Analog Circuits
Mini Project-1

Sahukari Chaitanya Varun
EE19BTECH11040

MOS Charecteristics and Modelling

September 26, 2021

From the model files downloaded, we were able observe many parameter operating on a given MOS transistors. In the following exercise, we find a region of operation which ensures us the operation to be in saturation region with significant gain.

1 General Procedure

The procedure is common for all the MOSFET's we operate on.

1. Firstly, we need to adjust the V_{ds} as per the given value from the supply. For this purpose we use a pair of op-amps, one for required amplification other acting as a buffer.

2. Now, we do a dc sweep with the V_{gs} keeping V_{ds} constant and also plot its derivative on the same plot.

3. From the graph obtained above, using a scale, we try to draw line for the approximate linear behaviour of the derivative (as derivative is proportional to $V_{gs} - V_T$). Then try to locate the endpoints of the linear region and find the centre point of this segment.

4. Call the corresponding V_{gs} as V_{gs0} and corresponding gain as g_{m0}. Extrapolate the line segment to the $I_{ds} = 0$ to find the corresponding threshold voltage - V_T.

5. With obtained values, find $\beta = \mu^* C_{ox}$ as

$$\beta = \frac{g_{m0}}{\frac{W}{L}(V_{gs0} - V_T)}$$

where W and L are the given size parameters.

6. Now find the range of voltage where the g_m has an error within 50% of the estimated g_{m0}.

7. Now as we know the V_{gs0}, using it do dc sweep for V_{ds} to get the graphs of I_{ds} vs V_{ds} and the derivative, g_{ds} vs V_{ds}. Find the corresponding I_{ds} and g_{ds} (i.e, g_{ds0}) for the earlier operated V_{ds} (i.e, 0.55V).

8. Now find λ as

$$\lambda = \frac{g_{ds0}}{I_{ds}}$$

9. The procedure is defined in reference to NMOS and for PMOS, the same thing applies, by taking the modulus over the parameters.

