

Lab 1, Analog Integrated Circuits

Ole Jansen, Finn Rautenberg, 02.12.2022, Lübeck

1) Operation point

a) Task: Build up the common source amplifier

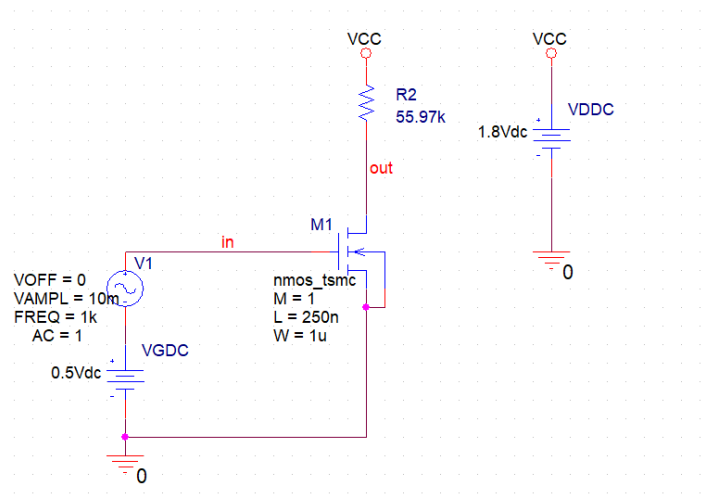


Figure 1: Common Source amplifier circuit

b) Task: Determine R_L value for $V_{out}=0,9V$ and Transistor biased for $I_{D,dc}=16,08\mu A$

$$R_L = \frac{V_{cc} - V_{out}}{I_{D,dc}} = \frac{1,8V - 0,9V}{16,08\mu A} = 55,97k\Omega$$

c) Task: Perform Bias Point Simulation and show that $V_{out} = 0,9V$

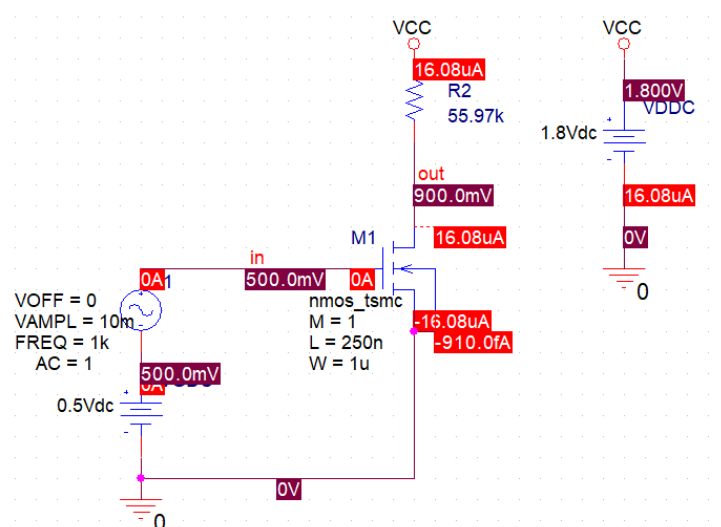


Figure 2: Circuit with bias voltages and currents simulated

V_{out} settles at 0,9V as expected

d) Task: Determine operation area of Transistor M1 and justify answer

$$V_{th} = 328mV, V_{OD} = V_{gs} - V_{th} = 500mV - 328mV = 172mV$$

$$\text{Condition 1 met: } V_{gs} > V_{th} \rightarrow 500mV > 328mV$$

$$\text{Condition 2 met: } V_{ds} > V_{OD} \rightarrow 900mV > 172mV$$

Transistor M1 is in saturation, due to fulfilment on condition 1 and 2

e, g) Task: Determine small-signal DC-gain, in-, output resistance, small signal transconductance and small signal resistance of transistor with bias point simulation

PSpice Output: SMALL-SIGNAL CHARACTERISTICS:

$$\frac{V_{out}}{V_{G,dc}} = -6,68, \quad R_{in} = 100 \text{ E}\Omega, \quad R_{out} = 50,45k\Omega,$$

$$r_{ds} = \frac{1}{g_{ds}} = 512,8k\Omega, \quad g_m = 132\mu S$$

The negativ voltage gain is expected, due to 180° Phase shift of to the common source amplifier.

