ECE 548: Electronic Design I

Homework #5 (Optional – Not for Grading)

Name: Thomas Collins

Do the following problems from Microelectronic Circuit Design by Jaeger & Blalock (5th Edition)

Solve the following problems from Chapter 5:

- 5.46, 5.48, 5.54, 5.71, 5.72

Note: Use the parameters in page 271 as needed for the problems above.

Solve the following problems from Chapter 10:

- 10.28, 10.38, 10.42, 10.46, 10.61, 10.69

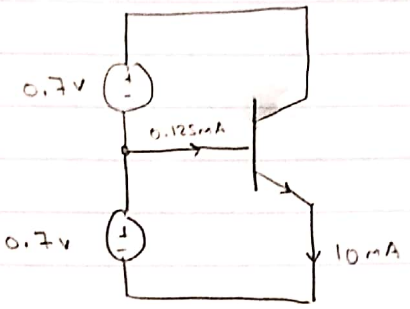
Note: The amplifier voltage gain given in decibels (dB) is $A[dB] = 20logA$.

Thomas Collins
ECE 548

Homework #5 (Optional)

Problem # 5.46

What are the values of β_F and I_S for the transistor



$$I_B = \left(\frac{I_S}{\beta_F}\right)^{\wedge}\left(\frac{V_{BE}}{V_T} - 1\right) \qquad I_E = \left(I_S + \frac{I_S}{\beta_F}\right)^{\wedge}\left(\frac{V_{BE}}{V_T} - 1\right)$$

$$\frac{I_E}{I_B} = \frac{\left(I_S + \frac{I_S}{\beta_F}\right)^{\wedge}\left(\frac{V_{BE}}{V_T} - 1\right)}{\left(\frac{I_S}{\beta_F}\right)^{\wedge}\left(\frac{V_{BE}}{V_T} - 1\right)} \qquad \frac{I_E}{I_B} = \left(I_S + I_S/\beta_F\right)\left(\beta_F/I_S\right)$$

$$\frac{I_E}{I_B} = (\beta_F + 1) \qquad \beta_F = \frac{I_E}{I_B} - 1 \qquad \beta_F = \left(\frac{10mA}{0.125mA}\right) - 1$$

$$\boxed{\beta_F = 79}$$

$$I_S = \frac{I_E}{\left(1 + \frac{1}{\beta_F}\right)^{\wedge}\left(\frac{V_{BE}}{V_T} - 1\right)}$$

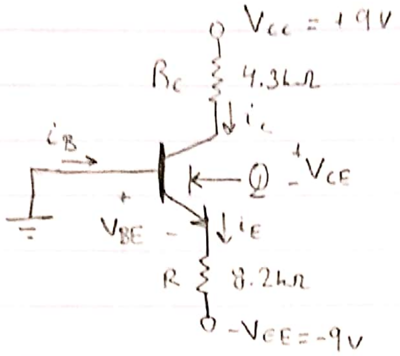
$$I_S = \frac{(10mA)}{\left(1 + \frac{1}{79}\right)^{\wedge}\left(\frac{0.7v}{0.025v}\right) - 1)}$$

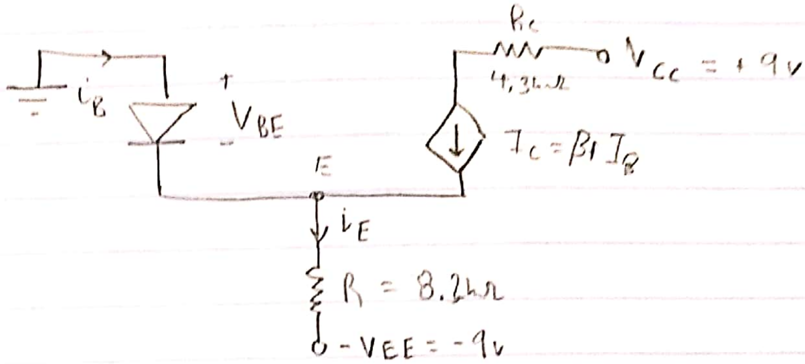
$$\boxed{I_S = 6.667 \times 10^{-15} A}$$

Scanned by CamScanner

Thomas Collins

Problem #2 5.48





What are i_B, i_E, i_C w/ $V_{EE} = 3.3V$ $R = 47k\Omega$ $\beta_F = 80$

$I_E = \frac{-V_{BE} - (-V_{EE})}{R}$ $\quad I_E = \frac{(-0.7v) - (-3.3v)}{47k\Omega}$