2 Circuits and Outputs

2.1 Voltage Divider

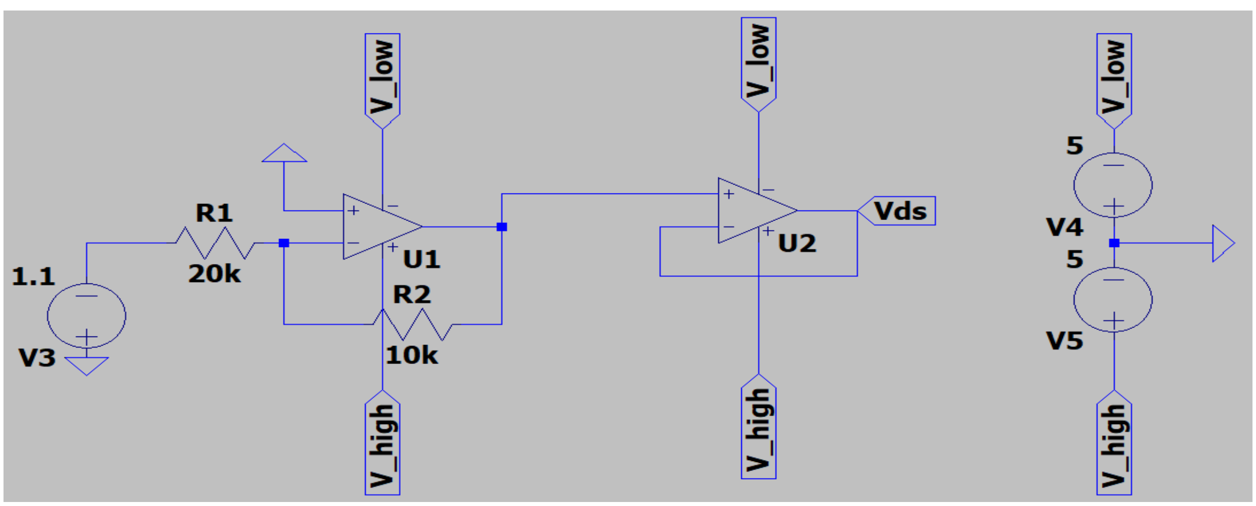

Figure 1: V_{ds} from V_{dd}

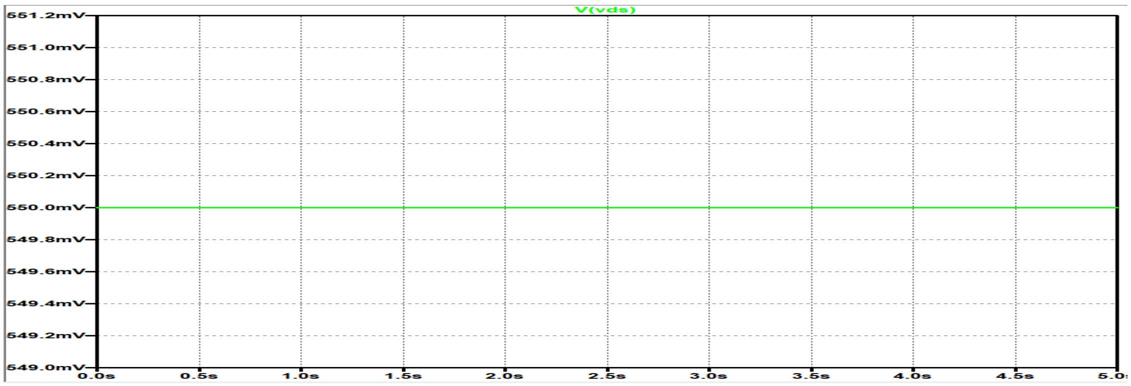

Figure 2: V_{ds} when used in operation

2.2 Short Channel NMOS

Given parameters are W = 1μm and L = 65nm. The following are the required circuits and graphs.

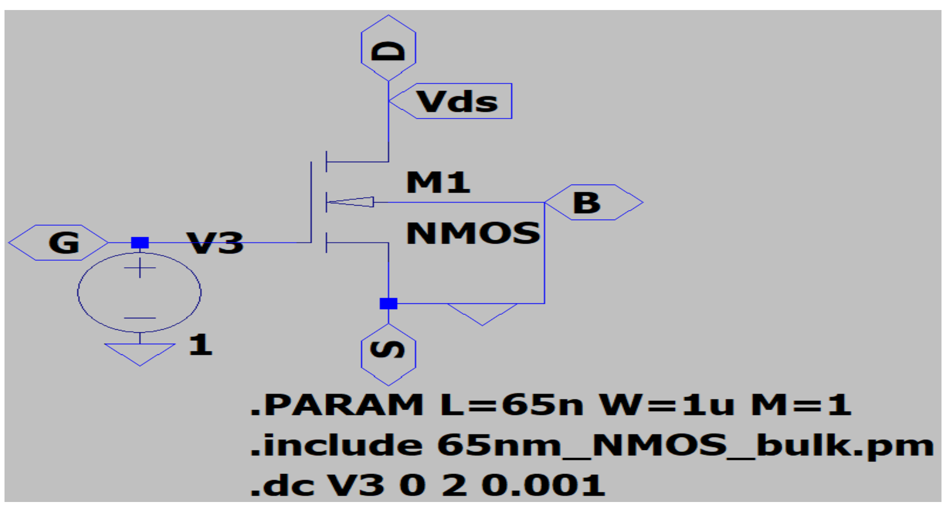

Figure 3: Circuit used for simulations

For the following plots, we follow a convention :
The points marked in red are the approximate endpoints of saturation region and the red line is the approximate line of interpolation.
The points in black show V_{gs0}, point marked in pink shows the threshold voltage.
The points marked in grey represent the range of voltages for g_m to lie with in 50% error region for sweep in V_{gs} and the corresponding values at V_{ds0} in V_{ds} sweep.
The green curve represent the current I_{ds} and blue curve represents its derivative wrt to the sweeping parameter.

