Microelectronics Circuit Analysis and Design Homework(9th)

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7.3 Consider the circuit in Figure P7.3. (a) Derive the expression for the voltage transfer function $T(s) = V_o(s)/V_i(s)$.(b) What is the time constant associated with this circuit? (c) Find the corner frequency. (d) Sketch the Bode magnitude plot of the voltage transfer function.

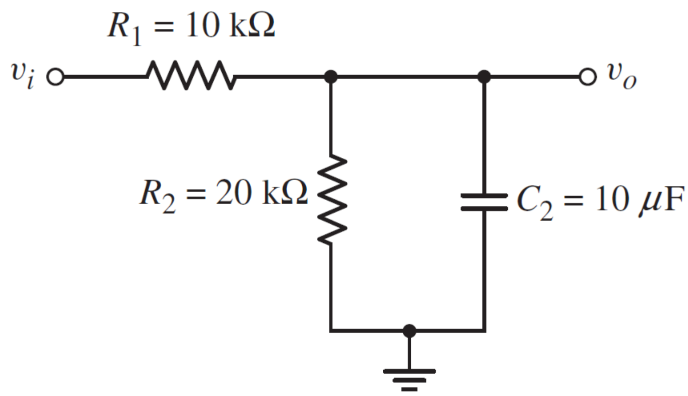

Figure 1: Problem 7.3

Solution:

(a)Because of "KVL", we have equation:

$$\frac{V_o}{R_2||\frac{1}{sC_2}}R_1 + V_o = V_i \Rightarrow T(s) = \frac{V_o(s)}{V_i(s)} = \frac{R_2\left|\right|\frac{1}{sC_2}}{R_2\left|\right|\frac{1}{sC_2} + R_1} = \frac{R_2}{R_1 + R_2 + sR_1R_2C_2}$$

(b)$\tau = (R_1||R_2)C_2 = 66.7\text{ms}$

(c)$f = \frac{1}{2\pi\tau} = 2.39\text{Hz}$

(d)The Bode Plot is as follow(Use Python):

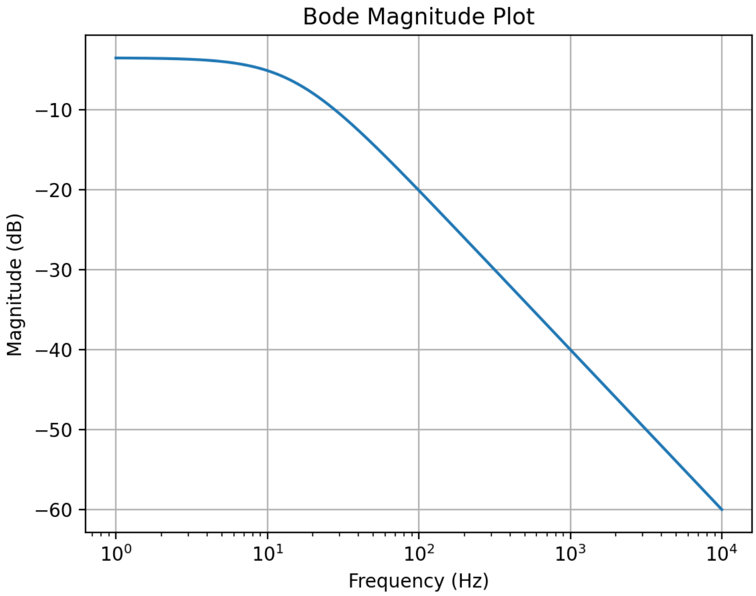

Figure 2: 7.3 Bode Plot

7.12 For the circuit shown in Figure P7.12, the parameters are $R_1 = 10\text{k}\Omega, R_2 = 10\text{k}\Omega, R_3 = 40\text{k}\Omega$, and $C = 10\mu\text{F}$. (a) What is the value of the voltage transfer function V_o/V_i at very low frequencies? (b) Determine the value of the voltage transfer function at very high frequencies. (c) Derive the expression for the voltage transfer function $T(s) = V_o(s)/V_i(s)$. Put the expression in the form$T(s) = K(1+s\tau_A)/(1+s\tau_B)$. What are the values of K, τ_A, and τ_B.

