Homework 9 Due Thursday, Apr 11th, 2013 (In Class)

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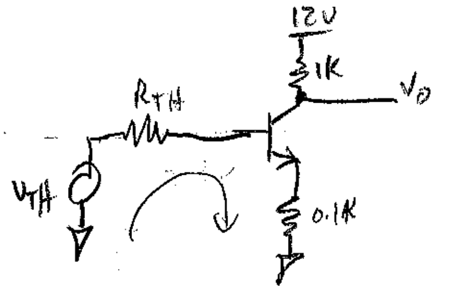
Problem 7.17

For the common-emitter circuit in Figure P7.17, the transistor parameters are: $\beta = 100$, $V_{BE}(\text{on}) = 0.7$ 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.



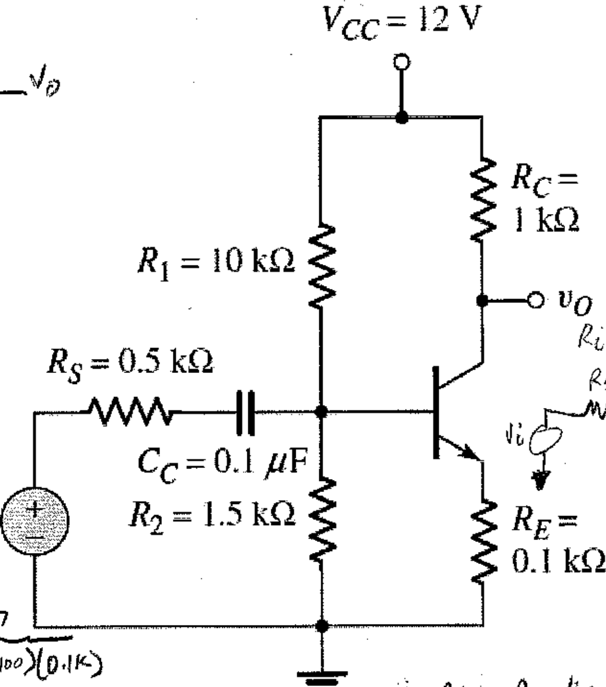


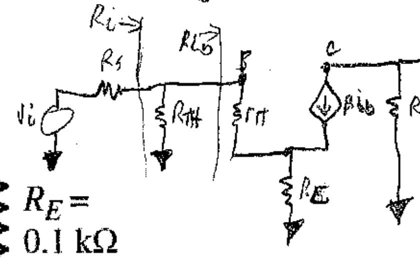
Figure P7.17

$r_\pi = \frac{V_T}{I_{BQ}} = \frac{0.026}{75.867\mu A}$

$r_\pi = 350.612\Omega$

$g_m = \frac{I_{CQ}}{V_T} = \frac{7.586mA}{0.026}$

$g_m = 0.292$



a)

$R_{TH} = 10K // 1.5K = 1.304K$

$V_{TH} = 1.565V$

$V_{TH} = i_b R_{TH} + V_{BE(on)} + i_E(0.1K)$

$V_{TH} = i_b R_{TH} + V_{BE(on)} + (1+\beta) i_b (0.1K)$

$\frac{V_{TH} - V_{BE(on)}}{R_{TH} + (1+\beta)(0.1K)} = i_b = \frac{1.565V - 0.7}{1.304K + (1+100)(0.1K)}$

$i_b = 75.867\mu A$

$i_c = \beta(i_b) = 7.586\ mA = i_c$

$i_E = i_c + i_b = 7.663\ mA = i_E$

Low freq:

$\tau_s = (R_s + R_i) C_c$

$(0.5K + 1.160K)\, 0.1\mu F \Rightarrow \tau_s = 165.962\mu s$

$F_L = \frac{1}{2\pi \tau_s} \Rightarrow \boxed{F_L = 958.987 Hz}$

$R_i = R_{TH} // (r_\pi + (1+\beta)R_E)$

$R_i = 1.304K // (350.612 + (1+100)(0.1K))$

$R_i = 1.160K\Omega$

$V_B = i_b r_\pi + i_E (R_E) \Rightarrow i_b(r_\pi + (1+\beta)R_E$

$\frac{V_B}{i_b} = R_{ib} = r_\pi + (1+\beta)R_E$

B) Common Emitter gain (midband)