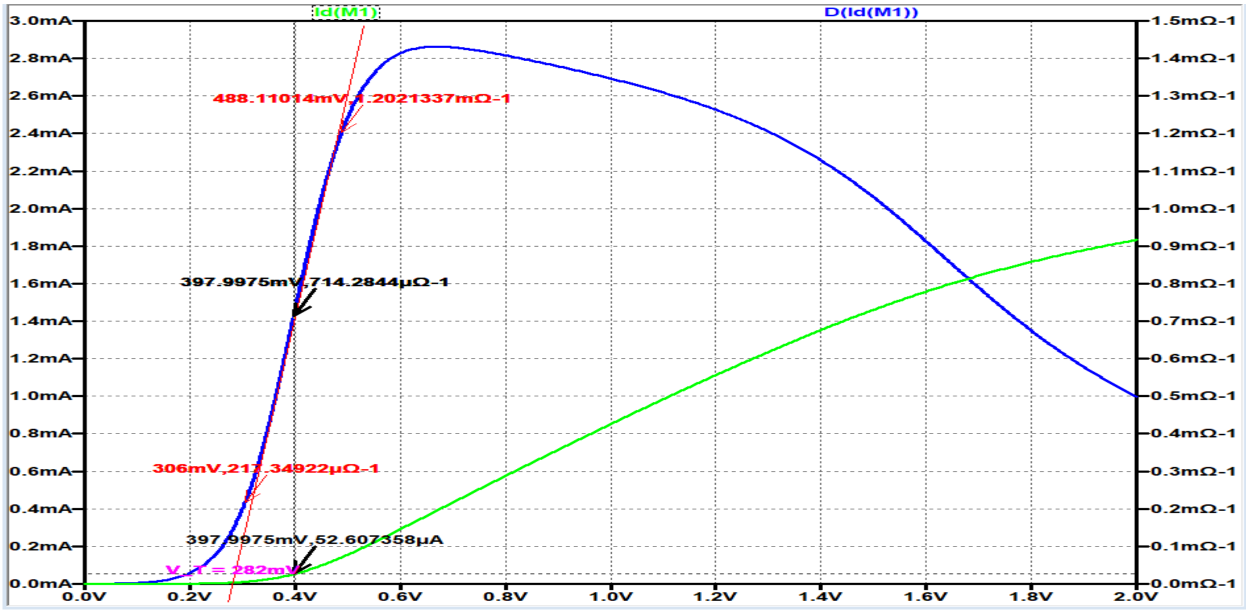

Figure 4: I_{ds} vs V_{gs}

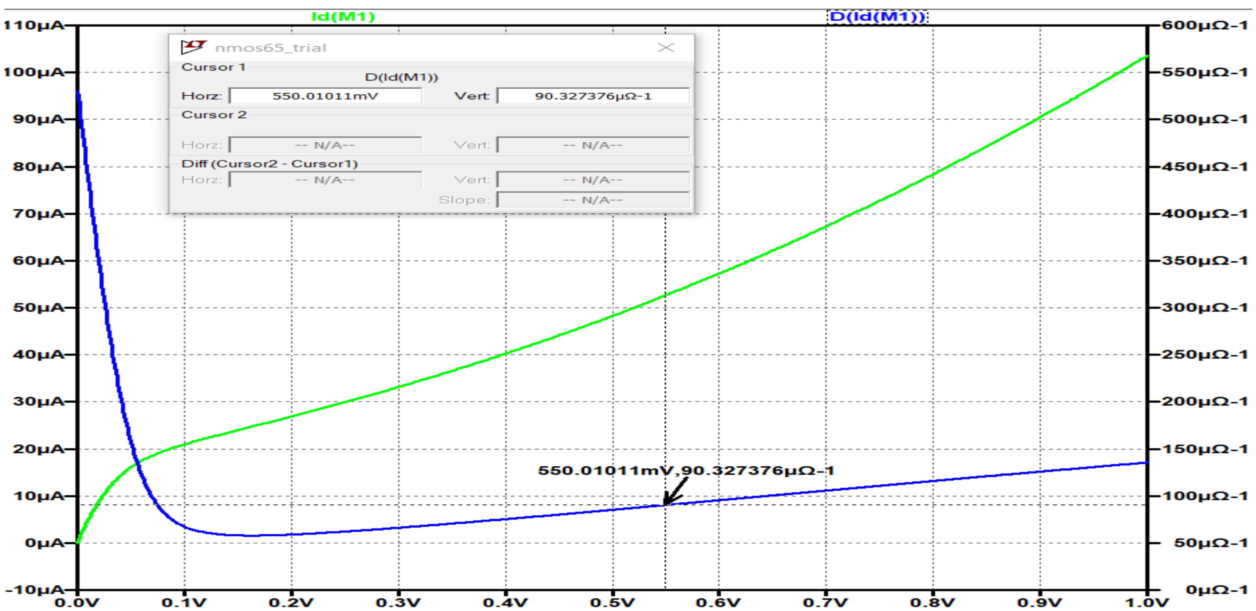

Figure 5: I_{ds} vs V_{ds}

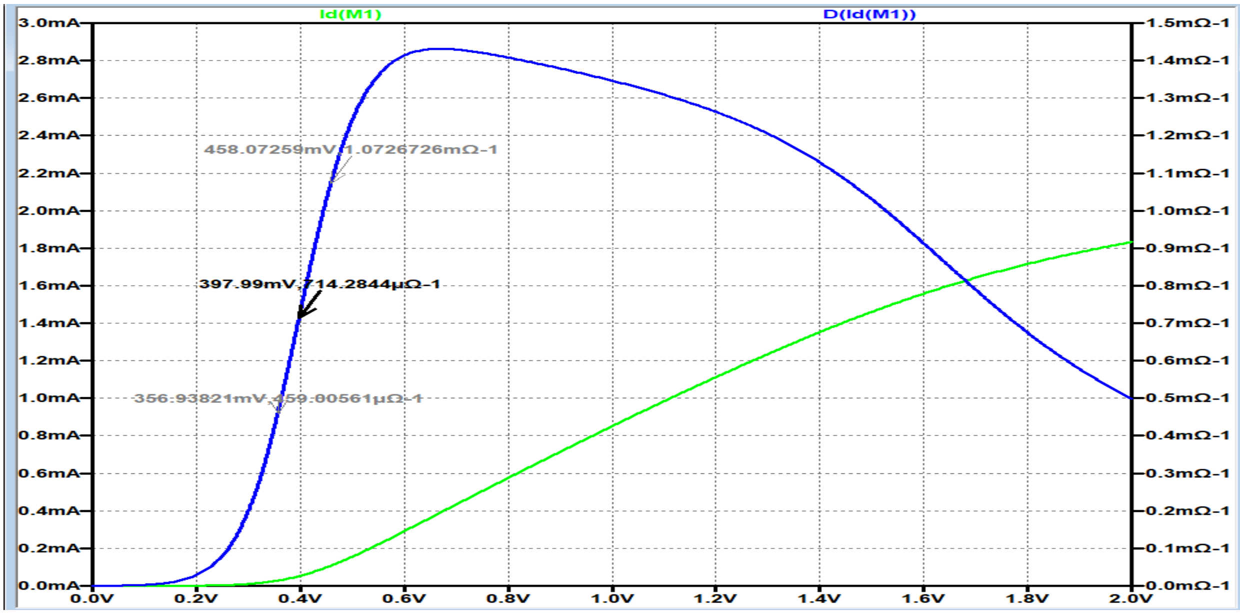

Figure 6: Range of V_{gs} for g_m to lie with in the 50% error

Obtained Results

- V_{gs0} = 392.817mV
- g_{m0} = 628.08101 $\mu℧$
- V_T = 282mV
- β = 400.255 $\mu℧\ V^{-1}$
- I_{ds} = 52.607μA
- g_{ds0} = 90.327$\mu℧$
- λ = 2.18036 V^{-1}
- Range of V_{gs} for g_m with in 50% error: (356.938mV,458.072mV)

2.3 Long Channel NMOS

Given parameters are W = 1μm and L = 1μ. The following are the required circuits and graphs.