$\boxed{I_E = 55.31 \times 10^{-6} A}$

$I_B = \frac{I_E}{\beta_f + 1}$ $\quad I_B = \frac{(55.31 \times 10^{-6} A)}{(80 + 1)}$

$\boxed{I_B = 0.6829 \times 10^{-6} A}$

$I_C = \beta_f I_B$ $\quad I_C = (80)(0.6829 \times 10^{-6} A)$

$\boxed{I_C = 54.63 \times 10^{-6} A}$

Thomas Collins

Problem #5.54

What is the saturation voltage of an npn transistor operating with $I_C = 1mA$ and $I_B = 1mA$ if $B_f = 50$ and $B_R = 2$? What is the forced β of this transistor? What is the value of VBE if $I_S = 10^{-15}$ A

$\alpha_R = \frac{B_R}{B_R + 1}$ $\alpha_R = 2/3$

$$V_{CEsat} = V_T \ln\left[\left(\frac{1}{\alpha_R}\right)\left(\frac{1 + \left(\frac{I_C}{(B_R+1)(I_B)}\right)}{\left(1 - \frac{I_C}{B_F I_B}\right)}\right)\right]$$

$$V_{CEsat} = 0.025 \ln\left(\left(\frac{3}{2}\right)\left(\frac{1 + \left(\frac{1mA}{(2+1)(1mA)}\right)}{\left(1 - \left(\frac{1mA}{(50)(1mA)}\right)\right)}\right)\right)$$

$$\boxed{V_{CEsat} = 17.76mV}$$

$\beta_{FOR} = I_C / I_B$ $\boxed{\beta_{For} = 1}$

$$V_{BE} = V_T \ln\left(\frac{I_B + (1-\alpha_R) I_C}{I_S\left(\frac{1}{B_F} + 1 - \alpha_R\right)}\right)$$

$$V_{BE} = 0.025 \ln \frac{(1mA + (1 - 2/3)(1mA))}{(1 \times 10^{-15} A)\left(\frac{1}{50} + 1 - 2/3\right)}$$

$$\boxed{V_{BE} = 0.723V}$$

Thomas Collins

Problem # 5.71

An npn transistor is operating in the forward active region with a base current of $3\mu A$. It is found that $I_c = 225\mu A$ for $V_{CC} = 5V$ and $I_C = 265\mu A$ for $V_{CC} = 10V$. What are the values of V_A and β_{FO} for this transistor

$$\beta_F = \beta_{FO}\left[1 + \frac{V_{CC}}{V_A}\right] I_B \qquad \beta_{FO}\left[1 + \frac{5}{V_A}\right] = \frac{225\mu A}{3\mu A}$$

$$\beta_{FO}\left[1 + \frac{10}{V_A}\right] = \frac{265\mu A}{3mA}$$

$$\frac{\frac{265\mu A}{3mA}}{\frac{225\mu A}{3mA}} = \frac{\beta_{FO}\left[1 + \frac{10}{V_A}\right]}{\beta_{FO}\left[1 + \frac{5}{V_A}\right]}$$

$$\left[1 + \frac{5}{V_A}\right]\left(\frac{265\mu A}{3mA}\right) = \left[1 + \frac{10}{V_A}\right]\left(\frac{225\mu A}{3mA}\right)$$

$$265\mu A\, V_A + 5 \cdot 265\mu A = 225\mu A\, V_A + 10 \cdot 225\mu A$$

$$\boxed{V_A = 23.125V}$$

$$\beta_F = I_C / I_B \qquad \beta_F = 265\mu A / 3\mu A \qquad \boxed{\beta_F = 88.333}$$

$$88.333 = \beta_{FO}\left[1 + \frac{10}{23.125V}\right] \qquad \boxed{\beta_{FO} = 61.666 \text{ for } 265\mu A}$$

$$\beta_F = I_C / I_B \qquad \beta_F = 225\mu A / 3\mu A \qquad \boxed{\beta_F = 75}$$

$$75 = \beta_{FO}\left[1 + \frac{5}{23.125V}\right] \qquad \boxed{\beta_{FO} = 61.666 \text{ for } 225\mu A}$$

Thomas Collins

Problem # 5.72

An npn transistor with $I_S = 5\times10^{-16} A$
$BF = 100$ $V_A = 65\,V$ is forward bias region
with $V_{BE} = 0.72V$ and $V_{CE} = 10\,V$

(a) What is the collector current I_C?

(b) What would be the collector current I_C if $V_A = \infty$?

(c) What is the ratio of the two answers in part (a) and (b)?

