

Second SPICE Exercise

Fundamentals Of Electronics - a.a. 2018-2019 - University of Padua (Italy)

Pietro Prandini (mat. 1097752)

June 4, 2019

Contents

1	Analytic solution	5
1.1	Designing by a DC analysis	5
1.1.1	R_D	5
1.1.2	R_S	6
1.1.3	V_{GS}	6
1.1.4	R_{G1}	6
1.1.5	g_m	7
1.1.6	r_0	7
1.2	AC analysis	7
1.2.1	Hybrid π model	7
1.2.2	R_{IN} from G	7
1.2.3	R_{OUT} from D	8
2	SPICE simulations	11

Chapter 1

Analytic solution

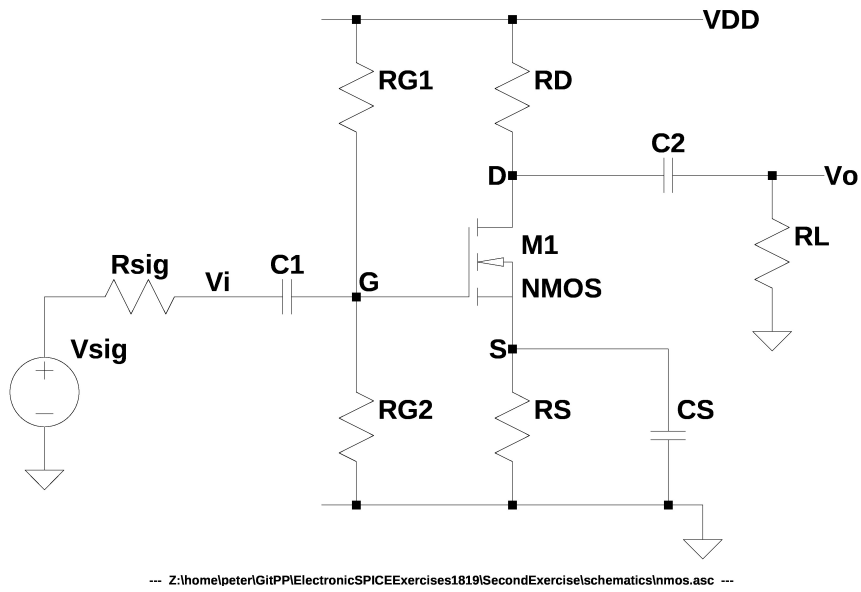


Figure 1.1: NMOS common source amplifier

Designing the common source amplifier of the figure 1.1 .
The MOSFET should have a $V_t = 1V$, a $K_n = 4mA/V$ and a $\lambda = 0$.
Other requested parameters are: $I_{DQ} = 0.5mA$, $V_S = 3.5V$, $V_D = 11V$, $V_{DD} = 15V$ and $R_{G2} = 1097752\Omega$.

1.1 Designing by a DC analysis

On a Direct Current analysis the capacitances can be considered as open circuits, the inductances can be considered as short circuits, the signal and the load are removed and the alternate current inputs are not considered.

The figure 1.2 represents the circuit for the DC analysis.

1.1.1 R_D

$$V_D = V_{DD} - R_D I_D \quad (1.1)$$

$$R_D = \frac{V_{DD} - V_D}{I_D} \quad (1.2)$$

$$R_D = \frac{15V - 11V}{0.5mA} = 8k\Omega \quad (1.3)$$

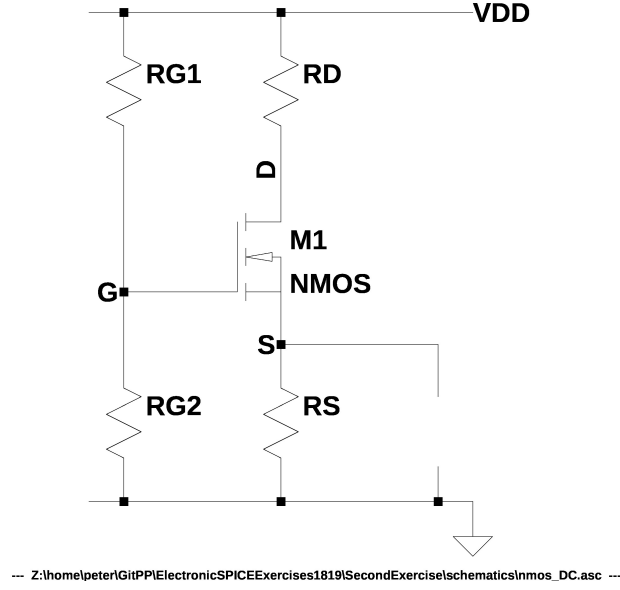


Figure 1.2: NMOS common source amplifier - DC analysis

1.1.2 R_S

$$V_S = R_S I_D \implies R_S = \frac{V_S}{I_D} \quad (1.4)$$

$$R_S = \frac{3.5V}{0.5mA} = 7k\Omega \quad (1.5)$$

1.1.3 V_{GS}

$$I_D = \frac{1}{2} K_n V_{ov}^2 \implies V_{ov} = \pm \sqrt{\frac{2I_D}{K_n}} \quad (1.6)$$