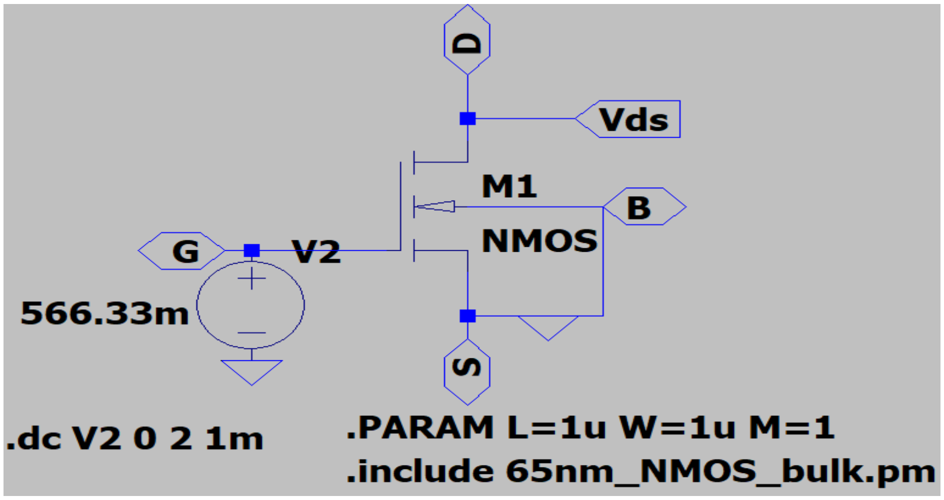

Figure 7: Circuit used for simulation

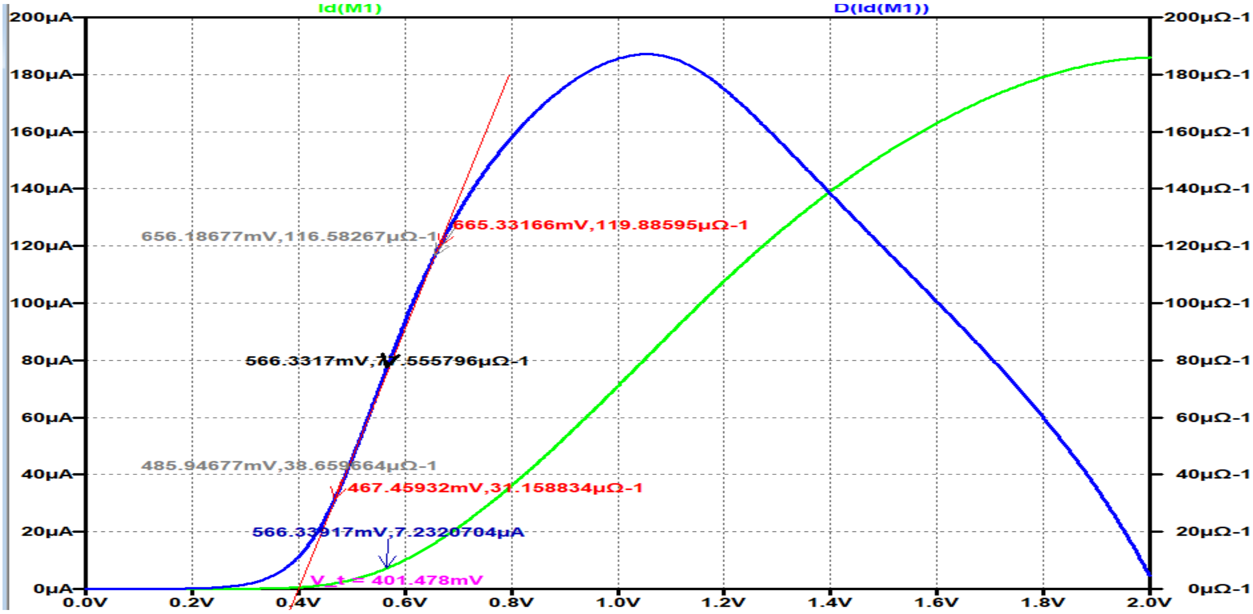

Figure 8: I_{ds} vs V_{gs}

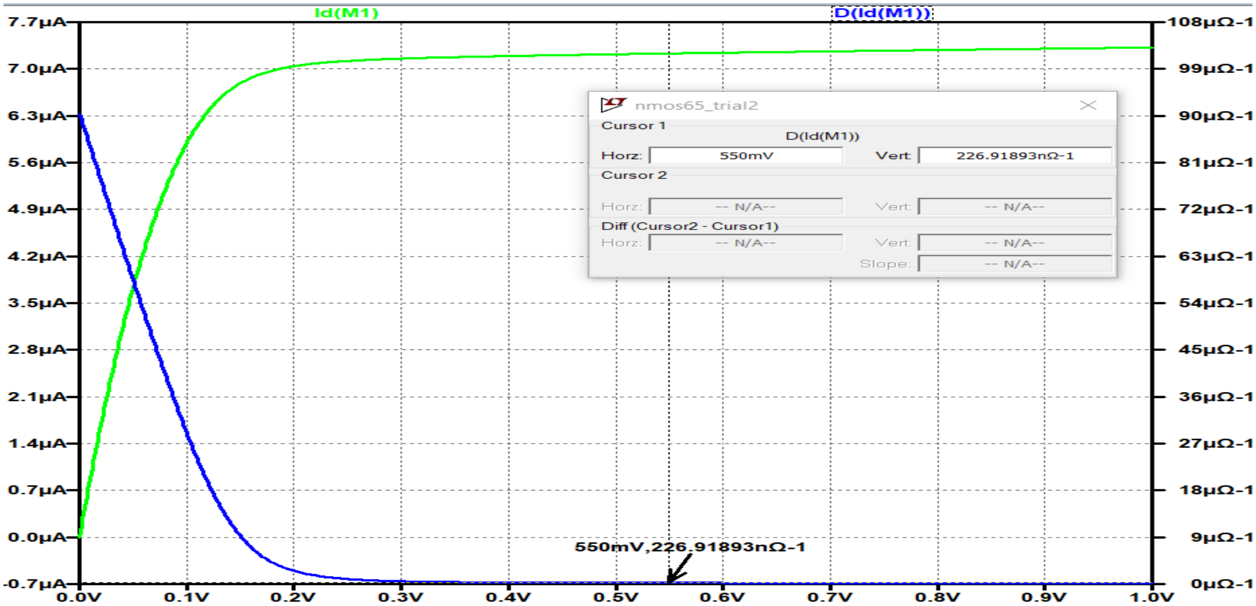

Figure 9: I_{ds} vs V_{ds}

Obtained Results

- $V_{gs0} = 566.3317\text{mV}$
- $g_{m0} = 77.55579\ \mu\mho$
- $V_T = 401.478\text{mV}$
- $\beta = 470.45\ \mu\mho\ V^{-1}$
- $I_{ds} = 7.2320\mu\text{A}$
- $g_{ds0} = 226.918\mu\mho$
- $\lambda = 0.03549\ V^{-1}$
- Range of V_{gs} for g_m with in 50% error: (485.946mV,656.186mV)

2.4 Small Channel PMOS

Given parameters are W = 1μm and L = 1μ. The following are the required circuits and graphs.

