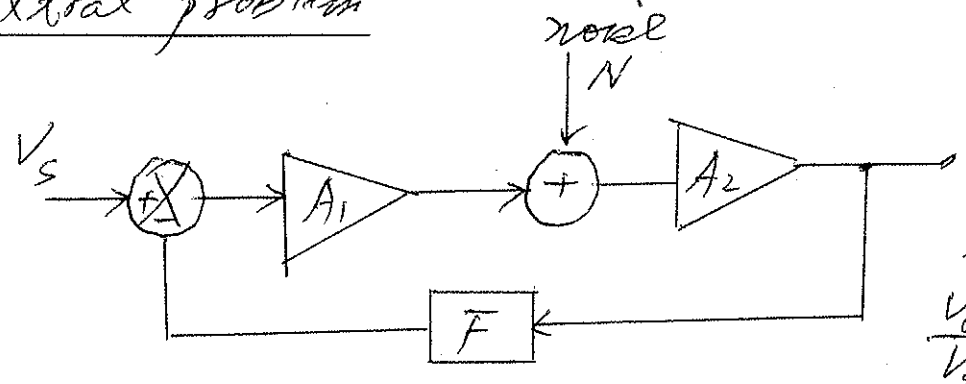
EECE-315 Exercise #7 Solutions

Extra problem



$A_2 = 0.9$

$\frac{V_o}{V_s} = A_f = 10$

$$V_o = [(V_s - FV_o)A_1 + N]A_2$$

$$V_o = (A_1V_s - A_1FV_o + N)A_2 = A_1A_2V_s - A_1A_2FV_o + NA_2$$

$$(1 + A_1A_2F)V_o = A_1A_2V_s + NA_2$$

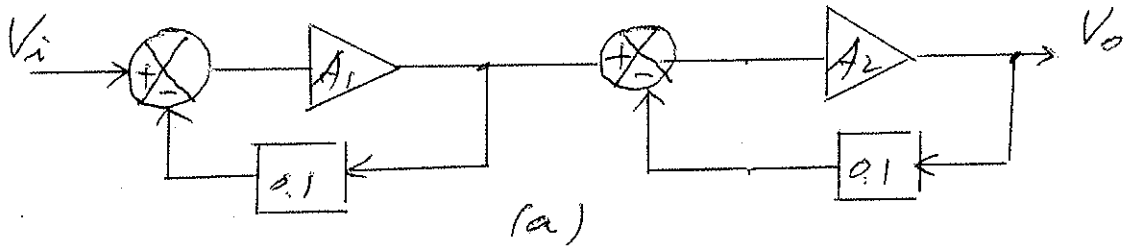
$$V_o = \left(\frac{A_1A_2}{1 + A_1A_2F}\right)V_s + \left(\frac{A_2}{1 + A_1A_2F}\right)N$$

$\frac{A_1A_2}{1 + A_1A_2F} = 10$ and output ripple noise $= \left(\frac{A_2}{1 + A_1A_2F}\right)N$

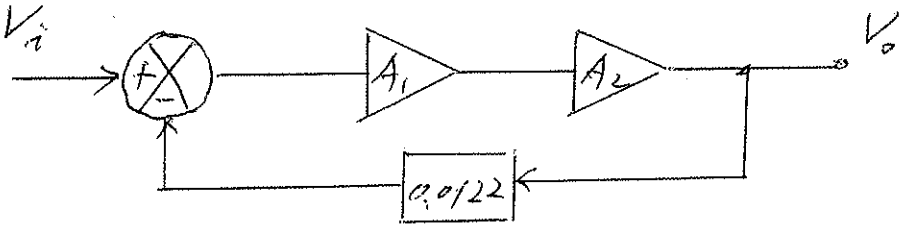
(a) $A_1 = 100$, $F = 0.0889$ (b) $A_1 = 1000$, $F = 0.0989$

(c) $A_1 = 10000$, $F = 0.09989$

12.15



(a)



(b)

(a) $$\frac{V_o}{V_i} = \frac{A_1}{1+\beta_1 A_1} \times \frac{A_2}{1+\beta_2 A_2} = \begin{cases} 81 & \text{for low input} \\ 73.47 & \text{for high input} \end{cases}$$