$$V_{ov} = \pm \sqrt{\frac{2 \cdot 0.5mA}{4mA/V^2}} \quad (1.7)$$

$$V_{ov} = \begin{cases} +0.5V & \text{Real value of } V_{ov}. \\ -0.5V & \text{No physical sense.} \end{cases} \quad (1.8)$$

$$(1.9)$$

$$V_{ov} = V_{GS} - V_t \implies V_{GS} = V_{ov} + V_t \quad (1.10)$$

$$V_{GS} = 0.5V + 1V = 1.5V \quad (1.11)$$

$$(1.12)$$

1.1.4 R_{G1}

$$V_{GS} = V_G - V_S \implies V_G = V_{GS} + V_S \quad (1.13)$$

$$V_G = 1.5V + 3.5V = 5V \quad (1.14)$$

$$(1.15)$$

$$I_G R_{G2} - V_{GS} - I_D R_S = 0 \implies I_G = \frac{V_{GS} + I_D R_S}{R_{G2}} \quad (1.16)$$

$$I_G = \frac{1.5V + 0.5mA \cdot 7k\Omega}{1097.752k\Omega} = 4.5547628\mu A \simeq 4.55\mu A \quad (1.17)$$

$$(1.18)$$

$$R_{G1} = \frac{V_{DD} - V_G}{I_G} \quad (1.19)$$

$$= \frac{15V - 5V}{4.5547628\mu A} \quad (1.20)$$

$$= 2.19550M\Omega \simeq 2.20M\Omega \quad (1.21)$$

1.1.5 g_m

$$g_m = K_n V_{ov} = 4mA/V^2 \cdot 0.5V = 2mA/V \quad (1.22)$$

1.1.6 r_0

$$r_0 = \frac{1}{\lambda I_D} \xrightarrow{\lambda=0} r_0 = \infty \quad r_0 \text{ is considered as an open circuit.} \quad (1.23)$$

$$(1.24)$$

1.2 AC analysis

On an Alternate Current analysis the capacitances can be considered as short circuits, the inductances can be considered as open circuits and the direct current inputs are not considered.

The figure 1.3 represents the circuit for the AC analysis.

Other requested parameters are: $R_{sig} = 200k\Omega$ and $R_L = 8k\Omega$.

