# How To Plot Transconductance and Even More

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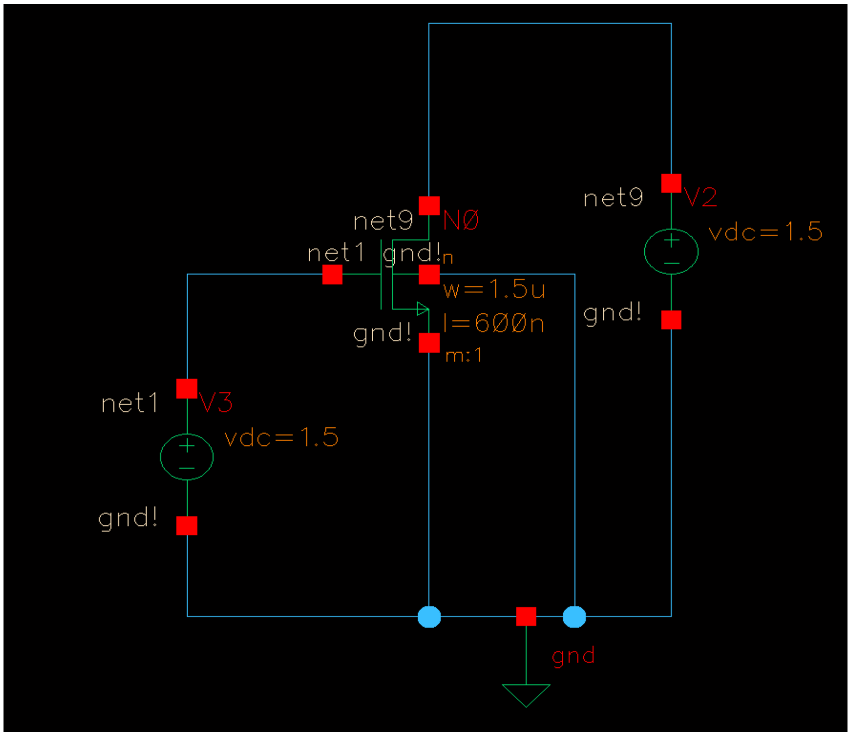
$g_m/I_d$ based methodology is preferred for short-channel length analog circuit design however there is no GUI support for this method in the current Cadence release. The process can be tedious and requires much more insight understanding about Cadence. This tutorial will walk through the process on how to generate the $g_m/I_D$ curves that can be used as a guide for future designs.

First of all, you need to create a simple schematic to simulate the device. Here NMOS transistor, N0, has a W/L = 10um/0.6um. The gate and drain voltages are both set to 1.5 volts.



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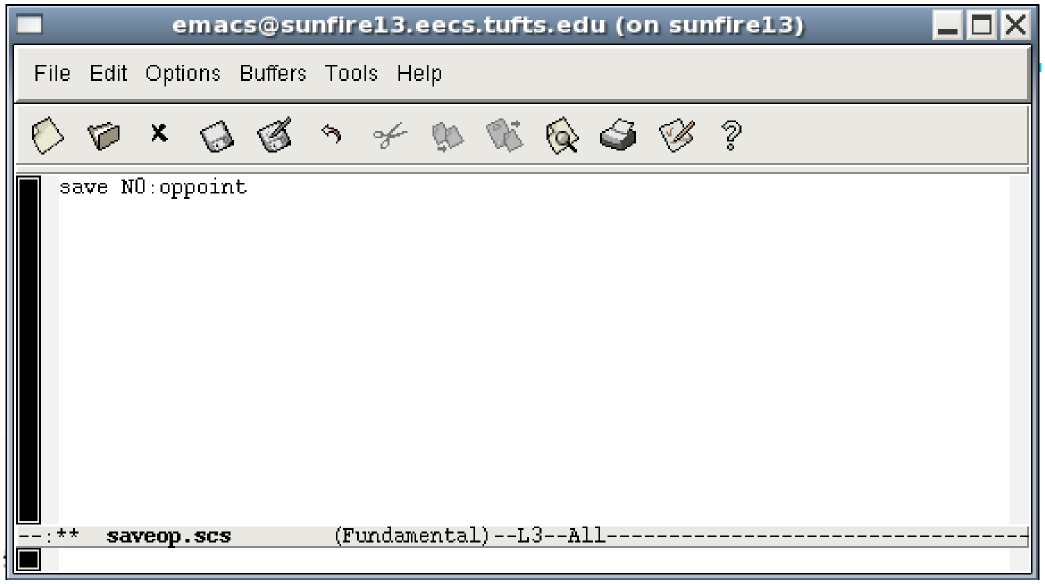
In order to use gm/Id methodology, one needs to know transconductance ($g_m$), gate capacitance ($C_{gs}$), output impedance ($r_o$) and well as other parameters. These parameters can be determined by performing a DC analysis of the circuit in the above figure. Unfortunately, Spectre/SpectreS usually does not save operating point parameters during a DC or transient simulation to keep the output PSF file slim. Spectre can be forced into saving these parameters by the following steps.

