Homework Assignment No. 11 - Solutions

1.) **18.8**

$$A_V = \frac{A}{1+A\beta} \quad | \quad \text{From Chapter 12, } GE = \frac{1}{1+A\beta} \approx \frac{1}{A\beta}$$

$$\frac{1}{\beta} = 200 \quad | \quad GE \approx \frac{200}{A} \le 0.002 \rightarrow A \ge \frac{200}{0.002} = 10^5 \quad | \quad A \ge 100 \text{ dB}$$

2.) **18.10** (a) Series-shunt (b) Shunt-series (c) Series-series (d) Shunt-shunt

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3.) **18.15** (a)

$$h_{11}^A = \left.\frac{v_1}{i_1}\right|_{v_2=0} = 15\text{k}\Omega \quad | \quad h_{11}^F = 4.3\text{k}\Omega \| 39\text{k}\Omega = 3.87\text{k}\Omega \quad | \quad h_{11}^T = 18.9\text{k}\Omega$$

$$h_{22}^A = \left.\frac{i_2}{v_2}\right|_{i_1=0} = (1\text{k}\Omega)^{-1} = (1\text{k}\Omega)^{-1} \quad | \quad h_{22}^F = (39\text{k}\Omega + 4.3\text{k}\Omega)^{-1} = (43.3\text{k}\Omega)^{-1} \quad | \quad h_{22}^T = 1.02\text{mS}$$

$$h_{21}^A = \left.\frac{i_2}{i_1}\right|_{v_2=0} = -\frac{15\text{k}\Omega(5000)}{1\text{k}\Omega} = -75,000 \quad | \quad h_{21}^F = \left.\frac{i_2}{i_1}\right|_{v_2=0} = -\frac{4.3\text{k}\Omega}{39\text{k}\Omega + 4.3\text{k}\Omega} = -0.0993$$

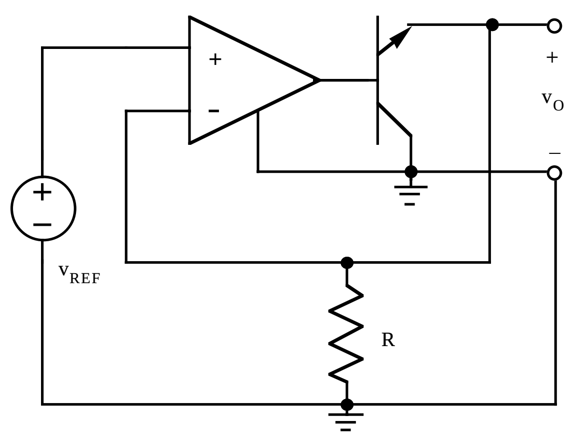
$$h_{12}^A = \left.\frac{v_1}{v_2}\right|_{i_1=0} = 0 \quad | \quad h_{12}^F = \left.\frac{v_1}{v_2}\right|_{i_2=0} = \frac{4.3\text{k}\Omega}{39\text{k}\Omega + 4.3\text{k}\Omega} = 0.0993$$

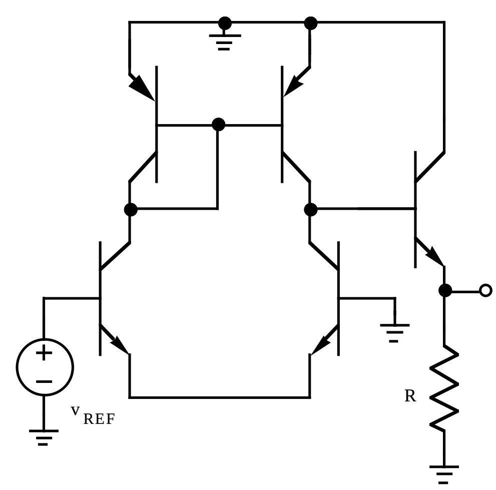
(b) $$A = \frac{-h_{21}^A}{\left(R_S + h_{11}^T\right)\left(h_{22}^T + G_L\right)} = \frac{-(-75000)}{(1\text{k}\Omega + 15\text{k}\Omega + 3.87\text{k}\Omega)\left(\frac{1}{5.6\text{k}\Omega} + \frac{1}{1\text{k}\Omega} + \frac{1}{43.3\text{k}\Omega}\right)} = 3140$$

$$\beta = 0.0993$$

(c) $$A_V = \frac{3140}{1 + 3140(0.0993)} = 10.0 \quad | \quad h_{21}^A >> h_{21}^F \quad | \quad h_{12}^F >> h_{12}^A \quad | \quad \left(R_{IN} = 6.22\ \text{M}\Omega, R_{OUT} = 2.66\ \Omega\right)$$

4.) **18.17**





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

$$A = g_{m1}\left(r_{o1}\|r_{o4}\|\left[r_{\pi5} + (\beta_o+1)R\right]\right)\frac{(\beta_o+1)R}{r_{\pi5} + (\beta_o+1)R} = g_{m1}\frac{r_{o1}\|r_{o4}}{\left(r_{o1}\|r_{o4}\right) + r_{\pi5} + (\beta_o+1)R}(\beta_o+1)R$$

