LAB 2 - INF3410

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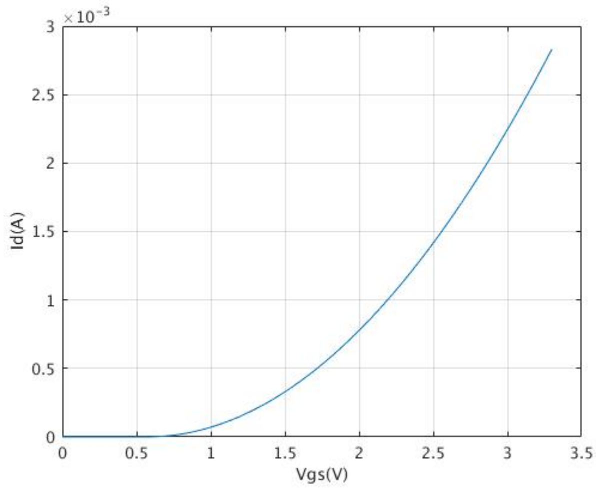
1. Task 1

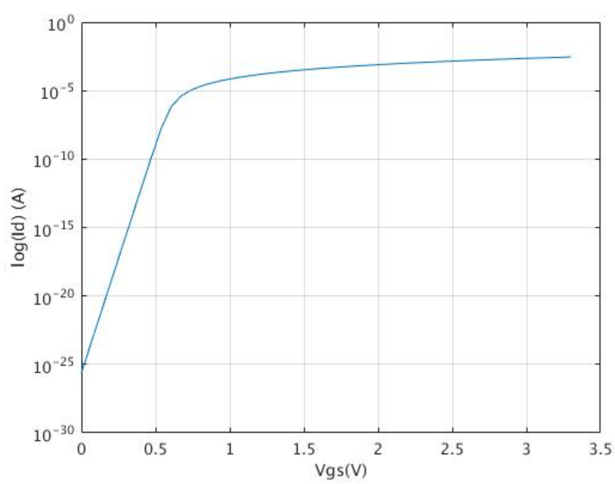
```matlab
%Oppgave 1.1 Vgs-sweep%

betaP=55*(10^-6);%P-type
betaN=190*(10^-6);%N-type
Vtn=0.57;
Vtp=0.71;
lambda=0.16;
VTemp=26*(10^(-3));
n=1;

Vgs=linspace(0,3.3,50);
Is= 2*n*betaN*(VTemp^2);
Vs=0;
Vd=1;
%Idmax=2.832mA
%For active region Vds>Vgs-Vtn
%For triode region 0<Vds<Vgs-Vtn

for i=1: length(Vgs)
If(i)=Is*(log(1+exp((Vgs(i)-Vtn-n*Vs)/(n*VTemp)))^2)*(1+lambda*Vs);
Ir(i)=Is*(log(1+exp((Vgs(i)-Vtn-n*Vd)/(n*VTemp)))^2)*(1+lambda*Vd);
Id(i)=If(i)-Ir(i);
end

figure(1);
plot(Vgs,Id);
xlabel('Vgs(V)');
ylabel('Id(A)');
grid on;
figure(2);
semilogy(Vgs, Id);
xlabel('Vgs(V)');
ylabel('log(Id) (A)');
grid on;
```

Matlab code used for task 1.1 and 1.2

Task 1.1



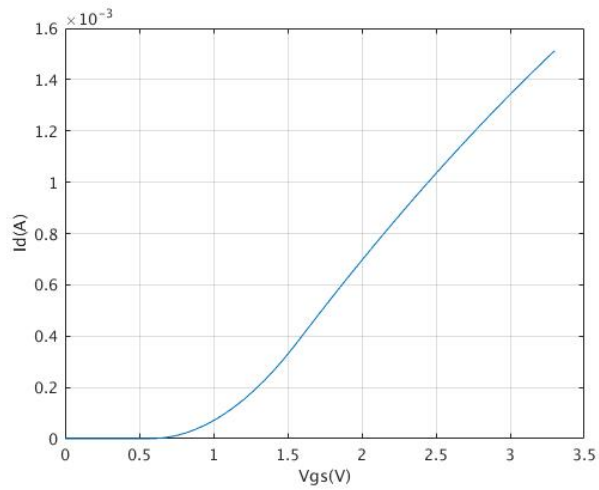
Figur 1. Linear plot of Vgs as a function of Id



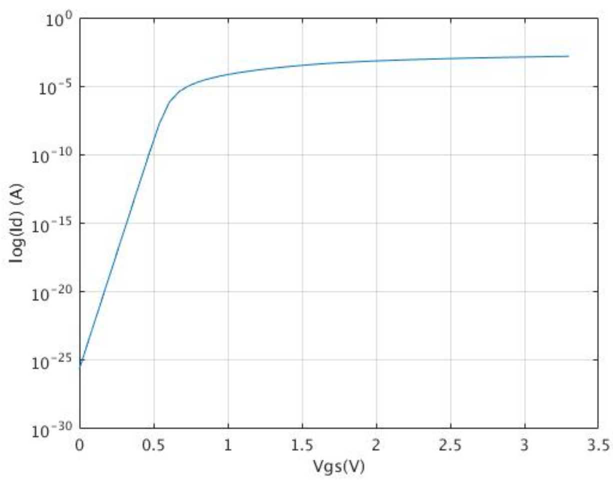
Figur 2. Log plot of Vgs as a function of Id

As long as $V_{ds} > V_{ov}$ the transistor will be in the active region. As long as $V_{gs} < V_{tn}$ the transistor is off. This means that the active region is when $V_{gs} > V_{tn}$. V_d is set higher than $V_{gs(max)}$. That means that no matter how high we set V_{ds}, I_{ds} does not get higher than approx. 2.8mA.