$V_o = -\beta I_b R_c$

Source current

$I_s = \frac{V_i}{R_s + R_i} = \frac{V_i}{0.5K + 1.160K}$

$I_s = \frac{V_i}{1.660K}$

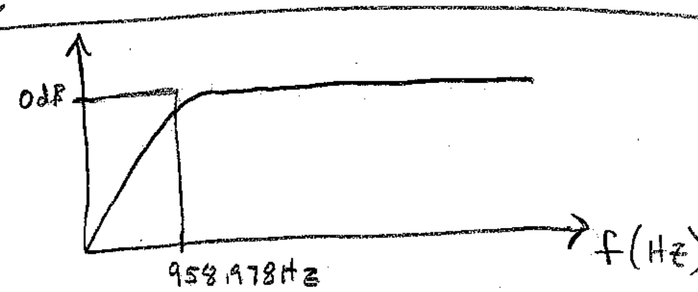
Current divider

$I_b = \frac{V_i}{1.660K}\left(\frac{R_{TH}}{R_{TH} + R_{ib}}\right)$

$V_o = -\beta \left(\frac{V_i}{1.66K}\right)\left(\frac{1.304K}{1.304K + 350.612\Omega + (1+100)(0.1K)}\right)(1K)$

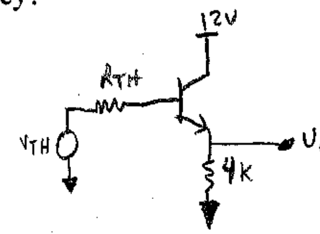
$\frac{V_o}{V_i} = A_v = -6.686$

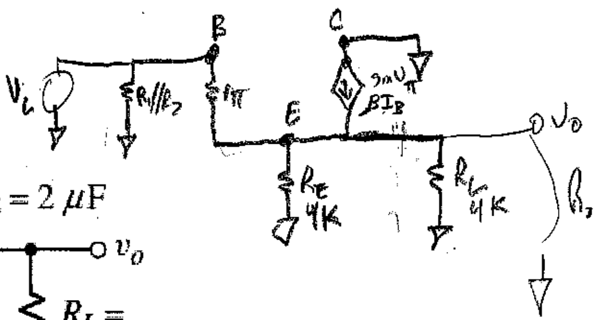
c)



Problem 7.21

For the circuit in Figure P7.21, the transistor parameters are $\beta = 120$, $V_{BE}(on) = 0.7$ V, and $V_A = 50$ V. (a) Design a bias-stable circuit such that $I_{EQ} = 1.5$ mA. (b) Using the results of part (a), find the small-signal midband voltage gain. (c) Determine the output resistance R_o. (d) What is the lower 3-dB corner frequency?





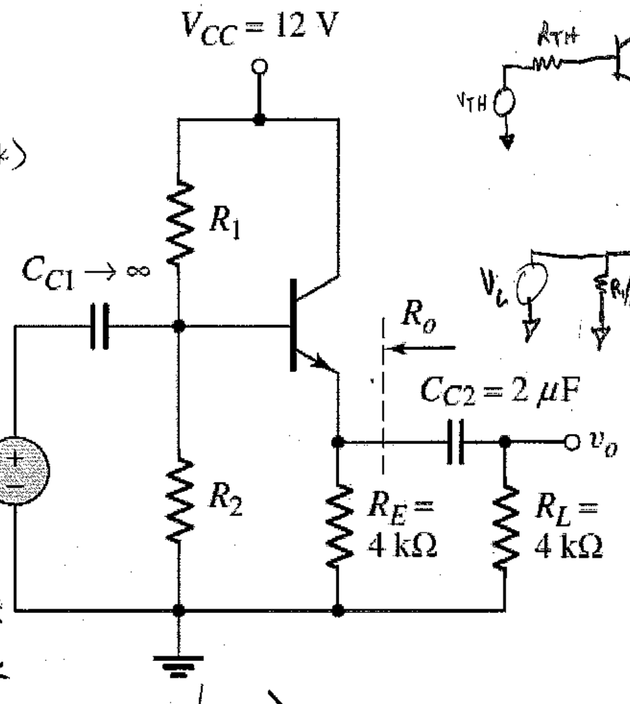


Figure P7.21

a)

$I_{CQ} = \alpha I_E = \frac{\beta}{1+\beta}(1.5mA)$

$I_{CQ} = 1.488$ mA

$I_b = I_E - I_c$

$I_b = 12.397\,\mu A$

$V_o = I_E(4k)$

$V_o = 6v$

(5.42) $R_{TH} = 0.1(1+\beta)R_E$

$R_{TH} = (0.1)(1+120)(4K) = $

$\boxed{R_{TH} = 48.4K}$

$V_{TH} = R_{TH}(I_{BQ}) + 0.7 + I_E R_E$

$V_{TH} = R_{TH}(I_{BQ}) + 0.7 + (1+120)I_b R_E$

$V_{TH} = 48.8K(12.397\mu A) + 0.7 + 6v$

$\boxed{V_{TH} = 7.3V}$

$r_\pi = \frac{V_T}{I_{BQ}} = \frac{0.026}{12.397\mu A} \Rightarrow r_\pi = 2.097K$