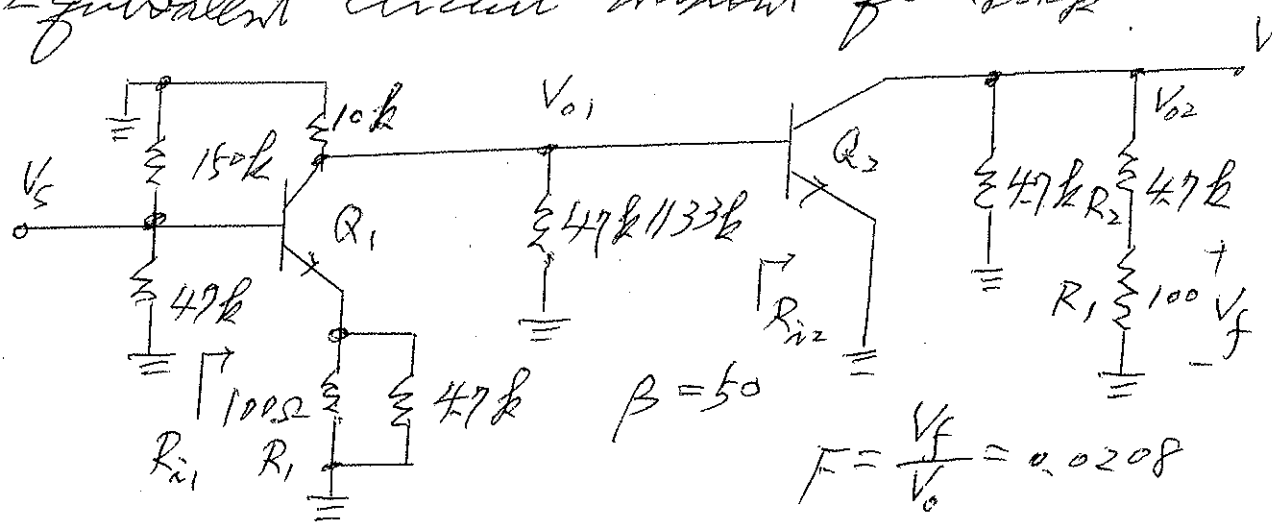
(b) $$\frac{V_o}{V_i} = \frac{A_1 A_2}{1+\beta A_1 A_2} = \begin{cases} 81.14 & \text{for low input} \\ 80.14 & \text{for high input} \end{cases}$$

Circuit (b) will result in less distortion.

12.42

This is a voltage amplifier.

Equivalent circuit without feedback (A-circuit)



From the dc analysis, $I_{CQ_1} = 0.935\ mA$

$I_{CQ_2} = 1.85\ mA$

$g_{m_1} = 37.4\ mA/V$, $r_{\pi 1} = \frac{\beta}{g_{m_1}} = 1.34\ k\Omega$

$g_{m_2} = 74\ mA/V$, $r_{\pi 2} = \frac{\beta}{g_{m_2}} = 0.676\ k\Omega$

$R_{i2} = r_{\pi 2}$, $R_{i1} = r_{\pi 1} + (1+\beta_1)(100 \parallel 4700)$

$$\frac{V_{o1}}{V_s} = -\frac{\beta(10 \parallel 47 \parallel 33 \parallel R_{i2})}{(\beta+1)(0.1 \parallel 4.7) + r_{\pi 1}} = -4.84$$

$$\frac{V_{o2}}{V_{o1}} = \frac{V_o}{V_{o1}} = -g_{m2} \times (47 \parallel 4.8) = -175.7$$

