Lab 1: Introduction To Cadence And PMOS/NMOS Circuit Design

ECE715: Introduction To VLSI

Prepared By: Andrew Peloquin & Nick Snyder
Prepared For: Dr. MD Shaad Mahmud

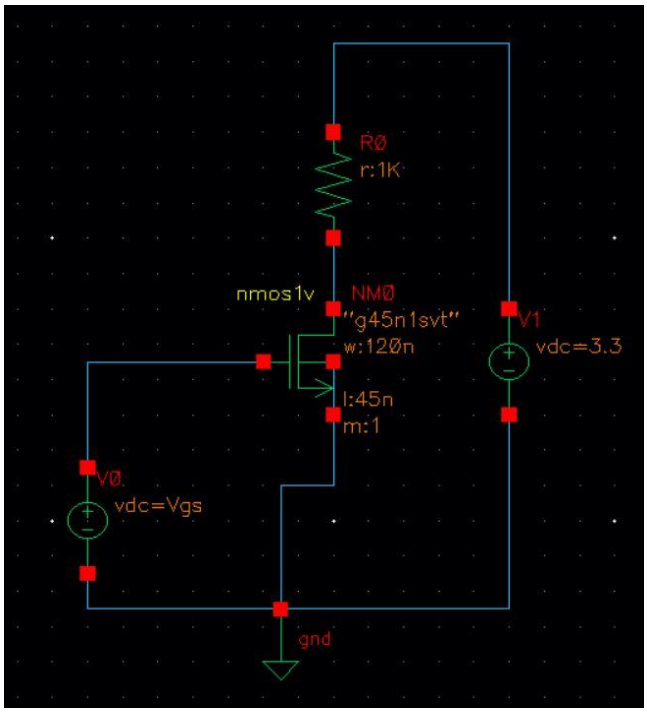
Due Date: 9/29/2023

Background

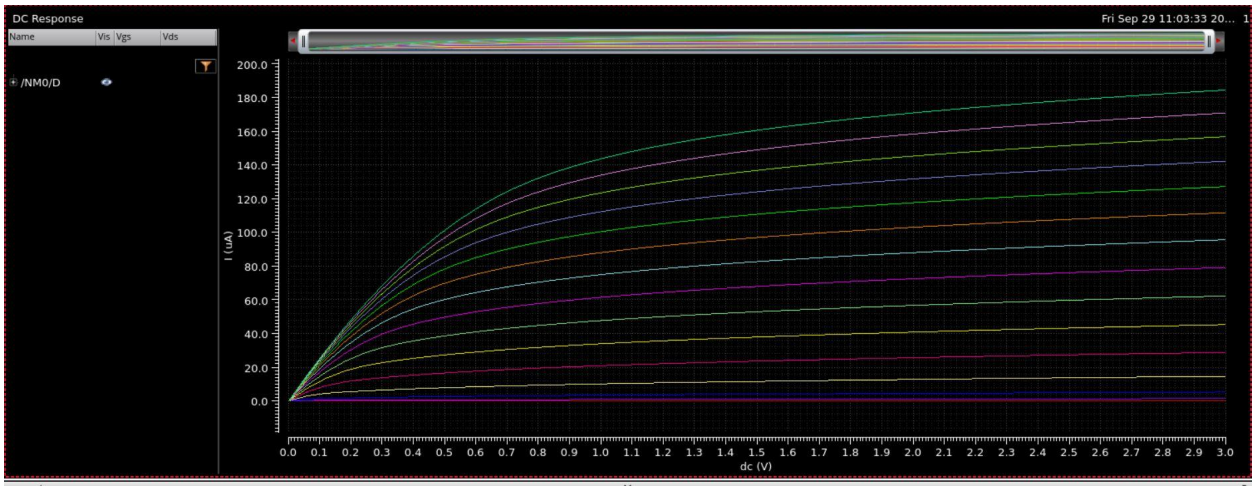
This lab was designed to familiarize students with the Cadence Virtuoso software and environment as there is definitely a large learning curve when it comes to this simulation environment. The objectives of this lab include getting comfortable with MobaXterm, Cadence, and Virtuoso as well as the various libraries within the design environment. This is done by the tasks included in the lab of designing two circuits, one with a PMOS and one with an NMOS. Students are then instructed to plot various important aspects of the circuits, and then calculate some other important variables involved within the circuit. This procedure is performed on both a PMOS and an NMOS based circuit.