First of all, change the simulator to Spectre and create a *saveop.scs* (any save file name is ok as long as you remember to save the extension as *.scs) from your favorite text editor. It is important to remember the directory that you created the file in. Open the file using any text editor. Type in on the first line:

```
save N0:oppoint
```

The final file, *saveop.scs*, should look like the figure below: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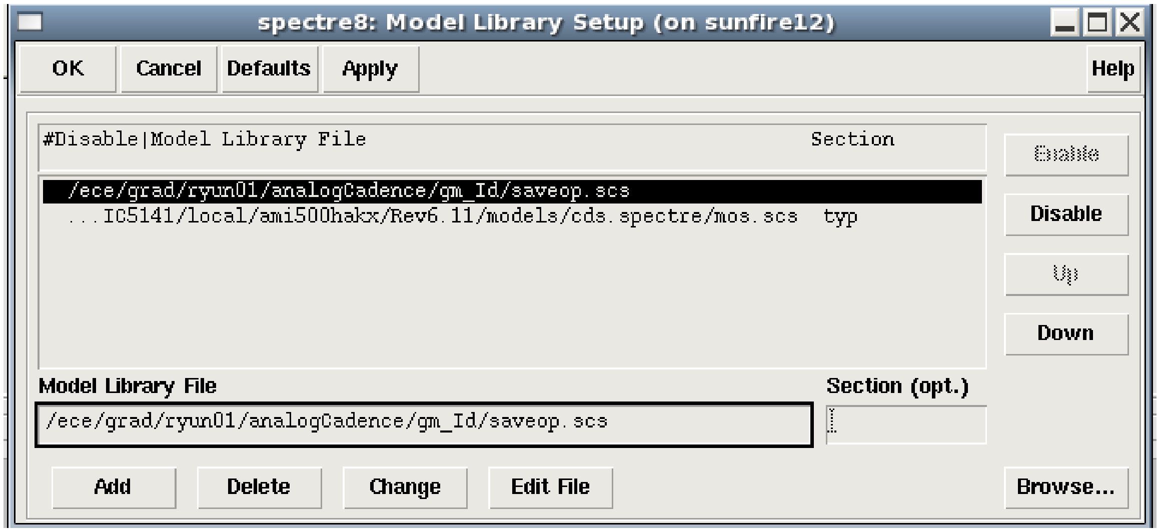
```
save N0:oppoint
```

--:** saveop.scs (Fundamental)--L3--All-----

Note that N0 is the instance name of the NMOS you just created. The option *oppoint* directs Spectre to save all DC operation point parameters for N0. You can find more about the command save from Spectre user guide.

Add this file as a model library file just like what you usually do to setup Spectre. Make sure the path to *saveop.scs* is correct.

