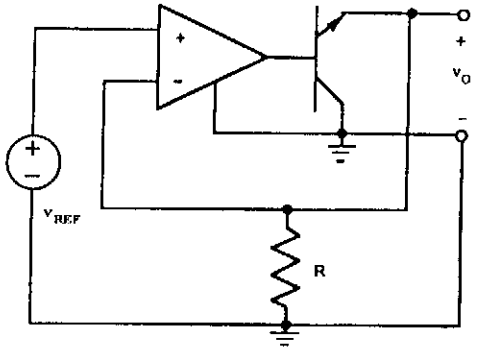
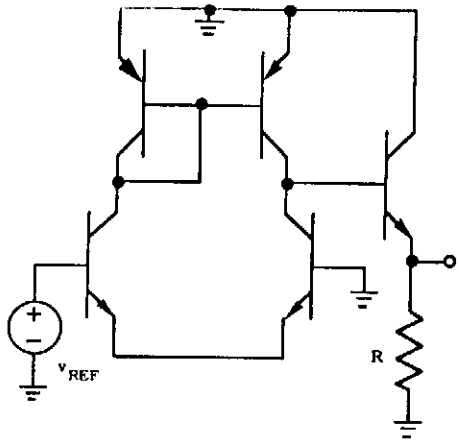
Homework Assignment No. 12 - Solutions

1.) Problem 18.11 of the text.





A-Circuit

$$h_{11}^F = \left.\frac{v_1}{i_1}\right|_{v_2=0} = 0 \quad | \quad h_{22}^F = \left.\frac{i_2}{v_2}\right|_{i_1=0} = \frac{1}{R} \quad | \quad h_{12}^F = \left.\frac{v_1}{v_2}\right|_{i_2=0} = 1$$

$$A = g_{m1}\left(r_{o1}\|r_{o4}\|\left[r_{\pi 5} + (\beta_o + 1)R\right]\right)\frac{(\beta_o + 1)R}{r_{\pi 5} + (\beta_o + 1)R} = g_{m1}\frac{r_{o1}\|r_{o4}}{(r_{o1}\|r_{o4}) + r_{\pi 5} + (\beta_o + 1)R}(\beta_o + 1)R$$

$$r_{o1} = \frac{50 + 1.4}{10^{-4}} = 514\text{k}\Omega \quad | \quad r_{o4} = \frac{50 + 11.3}{10^{-4}} = 613\text{k}\Omega \quad | \quad r_{o1}\|r_{o4} = 280\text{k}\Omega$$

$$I_{C5} = \frac{12}{10^4} = 1.2\text{mA} \quad | \quad r_{\pi 5} = \frac{100(.025)}{1.2\text{mA}} = 2.08\text{k}\Omega$$

$$A = 40\left(10^{-4}\right)(280\text{k}\Omega)\frac{(101)10\text{k}\Omega}{280\text{k}\Omega + 2.08\text{k}\Omega + (101)10\text{k}\Omega} = 876$$

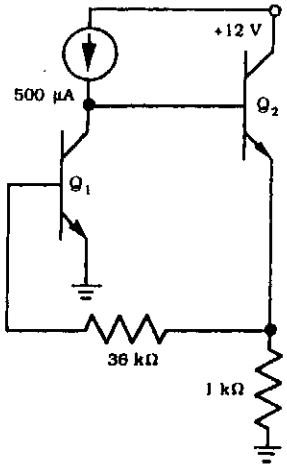
$$A_V = \frac{A}{1 + T} = \frac{876}{1 + 876(1)} = \frac{109}{110} = 0.999$$

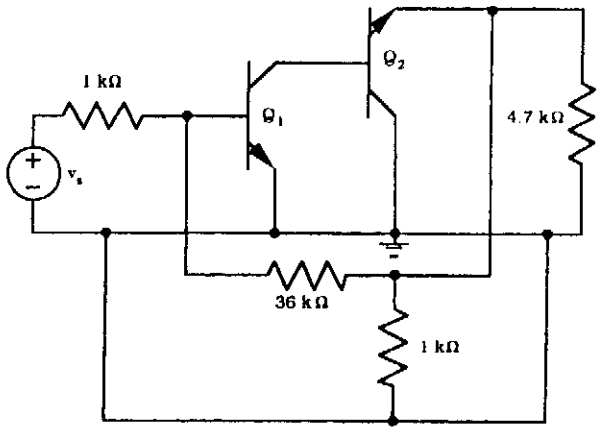
$$R_{IN} = R_{ID}(1 + T) = 2r_{\pi 1}(1 + T) = 2\frac{100(0.025)}{10^{-4}}(877) = 43.9\ \text{M}\Omega$$

