K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
SINGLE STAGE FET AMPLIFIER

23^{rd} **June, 2020** **Numericals**

1. For the circuit shown in Figure 1, find
   a) I_{DQ}
   b) V_{SQ}
   c) R_i
   d) R_o
   e) A_V
   Given: $I_{DSS} = 10$ mA, $V_P = -4$ V

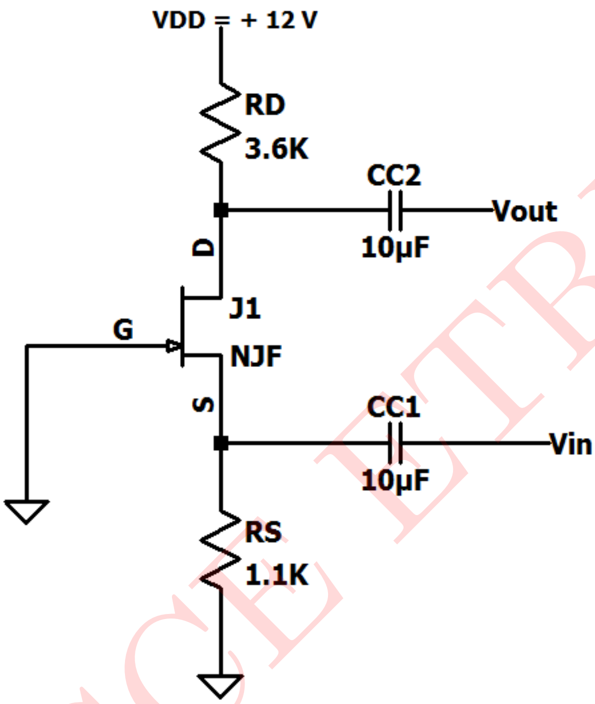

Figure 1: Circuit 1

Solution:

The above circuit is a common gate amplifier.

DC Analysis:
The capacitors act as open circuit.

$$f = 0, \quad \therefore X_C = \frac{1}{2\pi f C} = \infty$$

Applying KVL to input gate-source loop

$$-V_{GS} - I_D R_S = 0$$

$$\therefore V_{GS} = -I_D R_S = -1100 I_D$$

For JFET, $I_D = I_{DSS}\left(1 - \dfrac{V_{GS}}{V_P}\right)^2$

$$\therefore V_{GS} = -1100 \times I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$\therefore V_{GS} = -1100 \times 10 \times 10^{-3}\left(1 + \frac{V_{GS}}{4}\right)^2$$

$$\therefore V_{GS} = -11\left(1 + \frac{V_{GS}}{2} + \frac{V_{GS}^2}{16}\right)$$

$$\therefore 0.6875V_{GS}^2 + 6.5V_{GS} + 11 = 0$$

$$\therefore V_{GS} = -2.2079 \text{ V or } V_{GS} = -7.2466 \text{ V}$$

Since $V_{GS} > V_P$, $V_{GS} = -2.2079$ V

$$\therefore I_D = \frac{V_{GS}}{-1100} = \mathbf{2.00718\ mA}$$

Small-signal parameters:

$$g_m = \frac{-2I_{DSS}}{V_P} \times \left(1 - \frac{V_{GS}}{V_P}\right)$$

$$\therefore g_m = \frac{-2 \times 10 \times 10^{-3}}{-4} \times \left(1 - \frac{2.2079}{4}\right) = 2.25 \text{ mA/V}$$