h) Task: Draw small circuit equivalent circuit and calculate small signal voltage gain

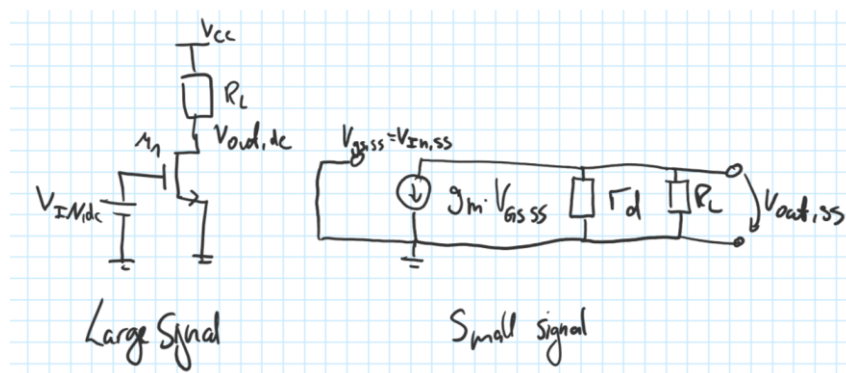


Figure 3: Common source amplifier with small signal equivalent

$$\frac{V_{out,ss}}{V_{in,ss}} = -g_m(r_{ds} || R_L) = -132\mu S (512,8k\Omega || 55,97k\Omega) = -6,66$$

The small voltage gain of -6,66 equals the simulated -6,68.

2) Transient analysis

b) Task: Perform a transient simulation with shown circuit and plot in- and output voltage