NMOS Tasks

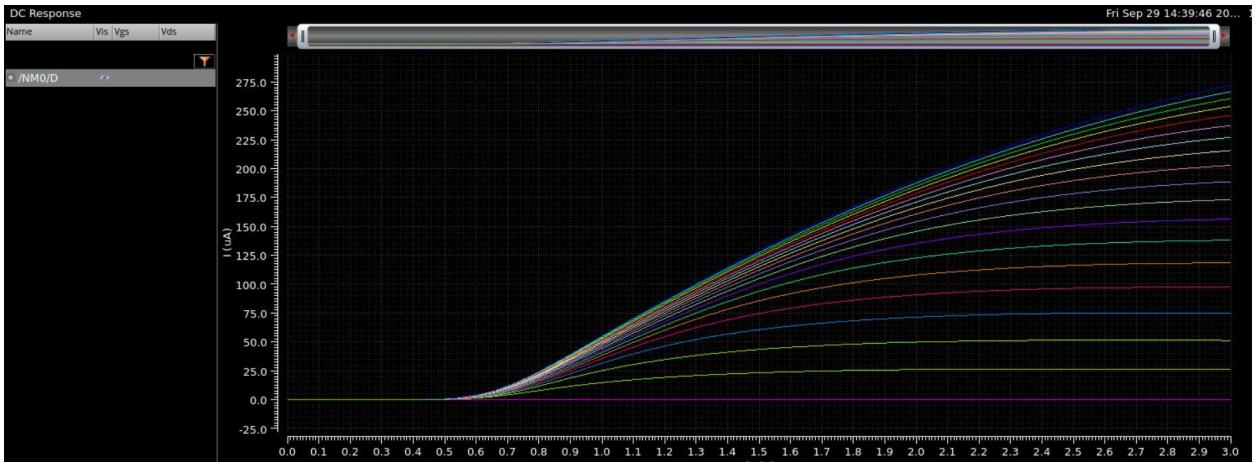
Design Schematic



ID vs VDS Plot

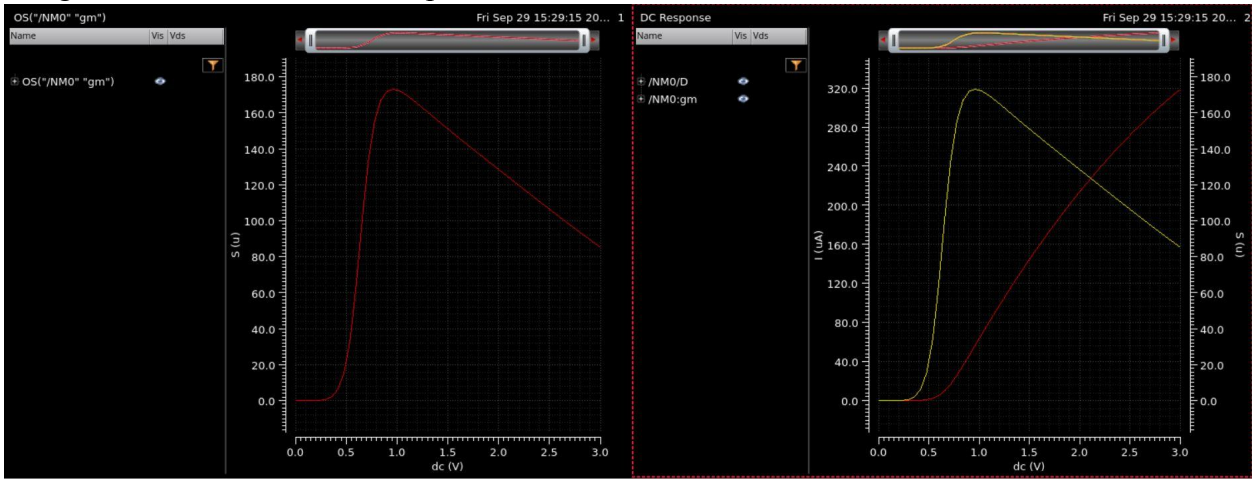


ID vs VGS Plot



Discussion

The gm value can be seen in this plot below.



Below are the values of Vth ,Vth0, and Gamma that were produced from the calculator. Unfortunately the Vth0 values are all null (NaN). In addition the gamma values are all 0, which would make sense due to the strange values or lack thereof for Vth0.

vth	vth0	pro_Gamma
