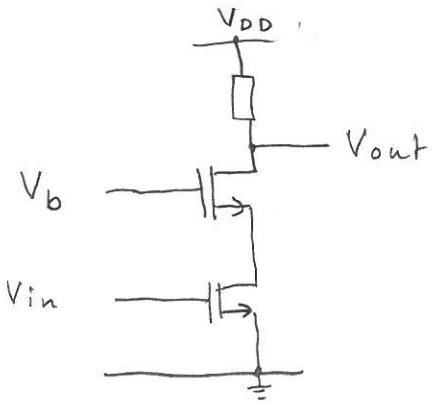
2010-01-20/BM

Design of a cascode amplifier



Use parameters from Table 2.1

Assume $\frac{W}{L} = \frac{50n}{0,5\mu}$ for both transistors $L_{eff} = 0.5\mu - 2 \cdot 0,08\mu = 0,34\mu m$

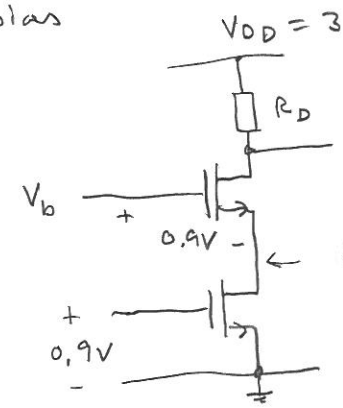
$V_{OV} = V_{GS} - V_{TH} = 0,2\ V \Rightarrow V_{GS} = 0,9\ V \quad V_{TH} = 0,7V$

$\mu_n C_{ox} = 350 \frac{cm^2}{Vs} \cdot \frac{8.85 \cdot 10^{-14} \cdot 3,9\ F/cm}{9 \cdot 10^{-7}\ cm} = 134\ \mu A/V^2$

$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} \cdot (V_{GS} - V_{TH})^2 =$

$= \frac{1}{2} 134\mu \cdot \frac{50}{0.34} \cdot 0.2^2 = 394\ \mu A$

DC bias



0,6 V min, 3,0 max $\Rightarrow$ 1,8 V DC in this node

0.4 V gives 0.2 V swing (same as input

$\Rightarrow V_b = 1.3V$

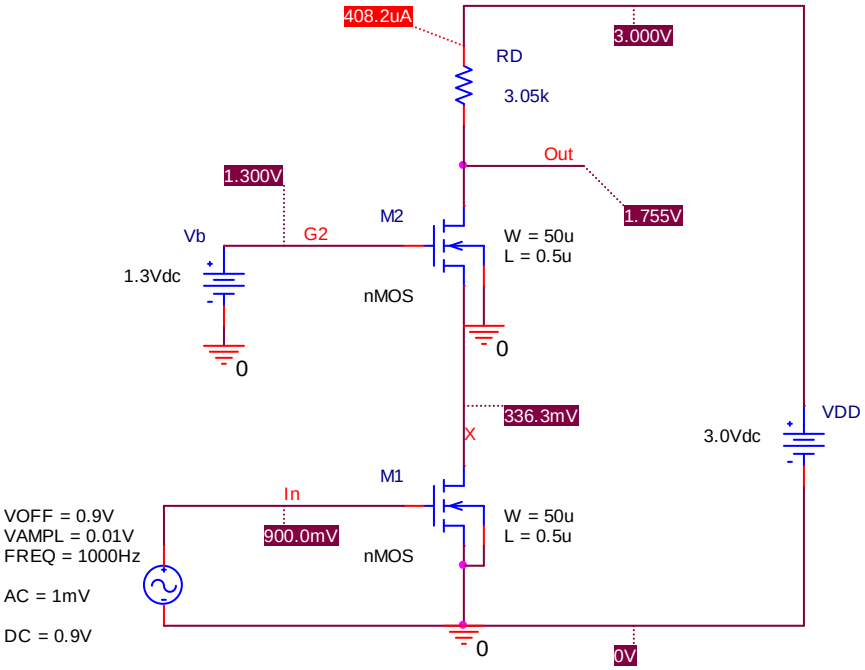
$R_D = \frac{3 - 1,8}{394\mu} = 3,05\ k\Omega$

$g_{m1} = g_{m2} = \frac{2 I_D}{V_{GS} - V_{TH}} = \frac{2 \cdot 0,394m}{0,2} = 3,94\ mA/V$

Quick and approximate design!
Check with simulation if it is ok!