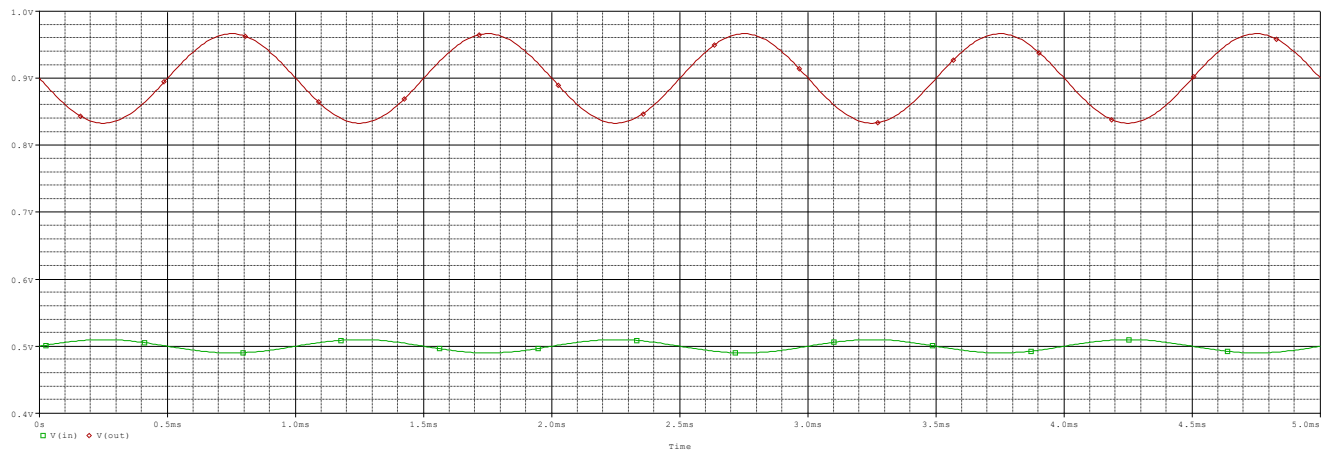


Figure 4: Transient analysis of in- and output signal

c) Task: Determine the small signal voltages of in- and output and its gain

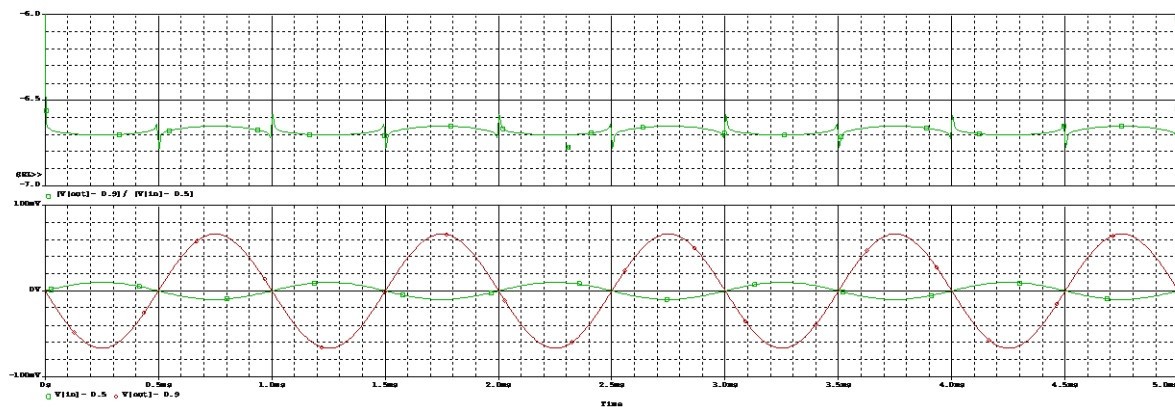


Figure 5: Gain, in- and output of small signals

$$V_{in,ss} = 10mV, V_{out,ss} = -67,01mV \text{ at } 1,75ms$$

$$A_v = \frac{V_{out,ss}}{V_{in,ss}} = -6,70$$

d) Task: Compare small signal voltage gain with bias point simulation

	Bias point simulation	Transient analysis
Small signal voltage gain	-6,68	-6,70

The gains are equivalent

e) Task: Calculate the maximum amplitude of the input voltage which results in a "clipping" of the output voltage and show in the simulation

Limiting factor is V_{ds} to stay in saturation: $V_{ds,min} > 172\text{mV}$

$$V_{in,ss,max} = \frac{V_{DD} - V_{ds,min}}{|A_V|} = \frac{0,9\text{V} - 172\text{mV}}{6,68} = 109\text{ mV}$$

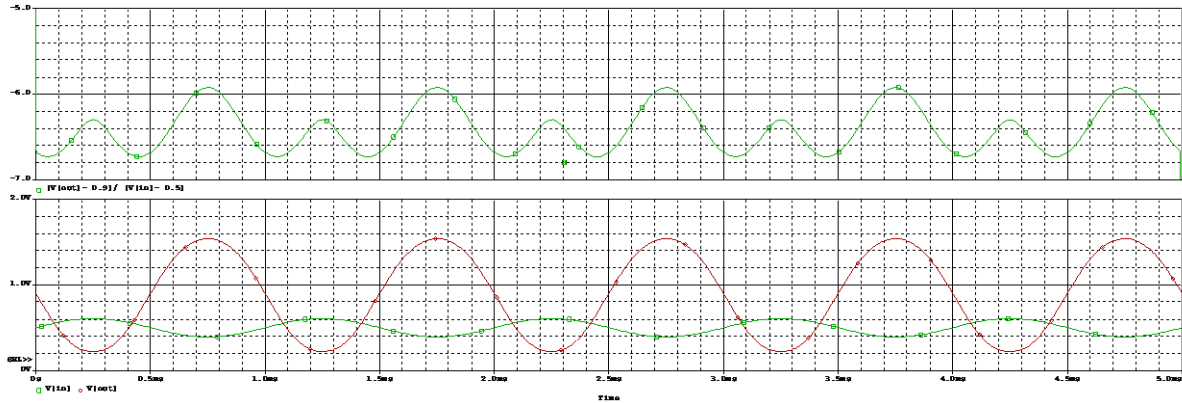


Figure 6: Gain of input and output voltage before clipping

The resulting Outputamplitude $V_{out} = V_{ds}$ beträgt: $V_{out,min} = 219\text{mV}$, $V_{out,max} = 1,54\text{V}$
 The gain A_V isn't constant accross the input voltage range, like shown in the upper plot of figure 6.
 The linearised gain is thereby not more applicable at high input voltages and none linear effects occure which result in not reaching $V_{ds,min} = 172\text{mV}$ but just $V_{out,min} = 219\text{ mV}$.