The small signal equivalent circuit is shown in Figure 2

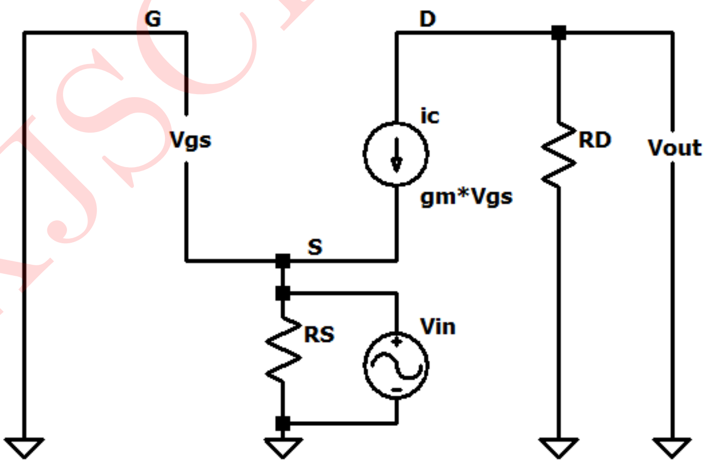

Figure 2: Small-signal equivalent circuit

Input resistance $R_i = R_S || \frac{1}{g_m} = \mathbf{316.5\ \Omega}$

Output resistance $R_o = R_D = \mathbf{3.6\ k\Omega}$

Voltage gain $A_V = g_m R_D = 2.25 \times 10^{-3} \times 3.6k$

$$\therefore A_V = \mathbf{8.1}$$

SIMULATED RESULTS:
Above circuit is simulated using LTspice and the results are presented below:

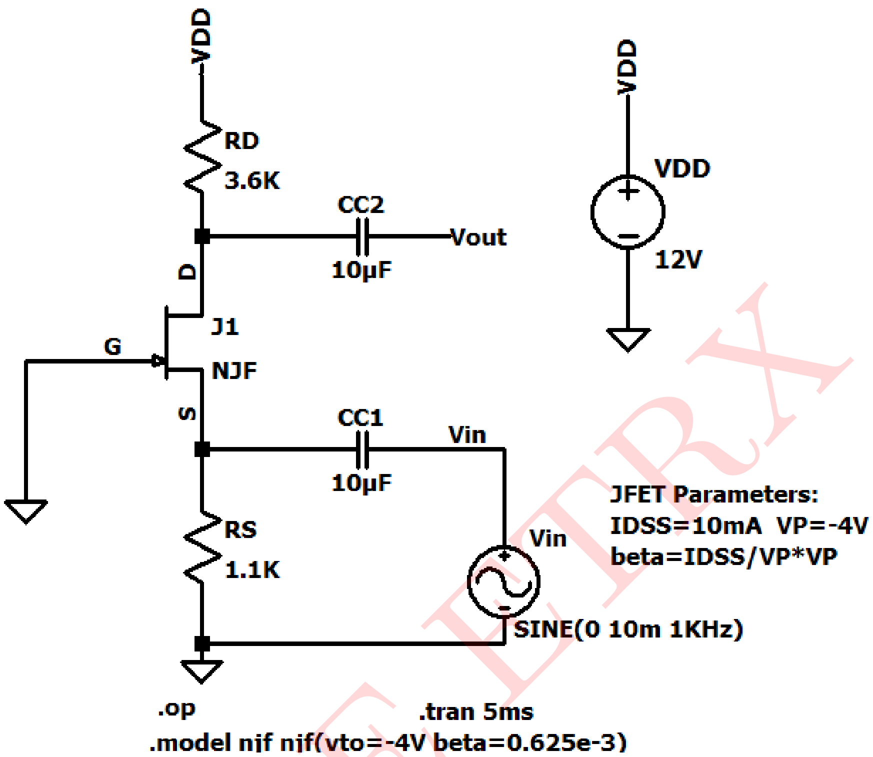

Figure 3: Circuit schematic

The waveforms for input and output voltage are shown in Figure 4.

