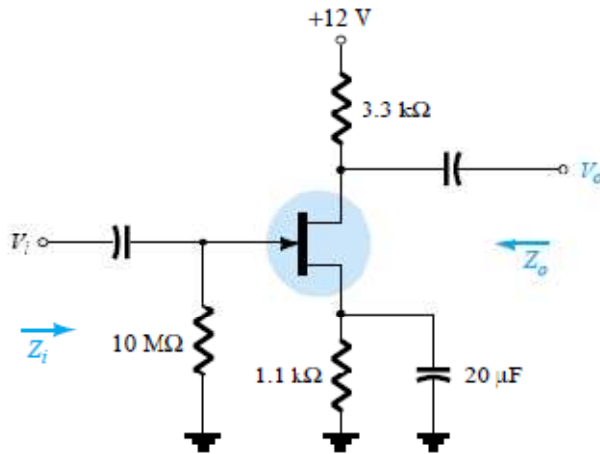


Soru 1.

Determine  $Z_i$ ,  $Z_o$ , and  $A_v$  for the network if  $y_{fs} = 3000 \mu S$  and  $y_{os} = 50 \mu S$ .



Çözüm 1.

$$g_m = y_{fs} = 3000 \mu S = 3 \text{ mS}$$

$$r_d = \frac{1}{y_{os}} = \frac{1}{50 \mu S} = 20 \text{ k}\Omega$$

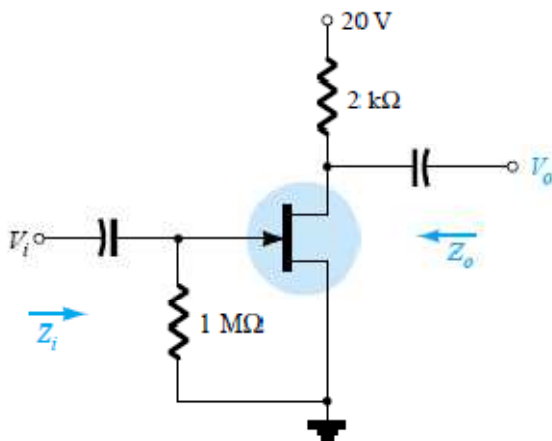
$$Z_i = R_G = 10 \text{ M}\Omega$$

$$Z_o = r_d \parallel R_D = 20 \text{ k}\Omega \parallel 3.3 \text{ k}\Omega = 2.83 \text{ k}\Omega$$

$$\begin{aligned} A_v &= -g_m(r_d \parallel R_D) \\ &= -(3 \text{ mS})(2.83 \text{ k}\Omega) \\ &= -8.49 \end{aligned}$$

Soru 2.

Determine  $Z_i$ ,  $Z_o$ , and  $A_v$  for the network if  $I_{DSS} = 6 \text{ mA}$ ,  $V_P = -6 \text{ V}$ , and  $y_{os} = 40 \mu S$ .



Cevap 2.

$$V_{GS_Q} = 0 \text{ V}, g_m = g_{m0} = \frac{2I_{DSS}}{|V_P|} = \frac{2(6 \text{ mA})}{6 \text{ V}}$$

$$= 2 \text{ mS}, r_d = \frac{1}{y_{os}} = \frac{1}{40 \mu S} = 25 \text{ k}\Omega$$

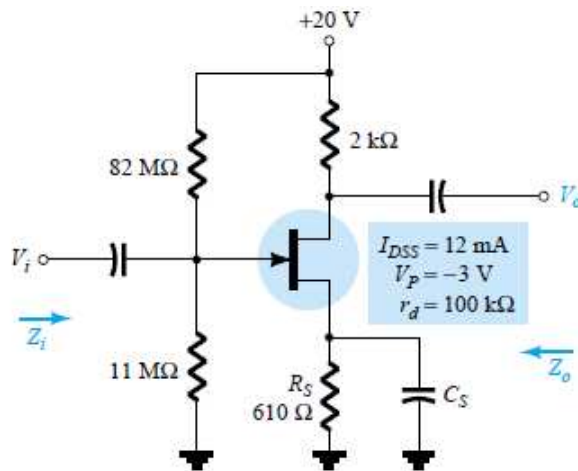
$$Z_i = 1 \text{ M}\Omega$$

$$Z_o = r_d \parallel R_D = 25 \text{ k}\Omega \parallel 2 \text{ k}\Omega = 1.852 \text{ k}\Omega$$

$$A_v = -g_m(r_d \parallel R_D) = -(2 \text{ mS})(1.852 \text{ k}\Omega) \cong -3.7$$

Soru 3.

