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DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
Single Stage FET Amplifier

23^{th} **June, 2020** **Numerical**

1. For the network shown in figure 1
   a) Find V_{GSQ}, I_{DQ}, V_{DS}
   b) Find A_v, R_i, R_o

   Given: $R_G = 1\text{M}\Omega$, $R_D = 1.8\text{k}\Omega$, $R_S = 240\Omega$, $V_{DD} = 12\text{V}$, $R_L = 10\text{k}\Omega$, $r_d = 50\text{k}\Omega$, $V_P = -3\text{V}$, $I_{DSS} = 8\text{mA}$, $C_{C1} = C_{C2} = 10\mu\text{F}$

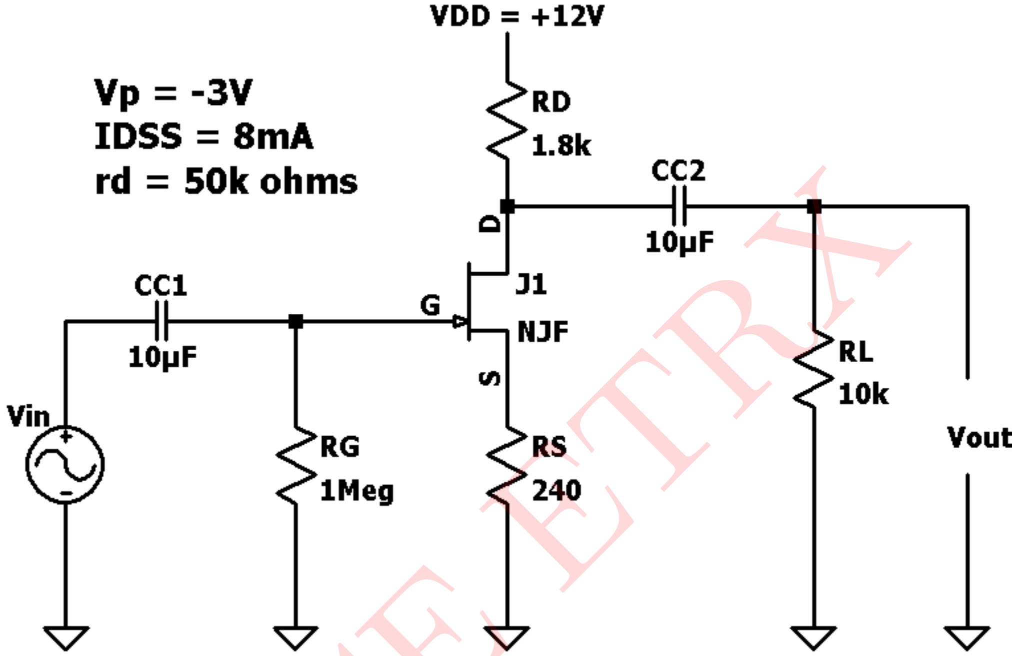

Figure 1: Circuit 1

Solution:

The above circuit is a self baised JFET amplifier

DC Analysis:

Assuming JFET is working in saturation region, $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2$

also,

$V_G = 0$

$V_S = I_D R_S$

$V_{GS} = -I_D R_S$

$V_{GS} = -I_D(240)$ ——— (1)

$I_D = 8 \times 10^3 \left(1 + \frac{V_{GS}}{3}\right)^2$ ——— (2)

Solving Equations (1) and (2)

$V_{GS} = -8 \times 10^{-3} \times 240 \left(1 + \frac{2V_{GS}}{3} + \frac{(V_{GS})^2}{9}\right)$

$V_{GS} = -1.92 \left(1 + \frac{2V_{GS}}{3} + \frac{(V_{GS})^2}{9}\right)$

$V_{GS} = -1.92 - 1.28V_{GS} - 0.2133(V_{GS})^2$

$0.2133(V_{GS})^2 + 2.28V_{GS} + 1.92 = 0$

$V_{GS} = -0.9215V or - 9.76V$

$V_{GS} = \mathbf{-0.9215V} \qquad \because (V_{GS} > V_P)$

$I_D = 8 \times 10^{-3} \left(1 - \frac{0.9215}{3}\right)^2$

$I_{DQ} = \mathbf{3.849\ mA}$

Applying KVL to the drain source loop:

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

$V_{DS} = 12 - (3.840 \times 1.8) - (3.84 \times 240)$

$V_{DS} = \mathbf{4.1664V}$

Small signal parameters:

