Inf3410 Lab2

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1 Prelab

1.1 Task 1

In this task I made a general EKV model based on the forumla given in the lecture notes and the EKV paper.

```
lambda = 0.16;
Vtn = 0.57;
VT = 0.026;
beta = 0.00019;
Is = 2*beta*(VT^2)
Mult = 1+lambda*VDS
Vov = VGS - Vtn;
id = ((log(1+exp(Vov/(0.026)))^2)-(log(1+exp((Vov-VDS)/(0.026)))^2))*Is*Mult;
```

Figure 1: Matlab code

Figure 1 shows my EKV model in matlab with VDS and VGS as variables

1 - If VDS is set to greater or equal to the end voltage of the VGS sweep (3.3V in this case) minus Vtn (0.57V) the curve will stay in the active region. This means the lowest value I could have given VDS for it to stay in the active region during the entire plot is 2.73V. The reason for this is Vsat is equal to VGS - Vtn, and for the curve to stay in the active region VDS needs to be greater or equal to Vsat. To stay on the safe side I used VDS = 3.3V in my plots.

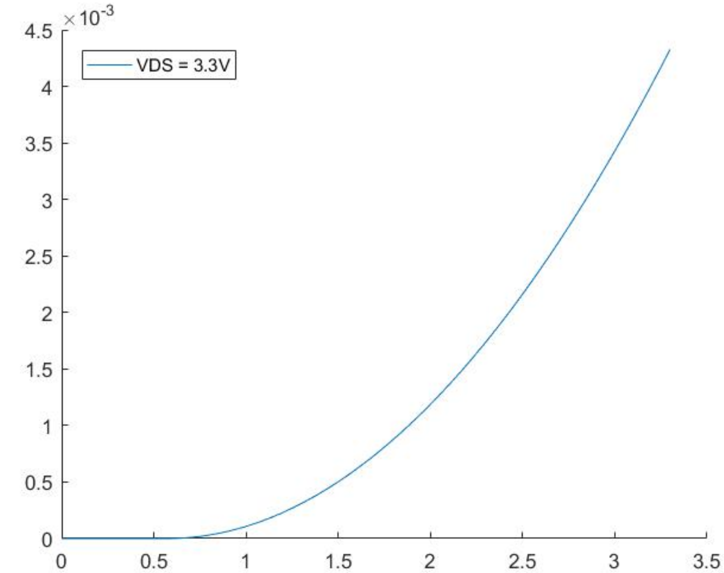

Figure 2: Id as a function of VGS

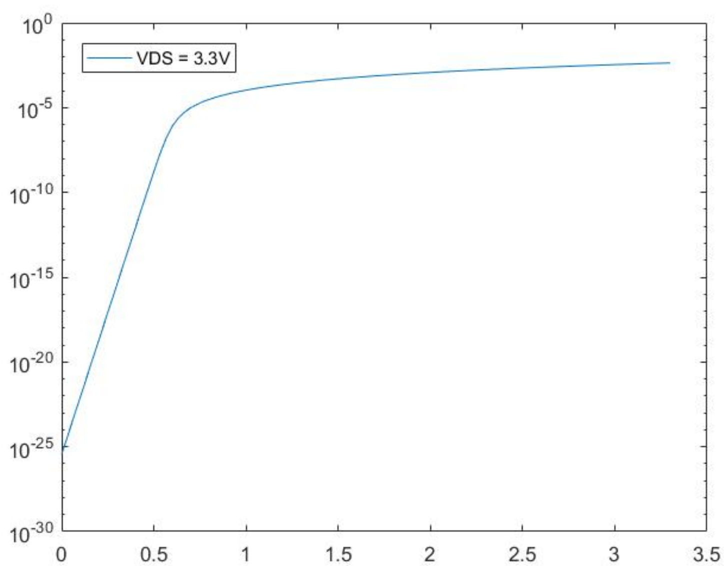

Figure 3: Id as a function of VGS with logarithmic Y axis

2 - In the transition from weak to strong region (moderate region) the Vsat will be so small that there will always be a point where VDS is greater than Vsat and a point where VDS = Vsat which will put the curve in active region. To make this gap as small as possible we can make VDS very small. This point will happen at VGS = Vtn. I have used VDS = 90mV in my model. I have marked this point on my graphs.

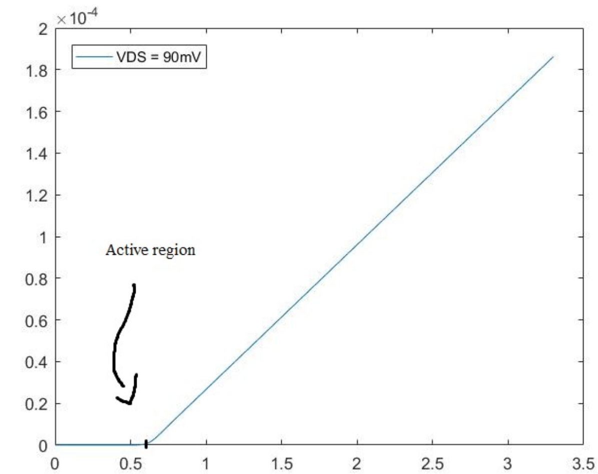

Figure 4: Id as a function of VGS

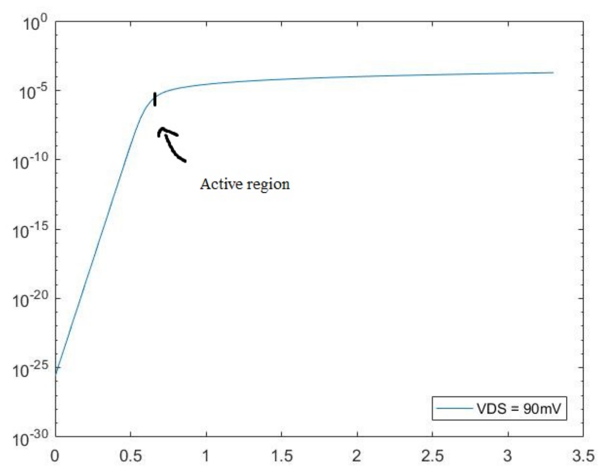

Figure 5: Id as a function of VGS with logarithmic Y axis

3 - To ensure the curve is in strong inversion I have selected VGS values larger than Vtn. In this Model I have used VGS values 0.9V, 1.3V, 1.7V, 2.1V, 2.5V, 2.9V, and 3.3V. Since these curves will always be in strong inversion we know that Vsat is equal to VGS - Vtn, and we can see how they enter the active region at the kneepoints (Vsat).