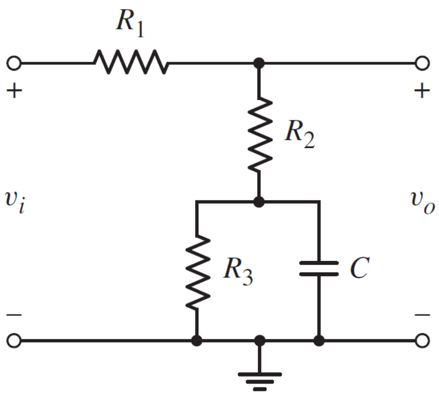

Figure 3: Problem 7.12

Solution:

(a)In this case, the capacitor can be regarded as open, so the conclusion is obvious:

$$\frac{V_o}{V_i} = \frac{R_2 + R_3}{R_1 + R_2 + R_3} = 0.833$$

(b)In this case, the capacitor can be regarded as shorted, so the conclusion is obvious:

$$\frac{V_o}{V_i} = \frac{R_2}{R_1 + R_2} = 0.5$$

(c)Because of voltage relationship, we have:

$$T(s) = \frac{R_2 + R_3 \left\| \frac{1}{sC} \right.}{1 + R_2 + R_3 \left\| \frac{1}{sC} \right.} = \frac{R_2 + R_3 + sR_2R_3C}{R_1 + R_2 + R_3 + s(R_1 + R_2)R_3C}$$

(d)We can easily get the answer by the conclusion of (c):

$$T(s) = \frac{R_2 + R_3 + sR_2R_3C}{R_1 + R_2 + R_3 + s(R_1 + R_2)R_3C} = \left(\frac{R_2 + R_3}{R_1 + R_2 + R_3}\right) \cdot \frac{1 + s\left(R_2 \| R_3\right)C}{1 + s\left(\left(R_1 + R_2\right) \| R_3\right)C}$$

$$\therefore K = \frac{R_2 + R_3}{R_1 + R_2 + R_3} = 0.833, \tau_A = \left(R_2 \| R_3\right)C = 80\text{ms}, \tau_B = \left(\left(R_1 + R_2\right) \| R_3\right)C = 133.3\text{ms}$$

7.17 For the common-emitter circuit in Figure P7.17, the transistor parameters are: $\beta = 100, V_{BE(on)} = 0.7\text{V}$, and $V_A = \infty$. (a) Calculate the lower corner frequency. (b) Determine the midband voltage gain. (c) Sketch the Bode plot of the voltage gain magnitude.

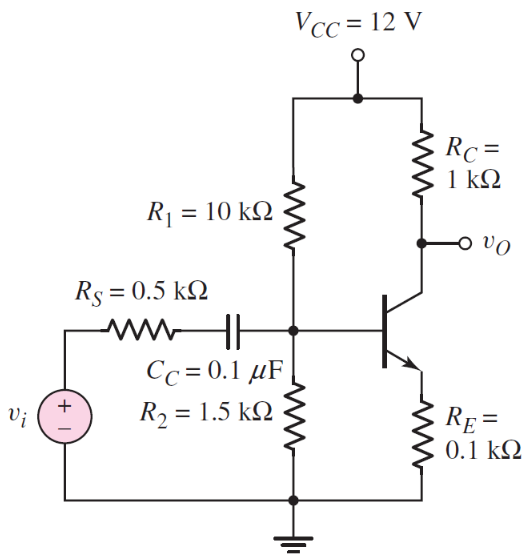

Figure 4: Problem 7.17

Solution:

(a)We first find Q-point: $V_{TH} = \frac{R_2}{R_1+R_2}V_{CC} = 1.565\text{V}, R_{TH} = R_1 \,||\, R_2 = 1.304\text{k}\Omega$. So KVL equation:

$$I_{BQ}R_{TH} + V_{BE(ON)} + (\beta+1)I_{BQ}R_E = V_{TH} \Rightarrow I_{BQ} = 0.0759\text{mA}$$

$\therefore I_{CQ} = 7.585\text{mA}, r_\pi = \dfrac{\beta V_T}{I_{CQ}} = 0.343\text{k}\Omega$

$\therefore R_{Si} = R_S = 0.5\text{k}\Omega, R_{ib} = (R_1\,||R_2\,)||(r_\pi + (\beta+1)R_E) = 1.159\text{k}\Omega \Rightarrow \tau = (R_{Si}+R_{ib})C = 0.1659\text{ms}$

$\therefore f = \dfrac{1}{2\pi\tau} = 959\text{Hz}$

(b)

$$A_v = \frac{-g_m\left(\dfrac{(R_1\|R_2)\|(r_\pi+(\beta+1)R_E)}{(R_1\|R_2)\|(r_\pi+(\beta+1)R_E)+R_S}v_i \cdot \dfrac{r_\pi}{r_\pi+(\beta+1)R_E}\right)R_C}{v_i} = 6.69$$