$r_o = \frac{V_A}{I_{CQ}} = \frac{50}{1.488mA} \Rightarrow r_o = 33.611K$

mult. by 1

$V_{TH} = V_{cc}\left(\frac{R_2}{R_1+R_2}\right)\left(\frac{R_1}{R_1}\right)$

$V_{TH} = V_{cc}\left(\frac{1}{R_1}\right)\underbrace{\left(\frac{R_1 R_2}{R_1+R_2}\right)}_{R_{TH}}$

$R_1 = \frac{V_{cc} R_{TH}}{V_{TH}} \Rightarrow \frac{12(48.4K)}{7.3v}$

$\boxed{R_1 = 79.562K}$

$V_{TH} = V_{cc}\left(\frac{R_1}{R_1+R_2}\right) \Rightarrow \boxed{R_2 = 123.57K}$

b)

$V_o = I_b(1+\beta)(r_o \| R_E)$

$V_{in} = I_b(r_\pi + (1+\beta)(r_o \| R_E))$

$A_v = \frac{V_o}{V_{in}} = \frac{(1+\beta)(r_o \| R_E \| R_L)}{r_\pi + (1+\beta)(r_o \| R_E \| R_L)}$

$A_v = \frac{(1+120)(33.611K \| 4K \| 4K)}{(2.097K + (1+120)(33.611K \| 4K \| 4K)} = \boxed{A_v = 0.991}$

c) $R_o = \frac{r_\pi}{1+\beta} \| r_o \| R_E = \left(\frac{2.097K}{1+120}\right) \| 33.611K \| 4K$

$R_o = 17.249\ \Omega$

d) $Z = \frac{1}{2\pi f C} \Rightarrow f = \frac{1}{2\pi Z C}$

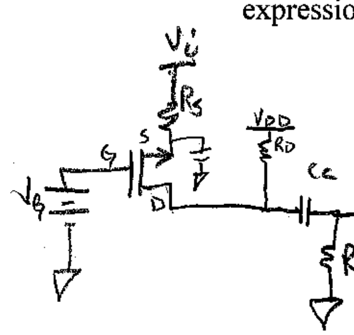
$Z = R_o + R_L$

$f_L = \frac{1}{2\pi(R_o + R_L)C} \Rightarrow f_L = \frac{1}{2\pi(17.249 + 4K)2\mu F}$

$\boxed{f_L = 19.809\ Hz}$

Problem 7.23

Consider the circuit shown in Figure P7.23. (a) Write the transfer function $T(s) = V_o(s)/V_i(s)$. Assume $\lambda = 0$ for the transistor. (b) Determine the expression for the time constant associated with the input portion of the circuit. (c) Determine the expression for the time constant associated with the output portion of the circuit.



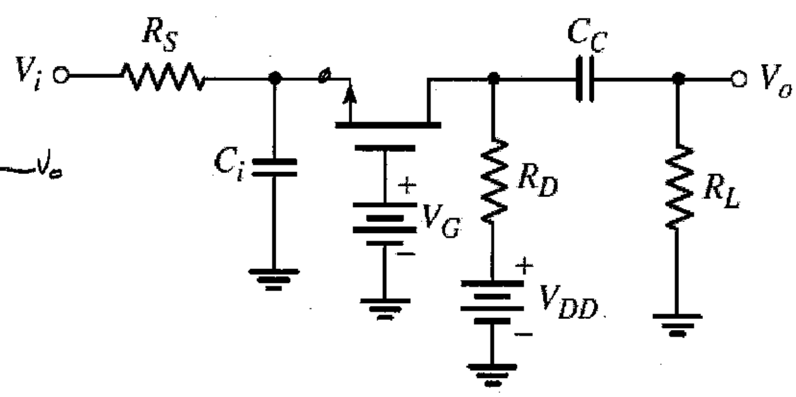


Figure P7.23

Problem 7.29

Reconsider the circuit in Figure P7.28. The transistor parameters are $\beta = 120$, $V_{BE}(on) = 0.7$ V, and $V_A = \infty$. The circuit parameters are $V^+ = 3.3$ V and $R_S = 100\,\Omega$. (a) Find R_B and R_E such that $I_{EQ} = 0.25$ mA and $V_{CEQ} = 1.8$ V. (b) Using the results of part (a), find the value of C_C such that $f_L = 20$ Hz. (c) Determine the midband voltage gain.