(a) $$I_c = I_s\, n\left(\frac{V_{BE}}{V_T}\right)-1) \cdot \left(1 + \frac{V_{CE}}{V_A}\right)$$

$$I_c = (5\times10^{-16}A)\, n\left(\frac{0.72}{0.025}\right)-1)\left(1 + \frac{10}{65}\right)$$

$$\boxed{I_c = 1.856\,mA}$$

(b) $$I_c = I_s\, n\left(\frac{V_{BE}}{V_T}\right)-1)\left(1 + \frac{V_{CE}}{\infty}\right)$$

$$I_c = (5\times10^{-16}A)\, n\left(\frac{0.72}{0.025}\right)-1)(1+0)$$

$$\boxed{I_c = 1.609\,mA}$$

(c) $$\boxed{1.609\,mA : 1.856\,mA}$$

Thomas Collins

Problem # 10.28

(a) What is the maximum value of VM that can be used and still have an undistorted sinusoidal signal at v_O?

(b) Write expressions for $v_I(t)$ and $v_O(t)$

(a) $v_I = V_B + V_m \sin(1000t)$ $\quad V_B = 0.6V \Rightarrow V_o = 8V$

$$A_v = \left.\frac{dv_o}{dv_t}\right|_{V_B = 0.6V} \qquad A_v = \frac{(12-4)}{(0.5-0.4)} \qquad \boxed{A_v = -40}$$

$$A_{vdB} = 20\log A_v \qquad A_{vdB} = 20\log(-40) \qquad A_{vdB} = 20\log(40)$$

$$\boxed{A_{vdB} = 32\ dB}$$

$$\boxed{V_m = 0.1V \sim 100mV}$$

(b) $V_t(t) = V_B + V_m \sin(1000t)$

$= (0.6 + 0.100\sin(1000t))\ V$

$$\boxed{V_t(t) = 0.6 + 0.1\sin(1000t)}$$

$$\boxed{V_o(t) = (8 - 4\sin(1000t))\ V}$$

Thomas Collins

Problem # 10.38

(a) Find the overall voltage gain A_v, current gain A_i and the power gain A_p for the amplifier, and express the results in dB

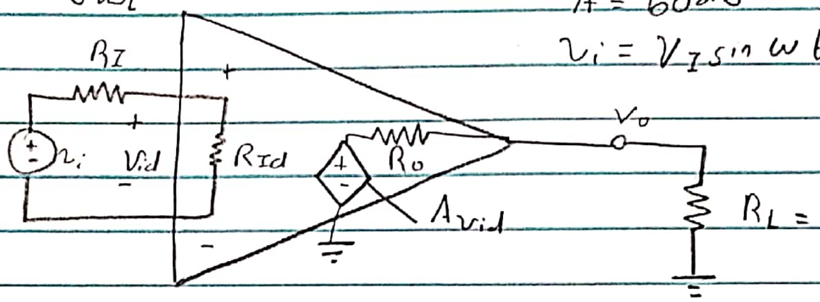
(b) What is the amplitude V_I of the sinusoidal input signal needed to develop a 20-V peak to peak signal at V_o?

Input Resistance $R_{id} = 1M\Omega$

Output Resistance $R_o = 25\Omega$

$A = 60dB$

$v_i = V_I \sin \omega t$



(a)

$A = 10^{dB/20}$ $\quad A = 10^{60/20}$ $\quad \boxed{A = 1000}$

$$v_o = v_i \frac{R_{in}}{R_I + R_{in}} A \frac{R_L}{R_{out} + R_L}$$

$$\frac{V_o}{V_i} = \frac{(1\times10^6)}{(5\times10^3)+(1\times10^6)} (1000) \frac{(600)}{(25)+(600)}$$

$$\boxed{\frac{V_o}{V_i} = A_v = 955.21\ V}$$

$A_v dB = 20 \log(A_v)$

$A_v(dB) = 20 \log(955.21)$

$\boxed{A_v(dB) = 59.6 dB}$

$I_o = V_o / R_L$ $\quad I_o = (955.21 V_i) / (600\Omega)$ $\quad$ w/ $I_i = \frac{V_i}{R_I + R_{in}}$

$I_i = \frac{V_i}{(5k\Omega)+(1\times10^6)}$ $\quad \frac{I_o}{I_i} V_i = A_v$

$$A_v = \frac{\frac{(955.2 V_i)}{(600\Omega)}}{\frac{V_i}{(5k\Omega)+(1\times10^6)}}$$

$A_v = 1.6 \times 10^6$ A

$A_i = 20 \log(A_v)$ $\quad A_i = 20 \log(1.6\times10^6 A)$ $\quad \boxed{A_i = 124.08 dB}$