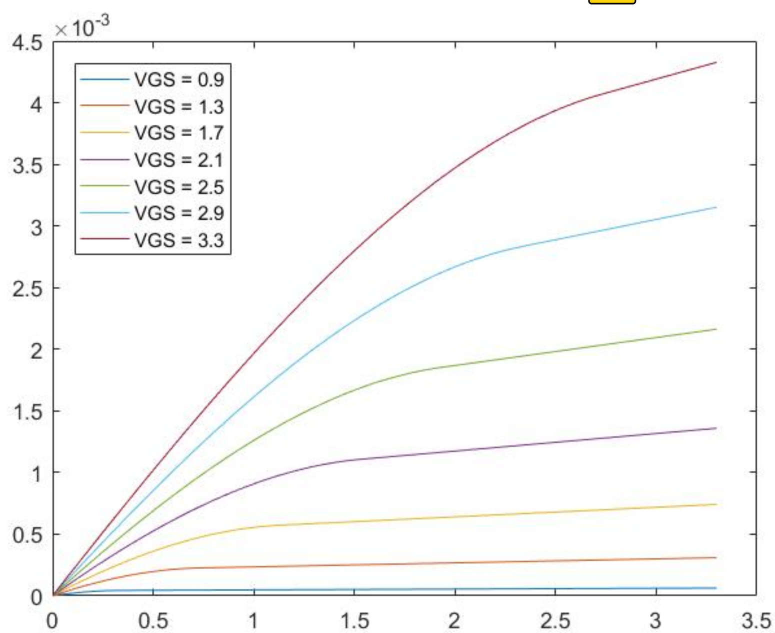

Figure 6: Id as a function of VDS

4 - To ensure the curve is in weak inversion I have selected VGS values smaller than Vtn. The issue I run into when I plot this model is my different VGS values will create results that are around 10^{-4} apart and the plot will only show one at the time. I added a logarithmic plot to show what values the curves are. From the plot we can at least see that the curve hits a kneeepoint much earlier than the previous plot. This happens because VGS is smaller than Vtn and Vsat = VT*4 $\approx$ 0.1V . The curves will enter the active region at around 0.1V.