Task 1.2



FIGUR 3. Linear plot of V_{gs} as a function of I_d



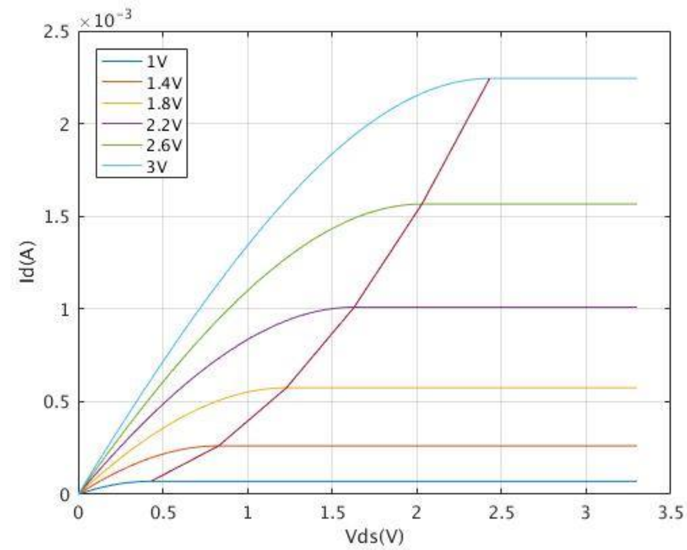
FIGUR 4. Log plot of V_{gs} as a function of I_d

To ensure that the curve is in the triode region $V_{ov} > V_{ds}$. The transistor needs to be turned on ($V_{gs} > V_{tn}$) for it to be in the triode region.

```matlab
%Oppgave 1.1 Vgs-sweep%
clear all;
betaP=55*(10^-6);%P-type
betaN=190*(10^-6);%N-type
Vtn=0.57;
Vtp=0.71;
lambda=0.16;
VTemp=26*(10^(-3));
n=1;

Vgs=linspace(Vtn-0.1,Vtn+0.1,6);
Is= 2*n*betaN*(VTemp^2);
Vd=linspace(0,3.3,100);
Vs=0;
%Idmax=2.832mA
%For active region Vds>Vgs-Vtn
%For triode region 0<Vds<Vgs-Vtn
for j=1: length(Vgs)
    Vov(j)=Vgs(j)-Vtn;
    for i=1: length(Vd)
        If(i)=Is*(log(1+exp((Vgs(j)-Vtn-n*Vs)/(n*VTemp)))
            ^2)*(1+lambda*Vs);
        Ir(i)=Is*(log(1+exp((Vgs(j)-Vtn-n*Vd(i))/(n*VTemp
            )))^2)*(1+lambda*Vd(i));
        Id(i)=If(i)-Ir(i);
        if Vd(i)-Vov(j)<0.05
            Sat(j)=Id(i);
        end

    end
    plot(Vd,Id);
    xlabel('Vds(V)');
    ylabel('Id(A)');
    grid on;
    hold on;
end
%plot(Vov,Sat);
legend('0.46V','0.51V','0.55V','0.59V','0.63V','0.67V','
    Location','northeast');
```

Matlab code used for task 1.3 and 1.4

Task 1.3

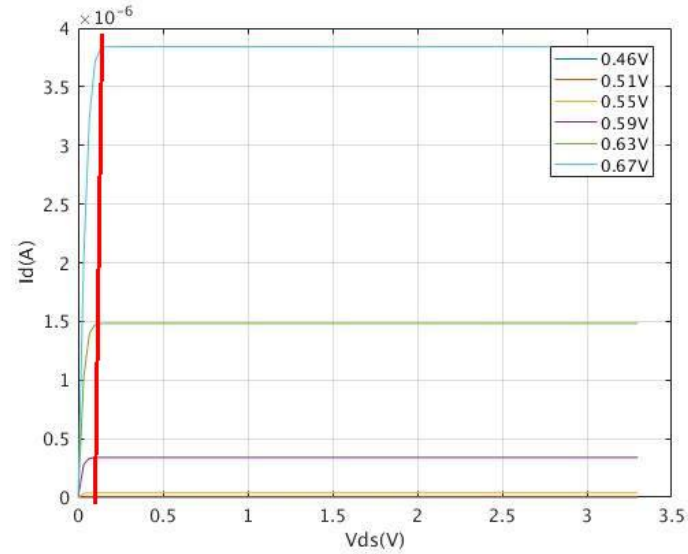


FIGUR 5. Plot of different voltages for Vgs. The line that grows exponentially marks where:

$$V_{ds} - V_{ov} < 50mV$$

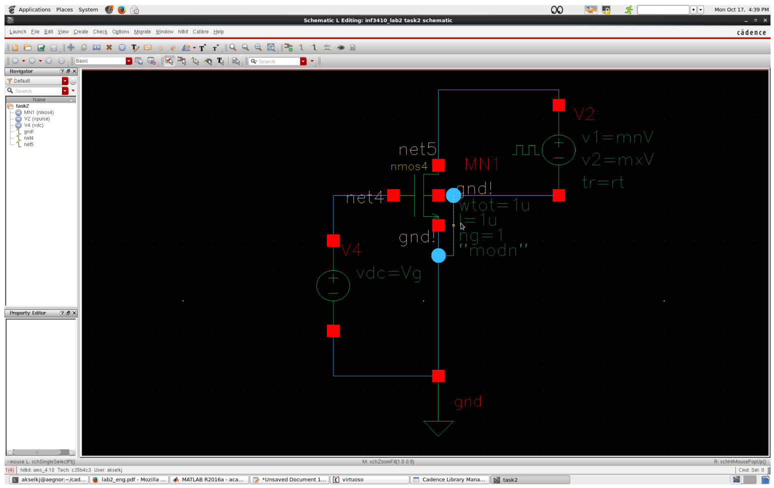
This means that every point left of the line is in triode region and every point right of the line is in saturation.

Task 1.4

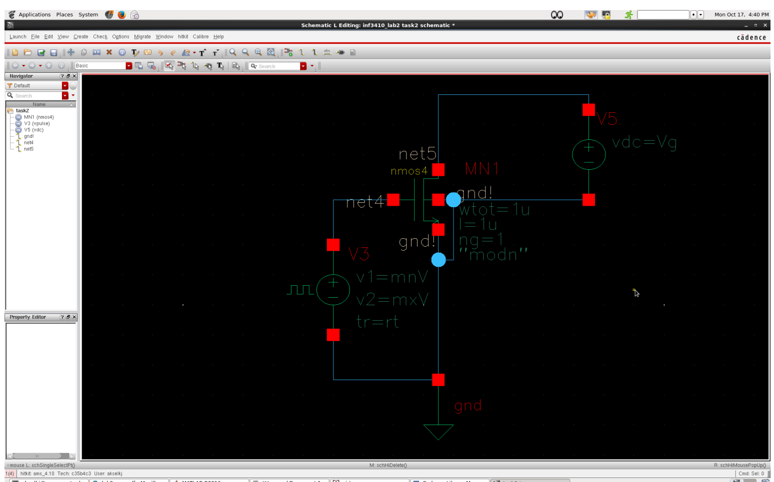


FIGUR 6. To ensure that the curve is in weak inversion we sweep V_{gs} within $\pm$100mV of V_{tn}. The constant behaviors is due to the EKV-model being inaccurate at this voltage range.