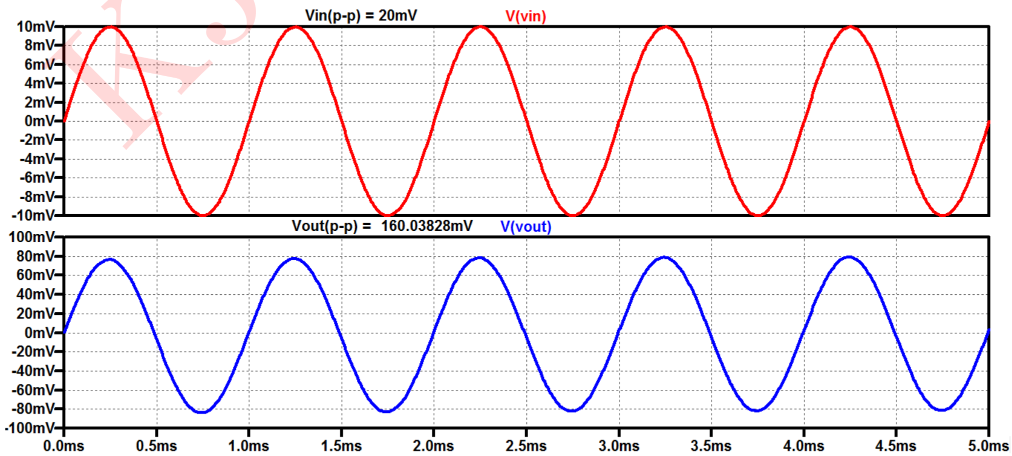

Figure 4: Input and output voltage waveforms

Comparison of theoretical and simulated values:

Parameters	Theoretical	Simulated
I_{DQ}	2.00718 mA	2.00721 mA
V_{GSQ}	-2.2079 V	-2.20793 V
A_V	8.1	8.001914

Table 1: Numerical 1

2. For the circuit shown in Figure 5, calculate
   a) Z_i
   b) Z_o
   c) V_{GSQ}
   d) I_{DQ}
   e) A_V
   Given: $k_n = 1 = 0.2mA/V^2$, $V_{GS(th)} = 3$V, $r_d = 100$ kΩ

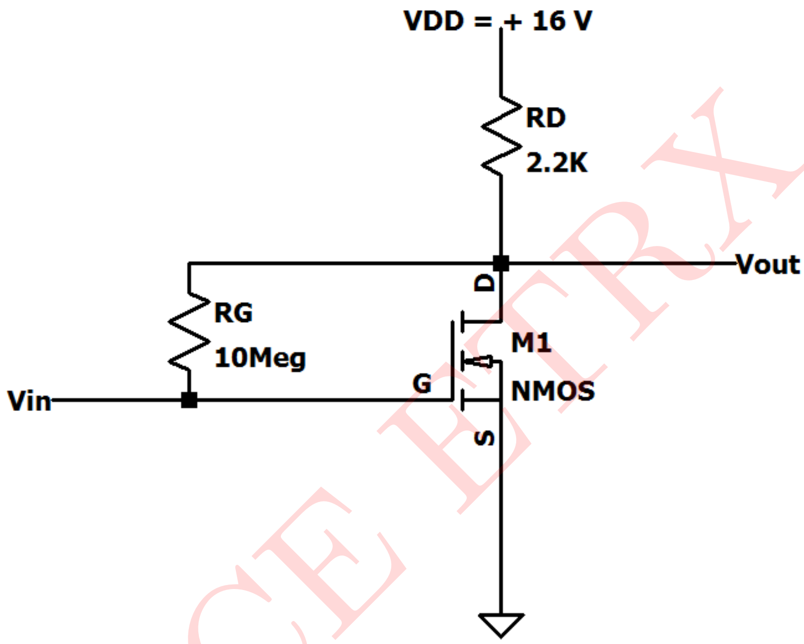

Figure 5: Circuit 2

Solution: The above circuit is a feedback amplifier circuit.

DC Analysis:

The capacitors act as open circuit. $f = 0$, $\therefore X_C = \dfrac{1}{2\pi f C} = \infty$

$$k_n = \frac{I_D}{[V_{GS} - V_{GS(th)}]^2}$$

$$\therefore 0.2 \times 10^{-3} = \frac{I_D}{[V_{GS} - 3]^2}$$

$$\therefore I_D = 0.2 \times 10^{-3} \times [V_{GS} - 3]^2 \qquad ....(1)$$

$$V_{GS} = V_{DD} - I_D R_D$$

$$\therefore V_{GS} = 16 - (0.2 \times 10^{-3} \times [V_{GS} - 3]^2 \times 2.3k)$$

