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DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
Single Stage FET Amplifier

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

Numerical 1: For the circuit shown in figure 1, Find A_V, Z_i, Z_o where $I_{DSS} = 12mA$, $V_P = -3V$, $r_d = 45k\Omega$

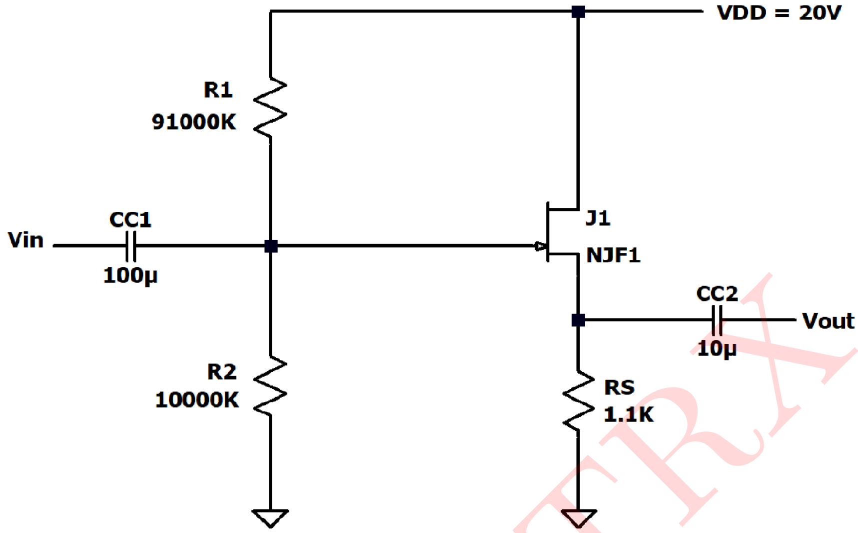

Figure 1: Circuit 1

Solution: The above circuit consists of a common drain amplifier consisting of a voltage divider configuration employing njfet

DC ANALYSIS:

For DC analysis, $f = 0$, thus $X_C = \dfrac{1}{2\pi fc} = \infty$, so we replace capacitors with open circuit.

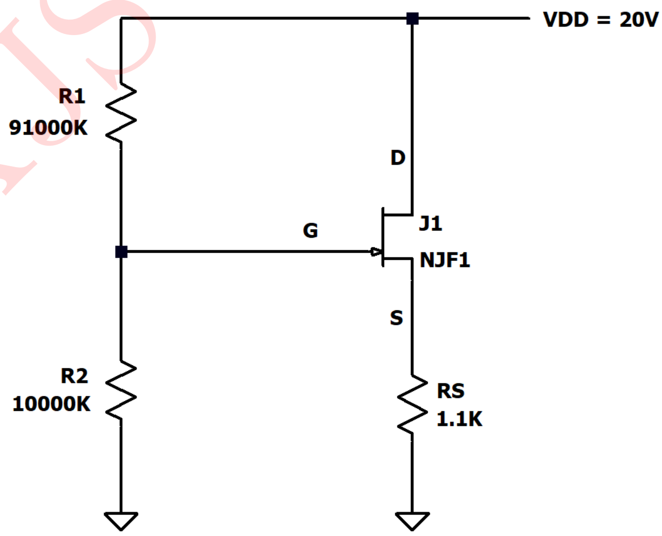

Figure 2: DC Equivalent Circuit

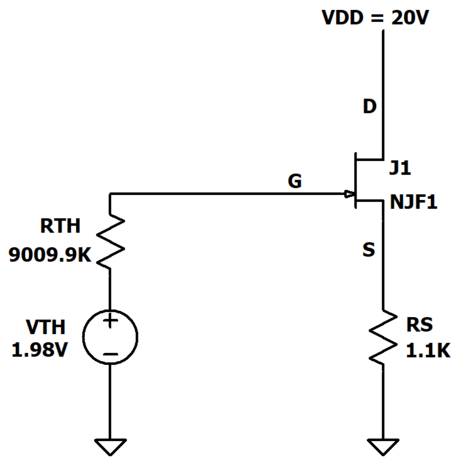

Figure 3: Thevenin equivalent circuit

Where, $R_{TH} = R_1 \parallel R_2 = 91M \parallel 10M = 9.0099M\Omega = \mathbf{9009.9k\Omega}$

$$V_{TH} = \frac{R_2}{R_1 + R_2} \times V_{DD} = \frac{10M}{91M + 10M} \times 20 = \mathbf{1.98V}$$