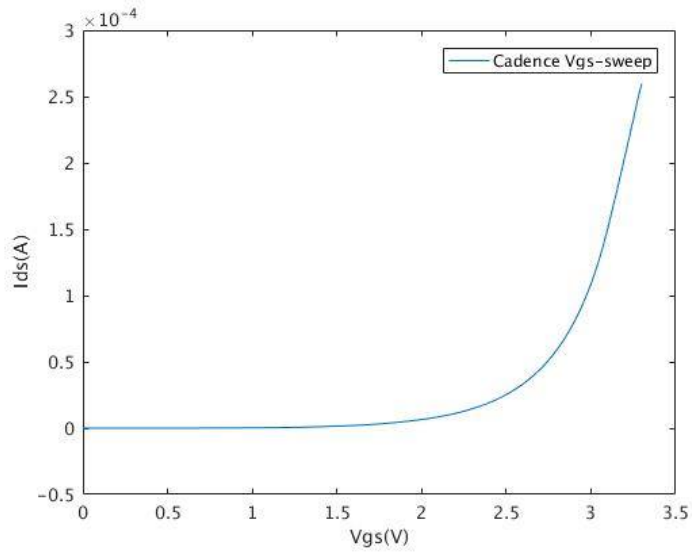
2. Task 2



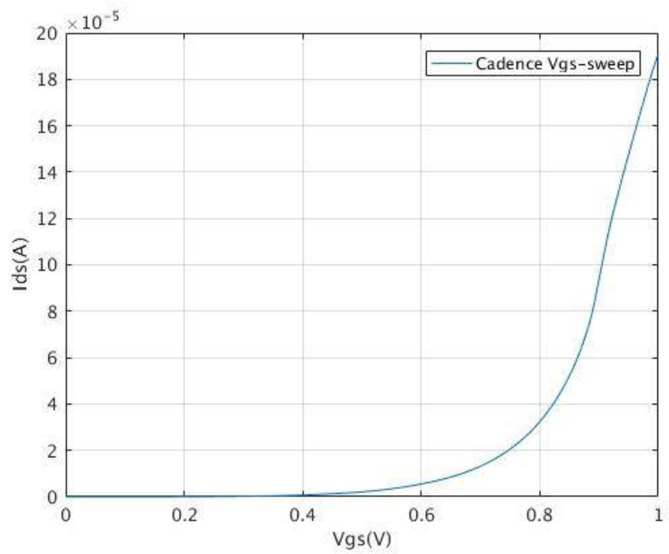
Figur 7. V_{ds} sweep configuration in cadence.



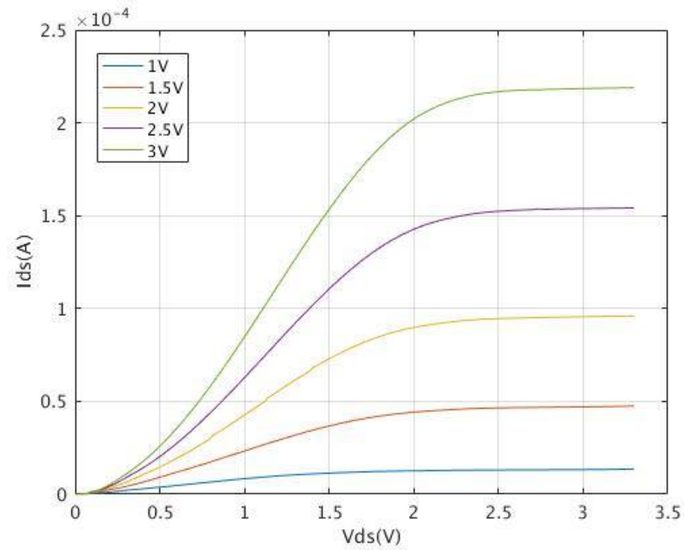
Figur 8. V_{gs} sweep configuration in cadence.



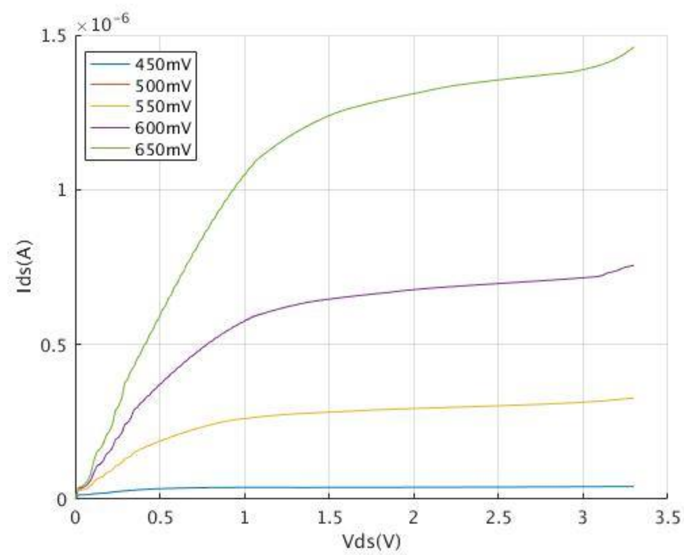
FIGUR 9. Cadence V_{gs} sweep of the saturation region (Linear).



FIGUR 10. Cadence V_{gs} sweep of the triode region (Linear).



FIGUR 11. Cadence V_{ds} sweep of the strong inversion (Linear).



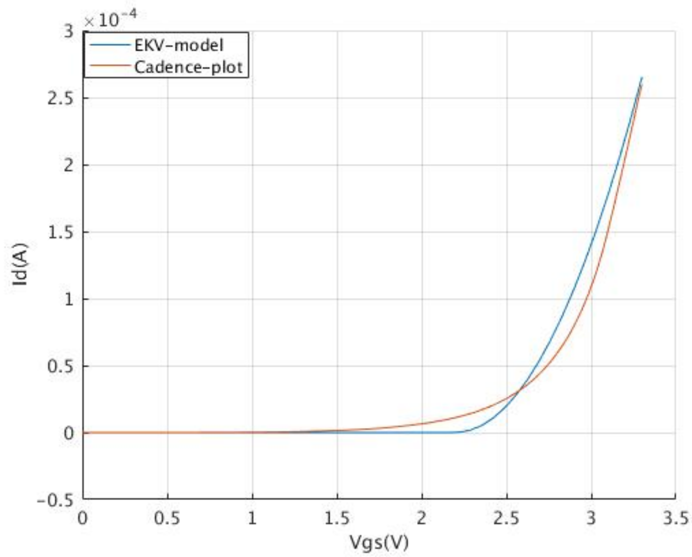
FIGUR 12. Cadence V_{ds} sweep of the weak inversion (Linear).