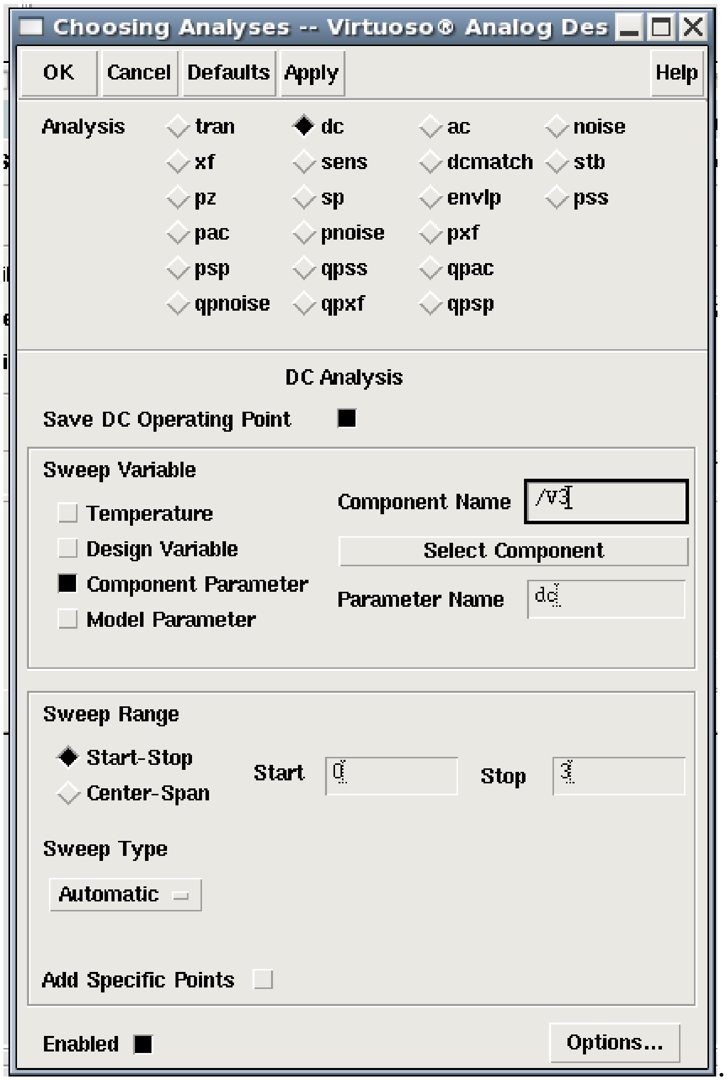


| #Disable\|Model Library File | Section |
|---|---|
| /ece/grad/ryun01/analogCadence/gm_Id/saveop.scs | |
| ...IC5141/local/ami500hakx/Rev6.11/models/cds.spectre/mos.scs | typ |

Model Library File: /ece/grad/ryun01/analogCadence/gm_Id/saveop.scs

Section (opt.):

It is important to know that AWD waveform tool was used for this tutorial rather than wavescan. In order to change from the default waveform tool, in the Analog Design Environment window, click on the session tab and click on options. On the option that says “waveform tool” select AWD and save/apply the changes.