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

$g_m = \frac{2 \times 8 \times 10^{-3}}{3}\left(1 - \frac{-0.9215}{-3}\right)$

$g_m = \mathbf{3.6951mA/V}$

Small signal equivalent circuit:

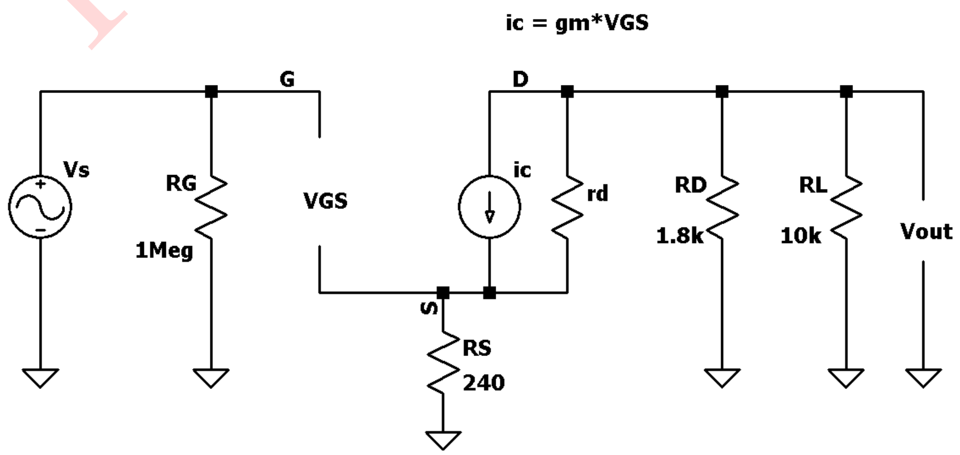

Figure 2: Small signal equivalent circuit

Input Resistance (R_i) = $1\mathrm{M}\Omega$

Output Resistance (R_o) = $R_D \mid\mid r_d \mid\mid R_L$

Output Resistance (R_o) = $1.8 \times 10^3 \mid\mid 50 \times 10^3 \mid\mid 10 \times 10^3$

Output Resistance (R_o) = $1.48\ \mathrm{k}\Omega$

$$\text{Voltage Gain } (A_v) = \frac{-(R_D \| r_o \| R_S)}{\frac{1}{g_m} + R_S}$$

$$A_v = \frac{-11.48 \times 10^3}{\frac{1}{3.695} + 240}$$

$$A_v = -\mathbf{2.898}$$

SIMULATED RESULTS:

Above circuit is simulated in LTspice and results are as follows

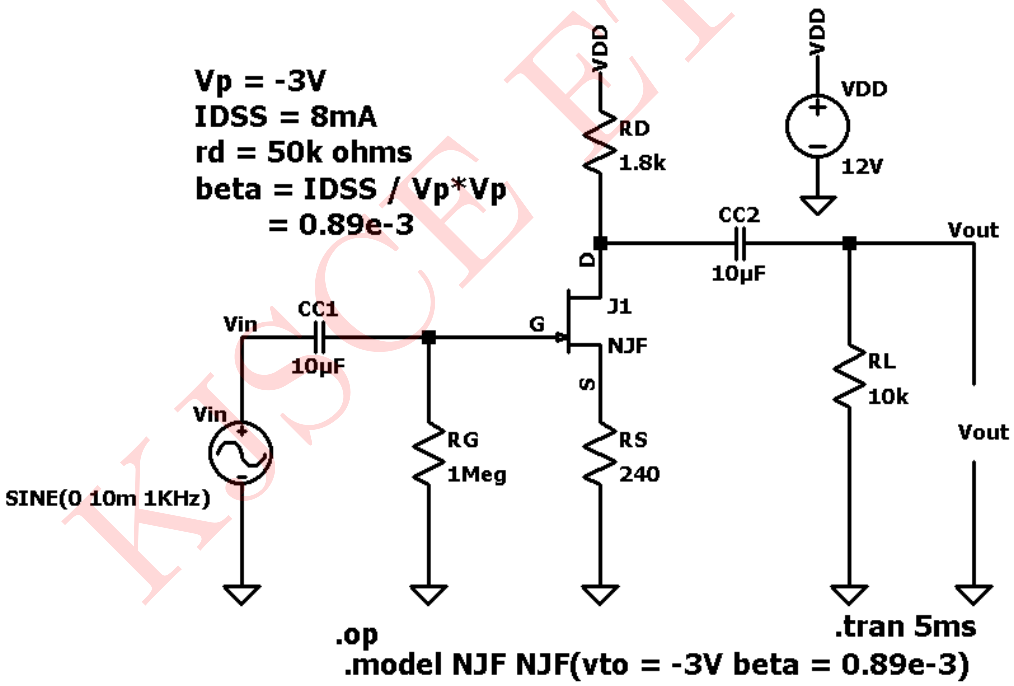

Figure 3: Circuit Schematic

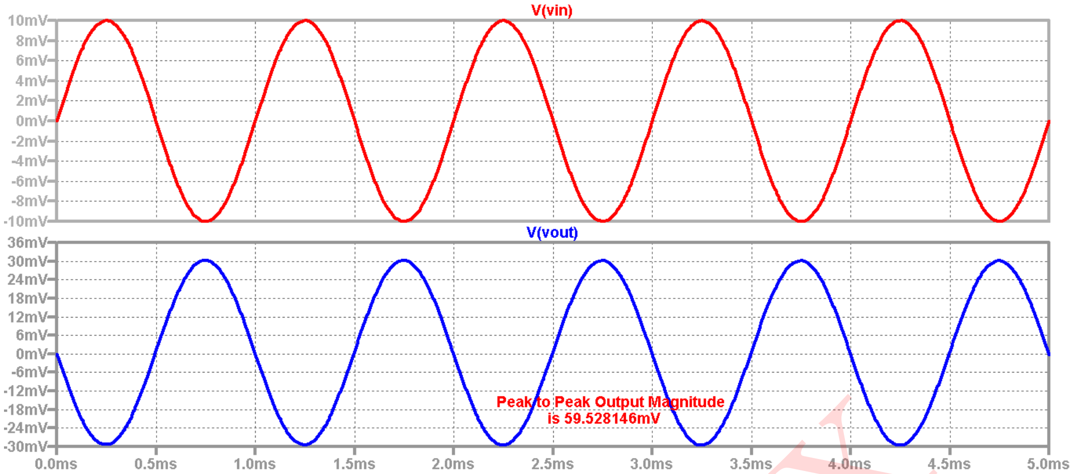

Figure 4: Input Output Waveform

Comparsion between simulated and theoretical values :

Parameters	Simulated	Theoretical
I_{DQ}	3.842mA	3.840mA
V_{GSQ}	−0.9221V	−0.9215
V_{DSQ}	4.1615V	4.1664V
A_v	−2.976	−2.898

Table 1: Numerical 1

2. For the network shown in figure 5

Find Z_i, Z_o, V_{out}

Given: R_1 = 40MΩ, R_2 = 10MΩ, R_S = 1.2KΩ, V_{DD} = 12V, R_D = 3.3kΩ, r_d= 40kΩ, V_{DD} = 30V, $V_{GS(th)}$ = 3V, $C_{C1} = C_{C2}$ = 22μF, C_S = 100μF, $k_n = 0.4 \times 10^{-3} mA/V^2$