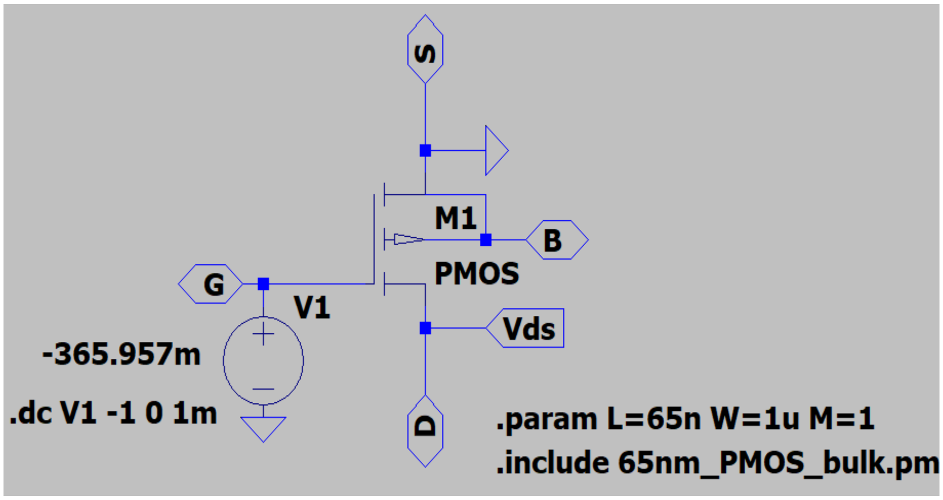

Figure 10: Circuit used for simulation

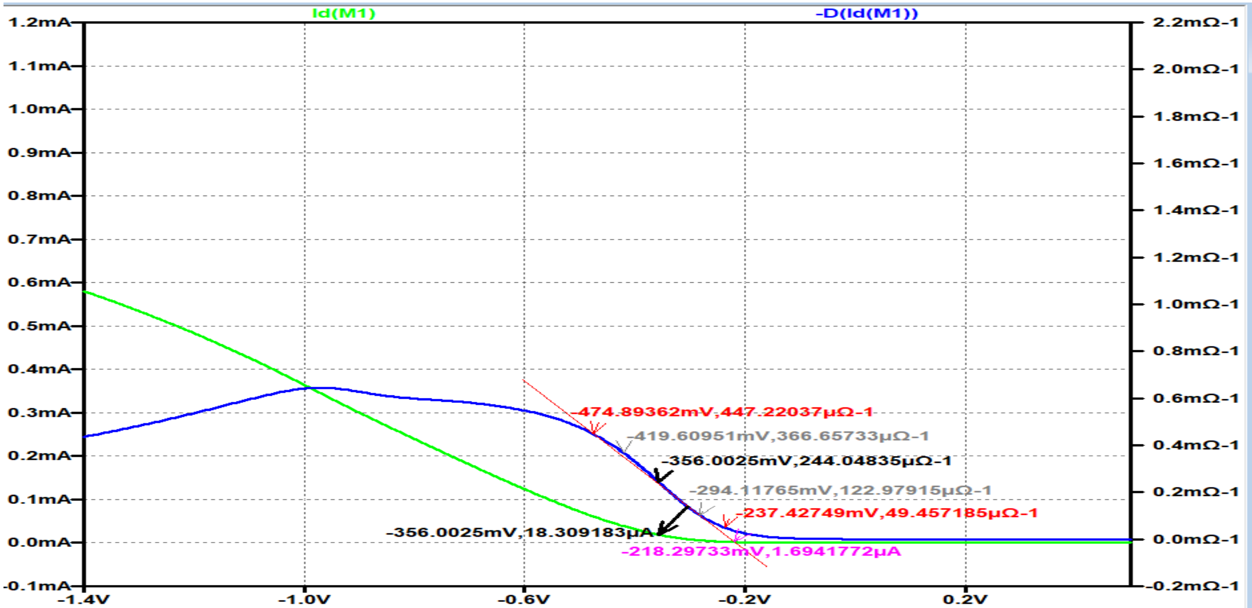

Figure 11: I_{sd} vs V_{gs}

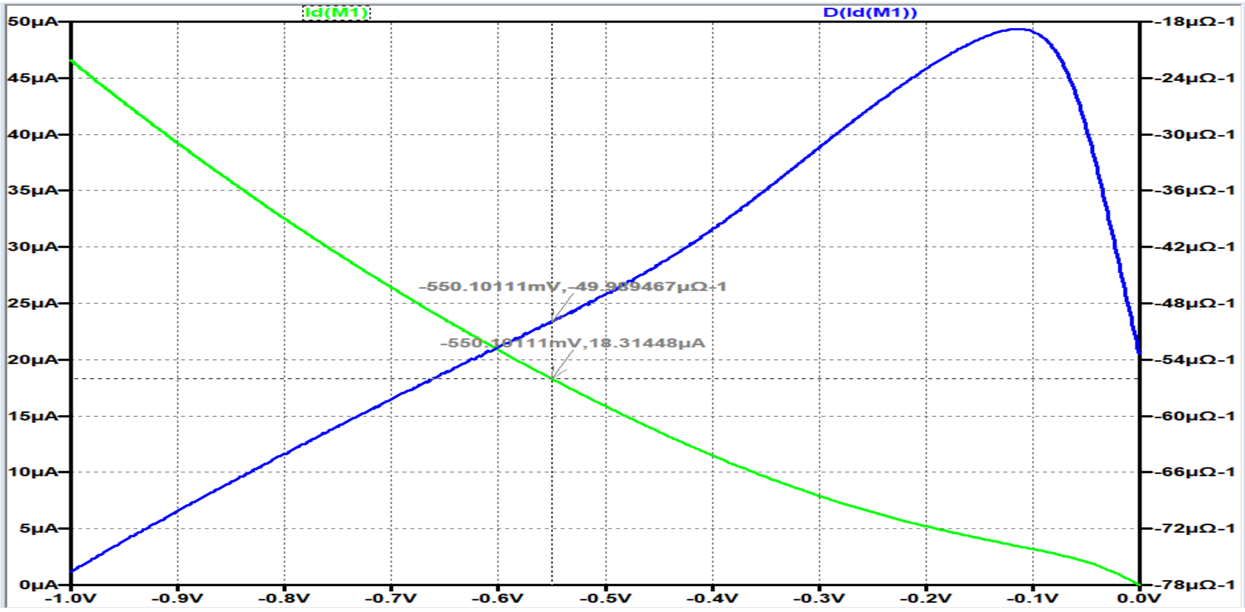

Figure 12: I_{sd} vs V_{ds}

Obtained Results

- $|V_{gs0}| = 356.002$mV
- $g_{m0} = 244.048\ \mu℧$
- $|V_T| = 218.297$mV
- $\beta = 0.115196$m $℧\ V^{-1}$
- $|I_{ds}|$ =18.309μA
- g_{ds0} =49.989$\mu℧$
- $\lambda = 2.9746\ V^{-1}$
- Range of $|V_{gs}|$ for g_m with in 50% error: (294.1176mV,474.89362mV)

2.5 Long Channel PMOS

Given parameters are W = 1μm and L = 1μ. The following are the required circuits and graphs.