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0
584.915m	NaN	0

Solving for λ

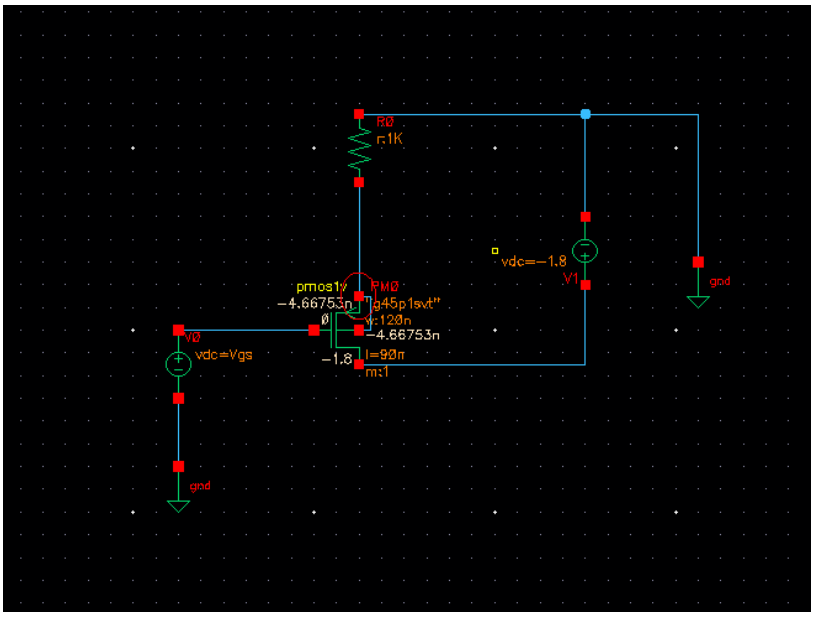
Since μ and Cox were not visible in virtuoso, two experimental values were selected.

$$\mu = 4cm^2/Vs$$
$$Cox = 450\, fF/\mu m^2$$
$$Vgs = 3.29994$$
$$Vth = 584.815m$$
$$iD = 342.112\mu$$
$$Vds = 2.957$$
$$L = 45nm$$
$$W = 140\, nm$$
$$\lambda = (L - W * Cox * \mu * (Vgs - Vth)^2 \,/\, iD) \,/\, Vds)$$
$$\lambda = 1.279x10^{-15}$$

