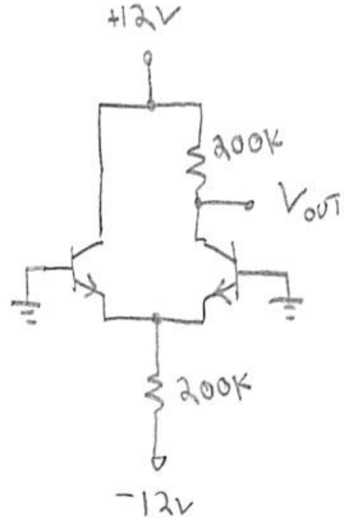
ECE 363
HW3 solns

Total = 100 pts



$\beta = 100$

$\alpha = \frac{100}{101} = 0.99$

(1) (+10)

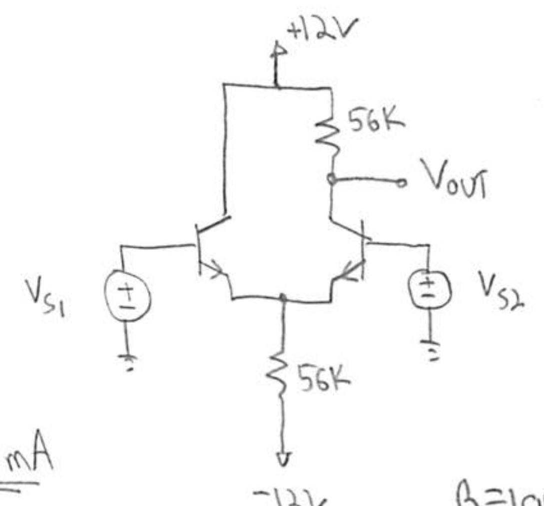
(a) Tail current $I_T = \frac{12 - 0.7}{200K}$

$\boxed{I_T = 0.0565 \text{ mA}}$

(b) $r_e' = \frac{.026}{\frac{1}{2}(.0565\text{mA})} = \boxed{0.92\,K}$

(c) $V_{CQ} = V_{CC} - \alpha \frac{1}{2} I_T R_C = 12 - 0.99 \frac{1}{2}(.0565\text{mA})(200K)$

$= \boxed{6.4\,V}$



$\beta = 100$

$\alpha = \frac{100}{101} = 0.99$

(2) (+10)

(a) $A_d = \frac{\alpha R_C}{2 r_e'}$ ← Need I_T!

$I_T = \frac{V_{EE} - V_{BE}}{R_E} = \frac{12 - 0.7}{56K} = \underline{\underline{0.202\text{ mA}}}$

$r_e' = \frac{.026V}{\frac{1}{2}(.202\text{mA})} = \underline{\underline{0.257K}}$

$\rightarrow A_d = \frac{0.99 \times 56K}{2(.257K)} = \boxed{107.9}$

(b) $V_{CQ} = 12 - 0.99 \frac{1}{2}(.202\text{mA})(56K) = 6.4V$

$\Delta V_{OUT} = A_d \Delta V_{IN} = 107.9\,(10\text{mV} - -10\text{mV}) = 2.16V$

$\Rightarrow V_{OUT} = 6.4 + 2.16 = \boxed{8.56V}$

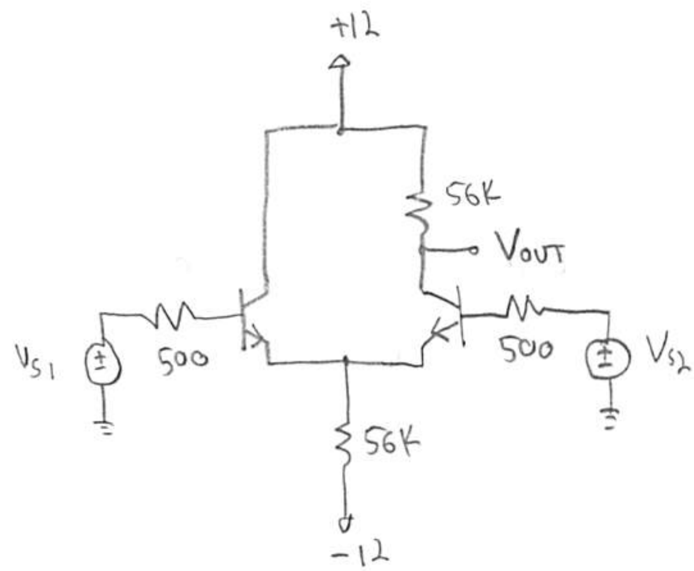
(c) Max (+) $\Delta V_{OUT} = V_{CC} - V_{CQ} = 12 - 6.4 = \underline{5.6V}$

