K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
Single Stage FET Amplifier

11^{th} **July, 2020**

Numerical 1:
For the network shown in figure 1, determine I_{DQ}, V_{GSQ}, V_{DS} in addition to voltage gain A_V if R_S is bypassed. Given: I_{DSS} = 12mA and $V_P = -3V$

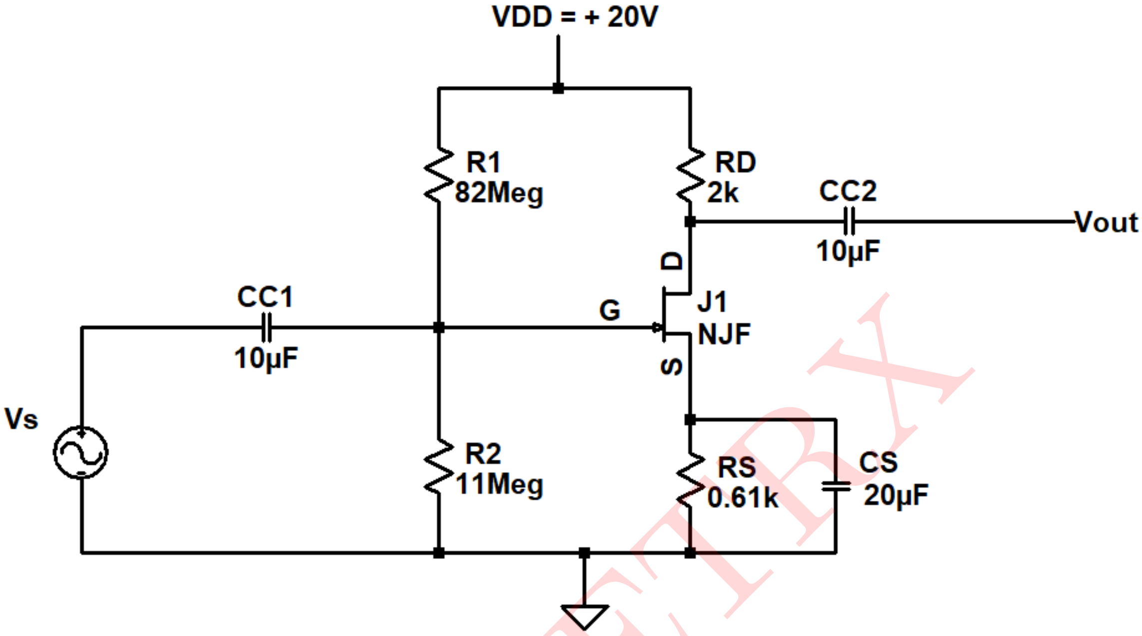

Figure 1: Circuit Diagram

Solution: The circuit shown in figure 1 is a common source n-channel JFET amplifier.

DC equivalent circuit is shown in figure 2:

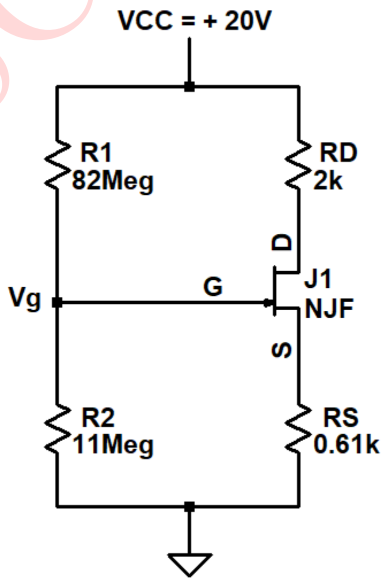

Figure 2: DC equivalent circuit

All capacitors are open circuited.

$$V_G = \frac{R_2}{R_1 + R_2} \times V_{DD} = \frac{11M\Omega}{82M\Omega + 11M\Omega} \times 20$$

$\therefore \mathbf{V_G = 2.3656V}$

Applying KVL to G-S loop:

$V_G - V_{GSQ} - I_{DQ}(0.61k\Omega) = 0$

$$\therefore I_{DQ} = \frac{V_g - V_{GSQ}}{0.61k\Omega} \qquad ...(1)$$

For JFET in saturation, drain current is given as:

$$I_{DQ} = I_{DSS}\left[1 - \frac{V_{GSQ}}{V_P}\right]^2 \qquad ...(2)$$

$I_{DSS} = 12mA$ and $V_P = -3V$ ...(given)