$$\therefore V_{GS} = 16 - 0.44[V_{GS} - 3]^2$$

$$\therefore V_{GS} = 16 - 0.44V_{GS}^2 + 2.64V_{GS} - 3.96$$

$$\therefore 0.44V_{GS}^2 - 1.64V_{GS} - 12.04 = 0$$

$\therefore V_{GS} = 7.4167325$ V or $V_{GS} = -3.68945$ V

Since $V_{GS} > V_{TN}$, $\therefore V_{GSQ} = \mathbf{7.4167235\ V}$

From equation (1), $I_{DQ} = 0.2 \times 10^{-3} \times [7.4167235 - 3]^2$

$\therefore I_{DQ} = \mathbf{3.901489\ mA}$

Small-signal parameters:

$g_m = 2k_n(V_{GSQ} - V_{TN}) = 2 \times 0.2 \times 10^{-3} \times (7.4167235 - 3)$

$\therefore g_m = 1.766689\dfrac{mA}{V}$

$r_d = \dfrac{1}{\lambda I_{DQ}}$

$\therefore \lambda = \dfrac{1}{r_d I_{DQ}} = \dfrac{1}{100 \times 10^3 \times 3.901489 \times 10^{-3}}$

$\therefore \lambda = 2.5631239 \times 10^{-3}\ V^{-1}$

The mid-frequency AC equivalent circuit is shown in Figure 6

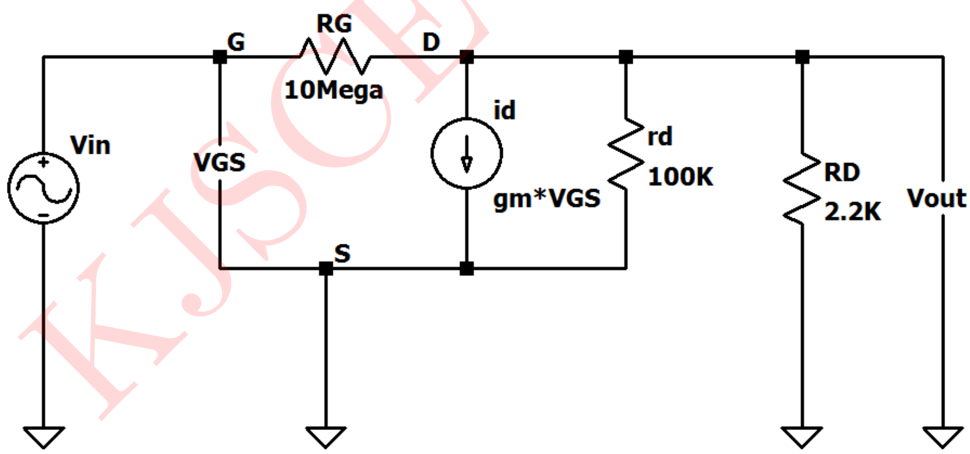

Figure 6: Mid-frequency equivalent circuit

Applying KCL at D, $I_i = g_m V_{gs} + \frac{V_o}{r_d||R_D}$

$I_i = \frac{V_i - V_o}{R_G}$ and $V_i = V_{gs}$

$\therefore \frac{V_i - V_o}{R_G} = g_m V_i + \frac{V_o}{r_d||R_D}$

$V_i \left(\frac{1}{R_G} - g_m\right) = V_o \left(\frac{1}{R_G} + \frac{1}{r_d||R_D}\right)$

$\frac{1}{R_G}$ is very small, hence $\left(\frac{1}{R_G} - g_m\right) \approx -g_m$

$\therefore V_i \times -g_m = V_o \left(\frac{1}{R_G} + \frac{1}{r_d||R_D}\right)$

$\therefore A_V = \frac{V_o}{V_i} = \frac{-g_m}{\left(\frac{1}{R_G||r_d||R_D}\right)}$

$\therefore A_V = -g_m(R_G||r_d||R_D) = 1.766689 \times 10^{-3} \times (10M||100k||2.2k)$