In the weak inversion plot we had some problems with plotting 450mV and 550mV. Somehow we got the same plot for the two, although the numbers provided by cadence was different from each other.

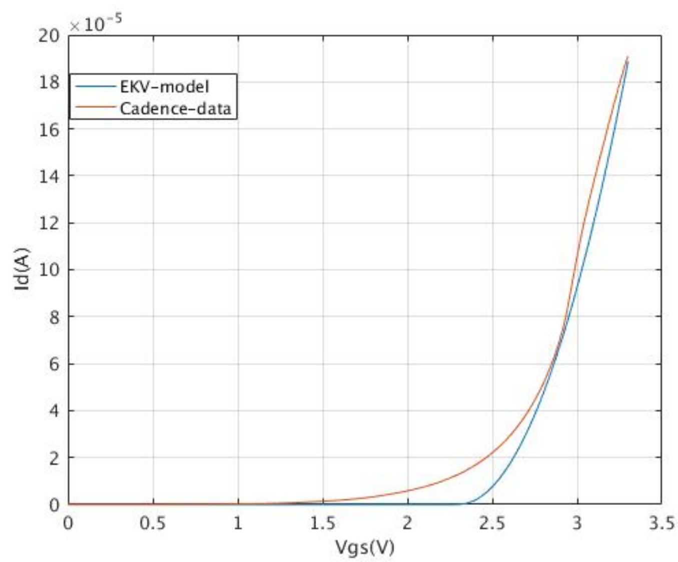
3. Task 3

```
%Oppgave 3
betaP=55*(10^-6);%P-type
betaN=185*(10^-7);%N-type
Vtn=0.57;
Vtp=0.72;
lambda=0.71;
VTemp=26*(10^(-3));
n=1;
Vgs=3;
Is= 2*n*betaN*(VTemp^2);
Vd=linspace(0,3.3,100);
Vs=0;
%For active region Vds>Vgs-Vtn
%For triode region 0<Vds<Vgs-Vtn
for j=1: length(Vgs)
    Vov(j)=Vgs(j)-Vtn;
    for i=1: length(Vd)
        If(i)=Is*(log(1+exp((Vgs(j)-Vtn-n*Vs)/(n*VTemp)))^2)*(1+lambda*Vs);
        Ir(i)=Is*(log(1+exp((Vgs(j)-Vtn-n*Vd(i))/(n*VTemp)))^2)*(1+lambda*Vd(i));
        Id(i)=If(i)-Ir(i);
        if abs(Vd(i)-Vov(j))<0.5
            Sat(j)=Id(i);
        end
    end
    plot(Vd,Id);
    xlabel('Vds(V)');
    ylabel('Id(A)');
    grid on;
    hold on;
end

hold on;
%plot(Oppgave2c_xaksel,Oppgave2c1vgs);
%plot(Oppgave2c_xaksel,Oppgave2c15vgs);
%plot(Oppgave2c_xaksel,Oppgave2c2vgs);
%plot(Oppgave2c_xaksel,Oppgave2c25vgs);
plot(Oppgave2c_xaksel,Oppgave2c3vgs);
grid on;
legend('EKV-model','Cadence','location','northwest');
hold off;
```

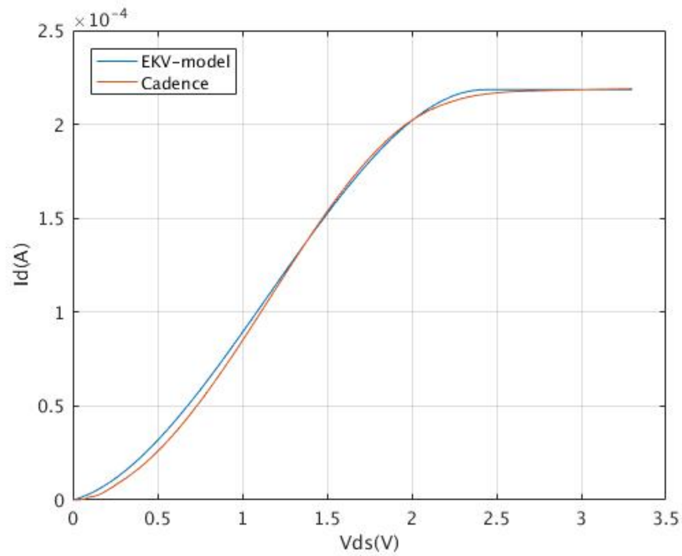
Our matlab code used in Task 3. Ofcourse with some changes throughout the task.



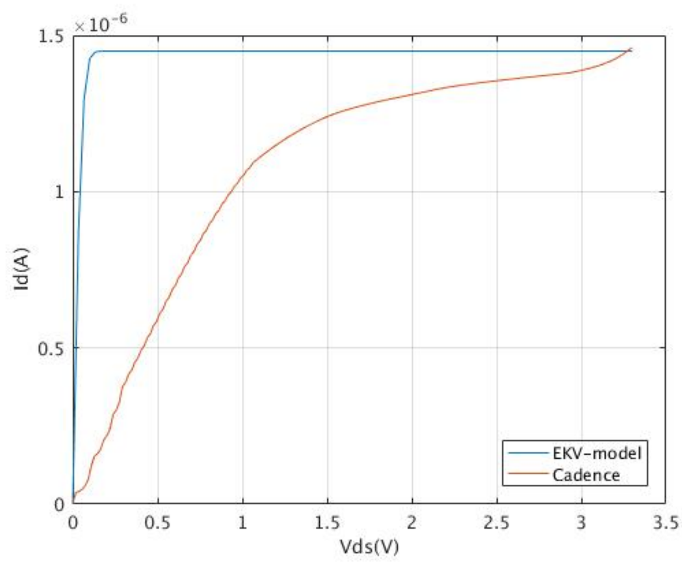
FIGUR 13. Changed values in EKV-model: $\beta_N = 900 * 10^{-7}$, $V_{tn} = 2.2V$, $\lambda = 0.14$, $n = 1.2$.



FIGUR 14. Changed values in EKV-model: $\beta_N = 80 * 10^{-6}$, $V_{tn} = 2.3V$, $\lambda = 0.18$, $n = 1$.