Analysis ◆ dc

DC Analysis

Save DC Operating Point ■

Sweep Variable

□ Temperature
□ Design Variable
■ Component Parameter
□ Model Parameter

Component Name /V3

Parameter Name dc

Sweep Range

◆ Start-Stop
◇ Center-Span

Start 0 Stop 3

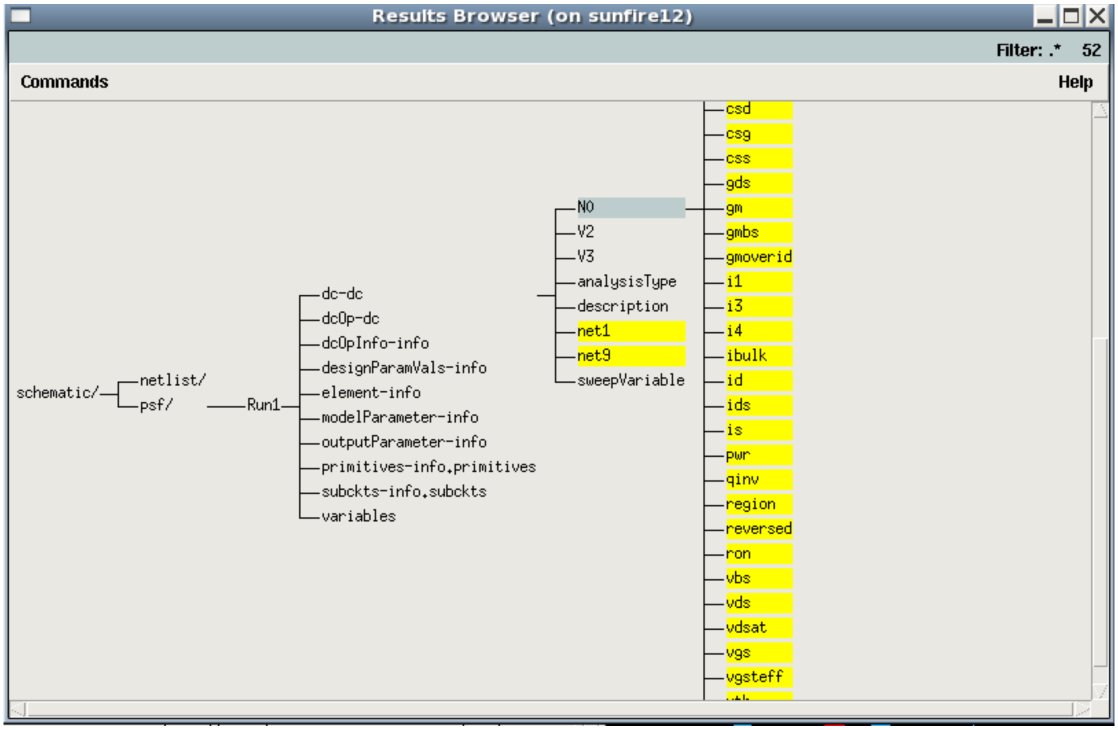
Sweep Type

Automatic

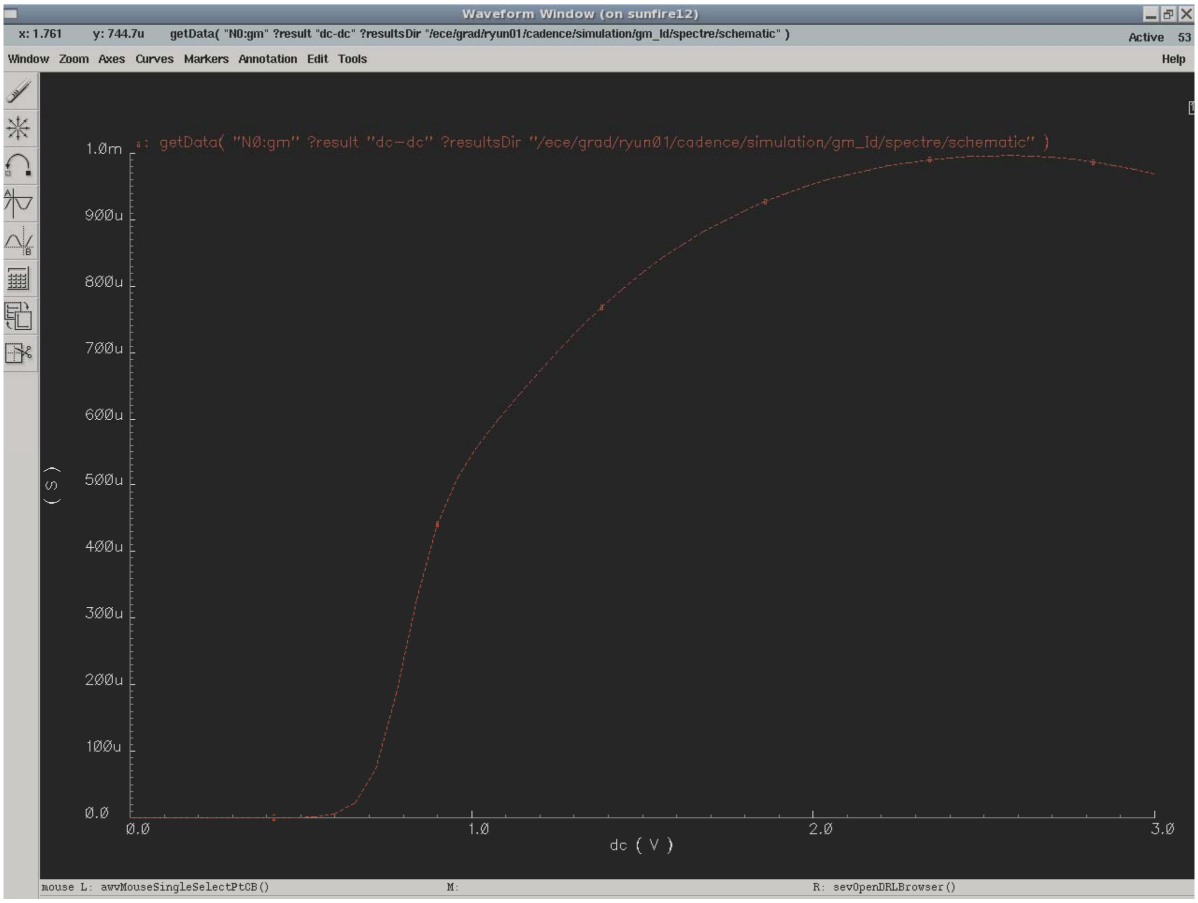
Add Specific Points □

Enabled ■

Now, setup a DC simulation and sweep the gate voltage from 0 to 3V. Run the simulation and open the Results Browser from Analog Design Environment. The results browser can be found in the Analog Design Environment by clicking on the tools tab and then selecting the results browser.



If you go to schematic-> psf/->Run1->dc-dc-> N0, you can see all the DC operating point parameters are saved and you can plot directly from Cadence. If you would like to plot the $g_m$ of the transistor for instance, right click $g_m$ and you should see a graph like this:



```
x: 1.761     y: 744.7u     getData( "N0:gm" ?result "dc-dc" ?resultsDir "/ece/grad/ryun01/cadence/simulation/gm_Id/spectre/schematic" )
```

```
getData( "N0:gm" ?result "dc-dc" ?resultsDir "/ece/grad/ryun01/cadence/simulation/gm_Id/spectre/schematic" )
```

```
mouse L: awvMouseSingleSelectPtCB()          M:          R: sevOpenDRLBrowser()
```

This is very cool because you can find the $g_m$ for different gate voltages; however, you need process the data to obtain the advanced curves. In order to generate these curves, you have to use OCEAN to save all these data. The data can be processed using any other software such as Matlab/Octave or Excel later on.