By applying KVL to gate - source loop,

$$V_{TH} - I_G R_{TH} - V_{GS} - I_{BS} R_S = 0$$

But $I_S = I_D$ and $I_G = 0$

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

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

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

$$I_D = \frac{V_{TH} - V_{GS}}{R_S} \qquad .....1$$

For JFET we know that $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$ 2

From 1 and 2, we get;

$$\frac{V_{th} - V_{GS}}{R_S} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$\frac{1.98 - V_{GS}}{1.1 \times 0^3} = 12 \times \times 10^{-3}\left(1 - \frac{V_{GS}}{-3}\right)^2$$

$$1.98 - V_{GS} = (12 \times 1.1)\left(1 + \frac{V_{GS}}{3}\right)^2$$

$$1.98 - V_{GS} = 13.2\left(1 + \frac{2V_{GS}}{3} + \frac{V_{GS}^2}{9}\right)$$

$$1.98 - V_{GS} = \frac{13.2}{9} V_{GS}^2 + \frac{(13.2 \times 2)}{3} V_{GS} + 13.2$$

$$1.467 V_{GS}^2 + 9.8 + 11.22 = 0$$

On solving we get;

$V_{GS} = -1.464V$ or $V_{GS} = -5.222V$

But, $V_{GS} > V_P$

$\therefore V_{GSQ} = -1.464V$

$$I_D = \frac{V_{TH} - V_{GS}}{R_S} = \frac{1.98 - (-1.464V)}{1.1 \times 10^3} = \mathbf{3.130mA}$$

AC Analysis:

a) Small-Signal parameters:

$$g_m = 2\frac{I_{DSS}}{|V_P|}\left(1 - \frac{V_GS}{V_P}\right) = 2 \times \frac{12 \times 10^{-3}}{3}\left(1 - \frac{(-1.464)}{(-3)}\right) = 8 \times 10^{-3}(0.512) = \mathbf{4.096mA/V}$$

b) Small signal equivalent circuit is shown in figure 4;

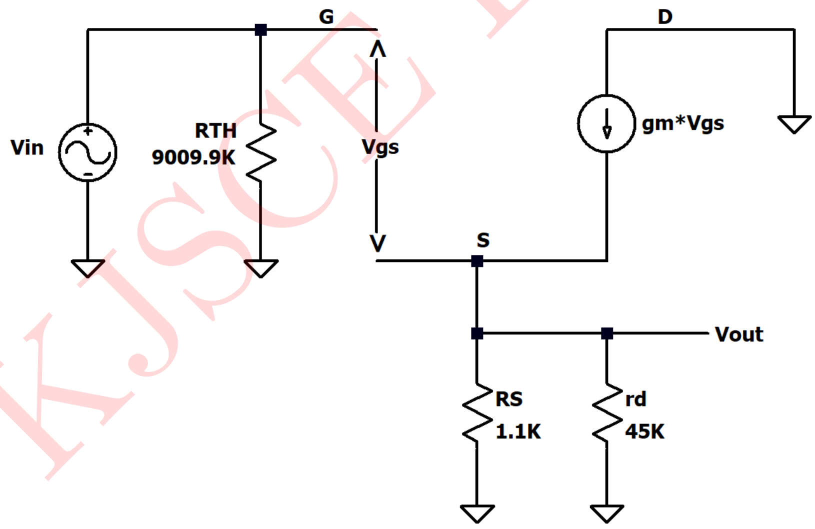

Figure 4: Small Signal Equivalent Circuit

c) A_V **(Small Signal Voltage Gain)**

$$A_V = \frac{g_m(R_S \ || \ r_d)}{1 + g_m(R_S \ || \ r_d)} = \frac{4.096 \times 10^{-3}(1.1k \ || \ 4.5k)}{1 + 4.096 \times 10^{-3}(1.1k \ || \ 4.5k)}$$