$$\therefore A = \frac{V_o}{V_s} = 850.4$$

$$A_{Vf} = \frac{V_o}{V_s}\ (\text{original circuit}) = \frac{A}{1+AF} = 45.5$$

12.51 This is a current amplifier.

(a) Do dc analysis $\beta = 120$

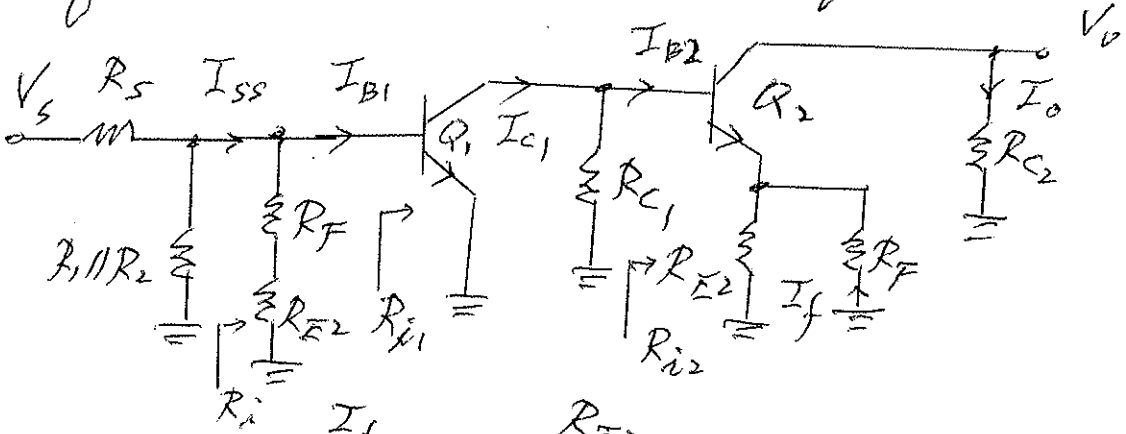
$I_{CQ_1} = 1.75\ mA$, $I_{CQ_2} = 0.50\ mA$

$g_{m_1} = 70\ mA/V$, $g_{m_2} = 20\ mA/V$

$r_{\pi 1} = 1.714\ k\Omega$, $r_{\pi 2} = 6\ k\Omega$

(b)

Equivalent circuit without feedback (A-circuit)



$$F = \frac{I_f}{I_o} \simeq \frac{R_{E2}}{R_{E2}+R_F} = \underline{0.871}$$

$$A = \frac{I_o}{I_{SS}} = \frac{I_o}{I_{B2}} \times \frac{I_{B2}}{I_{C1}} \times \frac{I_{C1}}{I_{B1}} \times \frac{I_{B1}}{I_{SS}}$$

$$R_{i1} = r_{\pi 1}, \quad R_{i2} = r_{\pi 2} + (1+\beta) \times (R_{E2} \| R_F)$$

$R_{i1} = 1.714\ k\Omega$, $R_{i2} = 132.46\ k\Omega$, $R_i = (R_F + R_{E2}) \| R_{i1} = 1.447 k\Omega$

$$\frac{I_o}{I_{B2}} = -\beta = -120, \quad \frac{I_{B2}}{I_{C1}} = \frac{R_{C1}}{R_{C1}+R_{i2}} = 0.0221$$

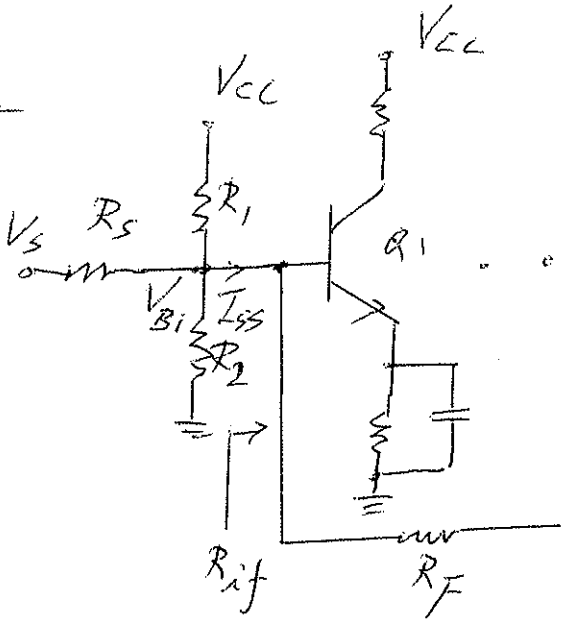
$$\frac{I_{C1}}{I_{B1}} = -\beta = -120, \quad \frac{I_{B1}}{I_{SS}} = \frac{R_F + R_{E2}}{R_F + R_{E2} + R_{i1}} = 0.844$$