FIGUR 15. Changed calues in EKV-model: $\beta_N = 185*10^{-7}$, $V_{tn} = 0.57V$, $\lambda = 0.71$, $n = 1$, $V_{gs} = 3V$

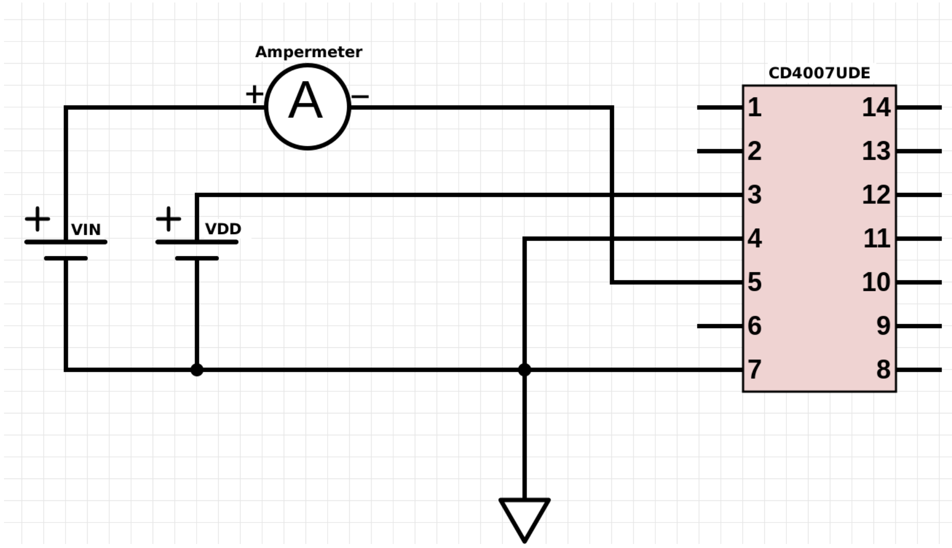


FIGUR 16. Because of the knee points, it was difficult to make the EKV-model fit the cadence simulations. Changes done in EKV-model: $\beta_N = 110 * 10^{-6}$, $\lambda = 1$, $V_{gs} = 0.65V$

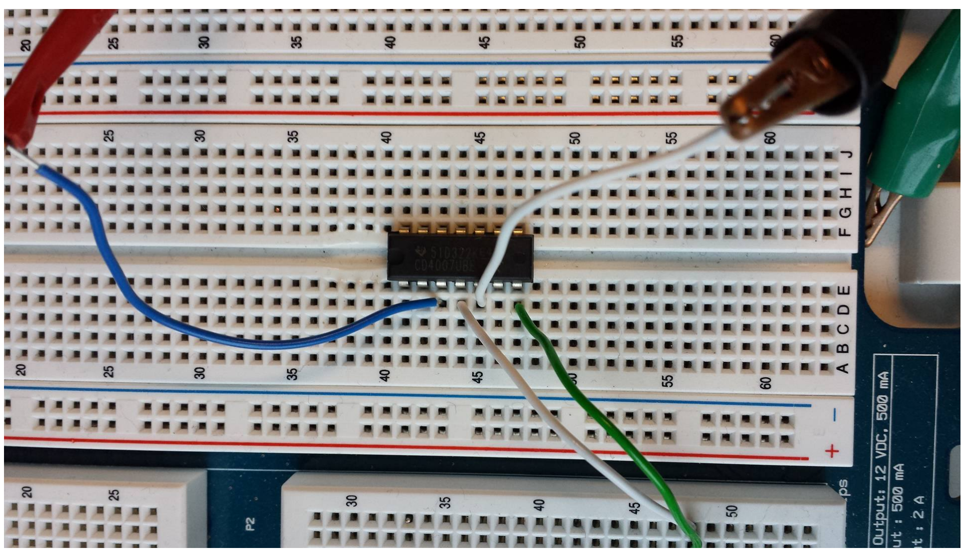
4. Task 4

```
clear all;
addpath(genpath('/hom/mes/src/matlab/gpib/linux'));
HPE3631_Init;
K617_Init;
K617_SetMode('A');

Vdd=3.3;
Vgs=linspace(0,3.3,40);
HPE3631_SetVolt(1,Vdd);
%Idmax=1.442 Vdd=0.5
%Idmax=2.387 Vdd=1
%Idmax=3.002 Vdd=2
%Idmax=3.125 Vdd=4
%Idmax=3.206 Vdd=8
%Idmax=3.264 Vdd=12




for i=1: length(Vgs)
 HPE3631_SetVolt(2,Vgs(i));
 pause(0.05);
 Ids(i)= K617_ReadQuick;
end
HPE3631_SetVolt (1, 0);
HPE3631_SetVolt (2, 0);
HPE3631_SetVolt (3, 0);





figure(1);
plot(Vgs,Ids);
xlabel('Vgs(V)');
ylabel('Id(A)');
grid on;
%{
figure(2);
semilogy(Vgs, Ids);
xlabel('Vgs(V)');
ylabel('log(Id) (A)');
grid on;
%}
```

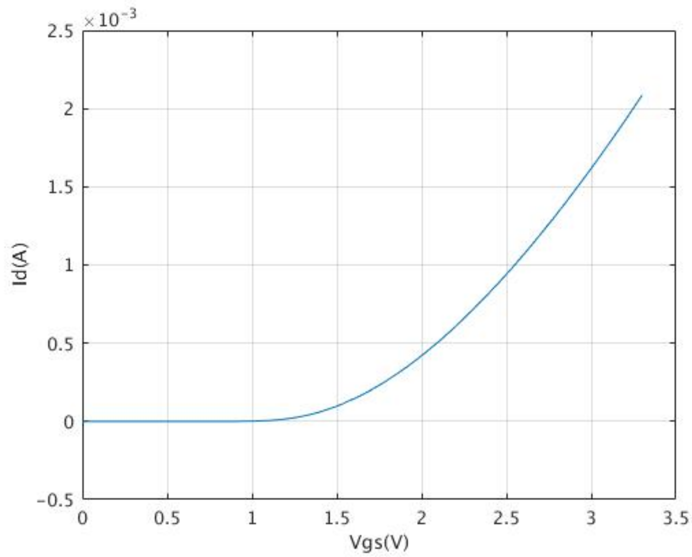
Matlab code used for the first two plots in task 4.