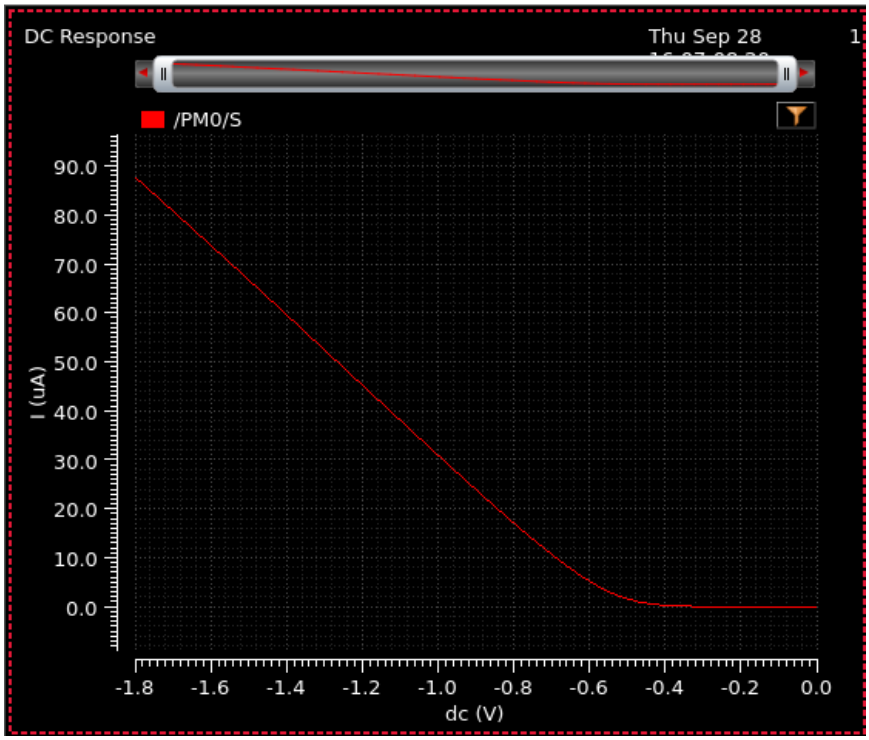
As stated earlier these values are all approximated and not a fully accurate calculation. How do these calculated and measured values make sense? As far as the gm (transconductance) and Vth they both make perfect sense as seeing the gm plotted against id shows exactly when gm starts decreasing which lines up with the threshold voltage as well as the increase in id.

PMOS Tasks

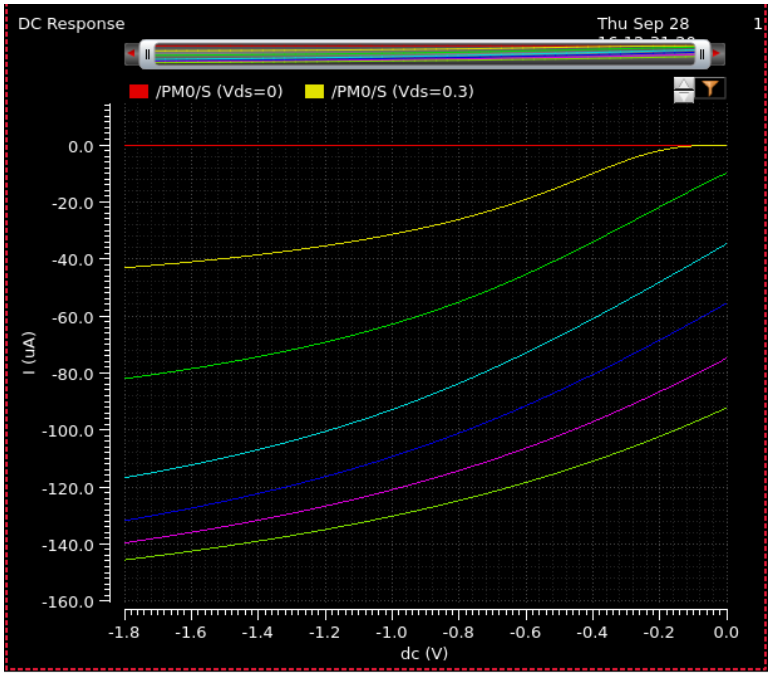
Schematic:



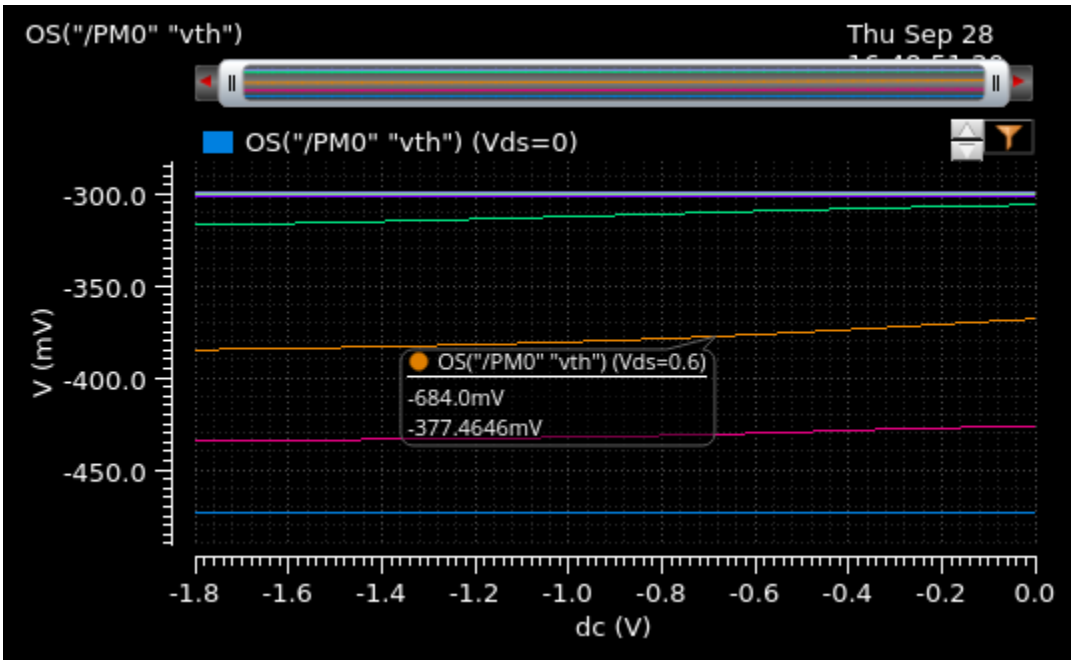
V_{gs} vs. I_d



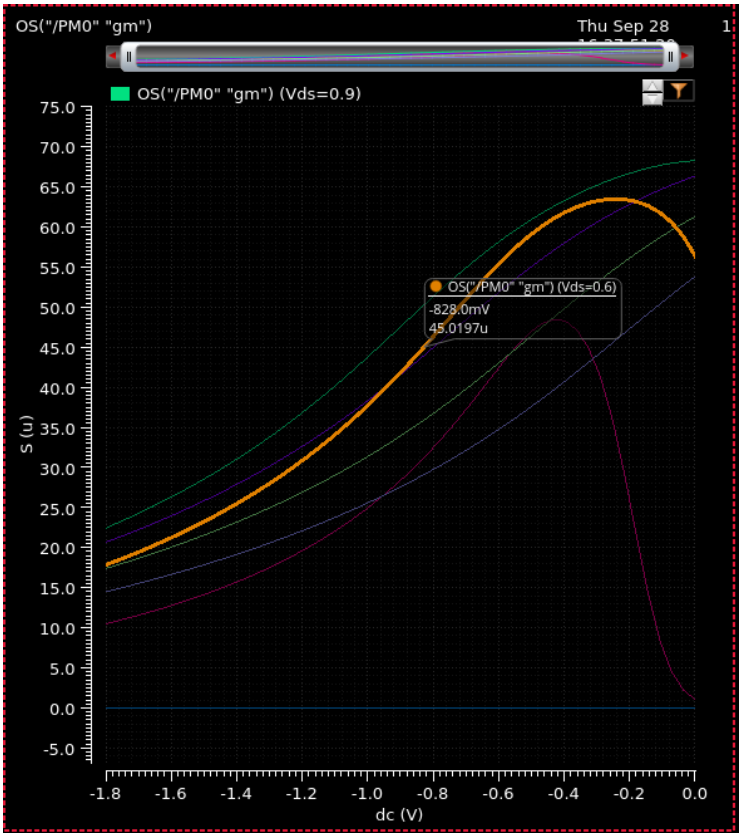
V_{ds} vs. I_d



V_{gs} vs. V_{th}



V_{gs} vs. g_m



Hand Calculations

λ

Due to VPN problems preventing me from accessing Cadence and getting the exact Q-point, I calculated lambda and gamma using a made up Q-point using non-exact points on the graphs pictured above.

$$\mu = 4cm^2/Vs \quad \text{Estimated}$$
$$Cox = 450\ fF/\mu m^2 \quad \text{Estimated}$$
$$Vgs = -684mV \quad \text{From Graph}$$
$$Vth = -377mV \quad \text{From Graph}$$
$$Id = 10\mu A \quad \text{From Graph}$$
$$Vds = 300mV \quad \text{From Graph}$$
$$L = 90nm \quad \text{From Schematic}$$
$$W = 120\ nm \quad \text{From Schematic}$$

$$(2*I_d)/(\mu * C_{ox} * W/L * (|V_{gs}| - |V_{th}|)^2 * V_{ds}) = \lambda$$

Plugging in the values results in $\lambda = 0.0128V^{-1}$

γ

V_{th0} was not measured beforehand so I used a similar value toV_{th}

$$2\varphi_F = 0.6V \quad \text{Estimated}$$
$$V_{SB} = 0V \quad \text{From Schematic}$$
$$V_{th0} = -500mV \quad \text{Not Exact}$$

$$V_{th0} - V_{th} / (\text{sqrt}(|-2\varphi_F + V_{SB}|) - \text{sqrt}(|-2\varphi_F|)) = \gamma$$

Plugging in the values results in $\gamma = 0.246V^{-1/2}$

Challenges

Andrew

The challenges faced mainly had to do with user error and poor planning. This lab should have been looked at sooner, but was left a little later than it should have been. Due to this factor the various issues associated with the learning curve of virtuoso lead to some slower progress at first. Forgetting some smaller yet very important options such as saving the DC Operating Points lead to some setbacks but nothing that was not overcome quickly.

Nick