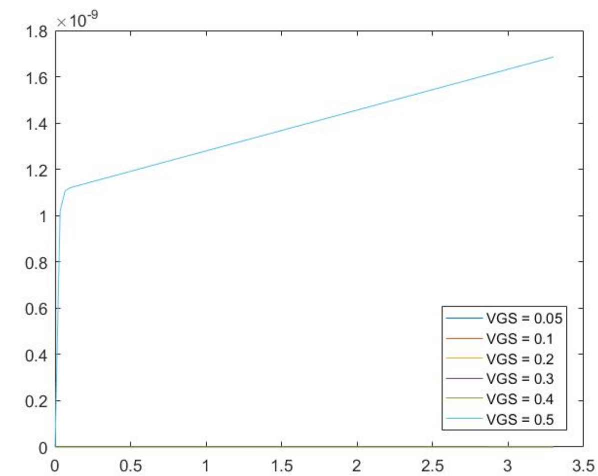

Figure 7: Id as a function of VDS

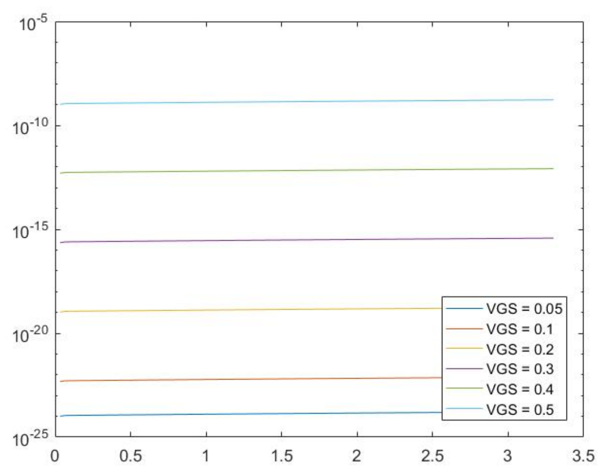

Figure 8: Id as a function of VDS with logarithmic Y axis

2 Simulation

2.1 Task 2

1 - Cadence simulations for a VGS sweep in the active region

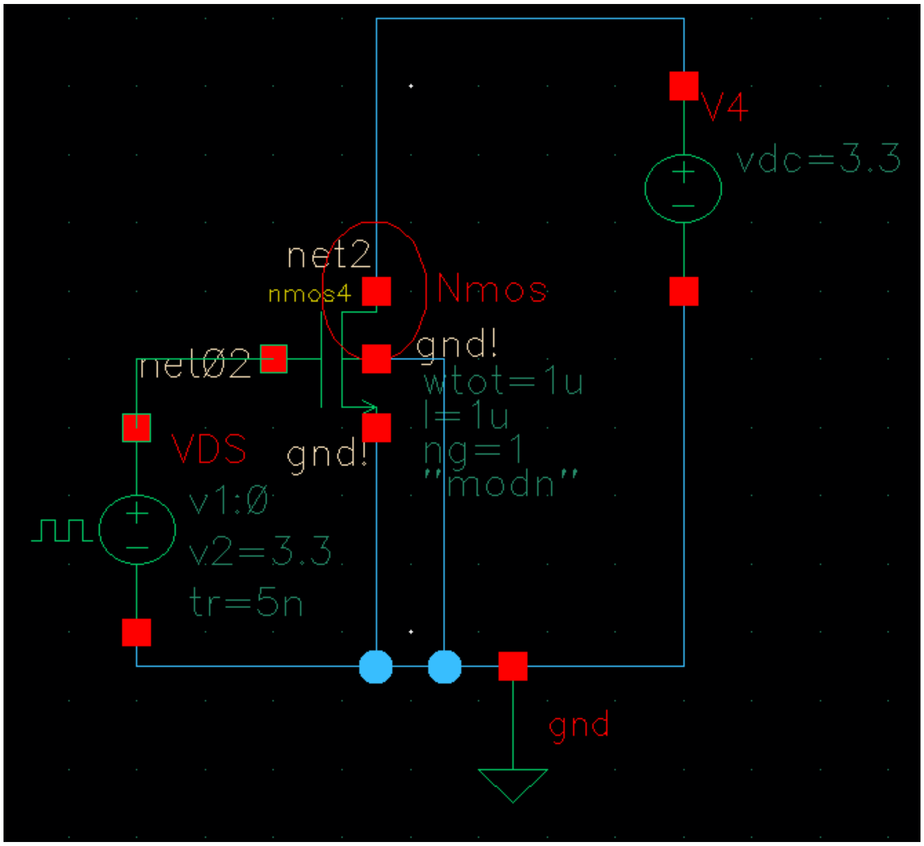

Figure 9: Schematic of a simulation over Ids as a function of VGS

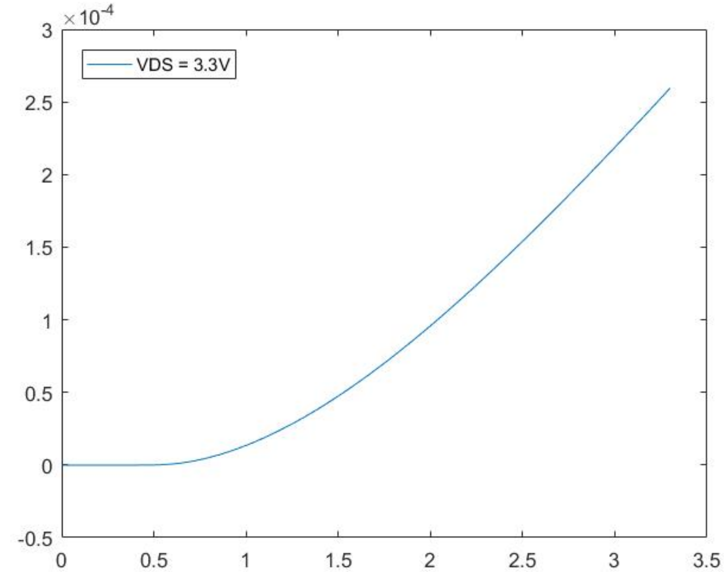

Figure 10: Id as a function of VGS

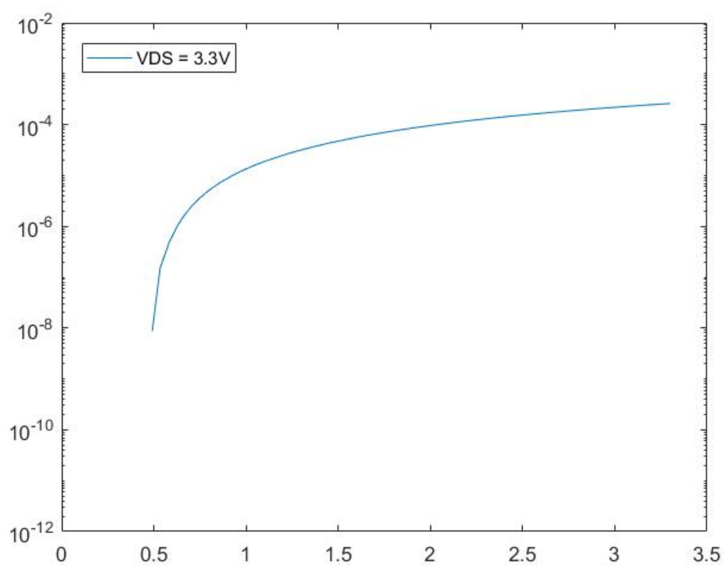

Figure 11: Id as a function of VGS with logarithmic Y axis

2 - Cadence simulations for a VGS sweep in the triode region. Schematics are the same as figure 9, only different is VDC = 90mV for this simulation.

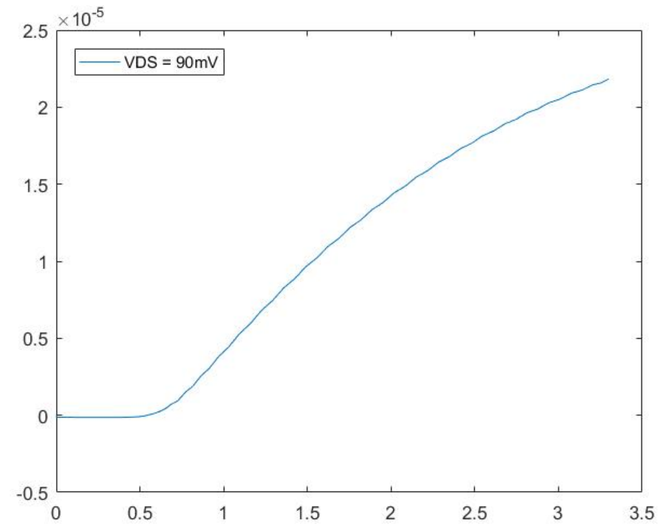

Figure 12: Id as a function of VGS

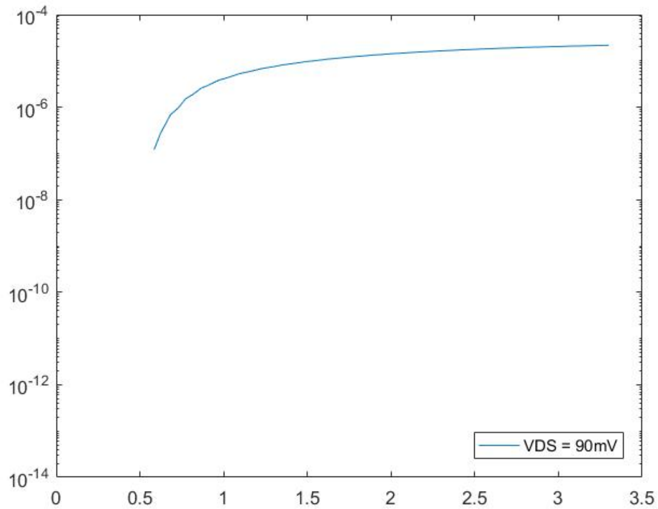

Figure 13: Id as a function of VGS with logarithmic Y axis

3 - Cadence simulations for a VDS sweep in strong inversion with different VGS values. VGS is set to the same values as in task 1.

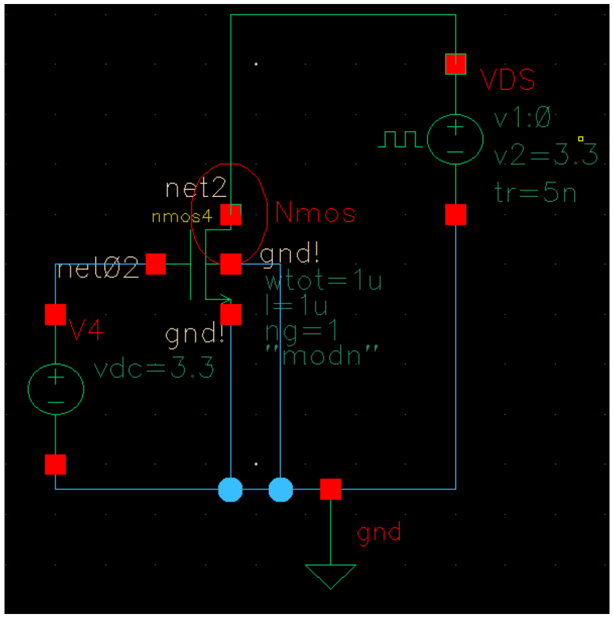

Figure 14: Schematic of a simulation over Ids as a function of VDS

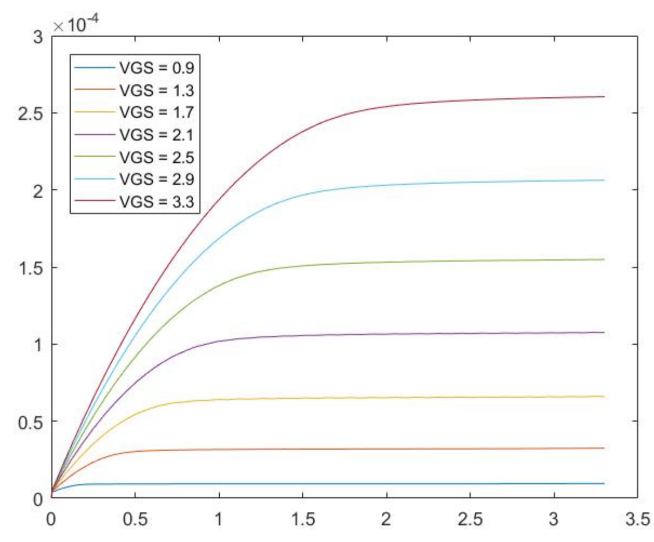

Figure 15: Id as a function of VDS

4 - Cadence simulations for a VDS sweep in weak inversion. Schematics are the same as figure 14, only different is VGS is set to different values as shownn in the plot.