$$R_{OUT} = \frac{R\left\|\dfrac{r_{\pi 5} + r_{o2}\|r_{o4}}{\beta_o + 1}\right.}{1 + T} = \frac{10\text{k}\Omega\left\|\dfrac{2.08\text{k}\Omega + 280\text{k}\Omega}{101}\right.}{877} = 2.49\ \Omega$$

$$i_o = \alpha_o i_e = \alpha_o\frac{v_o}{R} \quad | \quad \frac{i_o}{v_{ref}} = \frac{\alpha_o}{R}\frac{v_o}{v_{ref}} = \frac{100}{101}\left(\frac{1}{10^4}\right)(0.999) = 98.9\ \mu\text{S}$$

Prob. 18.16



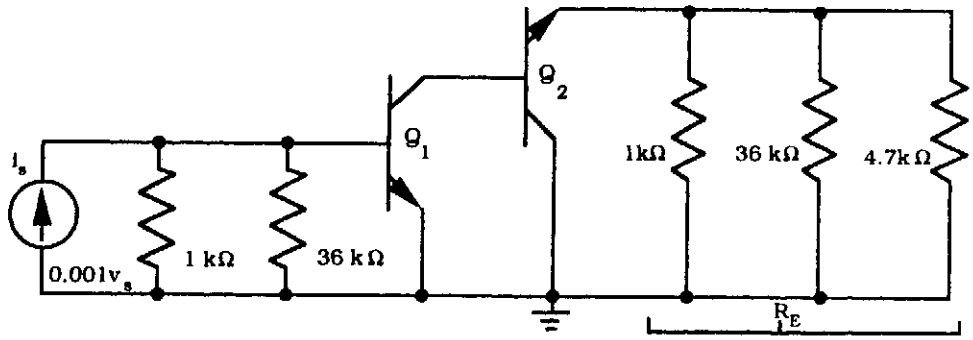


2.) Problem 18.16 of the text – continued

$$I_{C1} = 500\mu A - I_{B2} \quad I_{E2} = I_{B1} + \frac{36000I_{B1} + 0.7}{1000} = 37I_{B1} + 700\mu A \quad I_{B2} = \frac{I_{E2}}{101}$$

$$I_{C1} = 500\mu A - \frac{37I_{B1} + 700\mu A}{101} = 493\mu A - 0.366I_{B1} \rightarrow I_{C1} = 491.2\mu A$$

$$I_{E2} = 37\frac{I_{C1}}{100} + 700\mu A = 881.7\mu A \quad I_{C2} = \frac{100}{101}I_{E2} = 873\mu A$$



$$y_{11}^F = \left.\frac{i_1}{v_1}\right|_{v_2=0} = \frac{1}{36k\Omega} \quad | \quad y_{22}^F = \left.\frac{i_2}{v_2}\right|_{v_1=0} = \frac{1}{36k\Omega \| 1k\Omega} \quad | \quad y_{12}^F = \left.\frac{i_1}{v_2}\right|_{v_1=0} = -\frac{1}{36k\Omega}$$

$$r_{\pi 1} = \frac{100(0.025)}{491\mu A} = 5.09k\Omega \; | \; r_{\pi 2} = \frac{100(0.025)}{873\mu A} = 2.86k\Omega \; | \; r_{o1} = \frac{50 + 1.6}{493x10^{-6}} = 105k\Omega$$

$$R_E = \left(1k\Omega \| 36k\Omega \| 4.7k\Omega\right) = 807\Omega$$

$$A = \frac{v_o}{i_s} = \left(1k\Omega \| 36k\Omega \| r_{\pi 1}\right) g_{m1}\left[r_{o1} \| \left(r_{\pi 2} + (\beta_o + 1)R_E\right)\right] \frac{r_{\pi 2} + (\beta_o + 1)R_E}{r_{o1} + r_{\pi 2} + (\beta_o + 1)R_E}$$

$$A = \frac{v_o}{i_s} = -\left(1k\Omega \| 36k\Omega \| 5.09k\Omega\right) g_{m1}\left[r_{o1} \| \left(r_{\pi 2} + (\beta_o + 1)R_E\right)\right] \frac{r_{\pi 2} + (\beta_o + 1)R_E}{r_{o1} + r_{\pi 2} + (\beta_o + 1)R_E}$$

$$\left(1k\Omega \| 36k\Omega \| r_{\pi 1}\right) = \left(1k\Omega \| 36k\Omega \| 5.09k\Omega\right) = 817\Omega \; | \; g_m = 40(491\mu A) = 19.6mS$$