Design of a cascode amplifier 2010-01-20 Bengt Molin

DC bias



From output file:

NAME	M_M2	M_M1
MODEL	nMOS	nMOS
ID	4.08E-04	4.08E-04
VGS	9.64E-01	9.00E-01
VDS	1.42E+00	3.36E-01
VBS	-3.36E-01	0.00E+00
VTH	7.73E-01	7.00E-01
VDSAT	1.90E-01	2.00E-01
GM	4.29E-03	4.08E-03
GDS	3.58E-05	3.95E-05
GMB	8.68E-04	9.68E-04

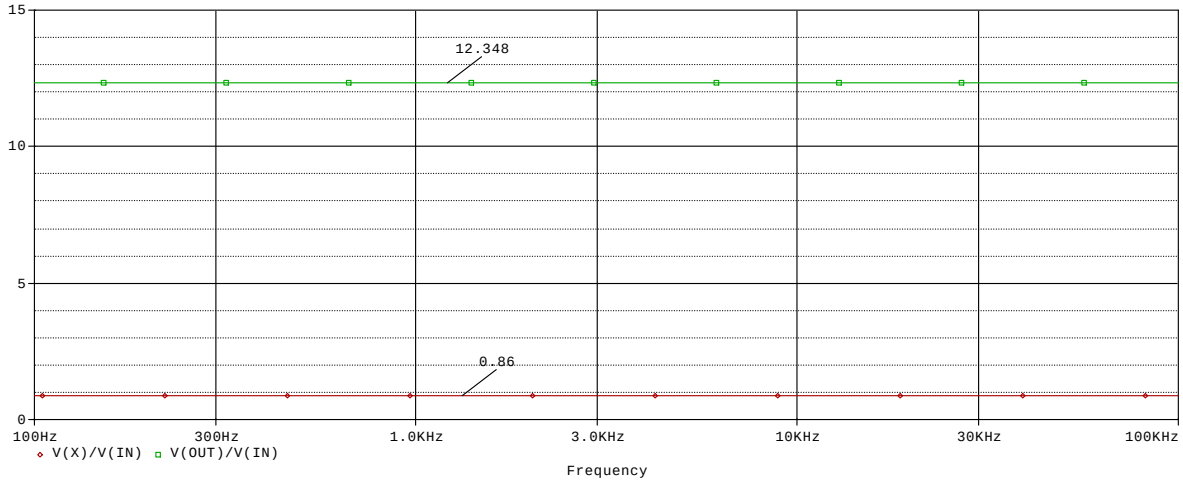
Disregarded in the hand calculation design:

- Body effect M2
- channel length modulation

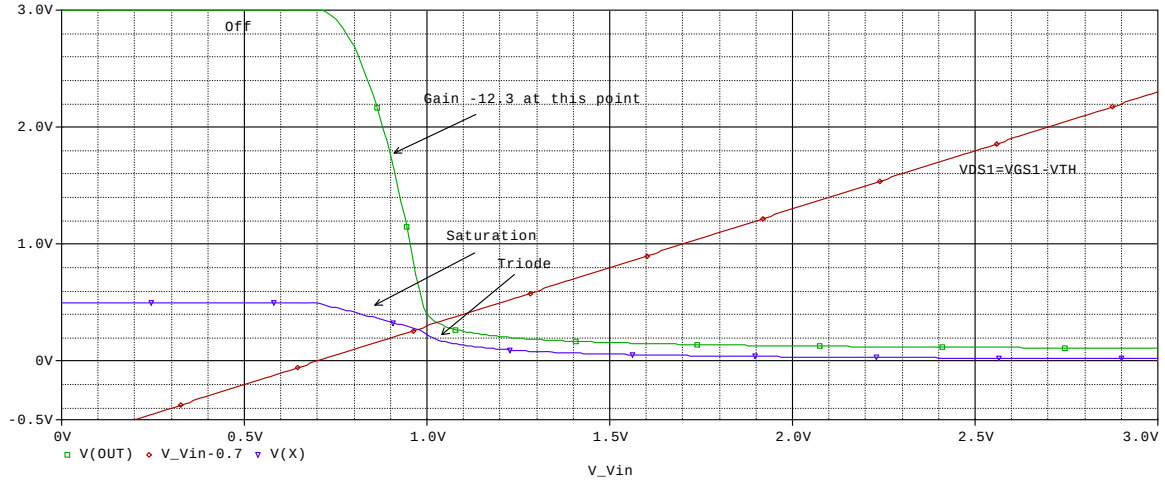
Comments: Current is slightly higher, Voltage at drain of M1 might be to low (can be adjusted by increasing Vb)