$A_P = A_v \cdot A_i$

$= (955.21)(1.6 \times 10^6)$

$A_P = 1.528 \times 10^9$

$A_{PdB} = 10 \log (1.528 \times 10^9)$

$\boxed{A_{PdB} = 91.84 dB}$

(b) $V_i = \frac{V_o}{A_v}$ $V_i = \frac{(20v/2)}{(955.2 V)}$ $V_i = 10.4 mA$

$\boxed{V_i = 10.4 mA}$

Scanned by CamScanner

Thomas Collins

Problem #10.42

What is the input voltage Vid? How large must the voltage gain be to make $V_{id} \le 1\mu V$? What is the input current i_+ if $R_{id} = 1M\Omega$

$A = 120dB \quad V_O = 15V$

$A = V_o / V_{id}$ w/ $A_{dB} = 20 \log(A_v) \Rightarrow A_{dB} = 10^{\left(\frac{A_{dB}}{20}\right)}$

$V_{id} = \frac{V_o}{10^{\left(\frac{A_{dB}}{20}\right)}} \qquad V_{id} = \frac{15V}{10^{\left(\frac{120}{20}\right)}} \qquad \boxed{V_{id} = 15\mu V}$

$A = \frac{V_o}{V_{id}} \qquad A = \frac{15v}{15\mu V} \qquad \boxed{A = 15 \times 10^6}$

$i_+ = \frac{A(V_{id})}{R_{id}} \qquad i_+ = \frac{(15 \times 10^6)(1\mu V)}{1M\Omega}$

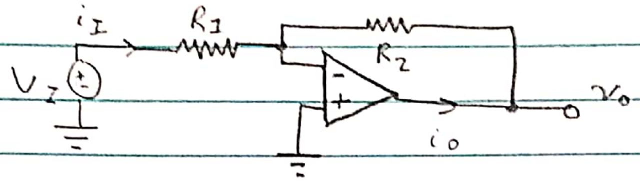
$\boxed{i_+ = 15\mu A}$

Thomas Collins

Problem # 10.46

Write an expression for the output voltage $V_o(t)$

$R_1 = 750\Omega$ $R_2 = 9.1k\Omega$ $V_i(t) = (0.05\sin(4638t))V$



$A_v = -\frac{R_2}{R_1}$ $A_v = -\frac{9.1\times10^3}{750\Omega}$ $\boxed{A_v = -12.13}$

$A_v = \frac{V_o}{V_i}$ $A_v V_i = V_o$ $(-12.13)(0.05) = V_o$ $\boxed{V_o = -0.606V}$

$V_o(t) = V_o \sin(4638t)$ $\boxed{V_o(t) = (-0.606V)\sin(4638t)}$

$I_i = \frac{V_i}{R_i}$ $I_i = \frac{(0.05V)}{(750\Omega)}$ $\boxed{I_i = 66.7\mu A}$

$i_I(t) = i_I(\sin(4638t))$

$\boxed{i_I(t) = (66.7\mu A)\sin(4638t)\ \mu A}$

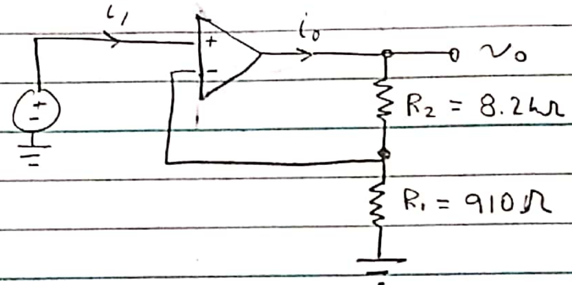
Scanned by CamScanner

Thomas Collins

Problem # 10.61

Write an expression for the output voltage $V_o(t)$

$R_1 = 910\,\Omega$ $R2 = 8.2k\Omega$ $v_i(t) = 0.04\sin(9125t)\,V$



$v^- = v^+$

$\frac{v^-}{R_1} + \frac{v^- - v_o}{R_o} = 0 \Rightarrow \frac{v_i}{R_1} + \frac{v_i - v_o}{R_o} = 0 \Rightarrow \frac{v_o}{R_2} = v_i\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

$V_o = v_i\left(1 + \frac{R_2}{R_1}\right)$

$v_o = (0.04\sin(9125t)\,V)\left(1 + \frac{8.2k\Omega}{910\,\Omega}\right)$

$\boxed{v_o = 0.36\sin(9125t)\ V}$