The main challenge was just using the software. Cadence Virtuoso is not a very intuitive program and everything asked to do in this lab was buried in separate menus and tabs. During the first in-class tutorial, I got an error preventing me from opening Virtuoso. That took away valuable experience as I could have followed along in the moment rather than waiting for the pdf instructions to be posted. I needed to be hand-held through the whole lab when I stayed after class on Thursday. When I needed to go back to Virtuoso because I forgot to get the Q-point, I couldn't because I went home for the weekend and didn't set up PulseSecure. The guides from UNH IT only resulted in errors so I was basically dead in the water.

Contributions

The various meetings and communications between group members were all conducted through Discord. As far as the delegation of tasks, Andrew took all tasks associated with the NMOS circuit while Nick took care of all of the tasks associated with the PMOS circuit. In addition the separate sections of the lab report were delegated evenly amongst the two. Andrew wrote the objectives, and contributions sections while Nick wrote the conclusion portion.

Conclusion

Some of the objectives of the lab were to get familiar with MobaXterm, Linux Operating System and Cadence Virtuoso, gain experience designing digital systems, developing skills to test and verify implementations, and inspiring self-education. Neither of us had used either MobaXterm or Cadence Virtuoso before this class and now we are able to design simple circuits using the design specifications. I wouldn't go as far as saying we are proficient, but we are on our way to the top of the steep learning curve. Our hand calculations helped verify our results from Virtuoso. We both faced challenges relating to time management and will try not to repeat that again. For the next labs, we will try to start sooner and finish sooner. We look forward to learning more and more about Cadence as time goes on.