a)

$I_B = \frac{I_E}{1+\beta} = \frac{0.25mA}{1+120} = \boxed{2.066\mu A = I_B}$

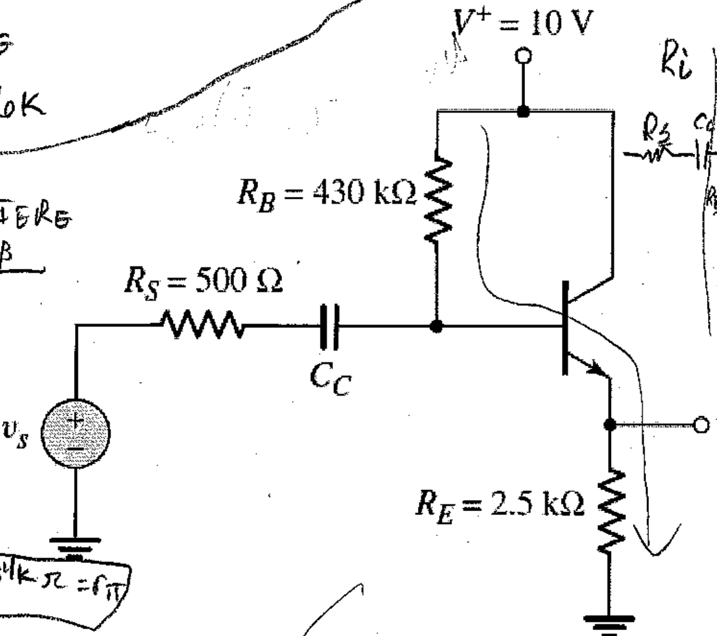
$3.3 = V_{CEQ} + I_E R_E$

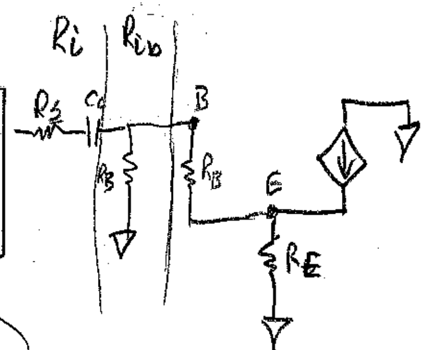
$\frac{3.3 - 1.8}{0.25mA} \Rightarrow R_E = 6K$

$3.3 = i_b R_B + V_{BE(on)} + I_E R_E$

$\frac{(3.3 - 0.7 - 0.25mA(6K))(1+\beta)}{0.25mA}$

$\boxed{R_B = 532.4K}$





b) $R_{ib} = r_\pi + (1+\beta)R_E$

$r_\pi = \frac{V_T}{I_{BQ}} = \frac{0.026}{2.066\mu A} = \boxed{12.584k\Omega = r_\pi}$

$R_{ib} = 12.584K + (1+120)(6K)$

$\boxed{R_{ib} = 738.584K\Omega}$

Figure P7.28

$R_i = R_B // R_{ib} = 309.384K = R_i$

$\tau_s = (R_s + R_i)C_c$

$\tau_s = (500 + 309.384K)C_c = 309.884K(C_c)$

$f_L = \frac{1}{2\pi\tau_s} \Rightarrow f_L = \frac{1}{2\pi(309.884k)C_c}$

$C_c = \frac{1}{2\pi(309.884K)(20)} = \boxed{C_c = 25.679\,nF}$

c) $A_v = \frac{(1+\beta)(r_o // R_E)}{r_\pi + (1+\beta)(r_o // R_E)}\left(\frac{R_i}{R_i + R_s}\right)$

$A_v = \frac{(1+120)(R_E)}{12.584k + (1+120)(R_E)}\left(\frac{738.584K}{738.584K + 500}\right)$

$\boxed{A_v = 0.982}$

Problem 7.39

For the circuit in Figure P7.39, the transistor parameters are: $K_n = 0.5$ mA/V^2, $V_{TN} = 2$ V, and ~~$\lambda = 0$.~~ Determine the maximum value of C_L such that the bandwidth is at least $B_W = 5$ MHz. State any approximations or assumptions that you make. What is the magnitude of the small-signal midband voltage gain? Verify the results with a computer simulation.