$$= \frac{4.096 \times 10^{-3} \times 1.073 \times 10^3}{1 + (4.096 \times 10^{-3} \times 1.073 \times 10^3)} = \mathbf{0.314}$$

d) Z_i **(Input Impedence)**

$Z_i = R_{TH} = 9009k\Omega = \mathbf{9.009M\Omega}$

e) Z_o **(Output Impedence)**

$$Z_o = \frac{1}{g_m} \;||\; R_S||\; r_d = \frac{1}{g_m} \;||\; (R_S \;||\; r_d) = \frac{1}{4.096 \times 10^{-3}} \;||\; (1.1 \times 10^3 \;||\; 45 \times 10^3)$$

$$= \frac{1}{4.096 \times 10^{-3}} \;||\; 1073.753 = 244.14 \;||\; 1073.753 = \mathbf{198.91\Omega}$$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and the result is as follows:

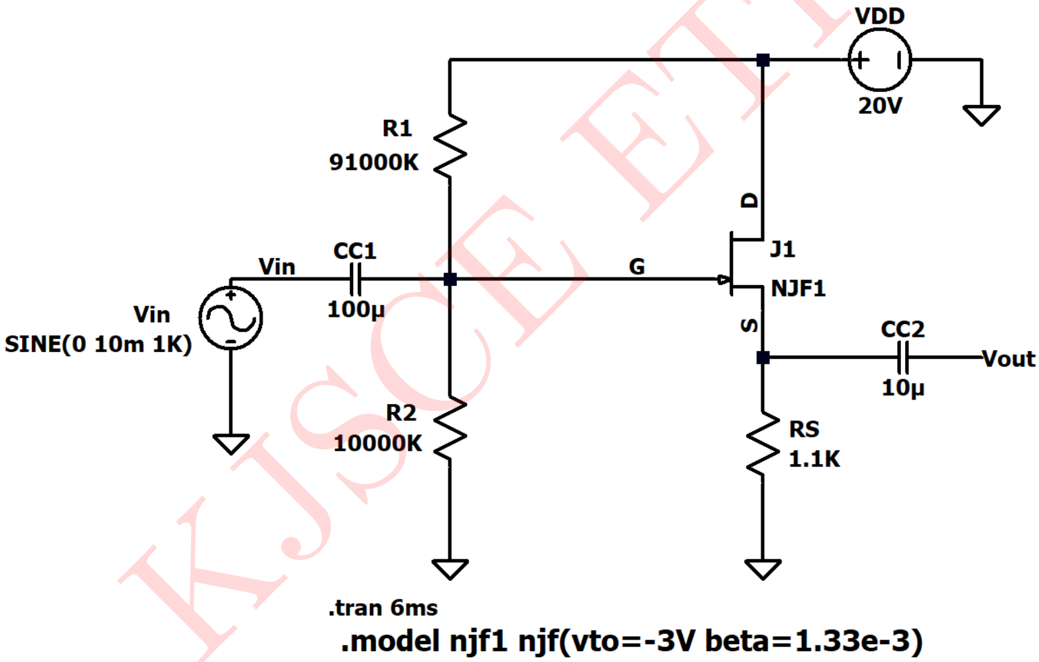

Figure 5: Circuit Schematic

The input and output waveforms are shown in figure 6.

