(PART TWO – 10 Marks for each question)

Solution

Answer all the following questions

Q1)

Set up a midpoint Self bias for N-channel JFET with I_{DSS} = 14 mA and $V_{GS(off)}$ = - 10 V. Use a 24 V dc source as the supply voltage. Show the circuit and resistor values. Indicate the values of I_D, V_{GS}, and V_{DS}.

Solution

$$I_D = \frac{I_{DSS}}{2} = \frac{14\text{ mA}}{2} = \mathbf{7\ mA}$$

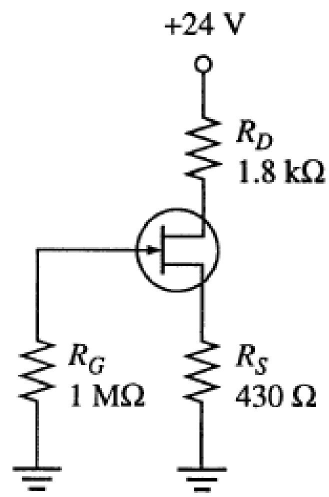
$$V_{GS} = \frac{V_{GS(off)}}{3.414} = \frac{-10\text{ V}}{3.414} = \mathbf{-2.93\ V}$$

Since $V_G = 0$ V, $V_S = V_G$.

$$R_S = \left|\frac{V_{GS}}{I_D}\right| = \frac{2.93\text{ V}}{7\text{ mA}} = \mathbf{419\ \Omega}\ \text{(The nearest standard value is 430 Ω.)}$$

$$R_D = \frac{V_{DD} - V_D}{I_D} = \frac{24\text{ V} - 12\text{ V}}{7\text{ mA}} = \mathbf{1.7\ k\Omega}\ \text{(The nearest standard value is 1.8 kΩ.)}$$

Select R_G = 1.0 MΩ. See Figure



Q2)

What is the total output voltage for the loaded amplifier in Figure 1? I_{DSS} = 8 mA; $V_{GS(off)}$ = - 7 V; $V_{in} = 50\ mV\ rms$.

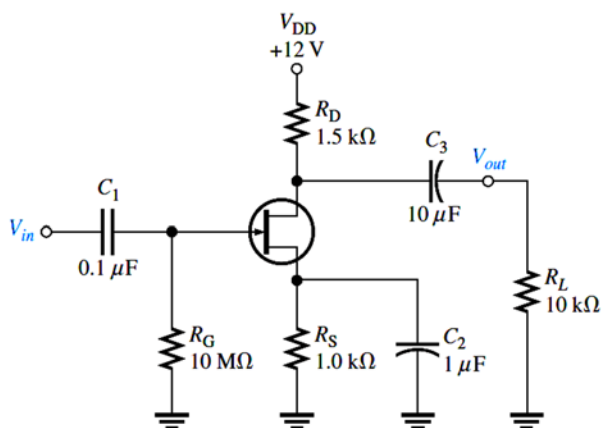


Figure 1.

Solution

Using mathematical approach we find:

يمكنك اثبات المعادلات الأتية الخاصة ب (A, B, C) او استخدامها مباشرة بدون اثباتها

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2 = I_{DSS}\left(1 - \left|\frac{I_D R_S}{V_{GS(off)}}\right|\right)^2$$

$$= I_{DSS}\left(1 - \frac{2I_D R_S}{\left|V_{GS(off)}\right|} + \left(\frac{I_D R_S}{\left|V_{GS(off)}\right|}\right)^2\right)$$

$$I_D = I_{DSS} - \frac{2I_{DSS}R_S}{\left|V_{GS(off)}\right|} I_D + \frac{I_{DSS}R_S^2}{V_{GS(off)}^2} I_D^2$$

Rearranging into a standard quadratic equation form,

$$\left(\frac{I_{DSS}R_S^2}{V_{GS(off)}^2}\right) I_D^2 - \left(1 + \frac{2I_{DSS}R_S}{\left|V_{GS(off)}\right|}\right) I_D + I_{DSS} = 0$$