1) AC analysis

b) Task: Perform an AC analysis of the in- and output voltage

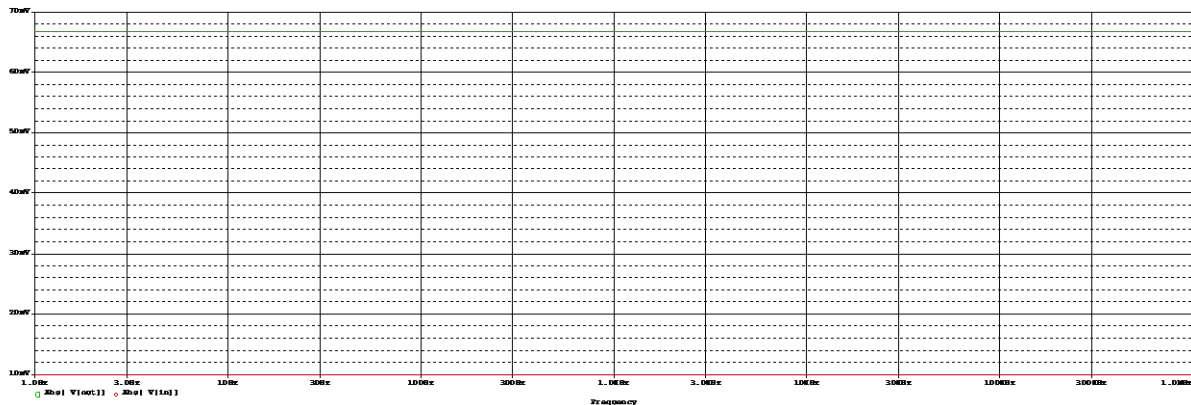


Figure 7: input and output magnitude voltage of ac analysis

The Magnitude of the input is 10mV and of the output 66,8 mV

c) Task: Plot the magnitude and phase of V_out

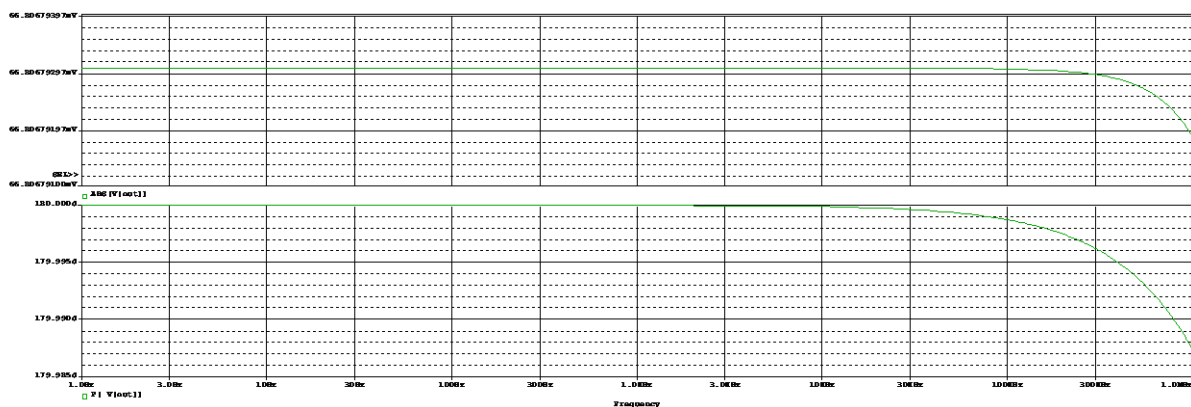


Figure 8: Magnitude and Phase of the output voltage of the common source amplifier in ac simulation

Small changes in amplitude and phase are very small but expected due to low pass effect of capacitances. This results in $A_V = -6,68$

d) Task: Compare results of ac analysis with bias point and transient analysis

	ac analysis	bias point analysis	transient analysis
A_V	-6,68	-6,68	-6,70

e) Task: Determine the small signal gain at an input voltage of 1V

At an input voltage of 1V the relation between input and output stays the same as in d) due to the linearisation of the circuit.

Discrepancies between the transient and the ac simulation are a result of neglecting nonlinearity at the ac simulation at input voltages other than the input voltage at this bias point.