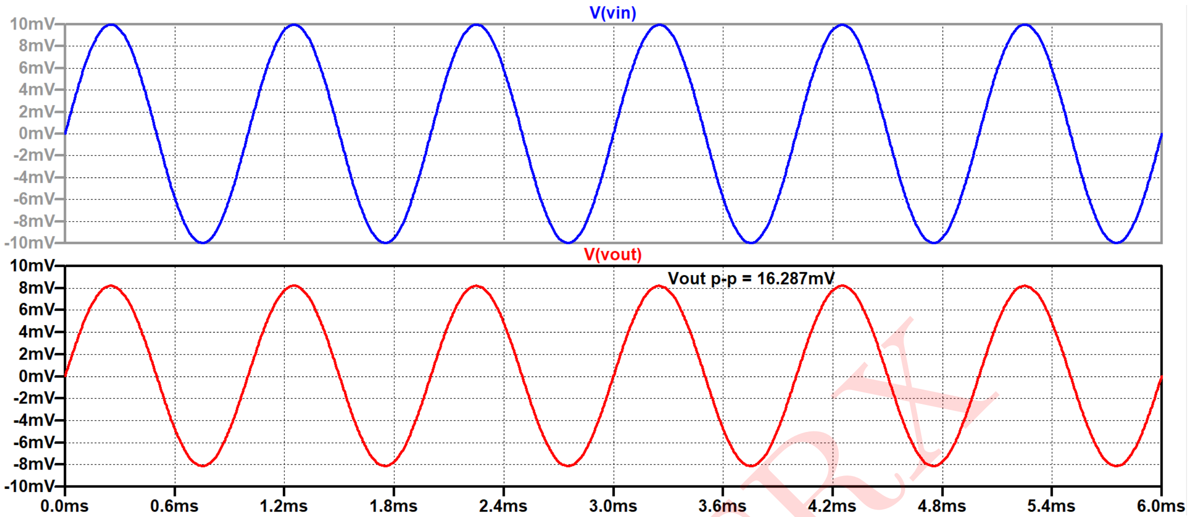

Figure 6: Input and Output Waveforms

Comparison between Theoretical and Simulated values :-

Parameter	Simulated	Theoretical
I_{DQ}	3.13mA	3.13mA
V_{GSQ}	$-1.465V$	$-1.464V$
A_V	0.8143	0.814

Table 1: Numerical 1

Numerical 2: For the common gate circuit shown in figure 7, the NMOS transistor configurations are $V_{TN} = 1V$, $k_n = 3mA/V^2$ and $\lambda = 0$

a) Determine I_{DQ} and V_{DSQ}

b) Find g_m and r_o

c) Find the small signal voltage gain A_V

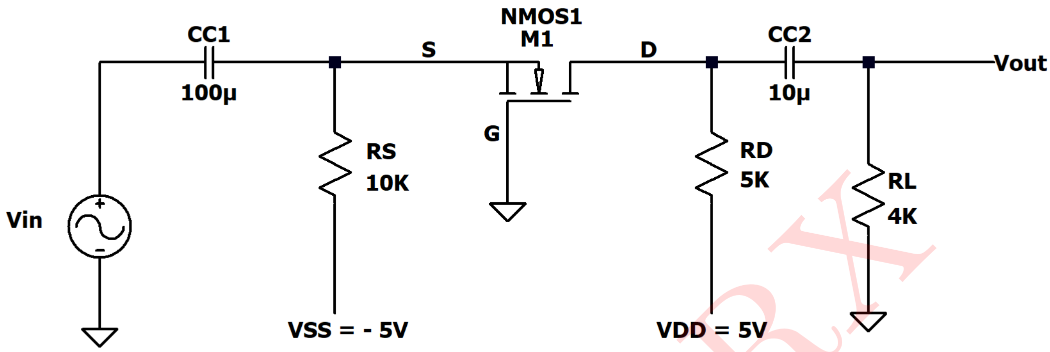

Figure 7: Circuit 2

Solution: The above circuit is a common gate configuration employing NMOS transistor

DC ANALYSIS:

For DC analysis, $f = 0$, thus $X_C = \dfrac{1}{2\pi fc} = \infty$, so we replace capacitors with open circuit.