Av = $-g_m \cdot R_D = -4.08m \cdot 3.05k = -12.44$

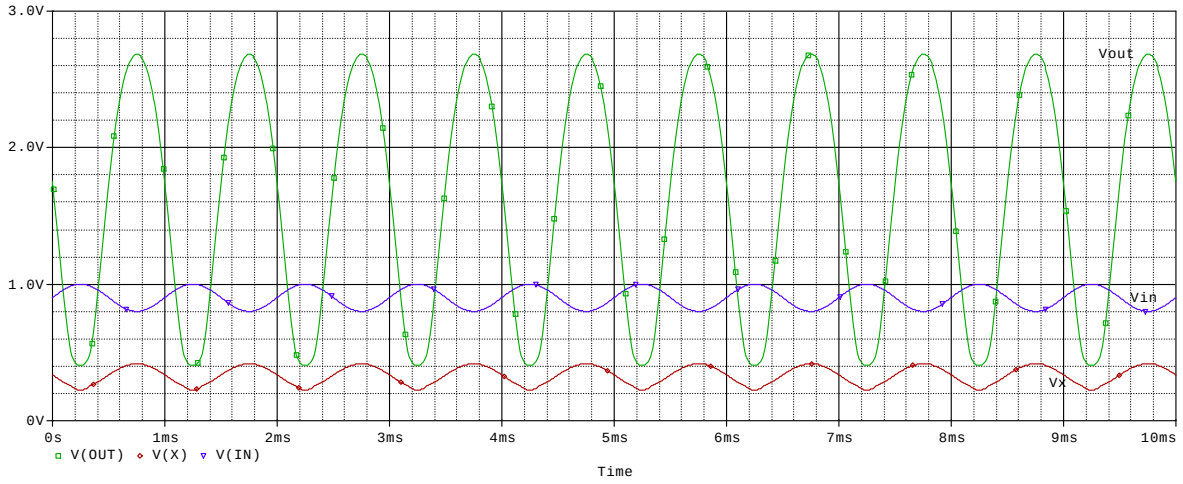
Checking small signal gain with AC-analysis: Av= 12.35 to output, Av = 0.86 to node X (drain M1)



DC sweep, transfer function



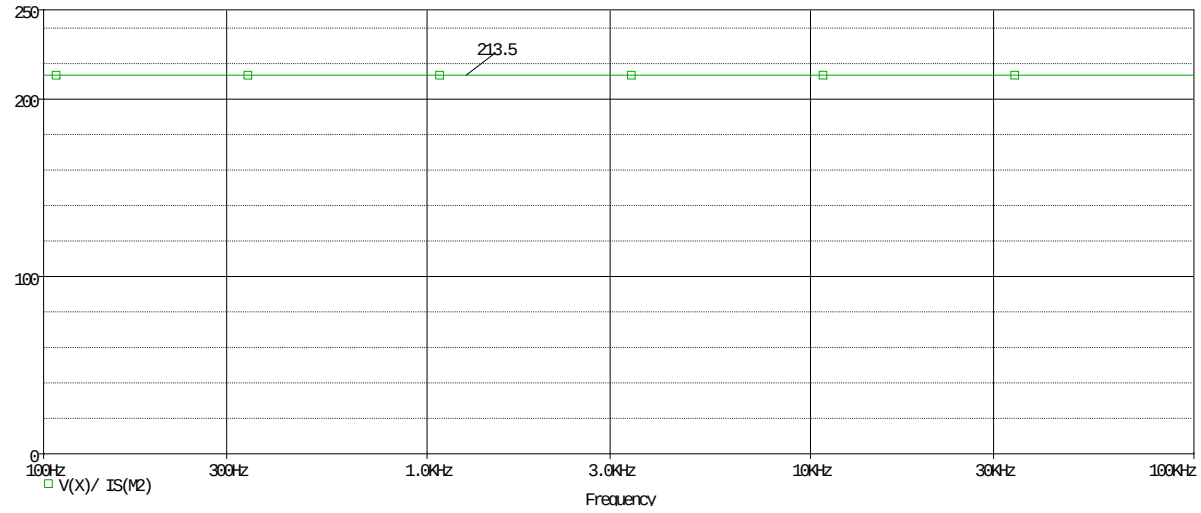
Transient analysis with sinusoidal 0.1 V peak value at input



Output peak-to-peak 2.28 V, gain 2.28/0.2= 11.4 large output signal. We can see that output is not a good sinus, distorted, non-linear amplifier.

M1 close to leave saturation, M2 close to leave saturation

Let us check output resistance at source of transistor M2 seen from drain of M1. Since the driving source is the input voltage, generating a small signal current at input of M2 source, we can use AC analysis.



The resistance is 213.5Ω.

Check with $\frac{1}{g_m + g_{mb}} = \frac{1}{4.29 \cdot 10^{-3} + 8.68 \cdot 10^{-4}} = 194\ \Omega$. Calculation to approximate!

Include transistor output resistance r_o and then also R_D will be affecting the resistance.

Check the formula 3.1019, p 80 in book, including r_o and R_D :

$$r_o = \frac{1}{g_d} = \frac{1}{3.58 \cdot 10^{-5}} = 27.9\ \text{k}\Omega$$

$$\frac{R_D + r_o}{1 + (g_m + g_{mb}) r_o} = \frac{3.05\text{k} + 27.9\text{k}}{1 + \left(4.29 \cdot 10^{-3} + 8.68 \cdot 10^{-4}\right) \cdot 27.9\text{k}} = 214\ \Omega$$

Very good!