From (1) & (2), we get:

$$\frac{V_G - V_{GSQ}}{0.61k\Omega} = I_{DSS}\left[1 - \frac{V_{GSQ}}{V_P}\right]^2$$

On substituting values,

$$\frac{2.3656 - V_{GSQ}}{0.61k\Omega} = (12mA)\left[1 + \frac{V_{GSQ}}{3}\right]^2$$

$$2.3656 - V_{GSQ} = 7.32\left[1 + \frac{V_{GSQ}^2}{9} + \frac{2V_{GSQ}}{3}\right]$$

$2.3656 - V_{GSQ} = 7.32 + 0.8133V_{GSQ}^2 + 4.88V_{GSQ}$

$\therefore 0.8133V_{GSQ} + 5.88V_{GSQ} + 4.9544 = 0$

$\therefore V_{GSQ} = -0.973V, -6.2561V$

Since $-0.9737 > V_P$, $\mathbf{V_{GSQ} = -0.9737V}$

$$\therefore I_{DQ} = (12mA)\left[1 - \frac{0.9737V}{3}\right]^2 = (12\text{mA})(0.6754)^2$$

$\therefore \mathbf{I_{DQ} = 5.4745mA}$

Applying KVL to D-S loop:

$20 - I_D(2K\Omega) - V_{DS} - I_S(0.61K\Omega) = 0$

$\therefore -I_D(2k\Omega + 0.61k\Omega) + 20 = V_{DS} \qquad ...(\because I_D = I_S \text{ for JFET })$

$V_{DS} = -(5.4745mA)(2.61k\Omega) + 20$

$\therefore \mathbf{V_{DS} = 5.7147V}$

Small signal parameters:

$$g_m = g_{mo}\left[1 - \frac{V_{GS}}{V_P}\right]$$

$$g_{mo} = \frac{2I_{DSS}}{\mid V_P \mid} = \frac{2 \times 12mA}{3V} = 8\text{mA/V}$$

$$\therefore g_m = 8\left[1 - \frac{0.9737}{3}\right]$$

$\therefore g_m = 5.4035$ mA/V

Small signal equivalent circuit is shown in figure 3:

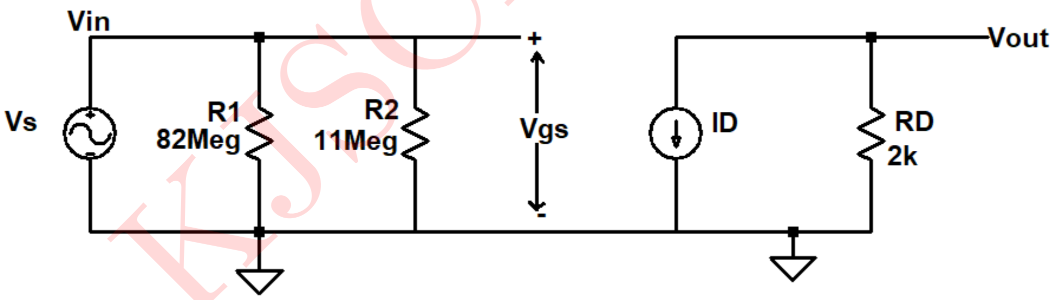

Figure 3: Small signal equivalent circuit

All the capacitors are short-circuited and R_S is bypassed.

Voltage gain, $A_V = \dfrac{V_{out}}{V_S}$

From small signal equivalent circuit, $V_S = V_{GS}$

Also, $V_{out} = -g_m V_{GS}(R_D)$

$$\therefore A_V = \frac{-g_m V_{GS}(R_D)}{V_{GS}} = -g_m R_D$$

$\therefore A_V = -(5.4035mA)(2k\Omega)$

$\therefore \mathbf{A_V = -10.8069}$

SIMULATED RESULTS:
Above circuit was simulated in LTspice and results obtained are as follows:

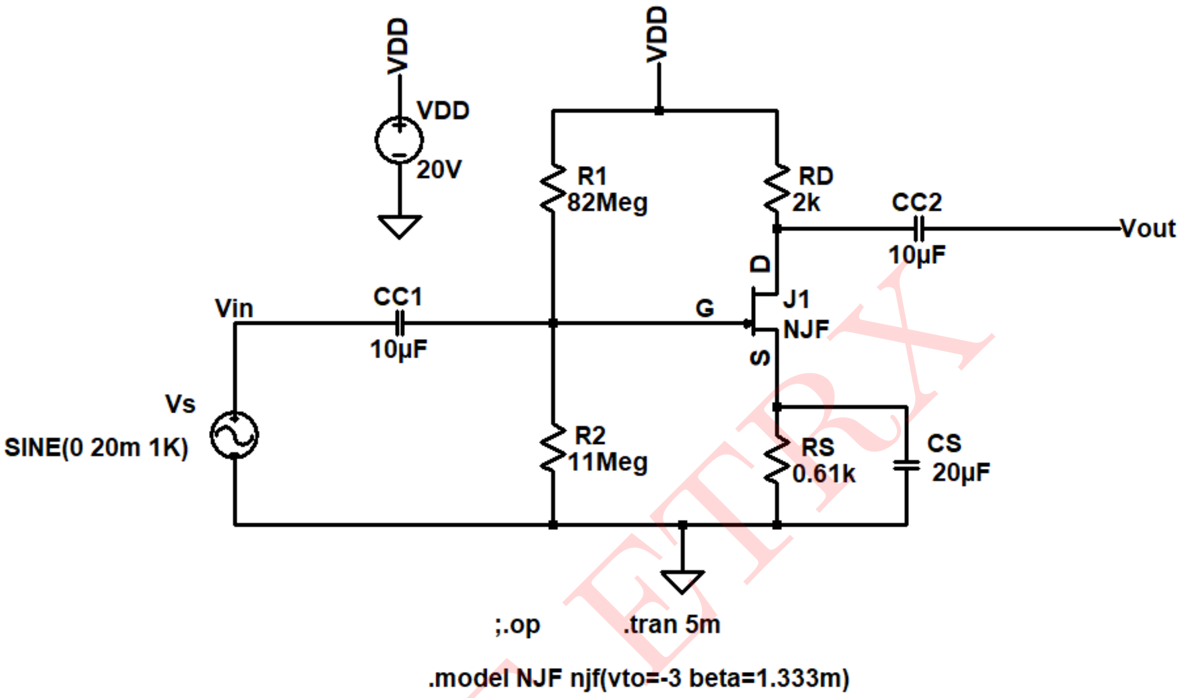

Figure 4: Circuit Schematic: Results

The input and output waveform is shown in figure 5:

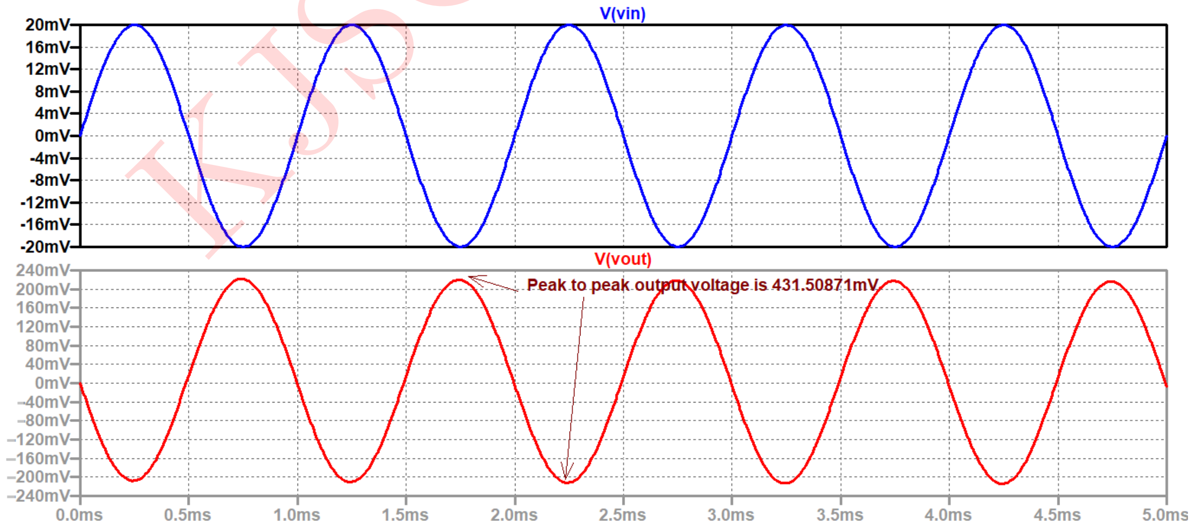

Figure 5: Input and output waveform

Comparsion between theoretical and simulated values:

Parameter	Theoretical value	Simulated value
I_{DQ}	5.4733mA	5.4741mA
V_{GSQ}	-0.9737V	-0.9735V
V_{DS}	5.7147V	5.7126V
A_V	-10.8069	-10.7877