4.) Continued

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

$$I_{C5} = \frac{12}{10^4} = 1.2\text{mA} \;\;|\;\; r_{\pi5} = \frac{100(.025)}{1.2\text{mA}} = 2.08\text{k}\Omega$$

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

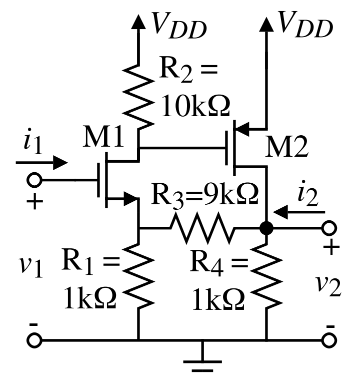
$$A_V = \frac{A}{1+T} = \frac{876}{1+876(1)} = \frac{109}{110} = 0.999$$

$$R_{IN} = R_{ID}(1+T) = 2r_{\pi1}(1+T) = 2\frac{100(0.025)}{10^{-4}}(877) = 43.9\ \text{M}\Omega$$

$$R_{OUT} = \frac{R\left\|\dfrac{r_{\pi5} + r_{o2}\|r_{o4}}{\beta_o + 1}\right.}{1+T} = \frac{10\text{k}\Omega\left\|\dfrac{2.08\text{k}\Omega + 280\text{k}\Omega}{101}\right.}{877} = 2.49\ \Omega$$

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

5.) A series-shunt feedback amplifier is shown. Use the methods of feedback analysis to find the numerical values of v_2/v_1, v_1/i_1, and v_2/i_2. Assume that all transistors are matched and that g_m = 1mS and $r_{ds} = \infty$.



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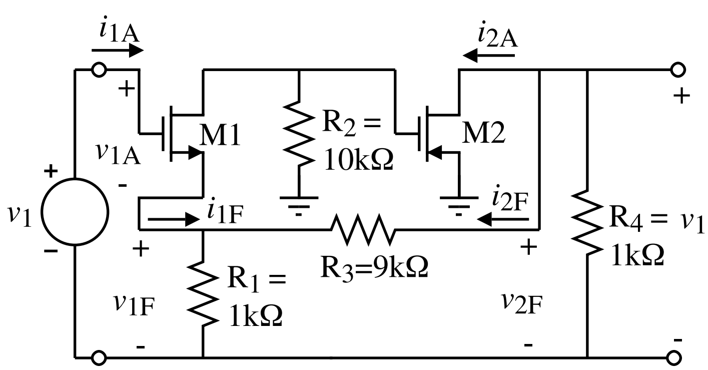
Solution

The circuit can redrawn as shown to identify more clearly the A circuit and the feedback circuit.



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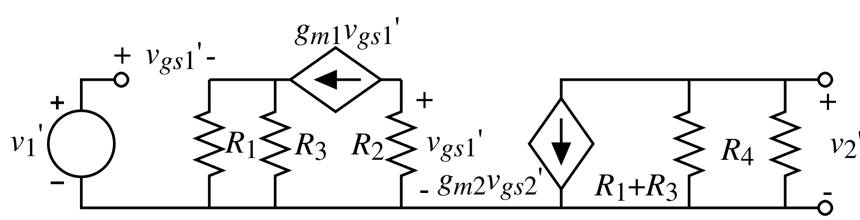
$$\beta = h_{12F} = \frac{v_{1F}}{v_{2F}}\bigg|_{i_{1F}=0} = 0.1(\text{V/V})$$

The small-signal model for the open-loop calculation of *A*.



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5.) Continued

$$A = \frac{v_2'}{v_1'} = \left(\frac{v_2'}{v_{gs2}'}\right)\left(\frac{v_{gs2}'}{v_{gs1}'}\right)\left(\frac{v_{gs1}'}{v_1'}\right) = [-g_{m2}(R_4 \| R_1 + R_3)](-g_{m1}R_2)\left(\frac{1}{1+g_{m1}(R_1 \| R_3)}\right)$$

$$= (-0.909)(-10)\left(\frac{1}{1+0.9}\right) = 4.785 \text{ V/V}$$

$$A_F = \frac{v_2}{v_1} = \frac{A}{1+A\beta} = \frac{4.785}{1+4.785\ (0.1)} = \frac{4.785}{1.4785} = \underline{\underline{3.236 \text{ V/V}}}$$

Because $h_{11\mathrm{T}} = \infty$, $R_{in} = v_1/i_1 = \underline{\underline{\infty}}$

The open-loop output resistance is,

$$R_o = R_4 \| (R_1 + R_3) = 909\Omega$$

$$\therefore\ R_{out} = \frac{v_2}{i_2} = \frac{R_o}{1+A\beta} = \frac{909\Omega}{1.4785} = \underline{\underline{614\ \Omega}}$$