Max (−) $\Delta V_{OUT} = V_{CQ} - (V_E + V_{CE,sat}) = 6.4 - (-0.7 + 0.3) = \underline{6.8V}$

This is the limiting factor

$$\text{Max } \Delta V_{IN} = \frac{5.6V}{107.9} = .052V = \boxed{52mV}$$

(3) +10



(a) $A_d = \dfrac{\alpha R_C}{2r_e'}$ ← Need I_T!

$$I_T = \frac{12 - 0.7}{56K} = \underline{0.202mA}$$

$$r_e' = \frac{.026}{\frac{1}{2}(.202mA)} = \underline{0.257K}$$

$\beta = 100$

$\alpha = \dfrac{100}{101} = 0.99$

$$\rightarrow A_d = \frac{.99 \times 56K}{2(.257K)} = \boxed{107.9}$$

(b) $R_{IN} = 2(\beta+1)r_e' = 2(100+1)(.257K) = \boxed{51.9K}$

(c) $\Delta V_{IN} = \Delta V_S \dfrac{R_{IN}}{R_{IN} + R_S} \rightarrow \dfrac{\Delta V_{IN}}{\Delta V_S} = \dfrac{51.9K}{51.9K + .5K + .5K} = \boxed{0.98}$

(d) $\Delta V_{OUT} = \underbrace{\boxed{\dfrac{\Delta V_{OUT}}{\Delta V_{IN}}}}_{A_d} \times \dfrac{\Delta V_{IN}}{\Delta V_S} \Delta V_S = 107.9 \times 0.98 \times (5 - -5mV)$

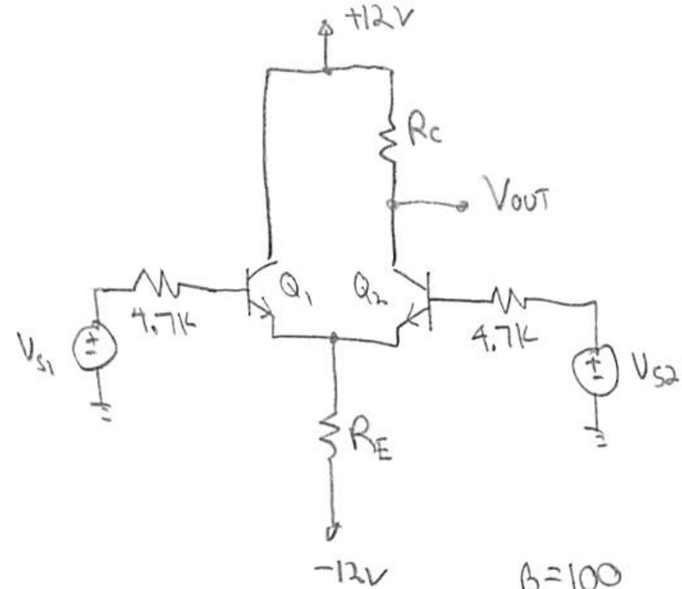
$= \boxed{1.057V}$

(4) +10

(a) $R_{IN} \geq 50K$

$2(\beta+1) r_e' \geq 50K$

$r_e' \geq \frac{50K}{2(101)} = \underline{0.248K}$



$\frac{.026V}{\frac{1}{2} I_T} \geq .248K$

$\rightarrow I_T \leq \boxed{0.21mA}$

$\beta = 100$

$\alpha = \frac{100}{101} = 0.99$

(b) $I_T = .21mA \geq \frac{12-0.7}{R_E} \Rightarrow R_E \geq \frac{12-0.7}{.21mA} = 53.8K$

choose $\boxed{R_E = 56K}$

(c) $I_T = \frac{12-0.7}{56K} = \boxed{0.202mA}$

$r_e' = \frac{.026}{\frac{1}{2}(.202mA)} = \underline{0.257K} \rightarrow R_{IN} = 2(101)(.257K) = \boxed{51.9K}$