12.51

$$A = \frac{I_o}{I_{ss}} = 268.6$$

$$1 + AF = 235$$

Original circuit



$$\frac{I_o}{I_{ss}} = A_f = \frac{A}{1+FA}$$

$$\frac{I_o}{I_{ss}} = 1.143$$

$$R_{if} = \frac{R_i}{1+FA} = 5.88\ \Omega$$

$$V_{B1} = I_{SS} \times R_{if} = V_S \times \frac{R_1 \parallel R_2 \parallel R_{if}}{R_S + R_1 \parallel R_2 \parallel R_{if}} = 0.0097\ V_S$$

$$\frac{V_o}{V_S} = \frac{I_o \times R_{C2}}{I_{SS} \times R_{if} / 0.0097} = A_f \times \frac{0.0097 \times R_{C2}}{R_{if}}$$

$$\frac{V_o}{V_S} = 7.54$$

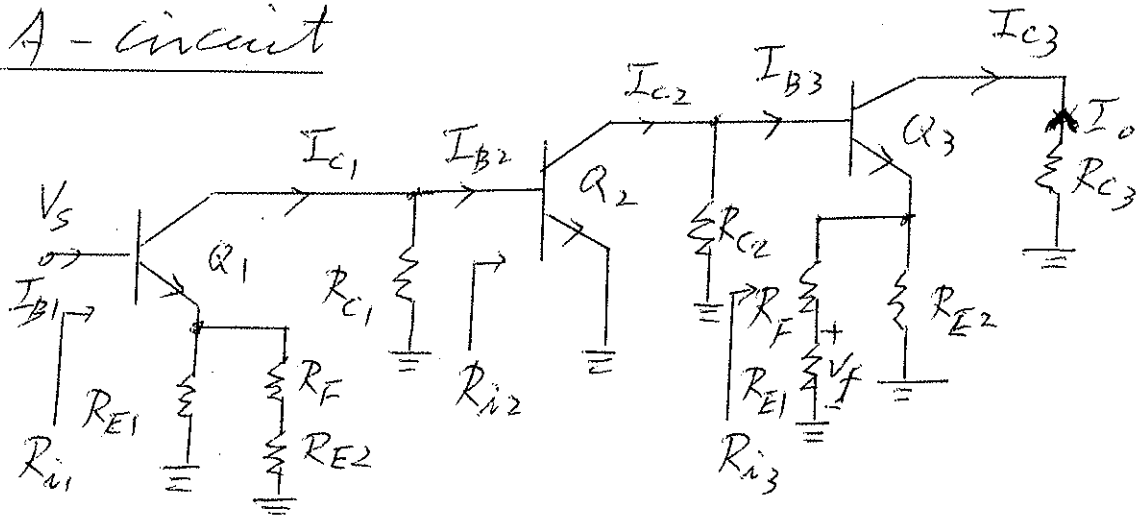
12.57 This is a transconductance amplifier.

$I_{C1} = 0.5\ mA$, $g_{m1} = 20\ mA/V$, $r_{\pi 1} = 6\ k\Omega$

$I_{C2} = 1\ mA$, $g_{m1} = 40\ mA/V$, $r_{\pi 2} = 3\ k\Omega$

$I_{C3} = 2\ mA$, $g_m = 80\ mA/V$, $r_{\pi 3} = 1.5\ k\Omega$

A-circuit



$$f = \frac{V_f}{I_{C3}} \simeq -\frac{R_{E2}}{R_{E2}+R_F+R_{E1}} \times R_{E1} = -0.01\ k\Omega V/A = -10\ V/A$$

$$A = \frac{I_{C3}}{V_S}, \quad R_{i3} = r_{\pi 3} + (120+1)\times\left[(R_F+R_{E1}) \,//\, R_{E2}\right] = 12.39\ k\Omega$$

$$R_{i2} = r_{\pi 2} = 3\ k\Omega, \quad R_{i1} = r_{\pi 1} + 121\times\left[R_{E1} \,//\, (R_F+R_{E2})\right]$$

$$\frac{I_{C3}}{I_{B3}} = -\beta = -120, \qquad R_{i1} = 16.89\ k\Omega$$

$$\frac{I_{C1}}{I_{B1}} = -\beta = -120, \quad \frac{I_{C2}}{I_{B2}} = -120$$

$$\frac{I_{B3}}{I_{C2}} = \frac{R_{C2}}{R_{C2}+R_{i3}} = 0.139, \quad \frac{I_{B2}}{I_{C1}} = \frac{R_{C1}}{R_{C1}+R_{i2}} = 0.625$$