$$\left[r_{o1} \| \left(r_{\pi 2} + (\beta_o + 1)R_E\right)\right] = \left[105k\Omega \| \left(2.86k\Omega + (101)806\Omega\right)\right] = 46.8k\Omega$$

$$\frac{r_{\pi 2} + (\beta_o + 1)R_E}{r_{o1} + r_{\pi 2} + (\beta_o + 1)R_E} = \frac{2.86k\Omega + (101)806\Omega}{105k\Omega + 2.86k\Omega + (101)806\Omega} = 0.430$$

$$A = -(817\Omega)(19.6mS)(46.8k\Omega)(0.430) = -322\ k\Omega$$

$$A_{TR} = \frac{A}{1 + A\beta} = \frac{-322k\Omega}{1 + (-322k\Omega)\left(-\frac{1}{36k\Omega}\right)} = -\frac{322k\Omega}{9.94} = -32.4\ k\Omega$$

$$R_{IN} = \frac{\left(1k\Omega \| 36k\Omega \| 5.09k\Omega\right)}{1 + A\beta} = \frac{817\Omega}{9.94} = 82.2\ \Omega$$

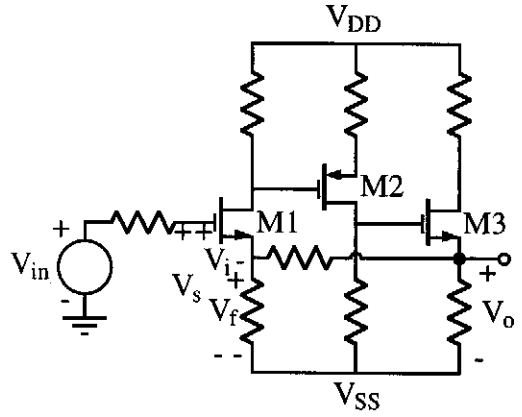
$$R_{OUT} = \frac{\left(1k\Omega \| 36k\Omega \| 4.7k\Omega \| \frac{r_{\pi 2} + r_{o1}}{101}\right)}{1 + A\beta} = \frac{\left(806\Omega \| \frac{2.86k\Omega + 105k\Omega}{101}\right)}{9.94} = 46.2\ \Omega$$

$$i_s = 10^{-3}v_s \rightarrow A_V = \frac{v_o}{v_s} = \frac{v_o}{1000i_s} = -32.4$$

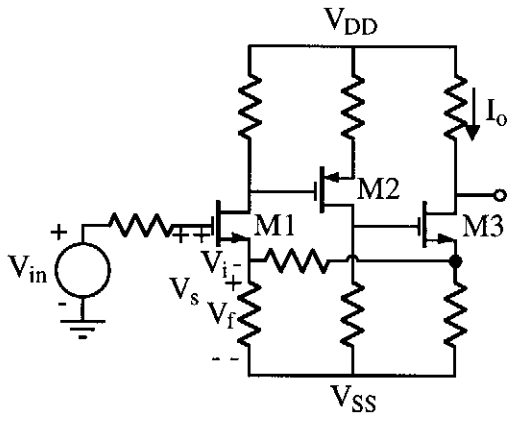
Note that this amplifier can be analyzed as a shunt-shunt feedback amplifier. This is good for student practice - See Problem 18.25.

3.) For each of the MOSFET amplifiers shown below, show how to connect a single resistor from the output to the input that achieves a series-shunt, series-series, shunt-shunt and shunt-series negative feedback amplifier. For each of the four configurations, identify on the schematic the correct variables (voltage or current) for x_s, x_f, x_i, and x_o. The outputs should be at the drain or source of M3.

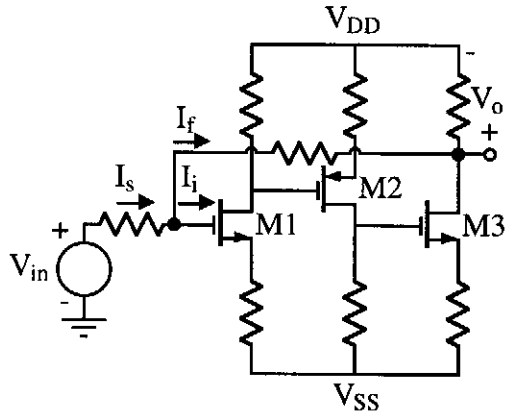
Series-Shunt



Series-Series



Shunt-Shunt



Shunt-Series