$\therefore A_V = -3.802154$

$Z_i = R_G = 10\ \text{M}\Omega$

$Z_o = R_G||r_d||R_D = 10M||100k||2.2k$

$\therefore Z_o = 2.152136\ \text{k}\Omega$

SIMULATED RESULTS:

Above circuit is simulated using LTspice and the results are presented below:

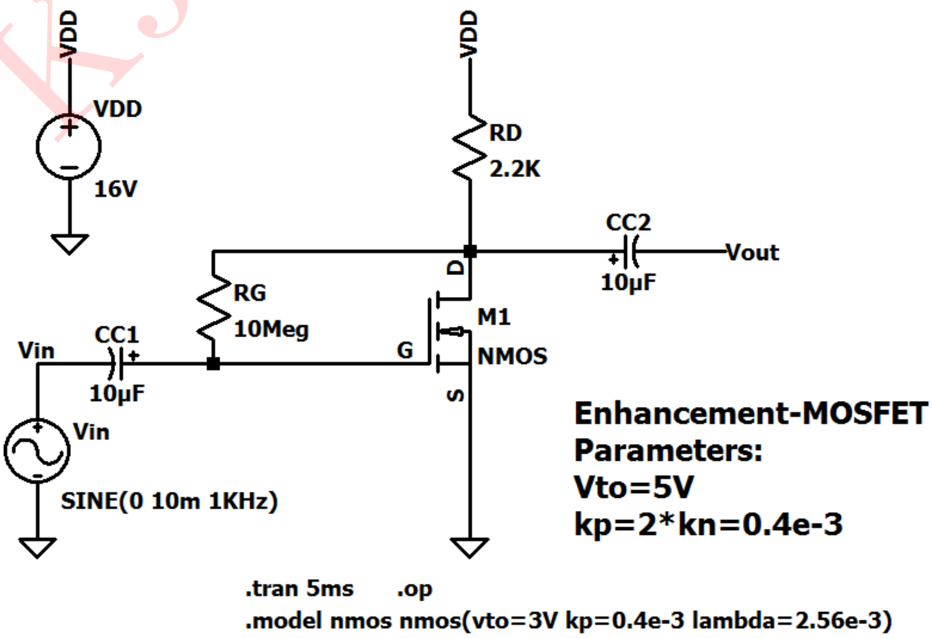

Figure 7: Circuit schematic

The input and output waveforms are shown in Figure 8

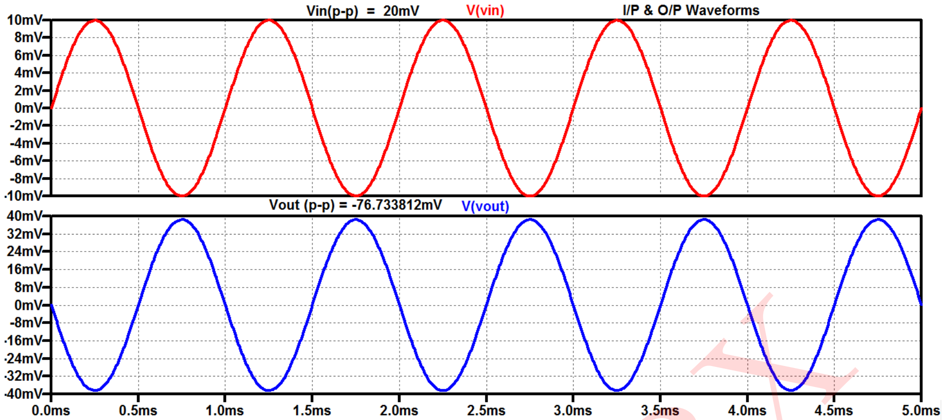

Figure 8: Input and output waveforms

Comparison of theoretical and simulated values:

Parameters	Theoretical	Simulated
I_{DQ}	3.901489 mA	3.90149 mA
V_{GSQ}	7.4167235 V	7.41672 V
A_V	-3.802154	-3.84098

Table 2: Numerical 2