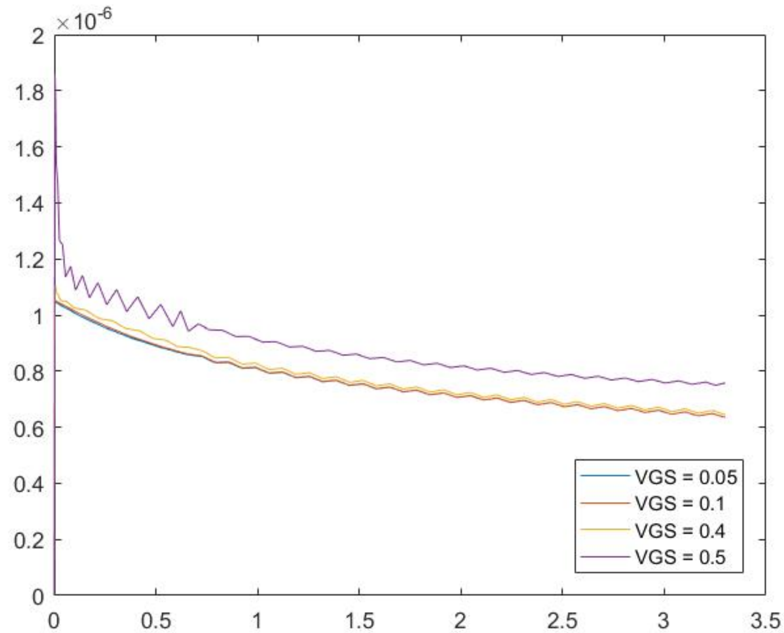

Figure 16: Id as a function of VDS

2.2 Task 3

I noticed my model starts curving upwards earlier than the cadence simulations, so I adjust Vtn upwards to make it reach strong inversion at a higher voltage to match the curve. After doing some tuning I end up setting it to Vtn = 0.6 to get a nice curve. Next I want to adjust the beta to make my model match the amplitude of the simulation, I tune it down by negative 10x and find I get a nice match at around $2.3 * 10^{-5}$. The angle of the curve is still a bit off so I tune the lambda value down by around negative 10x and set it to 0.016.

I end up with these values in my model:
Vtn = 0.6
$\beta = 2.3 * 10^{-5}$
$\lambda = 0.016$

I couldn't get it to fit all the different simulations perfectly, but I'm satisfied with the results I managed to get.

Note: I could not get the model for weak inversion to match the simulations with these new parameters.
I'm including plots showing both the model and the cadence simulated curves in the same plot for non adjusted and adjusted versions.

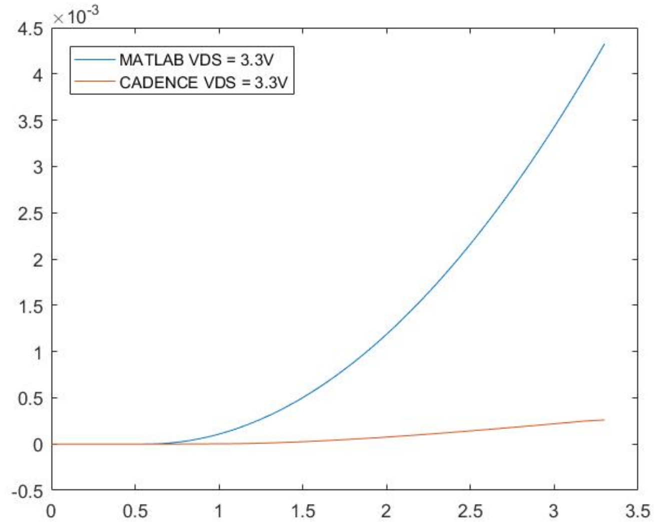

Figure 17: Id as a function of VGS

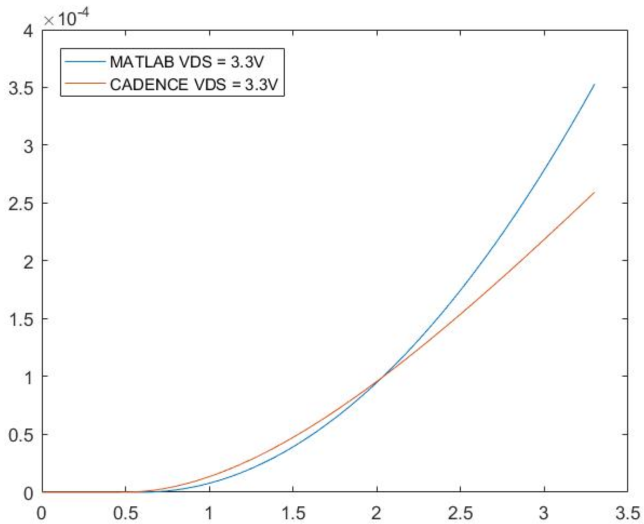

Figure 18: Id as a function of VGS with adjusted matlab model

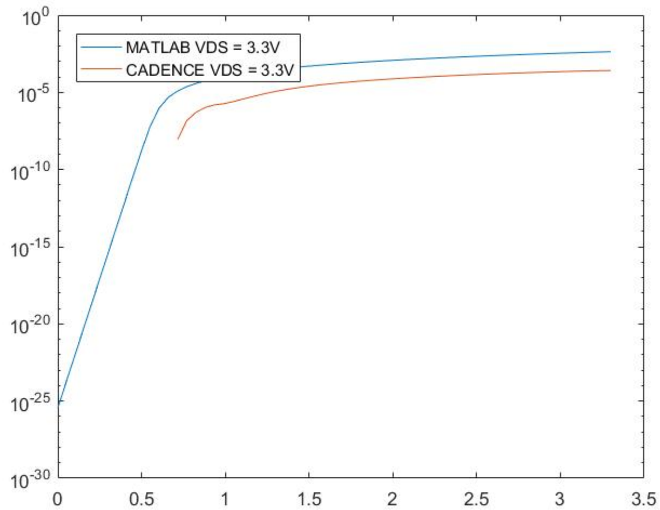

Figure 19: Id as a function of VGS with logarithmic Y axis

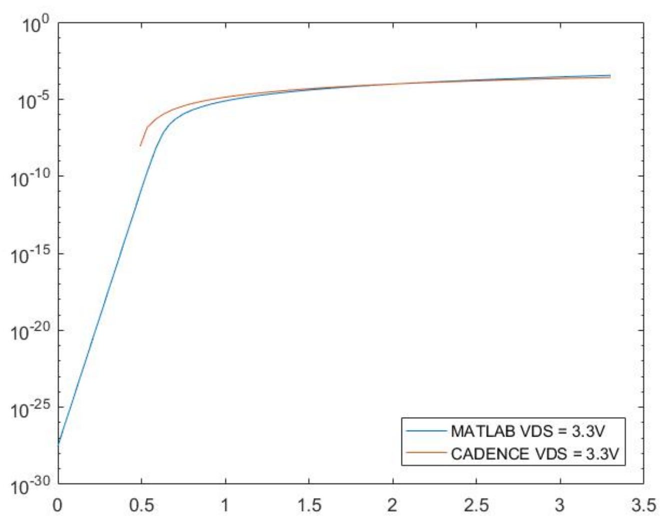

Figure 20: Id as a function of VGS with logarithmic Y axis and adjusted matlab model