Go to Analog Design Environment and click menu session, then save script. A window will pop up and that is the first OCEAN script you are going to use. Please note that this ocean script file will be saved in your default cadence directory. From the script file, you can find out that all these setups you made for simulation in here. *OcnWaveformTool* set the wave viewer to AWD. Command Simulator selects Spectre as the simulation engineer, so on and so forth.

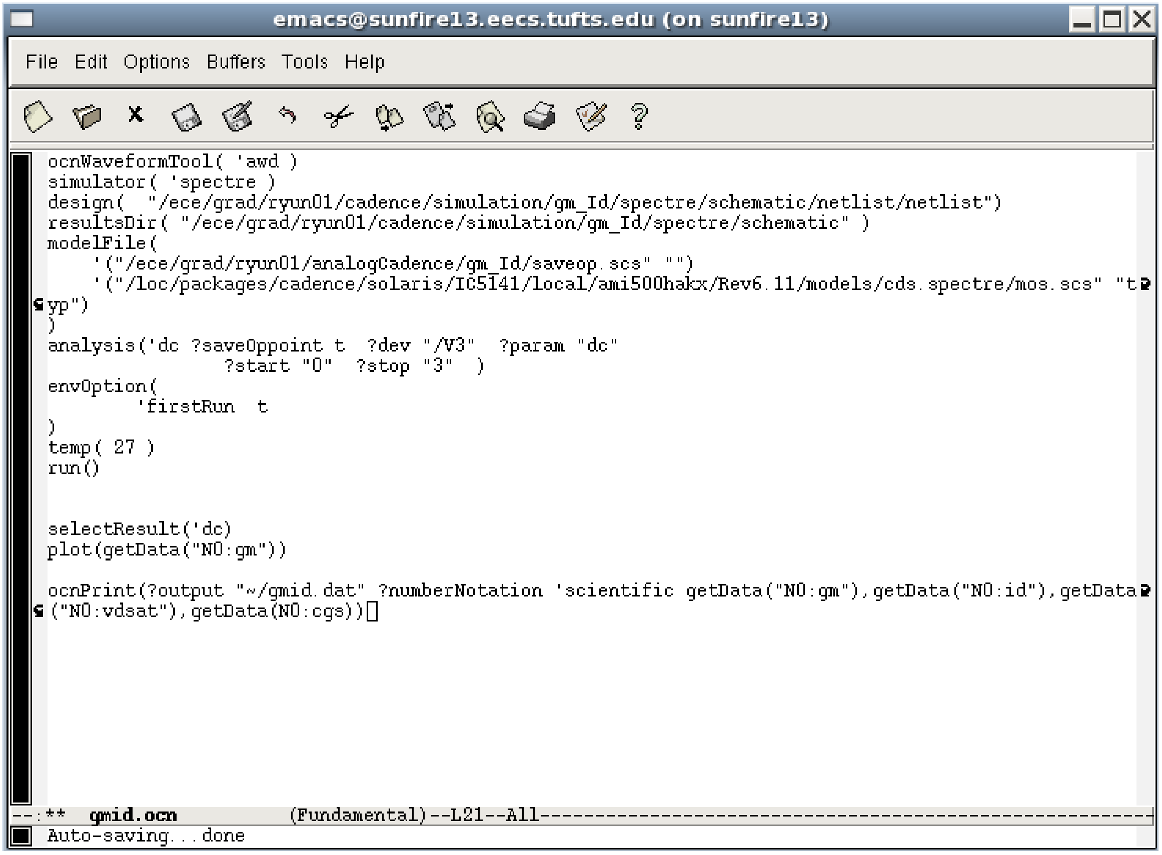
You have to add few lines to this simple script file to save the DC operating point parameters you are interested in (copy this text exactly):

```
selectResult('dc)
plot(getData("N0:gm"))

ocnPrint(?output "~/gmid.dat" ?numberNotation 'scientific
getData("N0:gm"),getData("N0:id"),getData("N0:vdsat"),getData(“N0:cgs”))
```

Here, *?output* means all data will be saved to a file called *gmid.dat*. You can modify the tag line **"~/gmid.dat"** in order to have the *gmid.dat* file saved any directory of your choice; otherwise the *gmid.dat* file will be saved in your root directory:

g*etData* select the parameter you want to save. The resulting *ocn* file should look like this:



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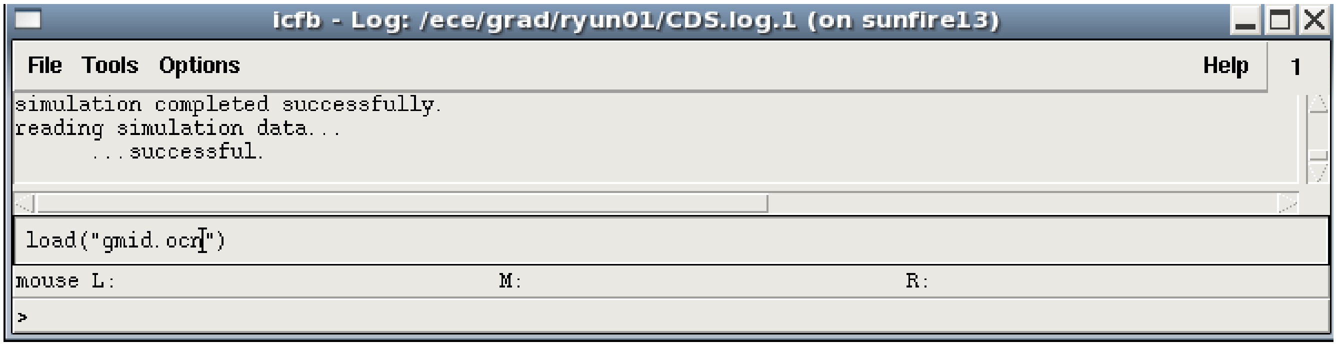
```
ocnWaveformTool( 'awd )
simulator( 'spectre )
design(  "/ece/grad/ryun01/cadence/simulation/gm_Id/spectre/schematic/netlist/netlist")
resultsDir( "/ece/grad/ryun01/cadence/simulation/gm_Id/spectre/schematic" )
modelFile(
    '("/ece/grad/ryun01/analogCadence/gm_Id/saveop.scs" "")
    '("/loc/packages/cadence/solaris/IC5141/local/ami500hakx/Rev6.11/models/cds.spectre/mos.scs" "t
yp")
)
analysis('dc ?saveOppoint t  ?dev "/V3"  ?param "dc"
                  ?start "0"  ?stop "3"  )
envOption(
        'firstRun  t
)
temp( 27 )
run()


selectResult('dc)
plot(getData("N0:gm"))

ocnPrint(?output "~/gmid.dat" ?numberNotation 'scientific getData("N0:gm"),getData("N0:id"),getData
("N0:vdsat"),getData(N0:cgs))
```

```
--:**  gmid.ocn        (Fundamental)--L21--All------------------------------------------------------
Auto-saving...done
```

*Please note that *getData(N0:cgs)* is missing a set of quotation marks in the figure above. Please do not forget to add those in your **.ocn* script file.

Now you can load this file and run the simulation again from CIW window by typing:

load(“gmid.ocn”)