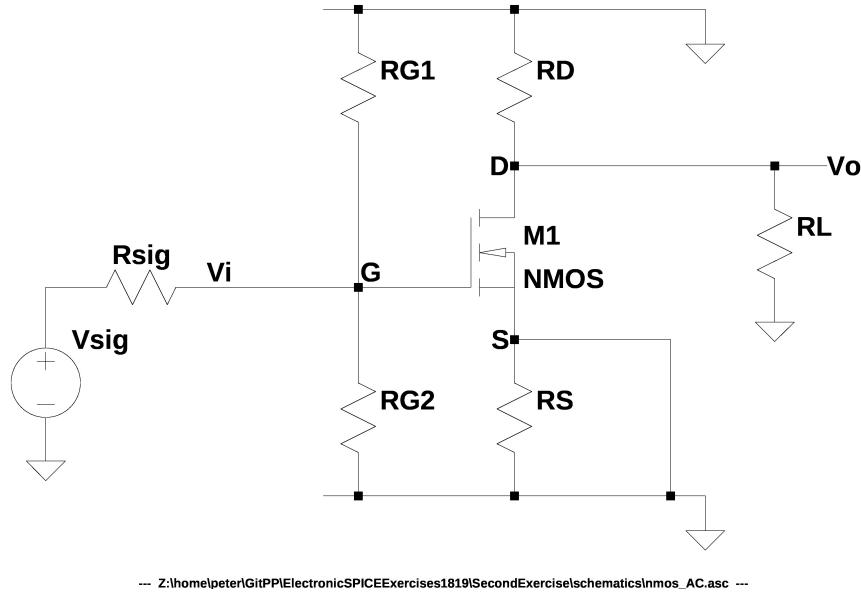


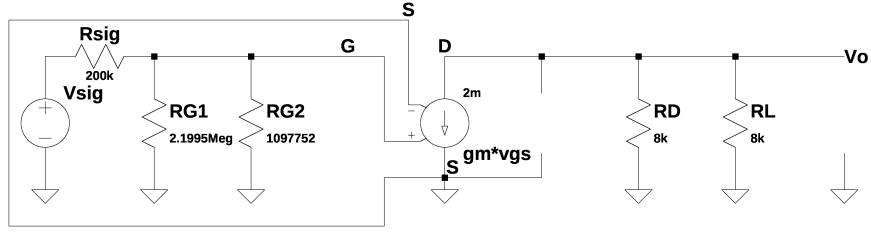
Figure 1.3: NMOS common source amplifier - AC analysis

1.2.1 Hybrid π model

For a small signal analysis it can be used an equivalent model to represent the behaviour of the transistor. In this case it is used the hybrid π model (figure 1.4).

1.2.2 R_{IN} from G

Removing the signal, the load and applying a test voltage source as in figure 1.5 it is possible to calculate the input's resistance R_{IN} .



--- Z:\home\peter\Git\PPI\ElectronicSPICEExercises\1819\SecondExercise\schematics\Inmos_small_signal.asc ---

Figure 1.4: NMOS common source amplifier - Hybrid π model

$$R_{IN} = \frac{V_x}{I_x} \quad (1.25)$$

$$(1.26)$$

$$I_x = \frac{V_x}{R_{G1} \parallel R_{G2}} \implies R_{G1} \parallel R_{G2} = \frac{V_x}{I_x} \implies R_{IN} = R_{G1} \parallel R_{G2} \quad (1.27)$$

$$(1.28)$$

$$R_{IN} = \frac{R_{G1} R_{G2}}{R_{G1} + R_{G2}} \quad (1.29)$$

$$= \frac{2.19550M\Omega \cdot 1097752\Omega}{2.19550M\Omega + 1097752\Omega} \quad (1.30)$$

$$= 733.16756k\Omega \simeq 733.2k\Omega \quad (1.31)$$

1.2.3 R_{OUT} from D

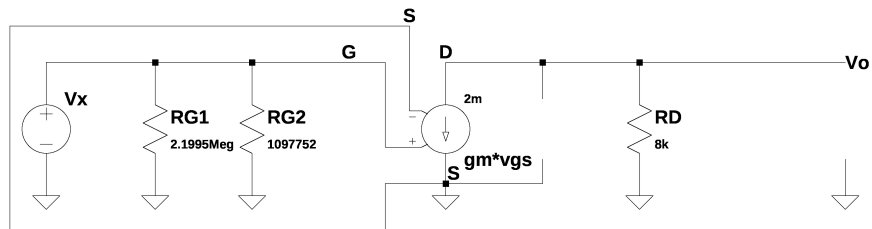
Removing the signal, the load and applying a test voltage source as in figure 1.6 it is possible to calculate the output's resistance R_{OUT} .

$$R_{OUT} = \frac{V_x}{I_x} \quad (1.32)$$

$$(1.33)$$

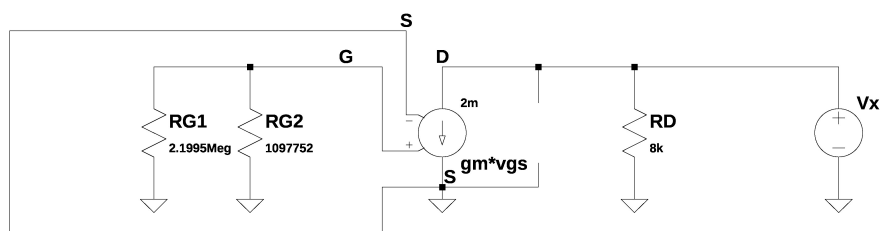
$$I_x = \frac{V_x}{R_D} \implies R_D = \frac{V_x}{I_x} \implies R_{OUT} = R_D \quad (1.34)$$

$$R_{OUT} = 8k\Omega \quad (1.35)$$



--- Z:\homelpeter\Git\PPI\ElectronicSPICEExercises1819\SecondExerciselschematics\Inmos_small_signal_RIN.asc ---

Figure 1.5: NMOS common source amplifier - Calculating R_{IN}



--- Z:\homelpeter\Git\PPI\ElectronicSPICEExercises1819\SecondExerciselschematics\Inmos_small_signal_ROUT.asc ---

Figure 1.6: NMOS common source amplifier - Calculating R_{OUT}

Chapter 2

SPICE simulations