The coefficients and constant are, $AI_D^2 + BI_D + C = 0$

$$A = \left(\frac{I_{DSS}R_S^2}{V_{GS(off)}^2}\right)$$

$$B = -\left(1 + \frac{2I_{DSS}R_S}{\left|V_{GS(off)}\right|}\right)$$

$$C = I_{DSS}$$

$$I_{D1,2} = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

$$A = \left(\frac{I_{DSS}R_S^2}{V_{GS(off)}^2}\right) = \frac{8 \times 10^{-3} \times 1000^2}{(7)^2} = 163.265$$

$$B = -\left(1 + \frac{2I_{DSS}R_S}{\left|V_{GS(off)}\right|}\right)$$

$$B = -\left(1 + \frac{2 \times 8 \times 10^{-3} \times 1000}{|-7|}\right) = -3.286$$

$$C = I_{DSS} = 8 \times 10^{-3}$$

$$I_{D1,2} = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

$$= \frac{3.286 \pm \sqrt{(-3.286)^2 - 4 \times 163.265 \times 8 \times 10^{-3}}}{2 \times 163.265}$$

$$I_{D1} = \frac{3.286 + \sqrt{5.571}}{326.53} = 17.292\ mA$$

$$I_{D2} = \frac{3.286 - \sqrt{5.571}}{326.53} = 2.835\ mA$$

We have two different solutions; we must choose the I_D value less than I_{DSS}. (Or, we must choose the value of I_D that makes $|V_{GS}| < |V_{GS(off)}|$.

$$I_D = 2.835 \text{ mA}$$

Using this value, calculate V_D.

$V_D = V_{DD} - I_D R_D = 12 \text{ V} - (2.835 \text{ mA})(1.5 \text{ k}\Omega) = 7.75 \text{ V}$

Next calculate g_m as follows:

$V_{GS} = -I_D R_S = -(2.835 \text{ mA})(1000\ \Omega) = -2.835 \text{ V}$

$$g_{m0} = \frac{2I_{DSS}}{|V_{GS(off)}|} = \frac{2 \times 8 \times 10^{-3}}{7} = 2.286\ mS$$

$$g_m = g_{m0}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right) = 2.286\ mS\left(1 - \frac{-2.835}{-7}\right) = 1.36\ mS$$

Finally, find the ac output voltage.

$$V_{out} = A_v V_{in} = (g_m R_D // R_L) V_{in} = 1.36\ mS \times \frac{1.5k\Omega \times 10k\Omega}{1.5k\Omega + 10k\Omega} \times 50\ mV$$

$$V_{out} = 88.69\ mV\ rms \cong 89\ mV\ rms$$

Q3)

For the unloaded E-MOSFET amplifier in Figure 2, if $I_{D(on)} = 8$ mA at $V_{GS} = 12$ V, $V_{GS(th)} = 4$V, and $g_m = 4500$ µS. Find V_{GS}, I_D, V_{DS}, and the rms output voltage V_{ds}.

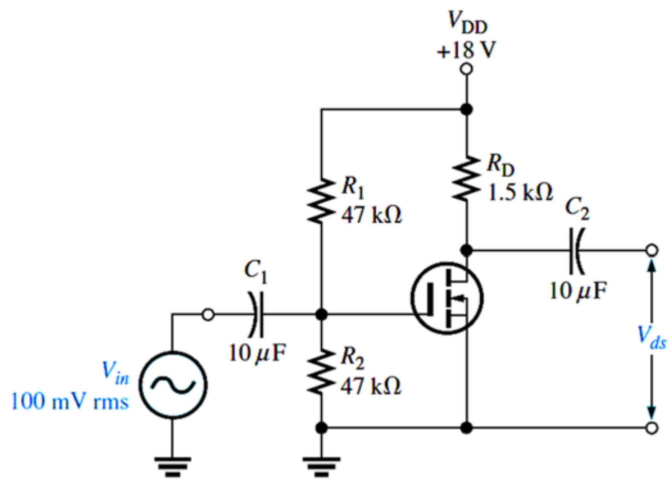


Figure 2.

Solution

$$V_{GS} = \left(\frac{R_2}{R_1 + R_2}\right)V_{DD} = \left(\frac{47\ \text{k}\Omega}{94\ \text{k}\Omega}\right)18\ \text{V} = \mathbf{9\ V}$$

$$K = \frac{I_{D(on)}}{(V_{GS} - V_{GS(th)})^2} = \frac{8\ \text{mA}}{(12\ \text{V} - 4\ \text{V})^2} = 0.125\ \text{mA/V}^2$$

$$I_D \quad = K(V_{GS} - V_{GS(th)})^2 = 0.125\ \text{mA/V}^2(9\ \text{V} - 4\ \text{V})^2 = \mathbf{3.13\ mA}$$

$$V_{DS} = V_{DD} - I_D R_D = 18\ \text{V} - (3.125\ \text{mA})(1.5\ \text{k}\Omega) = \mathbf{13.3\ V}$$

$$A_v = g_m R_D = 4500\ \mu\text{S}(1.5\ \text{k}\Omega) = 6.75$$

$$V_{ds} = A_v V_{in} = 6.75(100\ \text{mV}) = \mathbf{675\ mV\ rms}$$