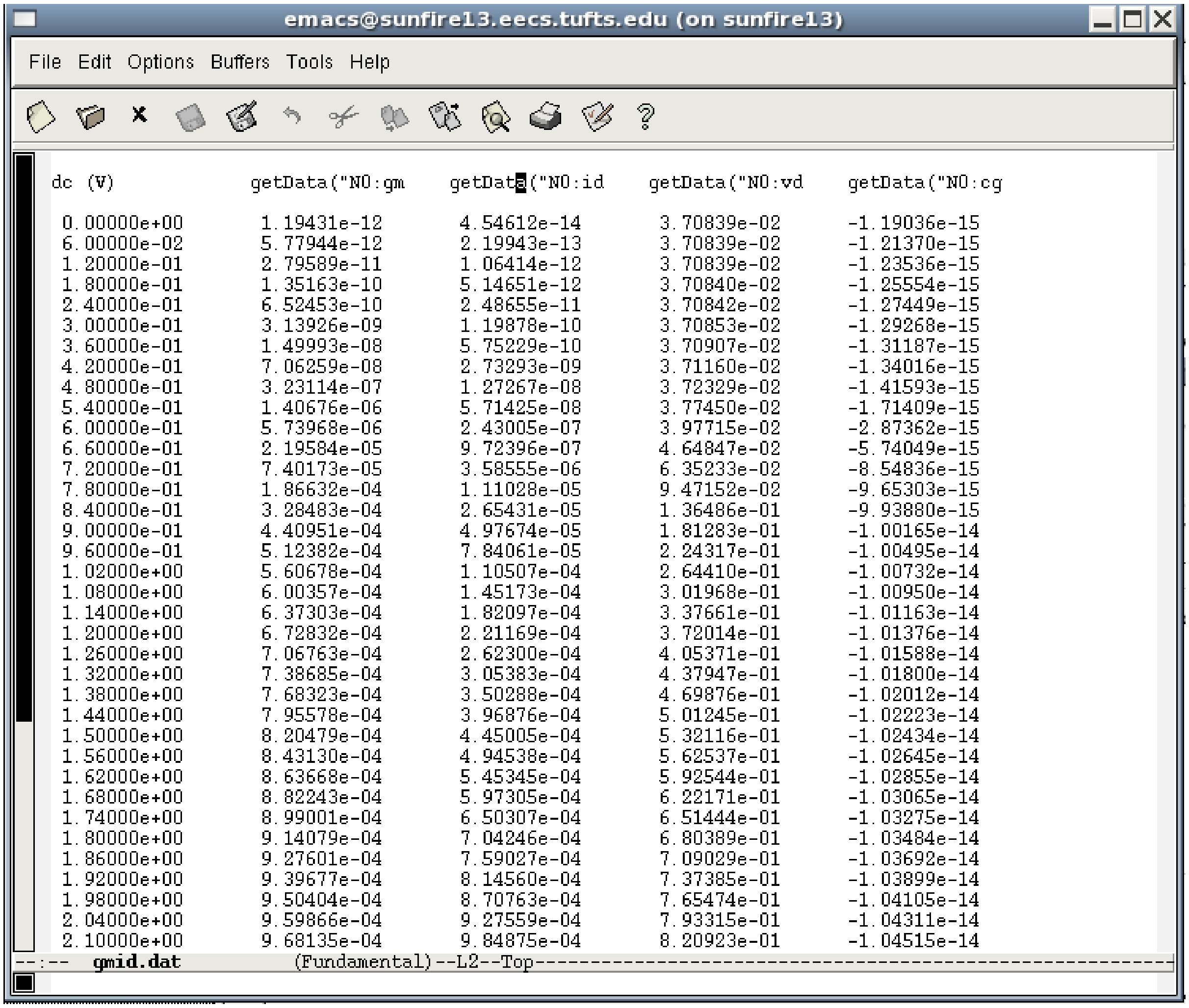


```
simulation completed successfully.
reading simulation data...
      ...successful.
```

```
load("gmid.ocn")
```

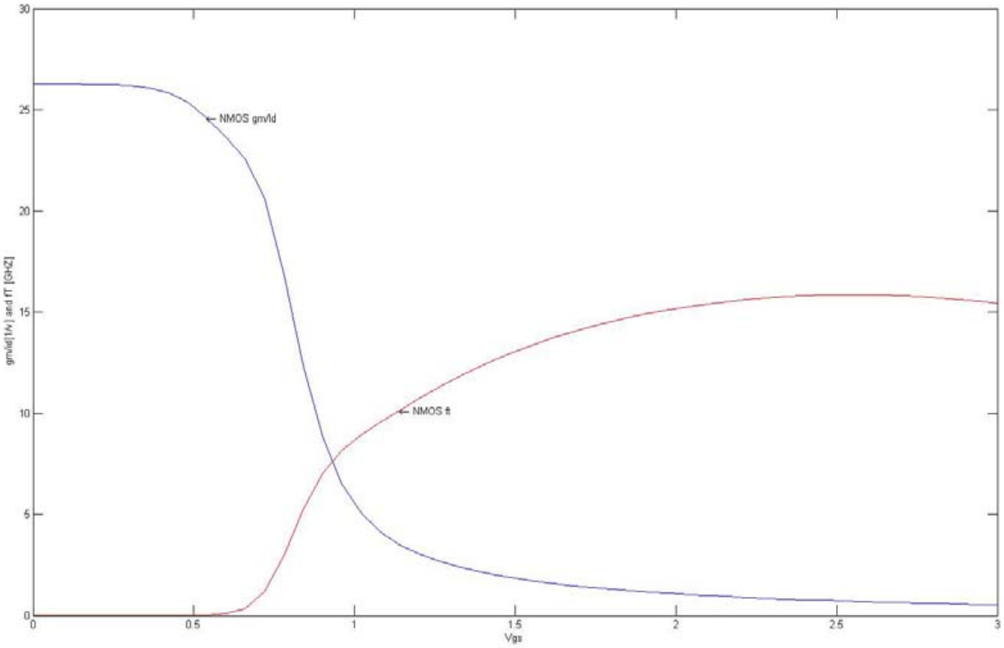
```
mouse L:                                   M:                                R:
>
```