12.57 $$\frac{I_{C3}}{I_{B1}} = \frac{I_{C3}}{I_{B3}} \times \frac{I_{B3}}{I_{C2}} \times \frac{I_{C2}}{I_{B2}} \times \frac{I_{B2}}{I_{C1}} \times \frac{I_{C1}}{I_{B1}} = -150120$$

$$V_S = I_{B1} \times R_{i1} = 16.89 \times I_{B1} \times 10^3$$

$$\therefore A = \frac{I_{C3}}{V_S} = \frac{I_{C3}}{I_{B1}} \times \frac{I_{B1}}{V_S} = -8888$$

$$AF + 1 = 89.88$$

Original circuit

$$A_f = \frac{I_{C3}}{V_S} = \frac{A}{1 + AF} = -0.0989$$

$$\therefore \frac{I_o}{V_S} = \frac{-I_{C3}}{V_S} = 0.0989 \text{ A/V} = \underline{98.9 \text{ mA/V}}$$

12.61 This is a transresistance amplifier.

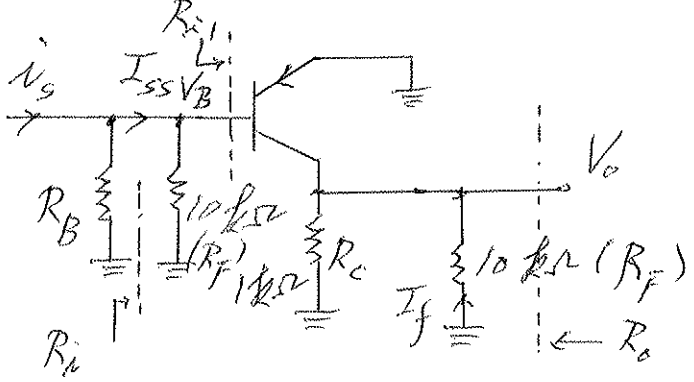
$\beta = 80$, $V_{EB} = 0.7\,V$, $V_A = 100\,V$.

DC analysis: $I_{CQ} = 2.448\,mA$

$V_{ECQ} = 1.31\,V$

$g_m = \frac{I_{CQ}}{0.025} = 97.92\,mA/V$, $r_\pi = \frac{80}{g_m} = 817\,\Omega$, $r_o = \frac{V_A}{I_{CQ}} = 40.85\,k\Omega$

A-circuit



$F = \frac{I_f}{V_o} = -\frac{1}{R_F} = -10^{-4}\,A/V$

$A = \frac{V_o}{I_{ss}}$, $R_{i1} = r_\pi = 0.817\,\Omega$

$\frac{V_o}{V_B} = -g_m(R_C \parallel R_F \parallel r_o)$

$\frac{V_o}{V_B} = -g_m \times 0.889 = -87.1$

$V_B = I_{ss} \times (10 \parallel R_{i1}) = 0.755\,I_{ss}$

$\therefore A = \frac{V_o}{I_{ss}} = \frac{V_o}{V_B} \times \frac{V_B}{I_{ss}} = \underline{-67.76\ k\Omega/A}$

$1 + AF = 2.576$, $R_i = R_{i1} \parallel R_F = 0.755\,k\Omega$

$R_o = R_C \parallel R_F \parallel r_o = 0.889\,k\Omega$

Original circuit: $R_{of} = \frac{R_o}{1+AF} = \underline{117.3\,\Omega}$

$R_{if} = \left(\frac{R_i}{1+AF}\right) \parallel R_B = 0.0997 \parallel 100 = \underline{99.6\,\Omega}$

$\frac{V_o}{i_s} = \frac{V_o}{I_{ss}} \times \frac{I_{ss}}{i_s} = (A_f) \times \frac{R_B}{R_B + \frac{R_i}{1+AF}} = \frac{-67.76}{2.576} \times \frac{100}{100 + 0.0997}$

$\frac{V_o}{i_s} = -8.944\ k\Omega/A$