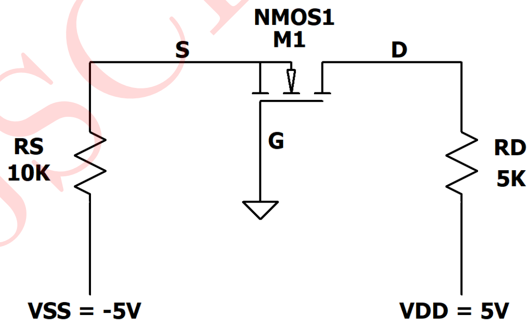

Figure 8: DC Equivalent Circuit

Applying KVL to gate - source loop,

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

But $I_S = I_D$

$\therefore -V_{GS} - I_D R_S - V_{SS} = 0$

$\therefore -V_{GS} - I_D(10 \times 10^3) + 5 = 0$ 1

Also for NMOS,

$I_D = k_n(V_{GS} - V_{TN})^2 = 3 \times 10^{-3}(V_{GS} - 1)$ 2

From 1 and 2 we get;

$-V_{GS} - (3 \times 10^{-3} \times 10 \times 10^3)(V_{GS} - 1)^2 + 5 = 0$

$-V_{GS} - 30(V_{GS}^2 - 2V_{GS} + 1) + 5 = 0$

$\therefore -30V_{GS}^2 + 60V_{GS} - V_{GS} - 30 + 5 = 0$

$\therefore -30V_{GS}^2 + 59V_{GS} - 25 = 0$

$\therefore 30V_{GS}^2 - 59V_{GS} + 25 = 0$

On solving we get,

$V_{GS} = 1.34V$ or $0.617V$

But $V_{GS} > V_{TN}$

$V_{GSQ} = \mathbf{1.34V}$

Substituting value of V_{GS} in 2, we get;

$I_D = 3 \times 10^{-3}(1.34 - 1)^2 = \mathbf{0.35mA}$

Applying KVl to drain - source loop,

$V_{DD} - I_D R_D - V_{DS} - I_S R_S - V_{SS} = 0$

But $I_D = I_S$

$V_{DD} - I_D R_D - V_{DS} - V_{SS} - I_D R_S = 0$

$V_{DS} = V_{DD} - V_{SS} - I_D(R_D + R_S) = 5 - (-5) - (0.35 \times 10^{-3})(10k + 5k) = 10 - 5.25 = \mathbf{4.75V}$

AC ANALYSIS:

a) Small Signal Parameters

$g_m = 2k_n(V_{GS} - V_{TN}) = (2 \times 3 \times 10^{-3})(1.34 - 1) = \mathbf{2.04mA/V}$

$$r_o = \frac{1}{\lambda I_{DQ}}$$

since $\lambda = 0$, $r_o = \infty$

b) Small signal equivalent circuit is shown in figure 9;

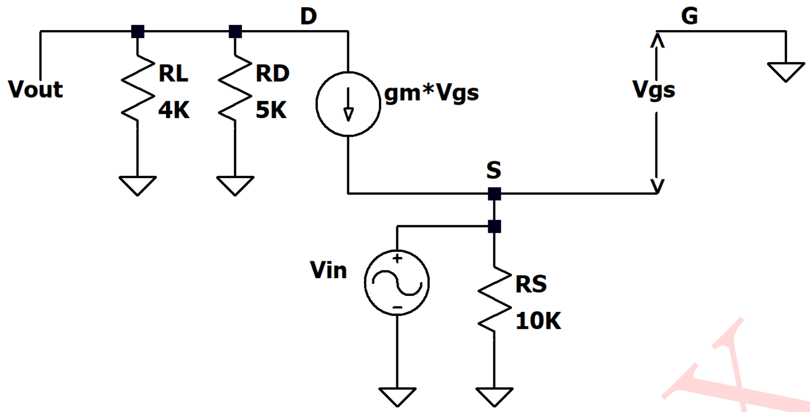

Figure 9: Small Signal Equivalent Circuit

c) A_V **(Small Signal Voltage Gain)**

$$A_V = \frac{V_{out}}{V_{in}} = g_m(R_D \; || \; R_L) = 2.04 \times 10^{-3}(4k \; || \; 5k) = \mathbf{4.53}$$

SIMULATED RESULTS:
Above circuit is simulated in LTspice and the result is as follows:

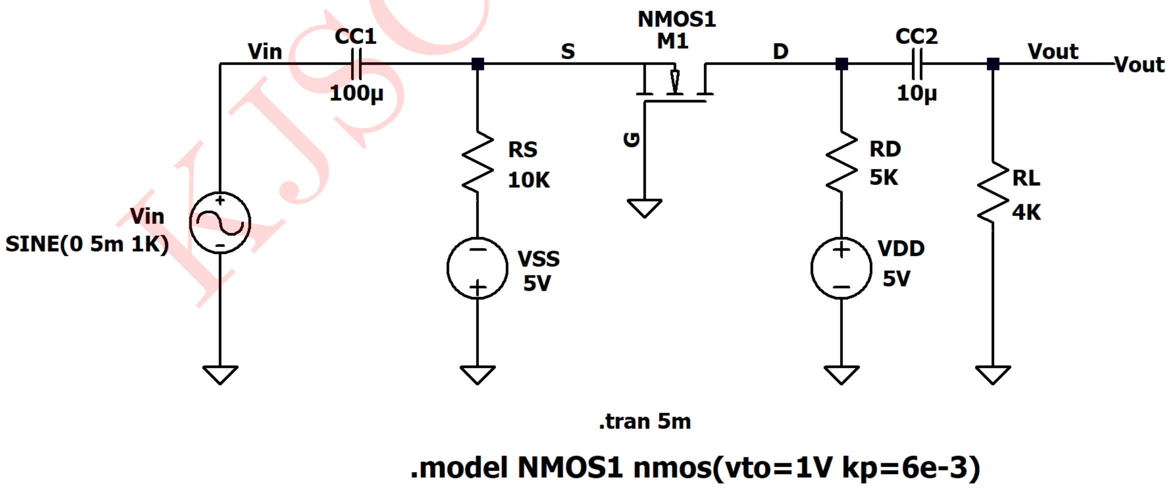

Figure 10: Circuit Schematic

The input and output waveforms are shown in figure 11.

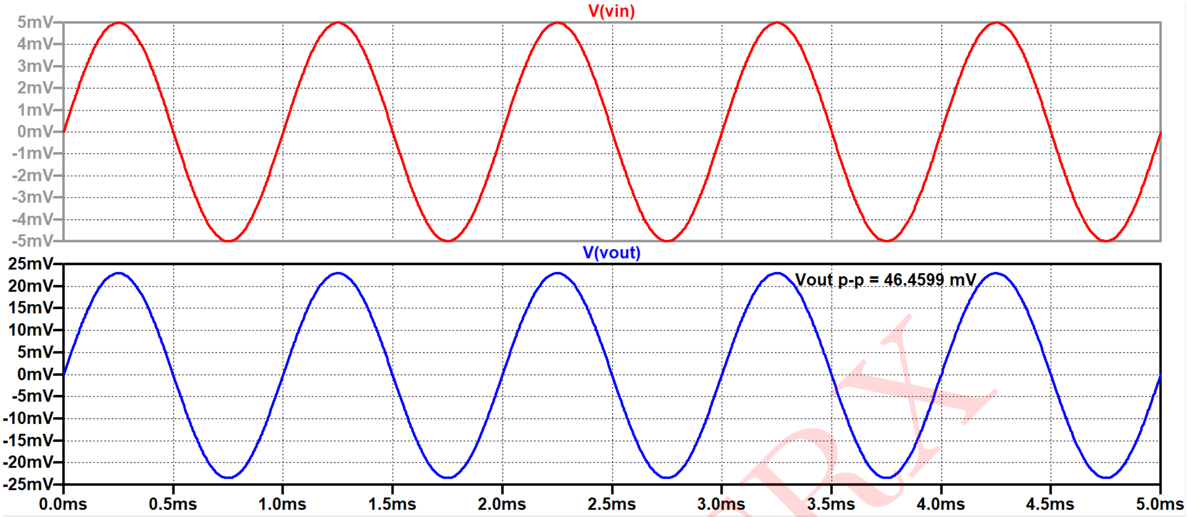

Figure 11: Input and Output Waveforms

Comparison between Theoretical and Simulated values :-

Parameter	Simulated	Theoretical
I_{DQ}	0.35mA	0.36mA
V_{DSQ}	4.75V	4.53V
V_{GSQ}	1.34V	1.34V
A_V	4.53	4.64

Table 2: Numerical 2

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