Determine  $Z_i$ ,  $Z_o$ , and  $V_o$  for the network if  $V_i = 20 \text{ mV}$ .



Cevap 3.

$$V_{GS_Q} = -0.95 \text{ V}$$

$$g_m = \frac{2I_{DSS}}{V_P} \left( 1 - \frac{V_{GS_Q}}{V_P} \right) = \frac{2(12 \text{ mA})}{3 \text{ V}} \left( 1 - \frac{-0.95 \text{ V}}{-3 \text{ V}} \right) = 5.47 \text{ mS}$$

$$Z_i = 82 \text{ k}\Omega \parallel 11 \text{ k}\Omega = 9.7 \text{ k}\Omega$$

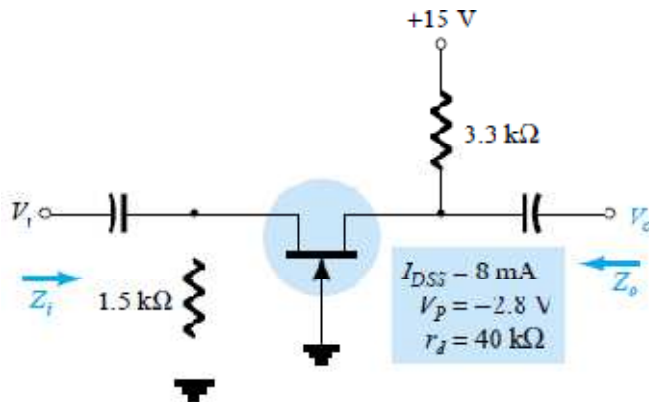
$$Z_o = r_d \parallel R_D = 100 \text{ k}\Omega \parallel 2 \text{ k}\Omega = 1.96 \text{ k}\Omega$$

$$A_v = -g_m(r_d \parallel R_D) = -(5.47 \text{ mS})(1.96 \text{ k}\Omega) = -10.72$$

$$V_o = A_v V_i = (-10.72)(20 \text{ mV}) = -214.4 \text{ mV}$$

Soru 4.

Determine  $Z_i$ ,  $Z_o$ , and  $V_o$  for the network if  $V_i = 0.1 \text{ mV}$ .



Cevap 4.

$$V_{GS_Q} = -2.85 \text{ V}, g_m = \frac{2I_{DSS}}{V_P} \left( 1 - \frac{V_{GS_Q}}{V_P} \right) = \frac{2(9 \text{ mA})}{4.5 \text{ V}} \left( 1 - \frac{-2.85 \text{ V}}{-4.5 \text{ V}} \right) = 1.47 \text{ mS}$$

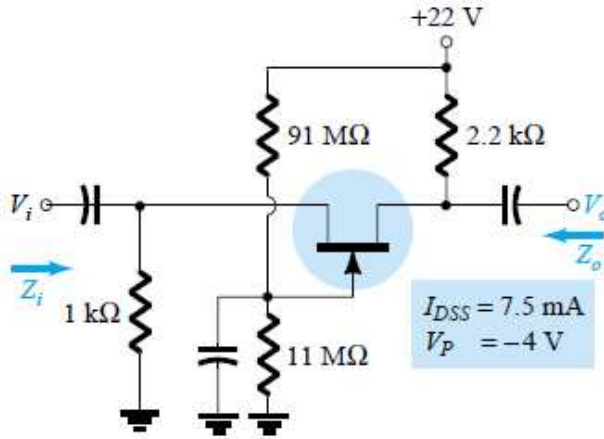
$$Z_i = R_G = 10 \text{ M}\Omega$$

$$Z_o = r_d \parallel R_S \parallel 1/g_m = 40 \text{ k}\Omega \parallel 2.2 \text{ k}\Omega \parallel \underbrace{1/1.47 \text{ mS}}_{680.27 \Omega} = 512.9 \Omega$$

$$A_v = \frac{g_m(r_d \parallel R_S)}{1 + g_m(r_d \parallel R_S)} = \frac{(1.47 \text{ mS})(40 \text{ k}\Omega \parallel 2.2 \text{ k}\Omega)}{1 + (1.47 \text{ mS})(40 \text{ k}\Omega \parallel 2.2 \text{ k}\Omega)} = \frac{3.065}{1 + 3.065} = 0.754$$

Soru 5.

Determine  $Z_i$ ,  $Z_o$ , and  $A_v$  for the network if  $r_d = 33 \text{ k}\Omega$ .