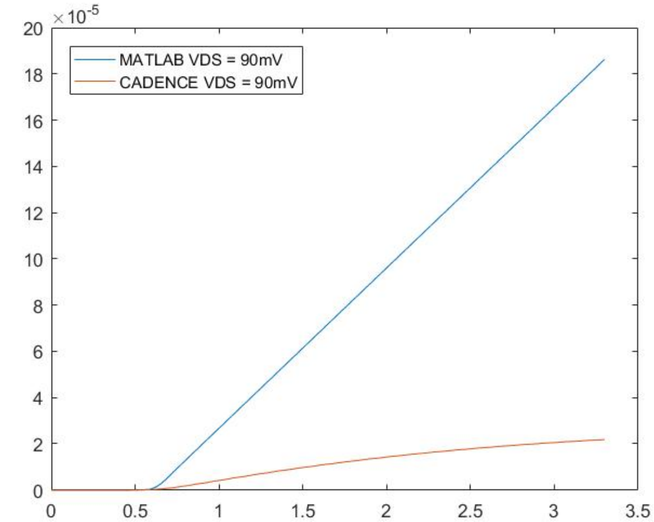

Figure 21: Id as a function of VGS

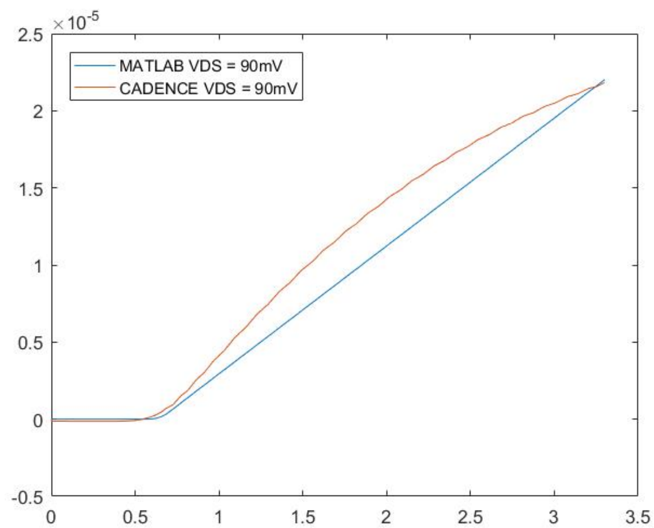

Figure 22: Id as a function of VGS with adjusted matlab model

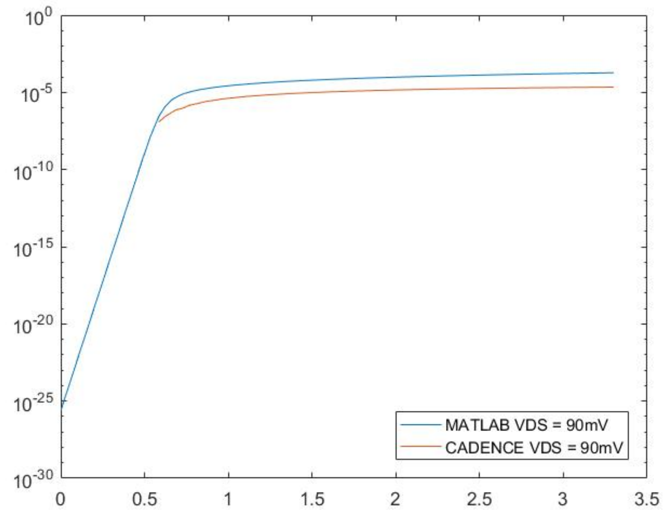

Figure 23: Id as a function of VGS with logarithmic Y axis

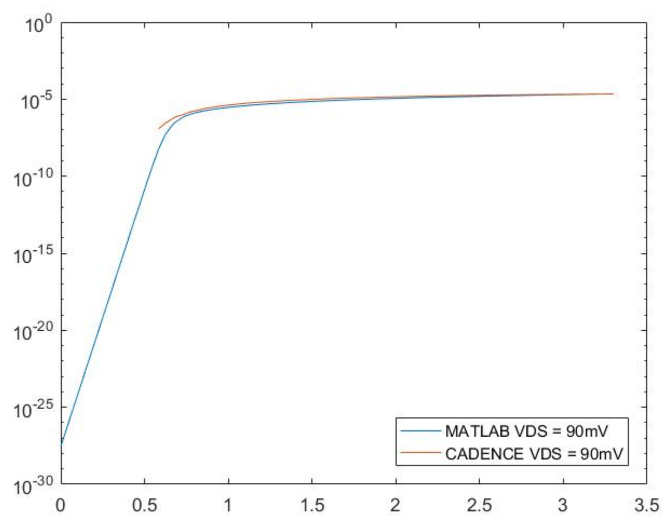

Figure 24: Id as a function of VGS with logarithmic Y axis and adjusted matlab model