$V_G = 10\left(\frac{166K}{234K + 166K}\right) = V_G = 4.15V$

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

$I_S = \frac{V_S}{R_S} = \frac{V_G - V_{GS}}{0.5K} = I_D$

$I_D = K_n[V_{GS} - V_{TN}]^2$

$\frac{V_G - V_{GS}}{0.5K} = K_n[V_{GS} - V_{TN}]^2$

$\frac{4.15V - V_{GS}}{0.5K} = 0.5mA[V_{GS} - 2]^2$

$V_{GS} = 3.55$ V

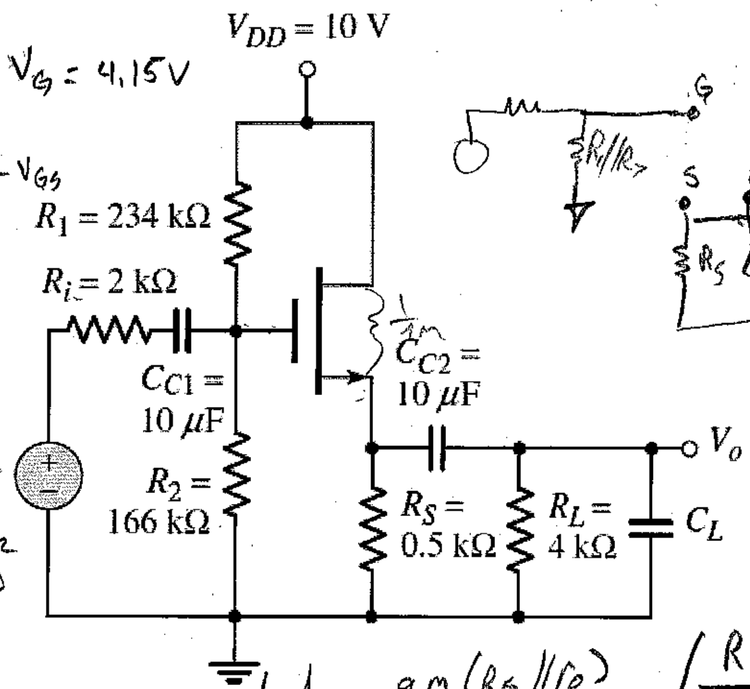
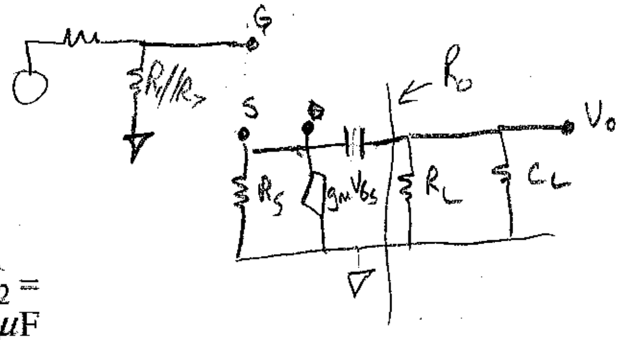


Figure P7.39



$R_o = \frac{1}{g_m} // R_S$

$r_o = \lambda K_n (V_{GSQ} - V_{TN})^2$

$\lambda = 0 \therefore r_o = \infty$

$g_m = \frac{I_d}{V_{gs}} = 2K_n(V_{GSQ} - V_{TN})$

$2(0.5)(3.55V - 2) = g_m = 1.549mA/V$

$R_o = \frac{1}{g_m} // R_S \Rightarrow R_o = \frac{1}{1.549} // 0.5K$

$R_o = 281.718\ \Omega$

$f_H = \frac{1}{2\pi \tau_p}$

$\tau_p = (R_o // R_L) C_S$

$\tau_p = 263.182 C_S$

$f_H = \frac{1}{2\pi\, 263.182 C_S}$

$C_S = \frac{1}{2\pi(263.182)\, 5MHz}$

$\boxed{C_S = 120.947pF}$

$A_V = \frac{g_m (R_S // r_o)}{1 + g_m (R_S // r_o)} \left(\frac{R_i}{R_i + R_{Si}}\right)$

$R_i = R_1 // R_2 = 97.11K$

$R_{Si} = 2K$

$A_V = \frac{1.549mA/V\,(0.5K)}{1 + 1.549mA/V\,(0.5K)}\left(\frac{97.11K}{2K + 97.11K}\right) \Rightarrow \boxed{A_V = 427.753m}$