Satisfies design requirement

(d) $A_d = \frac{\alpha R_c}{2 r_e'} \geq 100$

$R_c \geq \frac{100 \times 2 \times .257K}{.99} = 51.9K$

choose $\boxed{R_c = 56K}$

(e) $A_d = \dfrac{.99\,(56K)}{2\,(.257K)} = \boxed{107.9}$

$V_{CQ} = 12 - 0.99\,\tfrac{1}{2}\,(.202\,mA)(56K)$
$= \boxed{6.4V}$

(f) $\dfrac{V_{OUT}}{V_S} = \underbrace{\boxed{\dfrac{V_{OUT}}{V_{IN}}}}_{A_d}\,\dfrac{V_{IN}}{V_S} = A_d\,\dfrac{R_{IN}}{R_{IN}+R_S} = 107.9\,\dfrac{51.9K}{51.9K + 9.4K}$

$= \boxed{91.4}$

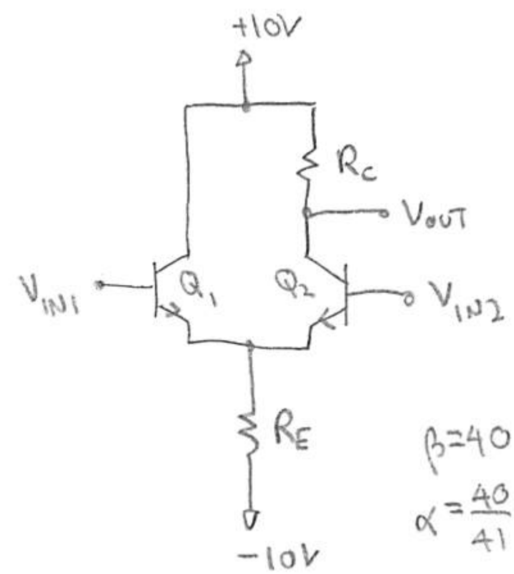
(5) (+10)

(a) $R_{IN} = 2(\beta+1)\,r_e' \geq 20K$

$r_e' \geq \dfrac{20K}{2(40+1)} = \underline{\underline{0.244K}}$

$\dfrac{.026}{\tfrac{1}{2}I_T} \geq .244K$

$\boxed{I_T \leq 0.213\,mA}$



$\beta = 40$
$\alpha = \dfrac{40}{41} = .976$

(b) $I_T = \dfrac{10 - 0.72}{R_E} < .213\,mA$

$R_E > 43.6K$ Choose $\boxed{R_E = 47K}$

(c) Actual $I_T = \dfrac{10 - 0.72}{47K} = \boxed{0.197\,mA}$

$r_e' = \dfrac{.026}{\tfrac{1}{2}(.197\,mA)} = 0.264K$

$R_{IN} = 2\,(41)(.264K) = \boxed{21.65\,K}$

(d) $A_d = \dfrac{\alpha R_C}{2r_e'} \geq 100 \rightarrow R_C \geq \dfrac{100 \times 2 \times .264K}{0.976} = 54.1K$ Choose $\boxed{R_C = 56K}$