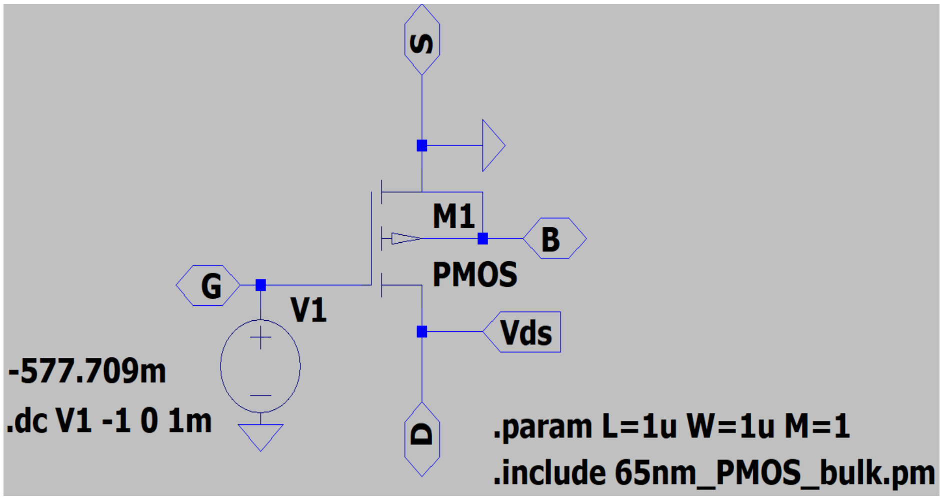

Figure 13: Circuit used for simulation

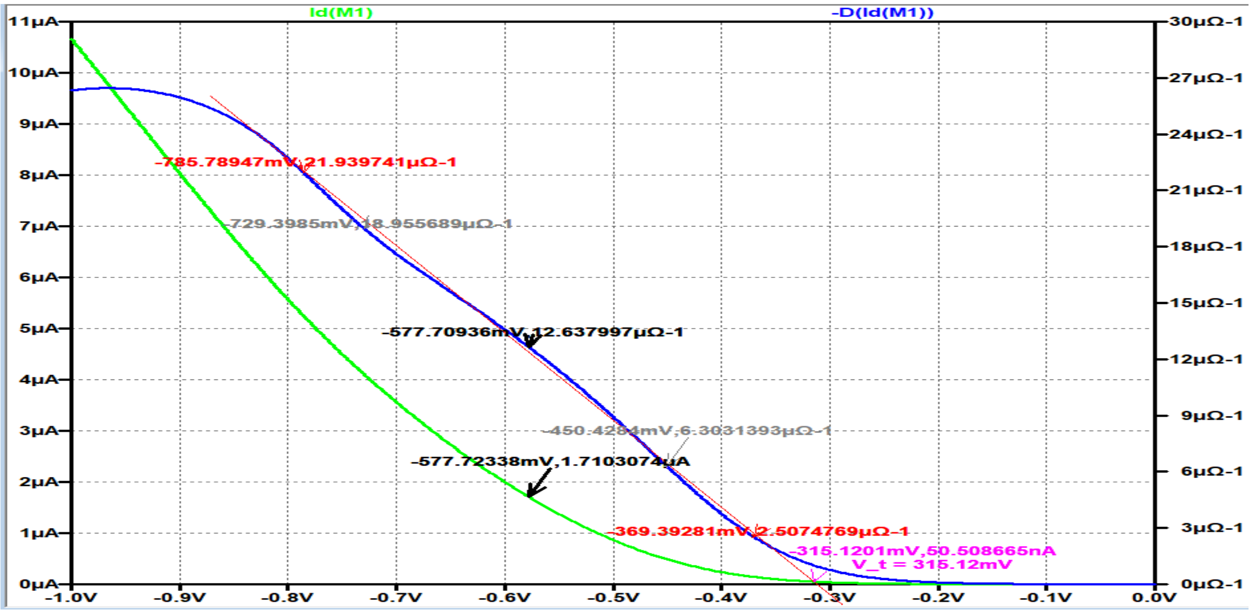

Figure 14: $|I_{ds}|$ vs V_{gs}

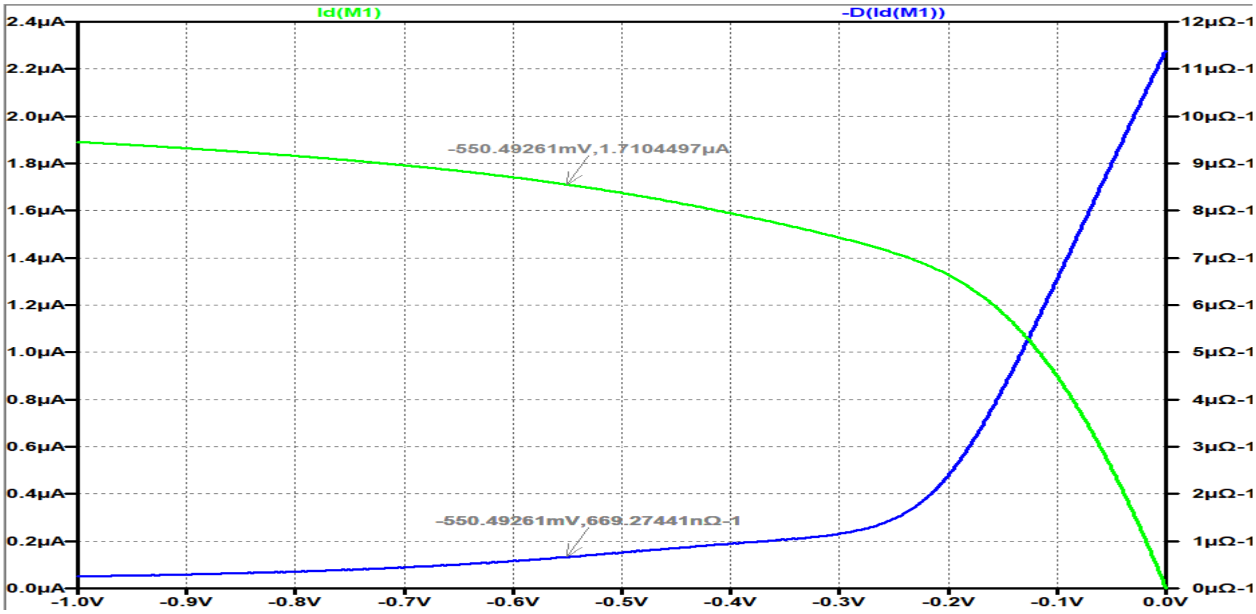

Figure 15: $|I_{ds}|$ vs V_{ds}

Obtained Results

- V_{gs0} = 577.7093mV
- g_{m0} = 12.637 $\mu\mho$
- V_T =315.12mV
- β = 481.246 $\mu\mho\ V^{-1}$
- I_{ds} = 1.710μA
- g_{ds0} = 669.2744$\mu\mho$
- λ = 0.4033 V^{-1}
- Range of V_{gs} for g_m with in 50% error: (485.946mV,656.186mV)

3 Observations and Conclusions

1. There are many intrinsic parameters in a MOSFET which can affect the characteristics.
2. The characteristics seem more deviated for short channel mosfets than long channel mosfets.
3. The affect of λ is more in short channel mosfets.
4. The estimates are not exact and can vary. With increase in precision and accuracy of measurements gives a better.