V_{DS} curves

The drain voltage will be Variable 1 and the gate voltage will be Variable 2. The measurement starts by setting the gate voltage at the initial value and then stepping through all of the drain voltages, measuring the drain current at each step. Then the gate voltage is changed to its next value and the drain voltage steps through the range of values again, measuring the current at every step. This continues for all of the values of gate voltage defined in the measurement set up.

1. Connect the transistor to the analyzer. There is a special connector that can be used for 14-pins DIPs (dual in-line packages), but it is probably just as easy to plug the CD4007 chip into a breadboard and use the small wires to connect to the analyzer:
    source —> SMU 1, drain —> SMU 2, and gate —> SMU 3.

2. Go to the Channel Definition page. Press the soft key labeled "MEM2 FET VDS-ID" to bring up the canned program. You should see that SMU 1 (the source) is defined as a constant and is labeled COMMON. SMU 2 (the drain) is defined as a voltage source, so it will set voltages and measure currents. It is labeled as VAR1. SMU 3 (the gate) is also configured as a voltage source and is labeled as VAR2.

3. Go the Sweep Setup page. For VAR 1 (drain) set the start voltage at 0 V, the stop voltage at 8 V, and the step size at 0.1 V. The compliance can be 25 mA. For VAR 2 (gate) set the starting voltage at 1 V, the step size to 1 V, and the number of steps to 6. (For some reason the parameters for VAR 1 and VAR 2 are entered slightly differently.) The compliance for the gate can be 1 mA. (We don't expect any current flowing into the gate.) For both variables, the SWEEP MODE should be SINGLE and the LIN/LOG option should be LINEAR. Also on this page, be sure to set the *SWEEP setting to "CONTINUE AT ANY".

4. Go to the Display Setup page. The graph should already be defined to have VDS on the x-axis and ID on the y-axis. Set the limits for the x-axis to have a minimum of 0 V and a maximum of 8 V. Since we can't know what the currents will be until after we have taken some data, there is no need to change the y-axis limits. We will use auto-scaling after the data has been gathered.

5. Go to the Graph/List page. You should see an empty graph, just waiting for some data to plot. Press the "Single" button to start the measurement. Since the first one sweep probably has $v_{GS} < V_T$, the current will likely be zero initially. (The green measurement LED will light until the measurement is complete. It may take a minute or so.)

6. Once the measurement is finished, press the "SCALE" soft key at the bottom and then "AUTO SCALE" soft key on the upper right side. The graph will be re-scaled and there should be a nice set of i_D-v_{DS} curves displayed on the graph.

7. Take a photo of the set of curves for your report.


I_D-V_{GS} curve

1. Return to the Channel Definition page. The SMU connections to the NMOS will stay the same, but we will need to change the SMU functions. First, change the function of SMU2 (the drain) to CONST. Then change the function of SMU3 (the gate) to VAR1.

2. Go to the Sweep Setup page. We want to sweep through a range of v_{GS} values while keeping the drain voltage constant. Under VAR1, (which is the gate voltage), set the start to 0 V, the stop to 6 V, and the step to 0.05 V (or 50 mV). The compliance can be set to 1 mA.

    Then move down to the "Constants" section of the Sweep Setup page. Change the constant voltage of SMU2 (the drain) to 8 V. Set the compliance at 25 mA. Holding the source voltage at a large value will guarantee that the NMOS is either off or operating in its saturation mode. If you forget to do this step, the drain voltage will remain at zero, and there won't be any drain current, which makes for a rather pointless measurement.

    Also, don't forget the "CONTINUE AT ANY" setting.

3. Go to the Display Setup page. Set the x-axis to the gate voltage and the y1-axis to the drain current. (The available axis options are shown as soft keys along the right hand side – use the keys to select the variables you want for each axis.) The min and max for the x-axis should be 0 V and 6 V. Set the y-axis MIN and MAX at 0 and 10 mA. (Although we really don't know what currents will be until we've done the measurements.