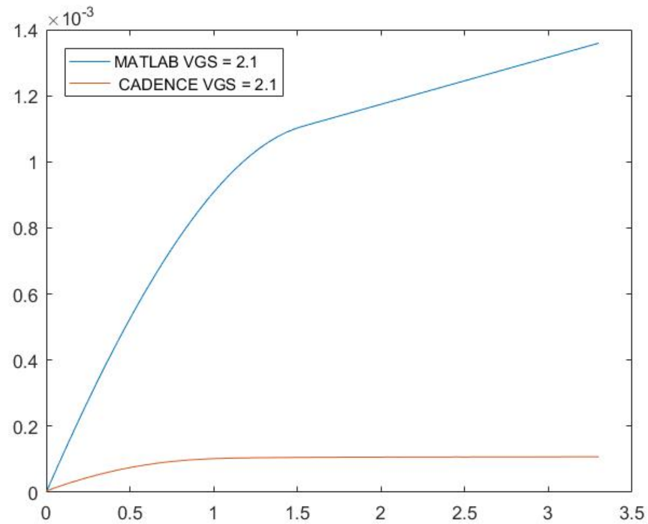

Figure 25: Id as a function of VDS

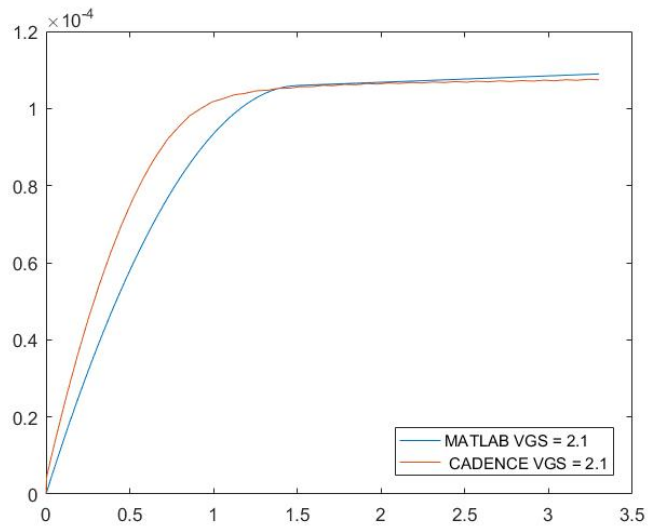

Figure 26: Id as a function of VDS with adjusted matlab model

3 Measurement

3.1 Task 4

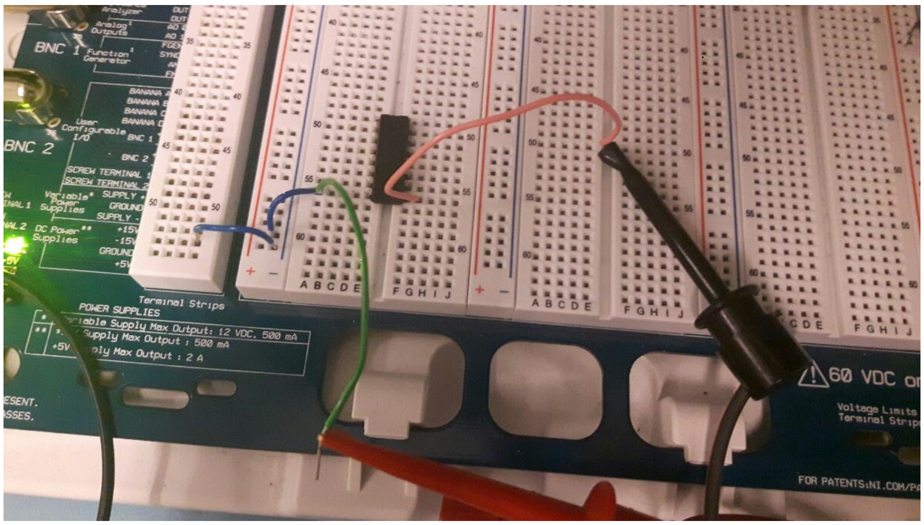

Figure 27: My PCB for task 4

To do my measurements I used the instruments for voltage supply and multimeter and measured over the same voltages as I used in the previous tasks.

1 - For this measurement I used VDS = 3.3V and a sweep of VGS from 0 - 3.3V with 100 iterations.

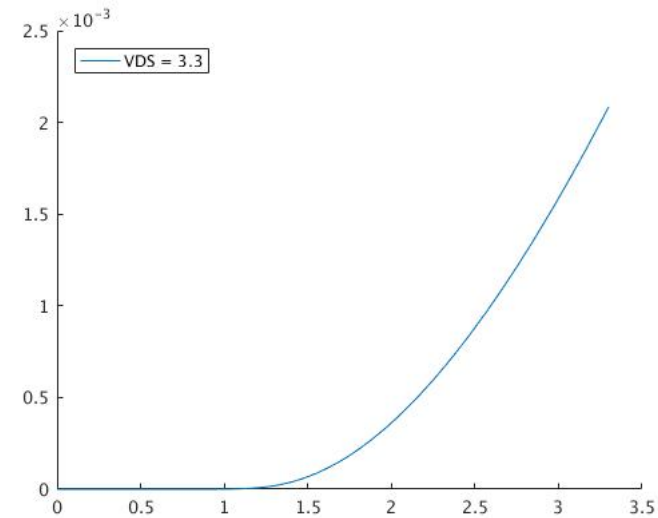

Figure 28: Id as a function of VGS

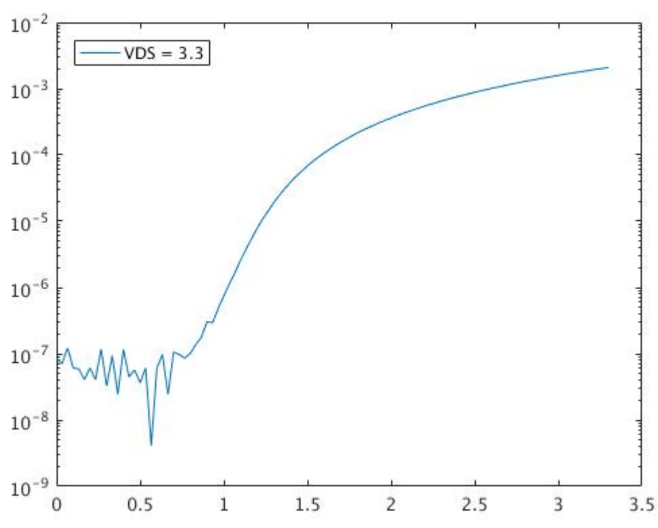

Figure 29: Id as a function of VGS with logarithmic Y axis

2 - For this measurment I used VDS = 90mV and a sweep of VGs from 0 - 3.3V with 100 iterations.

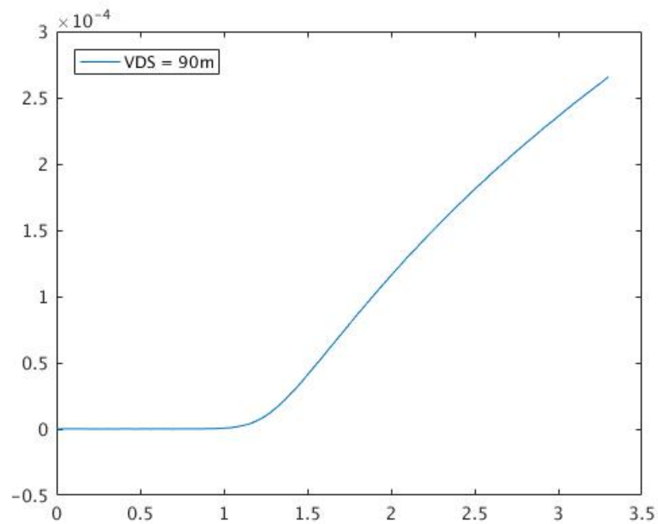

Figure 30: Id as a function of VGS

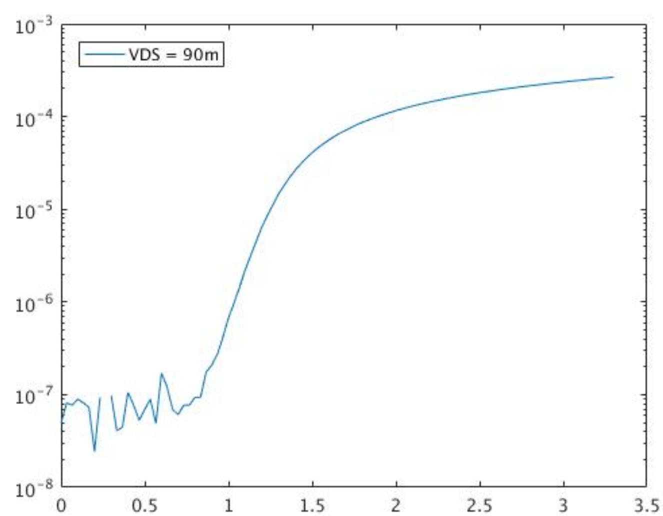

Figure 31: Id as a function of VGS with logarithmic Y axis

3 - For these measurements I used the same VGS values as the previous tasks and a sweep of VDS from 0 - 3.3V with 100 iterations.