(e) Actual $A_d = \dfrac{.976 \cdot 56K}{2 \cdot .264K} = \boxed{103.5}$

$V_{CQ} = 10 - .976\,\tfrac{1}{2}(.197\,mA)(56K) = \boxed{4.6V}$

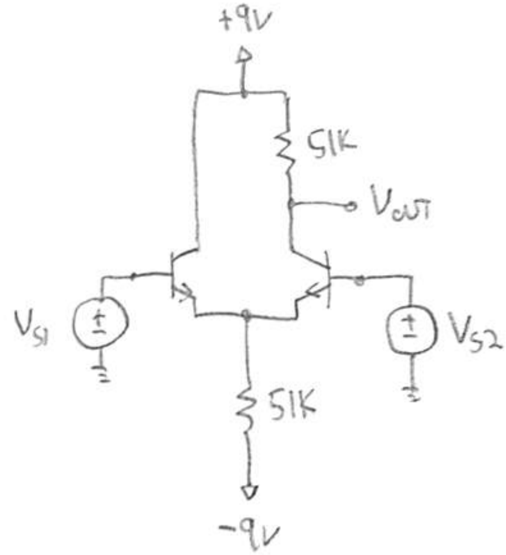
6

+10

ⓐ $I_T = \frac{9-0.7}{51K} = \underline{0.163\ mA}$

$r_e' = \frac{.026}{\frac{1}{2}(.163mA)} = 0.319K$

$R_{IN} = 2(100+1)(.319K) = \boxed{64.44K}$



ⓑ $A_d = \frac{\alpha R_c}{2r_e'} = \frac{.99 \times 51K}{2 \times .319K} = \boxed{79.1}$

ⓒ $A_{CM} = \frac{\alpha R_c}{2R_E} = \frac{.99 \times 51K}{2 \times 51K} = \boxed{0.495}$

ⓓ $CMRR = 20\log_{10} \frac{79.1}{.495} = \boxed{44.1\ dB}$

7

+10

Problem 4:

$\alpha = 0.99$

$r_e' = .257K$

$R_c = R_E = 56K$

$A_{CM} = \frac{.99 \times 56K}{2 \times 56K} = .495$

$A_d = 107.9$

$\Rightarrow CMRR = 20\log_{10} \frac{107.9}{.495} = \boxed{46.8\ dB}$

Problem 5:

$\alpha = .976$

$r_e' = .264K$

$R_c = 56K,\ R_E = 47K$

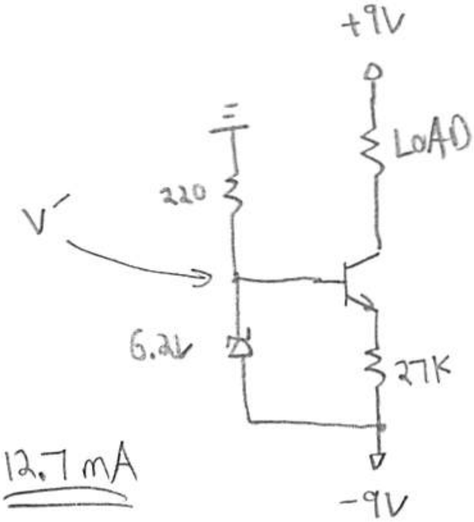
$A_{CM} = \frac{.976 \times 56K}{2 \times 47K} = 0.58$

$\Rightarrow CMRR = 20\log_{10} \frac{103.5}{0.58} = \boxed{45\ dB}$

$A_d = 103.5$

(8) +10

(a) $I_z = I_s - I_B$



Assuming zener is OK,

$V' = -9 + 6.2 = \underline{-2.8V}$

$I_s = \dfrac{0-(-2.8)}{220} = .0127A = \underline{12.7 mA}$

$I_B = \dfrac{1}{100+1} \dfrac{6.2-0.7}{27K} = .002 mA$ ← negligible

→ $\boxed{I_z = 12.7 \text{ mA}}$

(b) $I_L = \alpha I_E = 0.99 \times \underbrace{\boxed{\dfrac{6.2-0.7}{27K}}}_{.204mA} = \boxed{0.202mA}$

(c) $R_{OUT} = r_o \left[1 + \beta \dfrac{R_2}{R_2 + (\beta+1) r_e'} \right]$

$r_o = \dfrac{120V}{.202mA} = \underline{594.1K}$ $\quad r_e' = \dfrac{.026}{.204mA} = \underline{0.1275K}$