Table 1: Numerical 1

Numerical 2:
For the NMOS common source amplifier as shown in figure 6, the transistor parameters are $V_{TN} = 0.8$V, $k_n = 1mA/V^2$ and $\lambda = 0$. The circuit parameters are $V_{DD} = 5V$, $R_S = 1k\Omega$, $R_D = 4k\Omega$, $R_1 = 225k\Omega$ and $R_2 = 175k\Omega$
a. Calculate quiescent values of I_{DQ} and V_{DSQ}
b. Determine the small-signal voltage gain for $R_L = \infty$

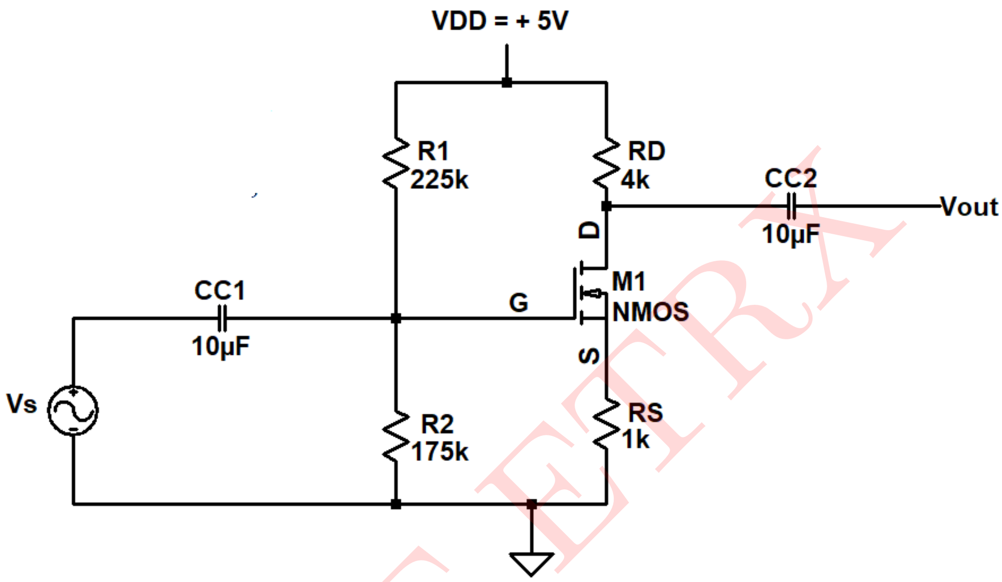

Figure 6: Circuit Diagram

Solution: The circuit shown in figure 6 is a common-source N-channel MOSFET amplifier. DC equivalent circuit is shown in figure 7:

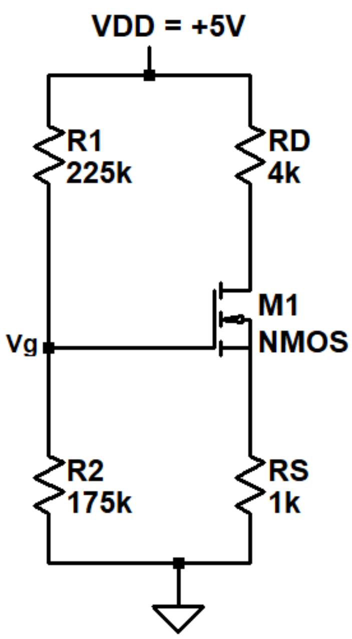

Figure 7: DC equivalent circuit

All capacitors are open circuited.

$$V_G = \frac{R_2 \times V_{DD}}{R_1 + R_2} = \frac{175k\Omega \times 5}{225k\Omega + 175k\Omega} = 2.1875\text{V}$$

$\therefore V_G = 2.1875\text{V}$

Applying KVL to G-S loop:

$V_G - V_{GSQ} - I_S R_S = 0$

$V_G - V_{GSQ} - I_{DQ} R_S = 0 \qquad ...(\because I_D = I_S)$

$\therefore 2.1875 - V_{GSQ} - I_D = 0$

$\therefore I_{DQ} = 2.1875 - V_{GSQ} \qquad ...(1)$

For N-MOSFET in saturation:

$I_D = k_n[V_{GS} - V_{TN}]^2$

$2.1875 - V_{GSQ} = k_n[V_{GSQ} - V_{TN}]^2 \qquad ...(\text{from } (1))$

$\therefore 2.1875 - V_{GSQ} = 1 \times 10^{-3}[V_{GSQ} - 0.8]^2$

$\therefore 2.1875 - V_{GSQ} = V_{GSQ}^2 + 0.64 - 1.6V_{GSQ}$

$\therefore V_{GSQ}^2 - 0.6V_{GS} - 1.5474 = 0$

$\therefore V_{GSQ} = 1.5796, -0.9796V$

Since $V_{GS} > V_{TN}$

$\therefore V_{GSQ} = 1.5796V$

For $V_{GSQ} = 1.5796V$, using (1) we get:

$I_{DQ} = 2.1875 - 1.5796$

$\therefore \mathbf{I_{DQ} = 0.6079mA}$

Applying KVL to D-S loop:

$5 - I_D R_D - V_{DS} - I_D R_S = 0$

$\therefore V_{DS} = 5 - I_{DQ}(R_D + R_S)$

$\therefore V_{DS} = 5 - (0.6079mA)(4k\Omega + 1k\Omega)$

$\therefore V_{DS} = 5 - (0.6079mA)(5k\Omega)$

$\therefore \mathbf{V_{DS} = 1.9605V}$

Small signal parameters:

$r_d = \infty$ (assumed)

We know, $g_m = 2k_n[V_{GSQ} - V_{TN}]$

$g_m = 2(1 \times 10^{-3})[1.5796 - 0.8]$

$\therefore g_m = 1.5592mA/V$

Small signal equivalent circuit is shown in figure 8:

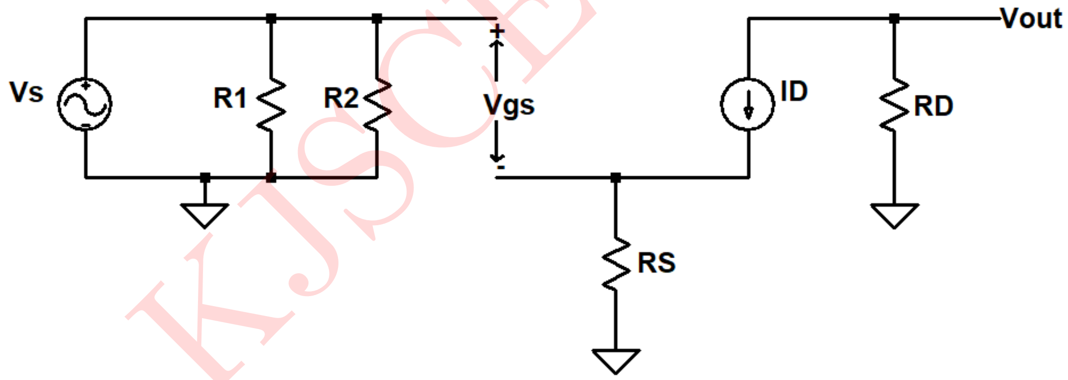

Figure 8: Small signal equivalent circuit

All the capacitors are short-circuited.

$I_D = V_{GS} \times g_m$

From small signal equivalent circuit:

$$V_{out} = -I_D R_D = -g_m V_{GS}(R_D) \qquad ...(2)$$

$$V_S = V_{in} = V_{GS} + g_m V_{GS}(R_D)$$

$$\therefore V_S = V_{GS}[1 + g_m R_D] \qquad ...(3)$$

Using (2) & (3), small signal voltge gain is given as:

$$\frac{V_{out}}{V_{in}} = \frac{-g_m V_{GS}(R_D)}{V_{GS}[1 + g_m(R_S)]}$$

$$\therefore A_V = \frac{-g_m(R_D)}{1 + g_m(R_S)}$$

$$\therefore \mathbf{A_V = -2.4370}$$

SIMULATED RESULTS:
Above circuit was simulated in LTspice and results obtained are as follows:

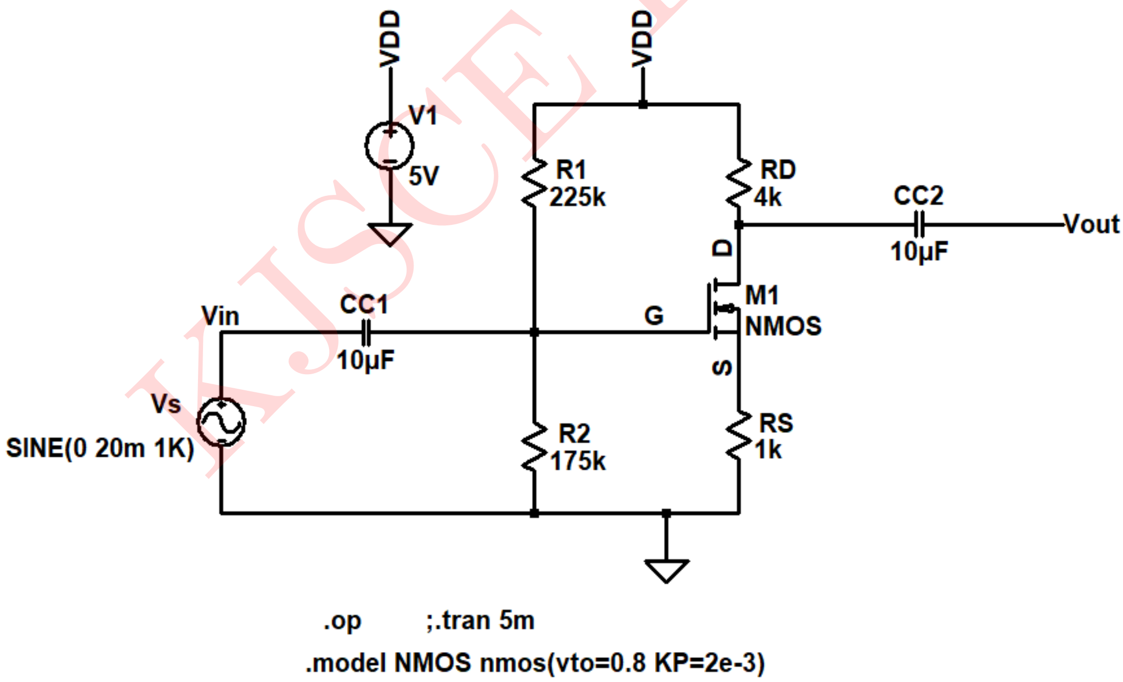

Figure 9: Circuit Schematic: Results

The input and output waveform is shown in figure 10:

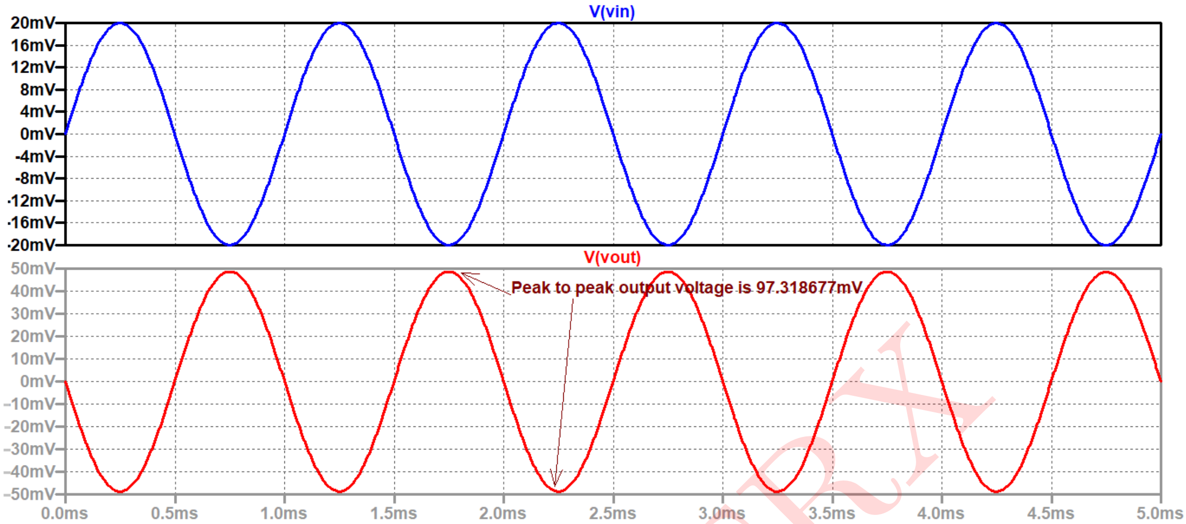

Figure 10: Input and output waveform

Comparsion between theoretical and simulated values:

Parameter	Theoretical value	Simulated value
I_{DQ}	0.6079mA	0.60785mA
V_{GSQ}	1.5796V	1.5796V
V_{DS}	1.9605V	1.9607V
A_V	-2.4370	-2.4332

Table 2: Numerical 2