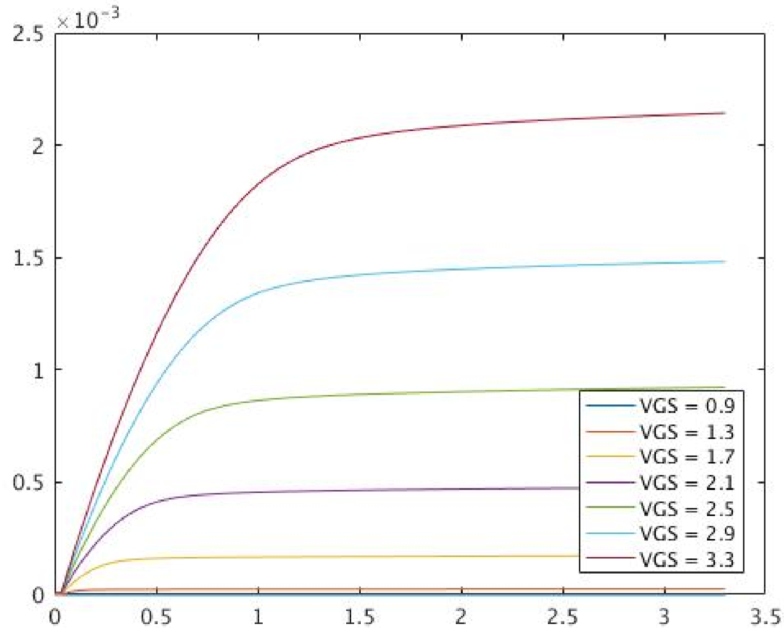

Figure 32: Id as a function of VDS

4 - For these measurements I used the same VGS values as the previous tasks and a sweep of VDS from 0 - 3.3V with 100 iterations. It seems like the multimeter had some issues correctly measuring voltages as small as these ones so it ended up with a lot of noise and a fairly unreadable plot. I have included a plot of just one VGS value aswell.

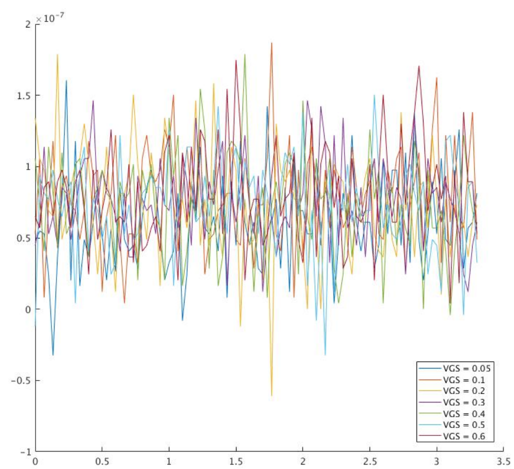

Figure 33: Id as a function of VDS

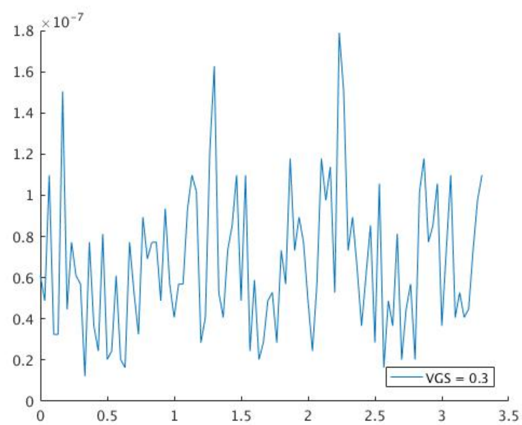

Figure 34: Id as a function of VDS

3.2 Task 6

I followed the same steps as I did in task 3 and started fine-tuning my parameters, it was hard to get a good fit for all models, but I ended up with a result I'm pleased with. The main change I made was the increased Vtn. It seems like the measured curves transitioned into strong inversion at higher voltages than the simulated curves.

I end up with these values in my model:
Vtn = 1.1
$\beta = 2.5 * 10^{-5}$
$\lambda = 0.016$

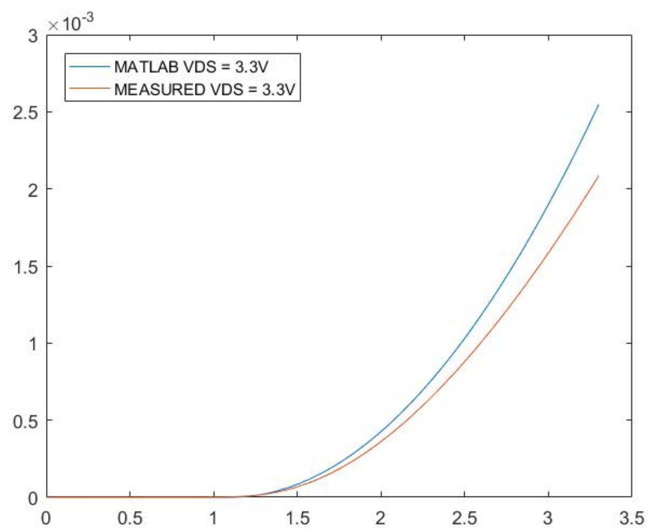

Figure 35: Id as a function of VGS with adjusted matlab model

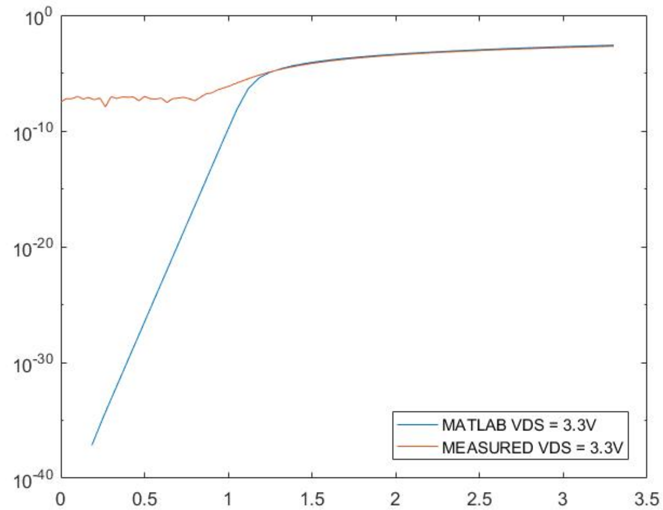

Figure 36: Id as a function of VGS with logarithmic Y axis and adjusted matlab model

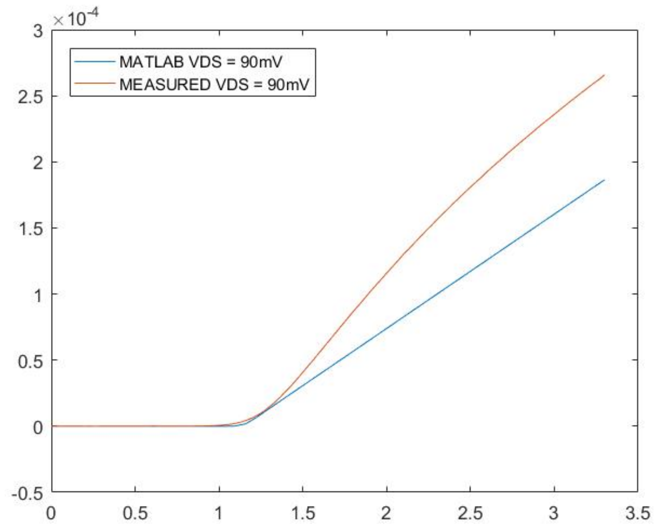

Figure 37: Id as a function of VGS with adjusted matlab model

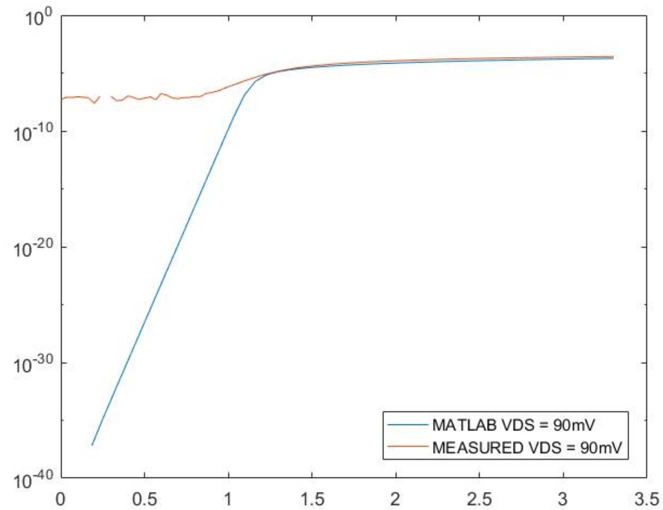

Figure 38: Id as a function of VGS with logarithmic Y axis and adjusted matlab model