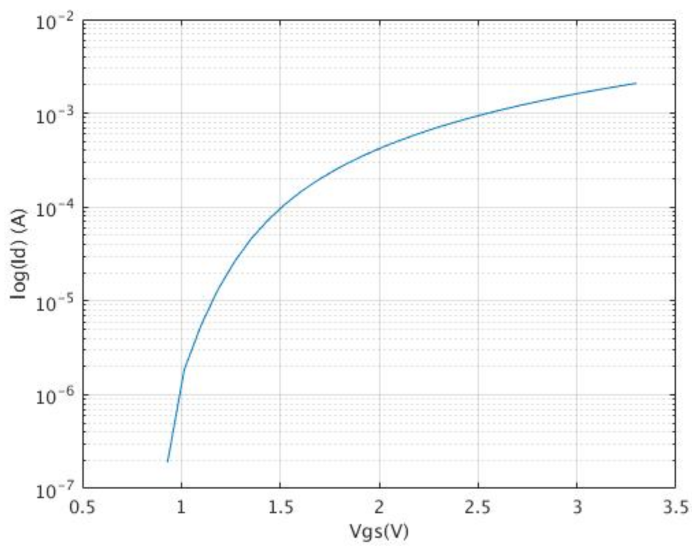
FIGUR 17. How we connected our circuit in Task 4. Voltage range is from 0V to 3.3V. Power is 3.3V.



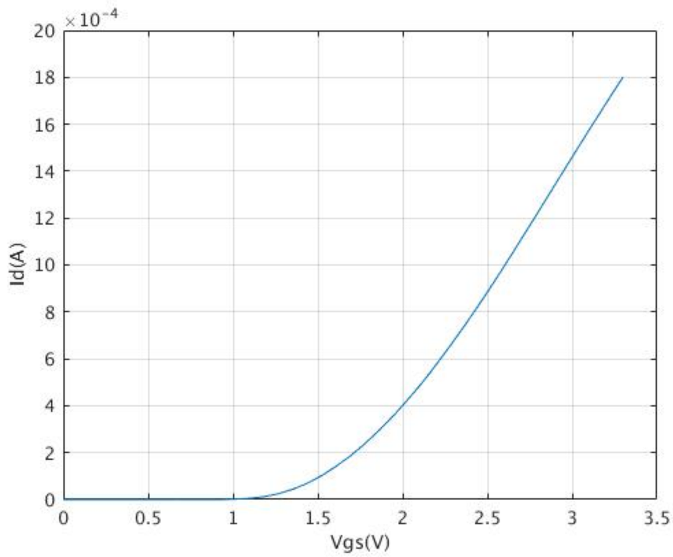
FIGUR 18. Elvis board setup.



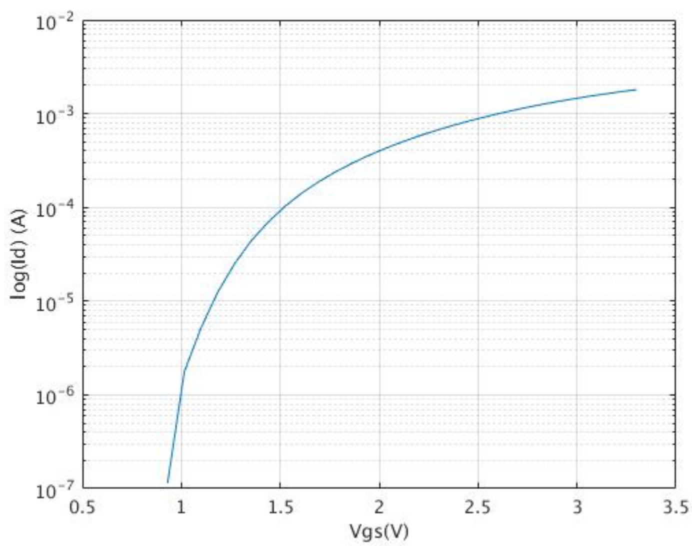
FIGUR 19. Sweep in the active region (Linear)



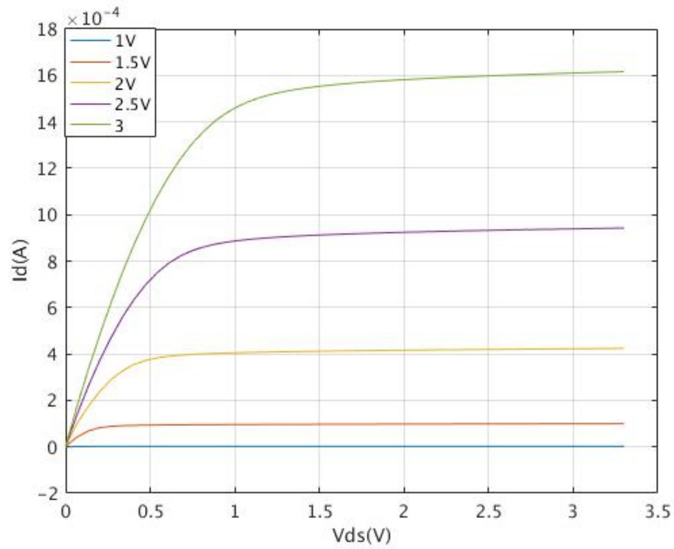
FIGUR 20. Sweep in the active region (Logarithmic)



FIGUR 21. Sweep in triode region (Linear)

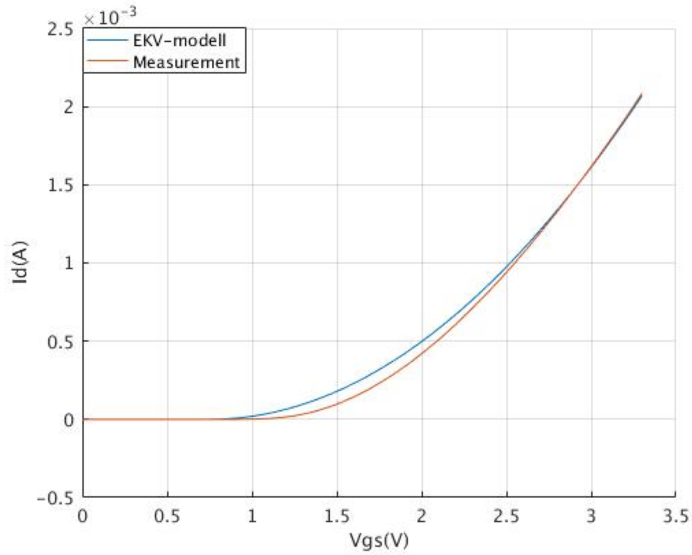


FIGUR 22. Sweep in triode region (Logarithmic)