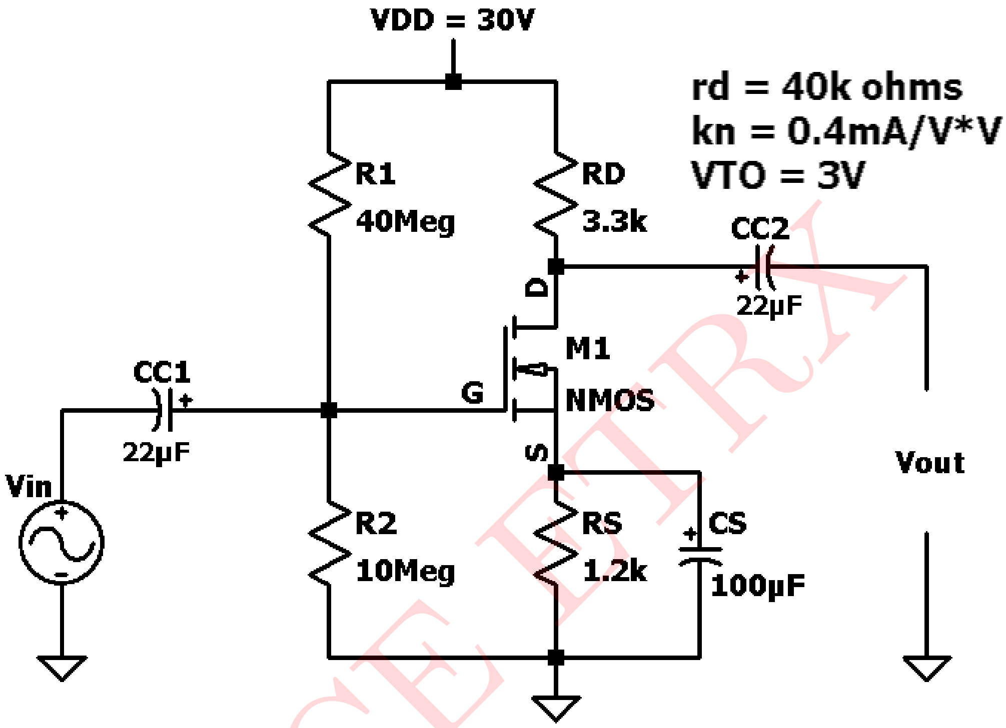

Figure 5: Circuit 2

Solution:

The above circuit is NMOS - CS amplifier

DC Analysis:

Assuming JFET is working in saturation region

$$V_G = \frac{R_2}{R_1 + R_2} \times V_{DD}$$

$$V_G = \frac{10}{40 + 10} \times 30$$

$$V_G = 6\text{V}$$

$$V_{GS} = V_G - V_S$$

$$\because V_S = I_D R_S$$

$$V_{GS} = 6 - I_D R_S$$

$$V_{GS} = 6 - I_D(1.2 \times 10^3) \text{ ——— } (1)$$

Assuming given NMOS is in Saturation region

$I_D = k_n(V_{GS} - V_{GS(th)})^2$

$I_D = 0.4 \times 10^{-3}(V_{GS} - 3)^2$ ——— (2)

Solving equation (1) and (2)

$V_{GS} = 6 - (1.2 \times 10^3 \times 0.4 \times 10^{-3})((V_{GS})^2 - 6V_{GS} + 9)$

$V_{GS} = 6 - 0.48V_{GS}^2 + 2.88V_{GS} - 4.32$

$0.48V_{GS}^2 - 1.88V_{GS} - 1.68 = 0 \; V_{GS} = 4.667V or - 0.75V$

$V_{GS} = \mathbf{4.667V} \qquad \because (V_{GS} > V_{TH})$

$I_{DQ} = 0.4 \times 10^{-3}(4.667 - 3)^2$

$I_{DQ} = \mathbf{1.111mA}$

Small signal parameters:

$g_m = 2k_n(V_{GS} - V_{GS(th)})$

$g_m = 2 \times 0.4 \times 10^{-3}(4.667 - 3)$

$g_m = \mathbf{1.3336\ mA/V}$

$r_d = \mathbf{40\ k\Omega}$ (Given)

Small signal equivalent circuit:

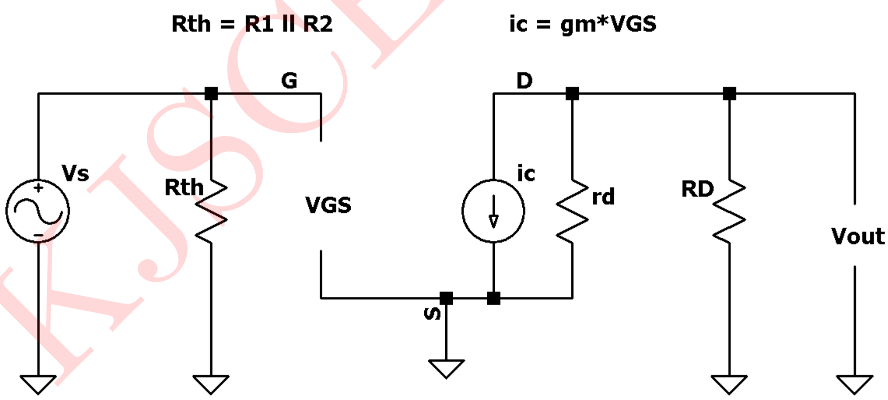

Figure 6: Small signal equivalent circuit

$Z_i = R_1||R_2 = 40 \times 10^6||10 \times 10^6$

$Z_i = \mathbf{8M\Omega}$

$Z_o = r_d||R_D = 40 \times 10^3||3.3 \times 10^3$

$Z_o = \mathbf{3048.498}\ \Omega$

$A_v = -gm(r_o||R_D)$

$A_v = -1.3336 \times (40 \times 10^3||3.3 \times 10^3)$

$A_v = \mathbf{-4.0654}$ (Negative sign indicates 180° out of phase between input and output)