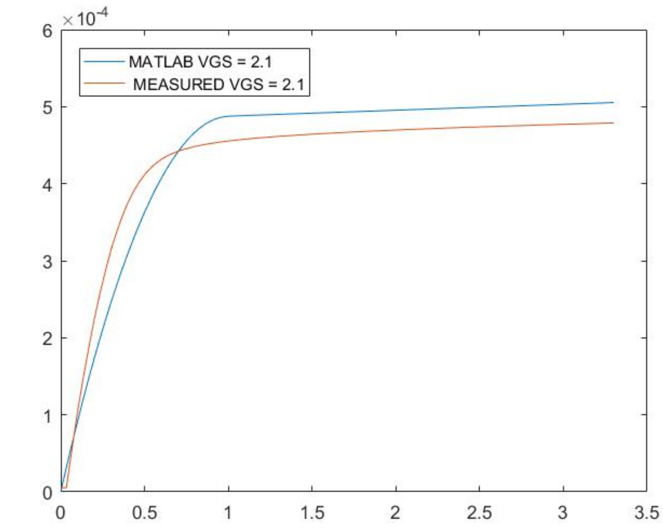

Figure 39: Id as a function of VDS with adjusted matlab model

4 Common Source Amplifier

4.1 Task 6

For this task I used resistors with value 1M, 330k, and 3.3k. I couldn't find any resistors larger than 1M at the lab. I used a VDD of 4V. The amplifier with the largest resistor has the largest gain.

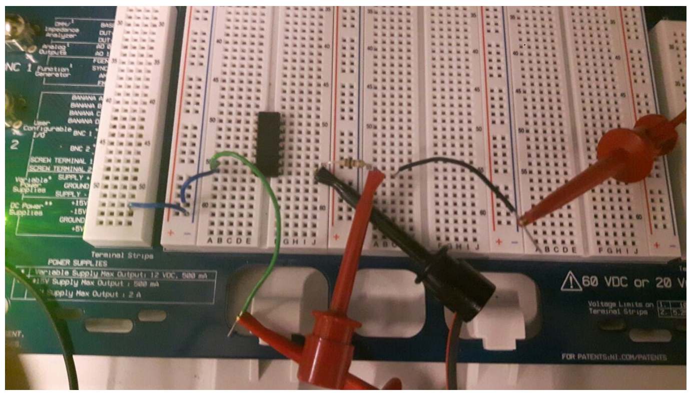

Figure 40: My PCB for task 6

It seems like the amplifier would be nicely biased with a VGS of around 1.1V. The gain of this amplifier is around 25. The current around this bias point should be around $1.1 * 10^{-6}$.

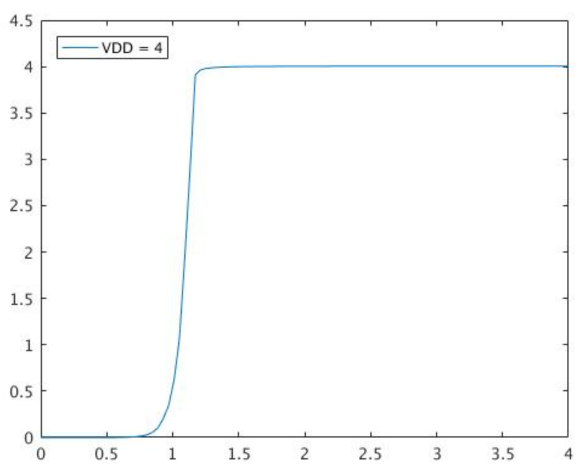

Figure 41: Common source amplifier with a 1M resistor

The amplifier would be nicely biased with a VGS of around 1.25V. The gain of this amplifier is around 12. The current around this bias point should be around $1.25 * 10^{-6}$.

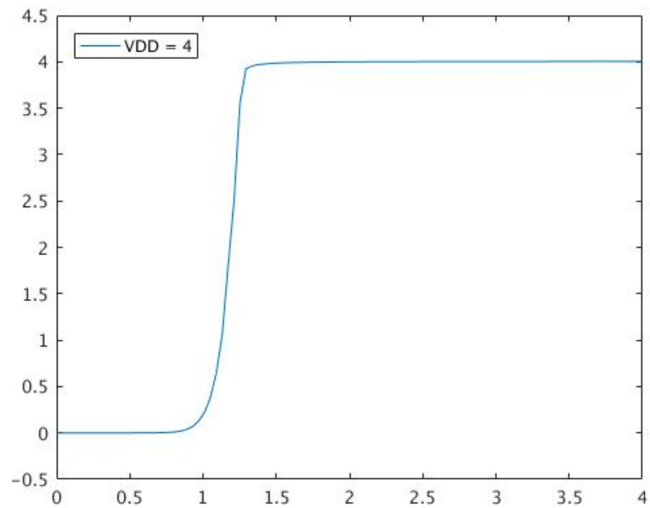

Figure 42: Common source amplifier with a 330k resistor

The amplifier would be nicely biased with a VGS of around 2.25V. The gain of this amplifier is around 3. The current around this bias point should be around $2.25 * 10^{-6}$.

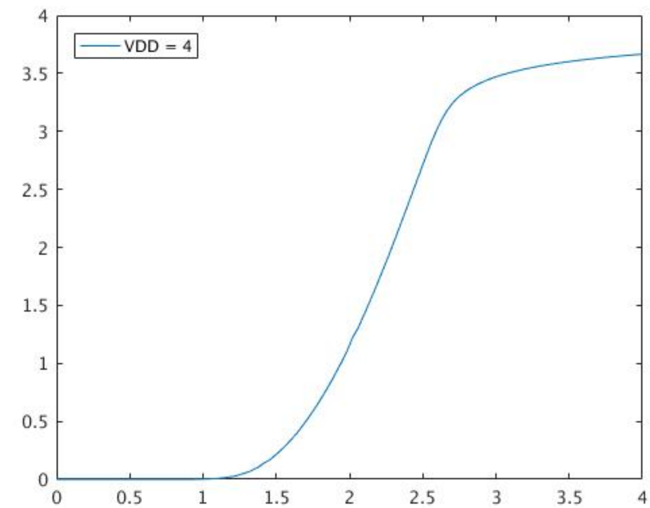

Figure 43: Common source amplifier with a 3,3k resistor