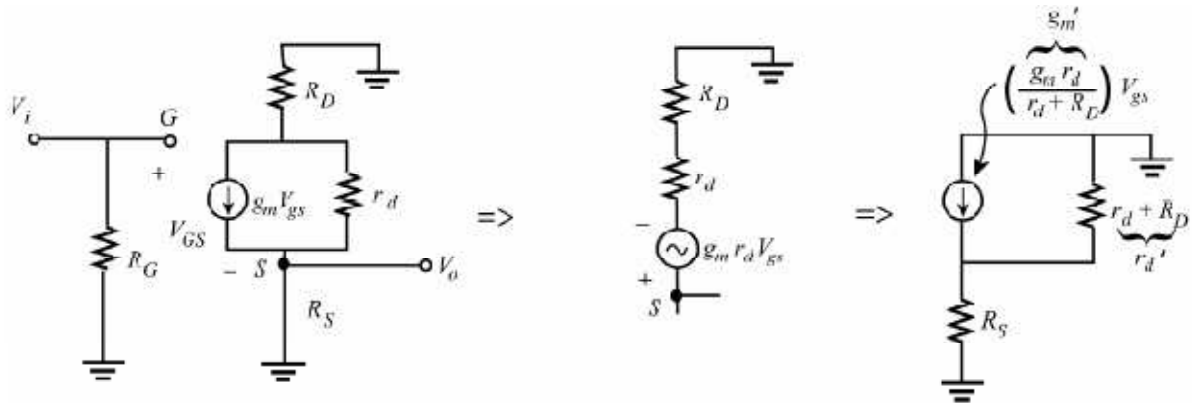


Cevap 5.

$$V_{GS_Q} = -3.8 \text{ V}$$

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

$$\frac{2(6 \text{ mA})}{6 \text{ V}} \left( 1 - \frac{-3.8 \text{ V}}{-6 \text{ V}} \right) = 0.733 \text{ mS}$$



The network now has the format examined in the text and

$$Z_i = R_G = 10 \text{ M}\Omega \quad r'_d = r_d + R_D = 30 \text{ k}\Omega + 3.3 \text{ k}\Omega = 33.3 \text{ k}\Omega$$

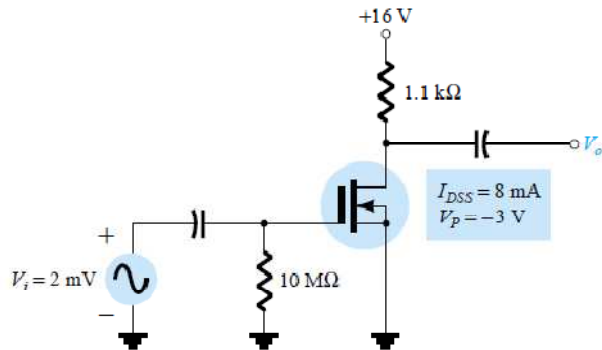
$$\begin{aligned} Z_o &= r'_d \parallel R_S \parallel 1/g'_m = g'_m = \frac{g_m r_d}{r'_d + R_D} = \frac{(0.733 \text{ mS})(30 \text{ k}\Omega)}{30 \text{ k}\Omega + 3.3 \text{ k}\Omega} = \frac{21.99}{33.3 \text{ k}\Omega} = 0.66 \text{ mS} \\ &= 33.3 \text{ k}\Omega \parallel 3.3 \text{ k}\Omega \parallel 1/0.66 \text{ mS} \\ &= 3 \text{ k}\Omega \parallel 1.52 \text{ k}\Omega \\ &\cong 1 \text{ k}\Omega \end{aligned}$$

$$\begin{aligned} A_v &= \frac{g'_m (r'_d \parallel R_S)}{1 + g'_m (r'_d \parallel R_S)} = \frac{0.66 \text{ mS}(3 \text{ k}\Omega)}{1 + 0.66 \text{ mS}(3 \text{ k}\Omega)} = \frac{1.98}{1 + 1.98} = \frac{1.98}{2.98} \\ &= 0.66 \end{aligned}$$

Soru 6.

Determine  $V_o$  for the network if  $y_{os} = 20 \mu S$ .