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

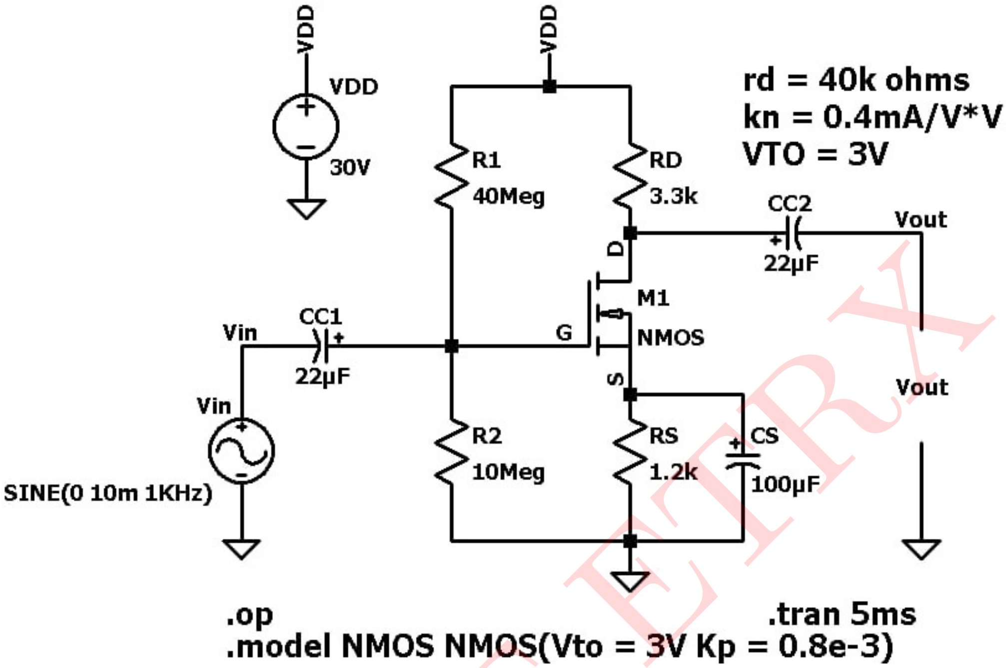

Figure 7: Circuit Schematic

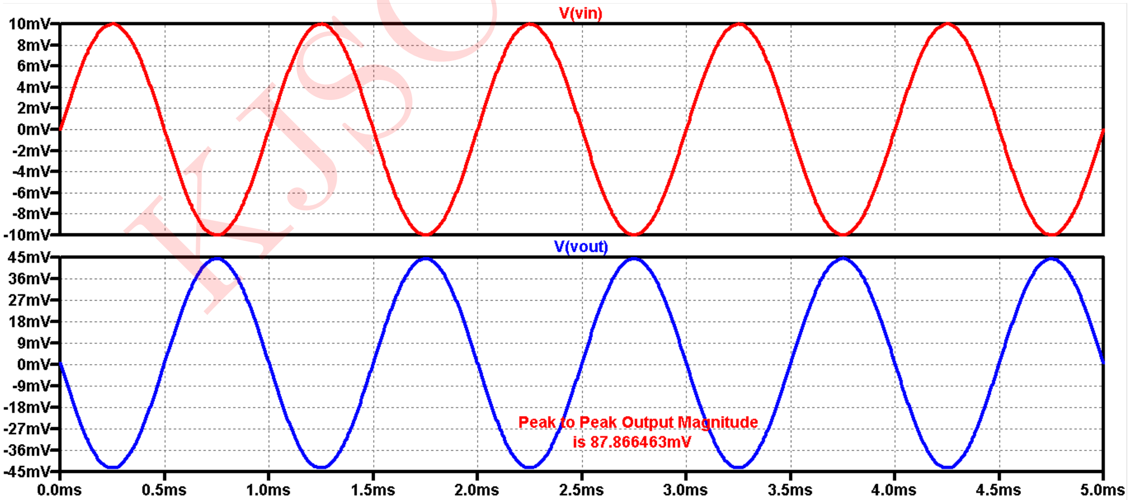

Figure 8: Input Output Waveform

Comparsion between simulated and theoretical values :

Parameters	Simulated	Theoretical
I_{DQ}	1.111mA	1.111mA
V_{GSQ}	4.667V	4.667V
A_v	-4.393	-4.0654

Table 2: Numerical 2

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