4. Go to the Graph/List page. Start a singe measurement – it should finish within a few seconds. Use the auto-scaling function to make the vertical axes fit the measured date. You should see that the current is zero for low values of v_{GS} (below V_T), but that it increase quadratically for voltages above the threshold.

5. Take a photo, if you would like. This curve is nice, but it isn't as useful as it could be.

6. Return to the Channel Definition page. Then use the "Next Page" soft key to advance to a screen where we can define a new function. (Don't use the Meas key to move ahead from the Channel Definition Page – it will skip over the function definition page.

7. On the function definition page is a small table where we enter a function. There is a space for a function name. Enter SQRTID. (The actual name is irrelevant. You could name the function "FRED" just as well.) There is a space for entering units, but this is irrelevant, too, we will it leave it blank. The function definition *is* important. Use the front panel keys to type in SQRT(ID) and press the Enter key. With this function the analyzer will calculate and display the square-root of the drain current.

8. When finished with function definition, use the "Next Page" soft key to advance to the Sweep Setup page. We don't need to change anything here – the measurement will be exactly the same.

9. Go to the Display Setup page. We want to change the y1-axis to plot our newly defined function. To find the "SQRTID" function, we need to press the "MORE 1/2" to go to the next menu of soft keys – SQRTID will show up there. Select it for the y1 axis.

10. Advance to the Graph/List page. Take a measurement and then auto-scale. You should see a curve something like the one shown below. For value of $v_{GS} < V_T$, the curve is zero. Above V_T, the curve increases linearly. For an ideal NMOS, the drain current in saturation increases with the square of the gate voltage.. Therefor, plotting of the square-root of the current gives a straight line. The slope of the line is equal to $K^{1/2}$ and the x-axis intercept is equal to the threshold voltage.
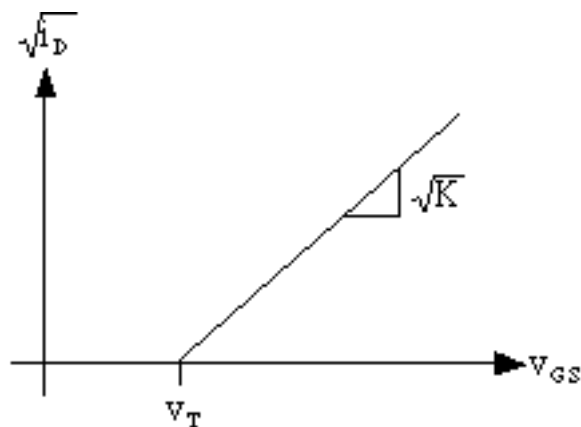
11. The parameter analyzer has some features to help extract information like slopes and intercepts from measured curves. Start by pushing the Marker/Cursor soft key at the bottom of the screen to bring up the menu of marker and cursor soft key option on the right-hand side of screen.

12. Turn on the marker by pushing the "MARKER" soft key. (It will switch from MARKER OFF to MARKER ON). The marker is small circle on the graph can be moved through the data using the dial.

13. Press the "Line" soft key at the bottom of the screen to bring up the line control soft keys on the right-hand side.

14. Press the "Line" soft key on the side of the screen. (It will switch from LINE OFF to LINE ON.)

15. Press the "Tangent Mode" soft key on the side of the screen. This draws a line that is tangent to the measured curve at the point where the marker is located.

16. Move the marker so that the tangent line coincides with the linear part of the curve. The $i_D^{1/2}$ curves are not always exactly straight – they sometime bend downwards from linear at higher gate voltages. If the trace is "curvy", position the tangent line at lower values where the trace is straightest.

17. The line information, slope (grad), x-intercept, and y-intercept are displayed on the screen. Again, the slope is equal to $K^{1/2}$ and the x-intercept is the threshold voltage. You can read these off directly.

18. Take a photo of the curve for your report.