Cevap 6.



$$r_d = \frac{1}{y_{os}} = \frac{1}{20 \mu S} = 50 \text{ k}\Omega, V_{GS_Q} = 0 \text{ V}$$

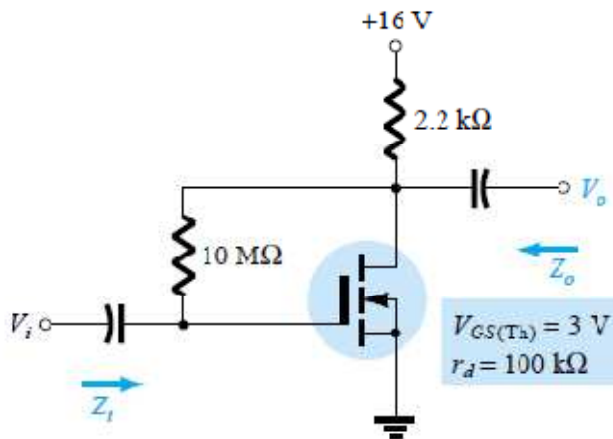
$$g_m = g_{m0} = \frac{2I_{DSS}}{V_p} = \frac{2(8 \text{ mA})}{3} = 5.33 \text{ mS}$$

$$A_v = -g_m R_D = -(5.33 \text{ mS})(1.1 \text{ k}\Omega) = -5.863$$

$$V_o = A_v V_i = (-5.863)(2 \text{ mV}) = 11.73 \text{ mV}$$

Soru 7.

Determine  $Z_i$ ,  $Z_o$ , and  $A_v$  for the amplifier if  $k = 0.3 \times 10^{-3}$ .



Cevap 7.

$$V_{GS_Q} = 6.7 \text{ V}$$

$$g_m = 2k(V_{GS_Q} - V_T) = 2(0.3 \times 10^{-3})(6.7 \text{ V} - 3 \text{ V}) = 2.22 \text{ mS}$$

$$Z_i = \frac{R_F + r_d \parallel R_D}{1 + g_m(r_d \parallel R_D)} = \frac{10 \text{ M}\Omega + 100 \text{ k}\Omega \parallel 2.2 \text{ k}\Omega}{1 + (2.22 \text{ mS})(100 \text{ k}\Omega \parallel 2.2 \text{ k}\Omega)}$$

$$= \frac{10 \text{ M}\Omega + 2.15 \text{ k}\Omega}{1 + 2.22 \text{ mS}(2.15 \text{ k}\Omega)} \cong 1.73 \text{ M}\Omega$$

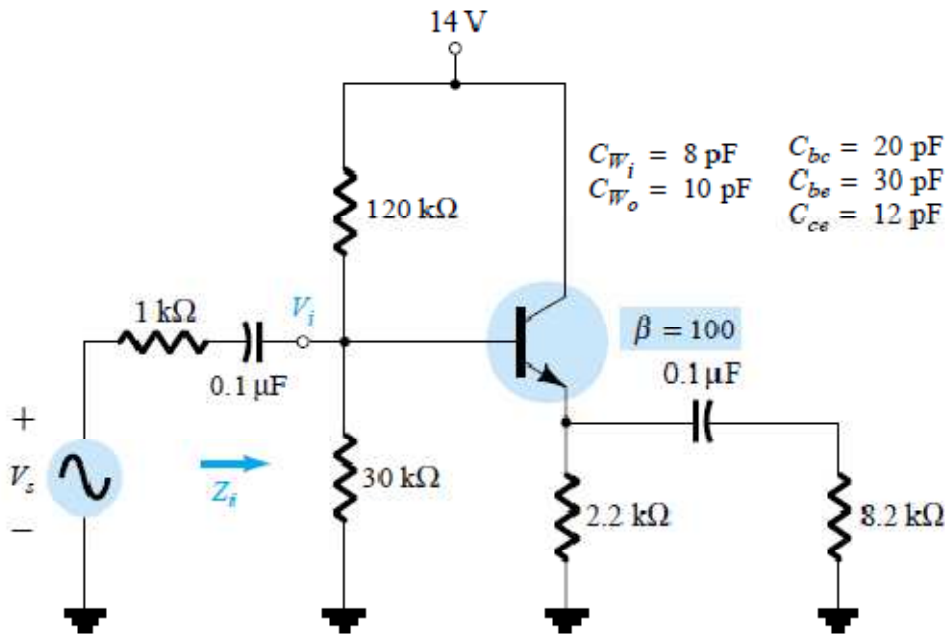
$$Z_o = R_F \parallel r_d \parallel R_D = 10 \text{ M}\Omega \parallel 100 \text{ k}\Omega \parallel 2.2 \text{ k}\Omega = 2.15 \text{ k}\Omega$$

$$A_v = -g_m(R_F \parallel r_d \parallel R_D) = -2.22 \text{ mS}(2.15 \text{ k}\Omega) = -4.77$$

Soru 8.

For the network

- Determine  $r_e$ .
- Find  $A_{v_{mid}} = V_o/V_i$ .
- Calculate  $Z_i$ .
- Find  $A_{v_{smid}} = V_o/V_s$ .
- Determine  $f_{L_S}$ ,  $f_{L_C}$  and  $f_{L_E}$ .
- Determine the low cutoff frequency.
- Sketch the asymptotes of the Bode plot defined by the cutoff frequencies of part (e).
- Sketch the low-frequency response for the amplifier using the results of part (f).