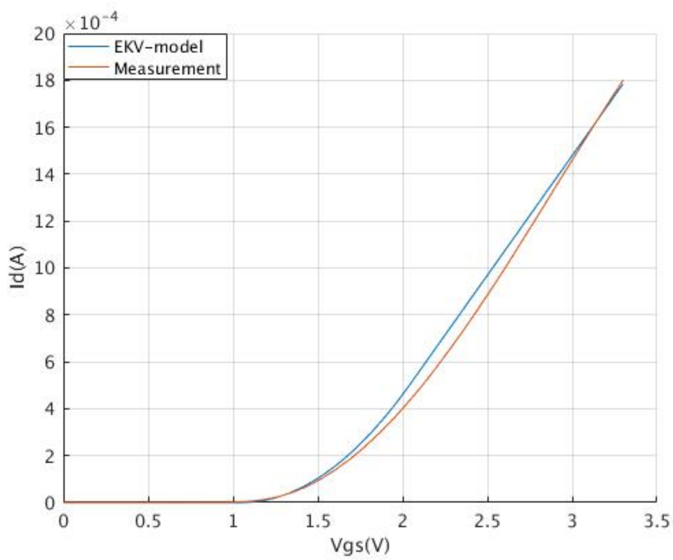


Figur 23

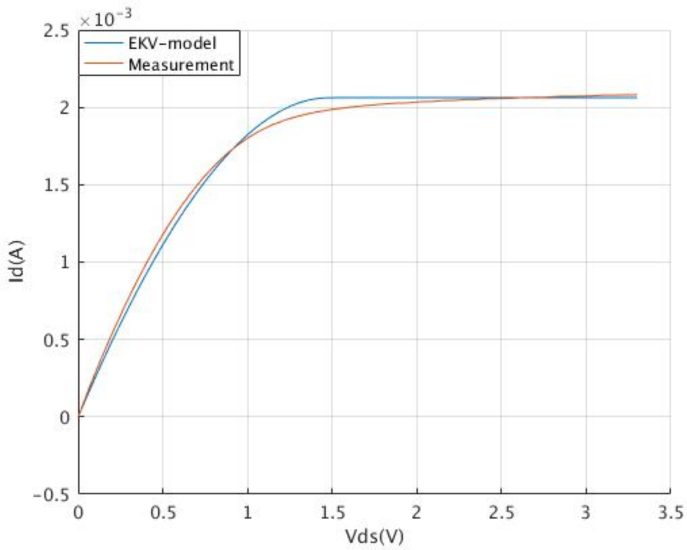
5. Task 5



Figur 24. Changed values in EKV-model: $\beta_N = 100 * 10^{-6}$, $V_{tn} = 0.75V$, $\lambda = 0.3$, $n = 1.25$.

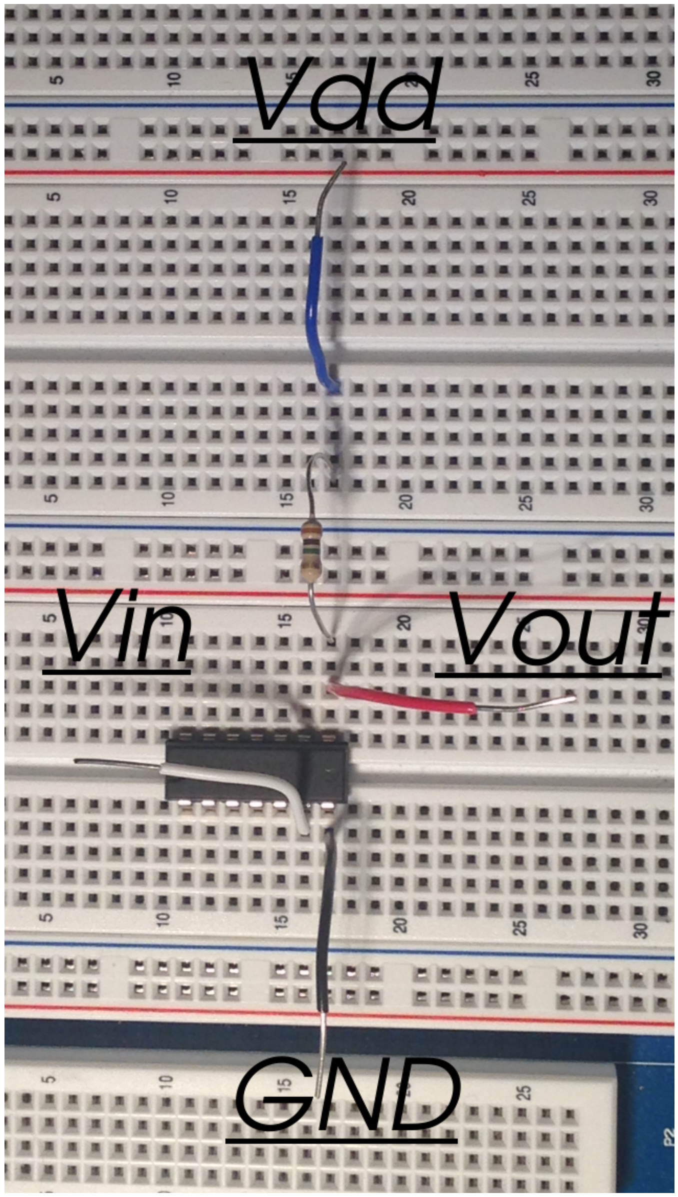


Figur 25. Changed values in EKV-model: $\beta_N = 204 * 10^{-6}$, $V_{tn} = 1.05V$, $\lambda = 0.25$, $n = 1$.



FIGUR 26. Changed values in EKV-model: $\beta_N = 290 * 10^{-6}$, $V_{tn} = 0.9V$, $\lambda = 0.1$, $n = 1.62$.