Go to the root directory (or where ever you saved the file) and you can find *gmid.dat.* All the parameters you want, $g_m$, $C_{gs}$, $I_d$, $V_{dsat}$ (Defined as vd) are saved here as shown in the figure below:


emacs@sunfire13.eecs.tufts.edu (on sunfire13)
File Edit Options Buffers Tools Help

```
dc (V)              getData("N0:gm      getData("N0:id      getData("N0:vd      getData("N0:cg

 0.00000e+00         1.19431e-12         4.54612e-14         3.70839e-02        -1.19036e-15
 6.00000e-02         5.77944e-12         2.19943e-13         3.70839e-02        -1.21370e-15
 1.20000e-01         2.79589e-11         1.06414e-12         3.70839e-02        -1.23536e-15
 1.80000e-01         1.35163e-10         5.14651e-12         3.70840e-02        -1.25554e-15
 2.40000e-01         6.52453e-10         2.48655e-11         3.70842e-02        -1.27449e-15
 3.00000e-01         3.13926e-09         1.19878e-10         3.70853e-02        -1.29268e-15
 3.60000e-01         1.49993e-08         5.75229e-10         3.70907e-02        -1.31187e-15
 4.20000e-01         7.06259e-08         2.73293e-09         3.71160e-02        -1.34016e-15
 4.80000e-01         3.23114e-07         1.27267e-08         3.72329e-02        -1.41593e-15
 5.40000e-01         1.40676e-06         5.71425e-08         3.77450e-02        -1.71409e-15
 6.00000e-01         5.73968e-06         2.43005e-07         3.97715e-02        -2.87362e-15
 6.60000e-01         2.19584e-05         9.72396e-07         4.64847e-02        -5.74049e-15
 7.20000e-01         7.40173e-05         3.58555e-06         6.35233e-02        -8.54836e-15
 7.80000e-01         1.86632e-04         1.11028e-05         9.47152e-02        -9.65303e-15
 8.40000e-01         3.28483e-04         2.65431e-05         1.36486e-01        -9.93880e-15
 9.00000e-01         4.40951e-04         4.97674e-05         1.81283e-01        -1.00165e-14
 9.60000e-01         5.12382e-04         7.84061e-05         2.24317e-01        -1.00495e-14
 1.02000e+00         5.60678e-04         1.10507e-04         2.64410e-01        -1.00732e-14
 1.08000e+00         6.00357e-04         1.45173e-04         3.01968e-01        -1.00950e-14
 1.14000e+00         6.37303e-04         1.82097e-04         3.37661e-01        -1.01163e-14
 1.20000e+00         6.72832e-04         2.21169e-04         3.72014e-01        -1.01376e-14
 1.26000e+00         7.06763e-04         2.62300e-04         4.05371e-01        -1.01588e-14
 1.32000e+00         7.38685e-04         3.05383e-04         4.37947e-01        -1.01800e-14
 1.38000e+00         7.68323e-04         3.50288e-04         4.69876e-01        -1.02012e-14
 1.44000e+00         7.95578e-04         3.96876e-04         5.01245e-01        -1.02223e-14
 1.50000e+00         8.20479e-04         4.45005e-04         5.32116e-01        -1.02434e-14
 1.56000e+00         8.43130e-04         4.94538e-04         5.62537e-01        -1.02645e-14
 1.62000e+00         8.63668e-04         5.45345e-04         5.92544e-01        -1.02855e-14
 1.68000e+00         8.82243e-04         5.97305e-04         6.22171e-01        -1.03065e-14
 1.74000e+00         8.99001e-04         6.50307e-04         6.51444e-01        -1.03275e-14
 1.80000e+00         9.14079e-04         7.04246e-04         6.80389e-01        -1.03484e-14
 1.86000e+00         9.27601e-04         7.59027e-04         7.09029e-01        -1.03692e-14
 1.92000e+00         9.39677e-04         8.14560e-04         7.37385e-01        -1.03899e-14
 1.98000e+00         9.50404e-04         8.70763e-04         7.65474e-01        -1.04105e-14
 2.04000e+00         9.59866e-04         9.27559e-04         7.93315e-01        -1.04311e-14
 2.10000e+00         9.68135e-04         9.84875e-04         8.20923e-01        -1.04515e-14
--:--  gmid.dat         (Fundamental)--L2--Top--------------------------------------------------------
```

The data can then be plotted using any program. A sample figure generated from Matlab is shown below.


gm/id[1/v] and fT [GHZ]
← NMOS gm/Id
← NMOS ft
Vgs