Cevap 8.

$$\begin{aligned}
 \text{(a)} \quad & \beta R_E \geq 10 R_2 \\
 & (100)(2.2 \text{ k}\Omega) \geq 10(30 \text{ k}\Omega) \\
 & 220 \text{ k}\Omega \not\geq 300 \text{ k}\Omega \text{ (No!)} \\
 & R_{Th} = R_1 \parallel R_2 = 120 \text{ k}\Omega \parallel 30 \text{ k}\Omega = 24 \text{ k}\Omega \\
 & E_{Th} = \frac{30 \text{ k}\Omega(14 \text{ V})}{30 \text{ k}\Omega + 120 \text{ k}\Omega} = 2.8 \text{ V} \\
 & I_B = \frac{E_{Th} - V_{BE}}{R_{Th} + (\beta + 1)R_E} = \frac{2.8 \text{ V} - 0.7 \text{ V}}{24 \text{ k}\Omega + 222.2 \text{ k}\Omega} \\
 & = 8.53 \mu\text{A} \\
 & I_E = (\beta + 1)I_B = (101)(8.53 \mu\text{A}) \\
 & = 0.86 \text{ mA} \\
 & r_e = \frac{26 \text{ mV}}{I_E} = \frac{26 \text{ mV}}{0.86 \text{ mA}} = 30.23 \Omega
 \end{aligned}$$

$$\begin{aligned}
 \text{(b)} \quad A_{v_{mid}} &= \frac{R_E \parallel R_L}{r_e + R_E \parallel R_L} \\
 &= \frac{2.2 \text{ k}\Omega \parallel 8.2 \text{ k}\Omega}{30.23 \text{ }\Omega + 2.2 \text{ k}\Omega \parallel 8.2 \text{ k}\Omega} \\
 &= \mathbf{0.983}
 \end{aligned}$$

$$\begin{aligned}
 \text{(c)} \quad Z_i &= R_1 \parallel R_2 \parallel \beta(r_e + R'_E) \quad R'_E = R_E \parallel R_L = 2.2 \text{ k}\Omega \parallel 8.2 \text{ k}\Omega = 1.735 \text{ k}\Omega \\
 &= 120 \text{ k}\Omega \parallel 30 \text{ k}\Omega \parallel (100)(30.23 \text{ }\Omega + 1.735 \text{ k}\Omega) \\
 &= \mathbf{21.13 \text{ k}\Omega}
 \end{aligned}$$

$$\text{(d)} \quad A_{v_s} = \frac{V_o}{V_s} = \frac{V_o}{V_i} \cdot \frac{V_i}{V_s} \quad \frac{V_i}{V_s} = \frac{Z_i}{Z_i + R_s} = \frac{21.13 \text{ k}\Omega}{21.13 \text{ k}\Omega + 1 \text{ k}\Omega} = 0.955$$

$$\begin{aligned}
 \text{(e)} \quad f_{L_s} &= \frac{1}{2\pi(R_s + R_i)C_s} \\
 &= \frac{1}{2\pi(1 \text{ k}\Omega + 21.13 \text{ k}\Omega)(0.1 \text{ }\mu\text{F})} \\
 &= \mathbf{71.92 \text{ Hz}}
 \end{aligned}$$

$$f_{L_c} = \frac{1}{2\pi(R_o + R_L)C_C}$$

$$\begin{aligned}
 R'_s &= R_s \parallel R_1 \parallel R_2 \\
 &= 1 \text{ k}\Omega \parallel 120 \text{ k}\Omega \parallel 30 \text{ k}\Omega \\
 &= \mathbf{0.96 \text{ k}\Omega}
 \end{aligned}$$

$$\begin{aligned}
 R_o &= R_E \parallel \left( \frac{R'_s}{\beta} + r_e \right) \\
 &= (2.2 \text{ k}\Omega) \parallel \left( \frac{0.96 \text{ k}\Omega}{100} + 30.23 \text{ }\Omega \right) \\
 &= \mathbf{39.12 \text{ }\Omega}
 \end{aligned}$$

$$\begin{aligned}
 f_{L_c} &= \frac{1}{2\pi(39.12 \text{ }\Omega + 8.2 \text{ k}\Omega)(0.1 \text{ }\mu\text{F})} \\
 &= \mathbf{193.16 \text{ Hz}}
 \end{aligned}$$

$$\text{(f)} \quad f_{l_{low}} \cong \mathbf{193.16 \text{ Hz}}$$