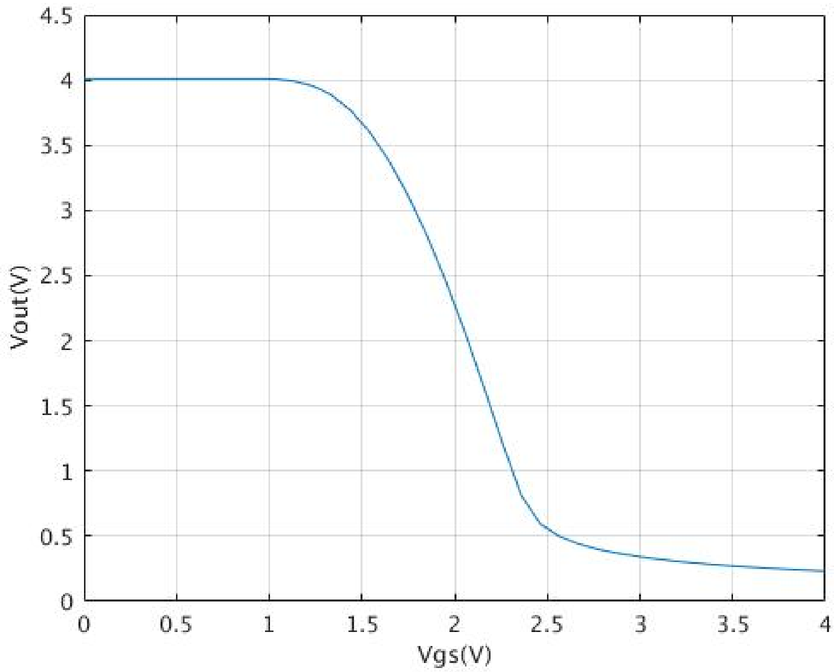
6. Task 6



Figur 27. Elvis board setup for task 6.

```
clear all;
addpath(genpath('/hom/mes/src/matlab/gpib/linux'));
HPE3631_Init;
K617_Init;
K617_SetMode('V');

%Setter Vdd = 4
Vdd=4;
HPE3631_SetVolt(2,Vdd);

%Setter antall ganger vi mÃ ler Vout
count = 40;
Vgs=linspace(0,Vdd,count);

for i=1: length(Vgs)
 HPE3631_SetVolt(1,Vgs(i));
 pause(0.1);
 Vout(i)= K617_ReadQuick;


end
HPE3631_SetVolt (1, 0);
HPE3631_SetVolt (2, 0);
HPE3631_SetVolt (3, 0);


figure(1);
plot(Vgs,Vout);
xlabel('Vgs(V)');
ylabel('Vout(V)');
grid on;
```

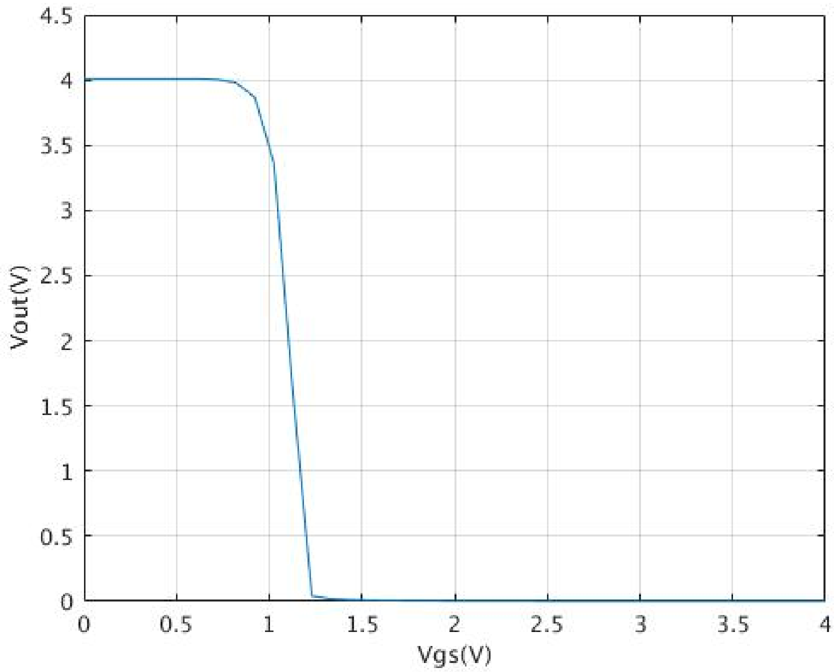
Matlab code used in task 6.



FIGUR 28. $R_D = 4,7k\Omega$. For this common source amp a V_{GS} that would bias the linear range nicely would be around 2V. The bias current at this point can be calculated using Ohm's law, $U = R * I => I = U/R => I_D = (V_{dd} - V_{out})/R_D =>$
$I_D = (4V - 2V)/4,7k\Omega = 0,42553mA$.

We found the gain of the common source amp to be -3,76.

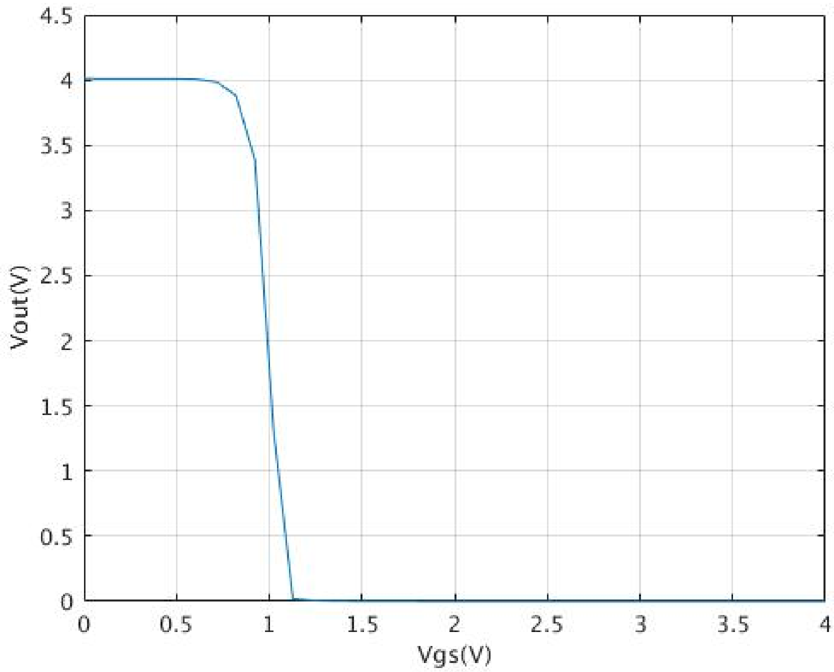
We can see that the common source amp is not in weak inversion. We assume that V_{tn} isn't bigger than 0,6V (couldn't find a threshold voltage in the datasheet for the MC14007UB) and the curve doesn't start falling before $V_{gs} = 1,1V$.



FIGUR 29. $R_D = 680k\Omega$. For this common source amp a V_{GS} that would bias the linear range nicely would be around 1,13V. The bias current at this point can be calculated using Ohm's law. $I_D = (4V - 1,13V)/680k\Omega = 0,00422mA$

We found the gain of the common source amp to be -16,19.

Using the same assumptions as in the last plot. We see that we're still not in weak inversion.



FIGUR 30. $R_D = 3M\Omega$. For this common source amp a V_{GS} that would bias the linear range nicely would be around 1,025V. The bias current at this point can be calculated using Ohm's law. $I_D = (4V - 1,025V)/3M\Omega = 0,00099mA$

We found the gain of the common source amp to be -20,37.

Using the same assumptions as in the first plot. We can now see that we're close to the threshold, but we're still in strong inversion.

We observe that when R_D has a higher resistance, the gain increases and the bandwidth decreases. The common source amplifier with $R_D = 3M\Omega$ has the biggest gain, and the common source amp with $R_D = 4,7k\Omega$ has the highest bandwidth.