(c)

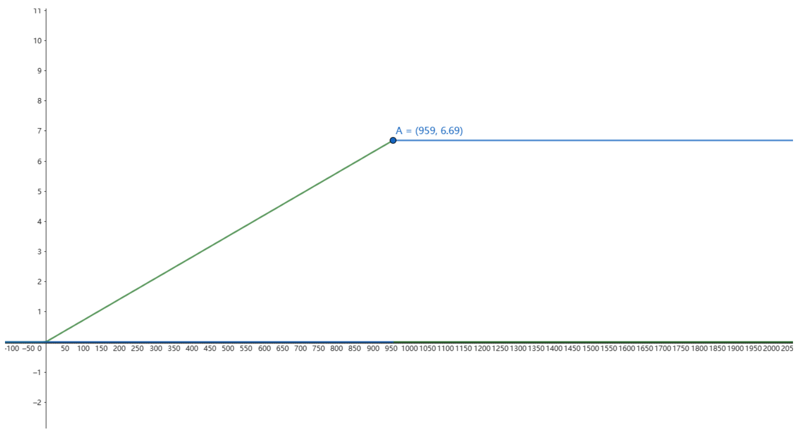

Figure 5: 7.17Bode plot

7.26 The parameters of the transistor in the circuit in Figure P7.26 are $K_p = 1\text{mA/V}^2, V_{TP} = -1.5\text{V}$, and $\lambda = 0$. (a) Determine the quiescent and small-signal parameters of the transistor. (b) Find the time constants associated with C_{C1} and C_{C2}. (c) Is there a dominant pole frequency? Estimate the -3 dB frequency.

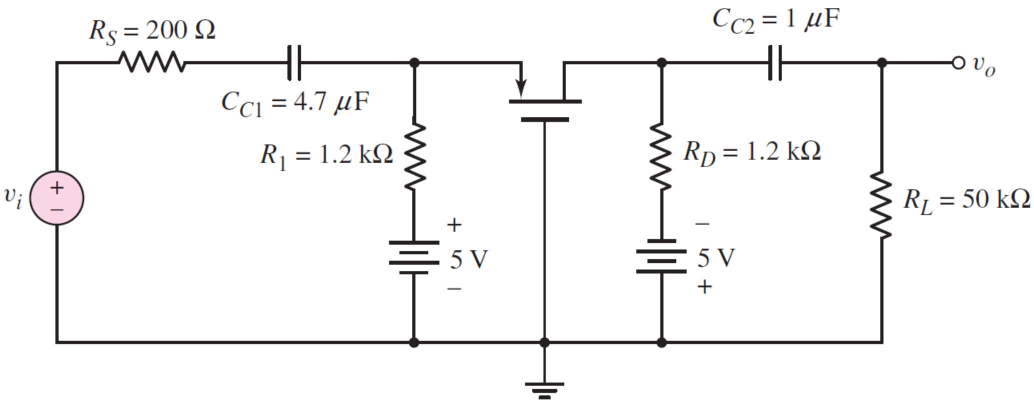

Figure 6: Problem 7.26

Solution:

(a)We assume the MOS work in saturation region:

$$\frac{5-V_{SG}}{R_1} = K_P\left(V_{SG}+V_{TP}\right)^2 \Rightarrow V_{SG} = 2.84\text{V} \Rightarrow I_{DQ} = 1.8mA$$

$\therefore V_{SDQ} = 10-1.8(1.2+1.2) \Rightarrow V_{SDQ} = 5.68\text{V}, g_m = 2\sqrt{K_P I_{DQ}} = 2.683\text{mA/V}$

(b)$R_{Si} = \dfrac{1}{g_m} = \dfrac{1}{2.68} = 0.3727\text{k}\Omega, R_i = 1.2 \parallel R_{Si} = 0.284\text{k}\Omega$

$C_{C1}, \tau_{s1} = (284+200)\left(4.7\times 10^{-6}\right) = 2.27\text{ms}$

$C_{C2}, \tau_{s2} = \left(1.2x10^3 + 50\times 10^3\right)\left(10^{-6}\right) = 51.2\text{ms}$

(c)C_{C2} dominates, $f_{3-dB} = \dfrac{1}{2\pi\tau_{s2}} = \dfrac{1}{2\pi\left(51.2\times 10^{-3}\right)} = 3.1\text{Hz}$