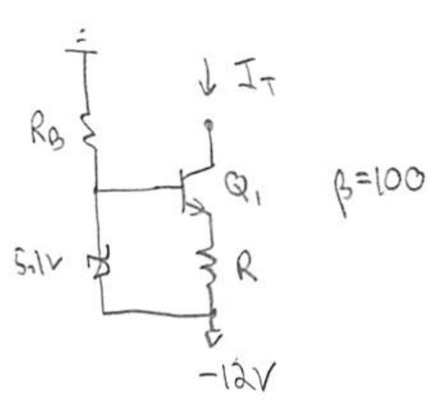
$R_{OUT} = 594.1K \left(1 + 100 \dfrac{27K}{27K + 101(.1275K)} \right) = 4.08 \times 10^4 K$

$= \boxed{40.8 M\Omega}$

(9) Problem 4: $I_T = .202mA$

+10

$I_T = \alpha I_E = 0.99 \dfrac{5.1-0.7}{R} = .202mA$



$R = 21.6K$

Choose $\boxed{R = 22K}$

Actual $I_T = 0.99 \boxed{\dfrac{5.1-0.7}{22K}} = \underline{\underline{0.198\,mA}}$

$\uparrow$

$.2\,mA$

want $I_Z = I_S - I_B > 10\,mA$

$$\frac{12-5.1}{R_B} - \frac{1}{101}(.2\,mA) > 10\,mA$$

$$R_B < \frac{6.9\,V}{10.002\,mA} = 0.69K \quad \text{Choose } \boxed{R_B = 680\,\Omega}$$

$$CMRR = 20\log_{10}\left(\frac{R_{OUT}}{r_e'}\right)$$

$$r_e' \leftarrow \frac{.026}{\frac{1}{2}(.198\,mA)} = 0.263K$$

$$R_{OUT} = r_o\left(1 + \beta\frac{R}{R+(\beta+1)r_{e3}'}\right) = 606.1K\left(1 + 100\frac{22K}{22K + 101(.13K)}\right)$$

$$r_{e3}' \leftarrow \frac{.026}{.2\,mA} = .13K \qquad = 3.86\times10^4\,K$$

$$r_o \leftarrow \frac{120V}{.198\,mA} = \underline{\underline{606.1\,K}}$$

$$CMRR = 20\log_{10}\left(\frac{3.86\times10^4\,K}{.263K}\right) = \boxed{103.3\,dB}$$

10

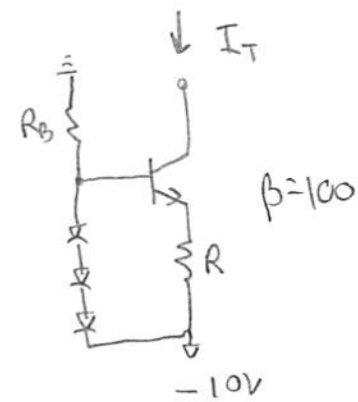
+10

Problem 5: $I_T = .197\,mA$

$$I_T = \alpha I_E = .99\,\frac{2.1-0.7}{R} = .197\,mA$$

$$R = 7.04K$$

Choose $\boxed{R = 6.8K}$



Actual $I_T = .99 \times \boxed{\frac{1.4V}{6.8K}} = \underline{\underline{0.204\,mA}}$ ← $\boxed{\text{Problem 5 required } I_T \leq .213\,mA}$ ✓

.206mA

want $I_o = I_s - I_B > 1\,mA$

$$\frac{10-2.1}{R_B} - \frac{1}{101}(.206mA) > 1\,mA$$

$$R_B < \frac{10-2.1}{1.002mA} = 7.88K$$

Choose $\boxed{R_B = 7.5K}$

$$CMRR = 20\log_{10}\left(\frac{R_{OUT}}{r_e'}\right)$$

$$r_e' = \frac{.026}{\frac{1}{2}(.204mA)} = \underline{\underline{0.255K}}$$

$$R_{OUT} = \left(\frac{120V}{.204mA}\right)\left[1 + 100\,\frac{6.8K}{6.8K + 101\,\frac{.026}{.206mA}}\right] = \underline{\underline{2.1 \times 10^4\,K}}$$

$$CMRR = 20\log_{10}\left(\frac{2.1\times10^4 K}{.255K}\right) = \boxed{98.3\,dB}$$