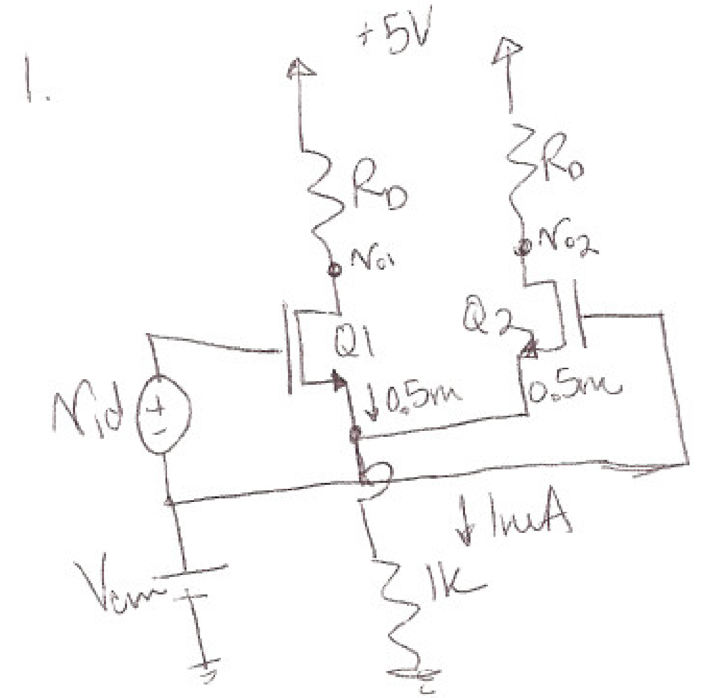
HW #3 sol'n

1.



$k_n' \frac{W}{L} = 3mA/V^2$

$V_t = .9V$

ignoring λ

a. To get 0.5mA through the transistor requires ⇒

$$0.5m = \frac{1}{2}(3m)(V_{ov})^2$$

$$V_{ov} \cong 0.6V$$

$V_s = 1m(1k) = 1V$

$\therefore V_G - V_S - V_t = 0.6V$

$\Rightarrow V_G = 1 + .9 + .6 = \boxed{2.5V = V_{cm}}$

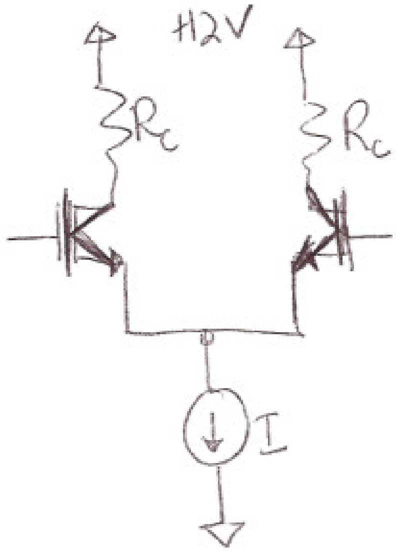
b. $A_d = 10V/V = g_m R_D$

$$g_m = \frac{2I_D}{V_{ov}} = \frac{2(0.5mA)}{0.6} = 1.7mA/V$$

$\therefore R_D = \boxed{5,882\ \Omega}$

c. $V_{o1} = V_{o2} = 5 - (0.5m)(5.882k) \cong \boxed{2.1V}$

2.



$R_{id} = 20K = 2r_\pi$

$r_\pi = 10K\Omega = \beta / g_m = \frac{\beta \cdot V_T}{I_c}$

$\therefore I_c = \frac{100 \cdot 25m}{10k} = 250\mu A$

$\boxed{I = 0.5mA}$

$A_d = 150 V/V = g_m R_c$

$g_m = \frac{I_c}{V_T} = \frac{250\mu}{25m} = .010 A/V$

$\therefore R_c = \boxed{15K\Omega}$

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3. $\frac{v_o}{v_{id}} = 100 V/V$ Refer to Fig. 7.28(a)

- Note that r_o only gives a single-ended gain $\Rightarrow$ $A_d = \frac{1}{2} g_m r_o = \frac{1}{2} \cdot \frac{2I_D}{V_{OV}} \cdot \frac{V_A}{I_D}$

$A_d = \frac{V_A}{V_{OV}}$

$100 = \frac{30}{V_{OV}} \Rightarrow V_{OV} = 0.3$ V.

Note that the output node has a summation of $2I_D$ (See page. 729)

$I = 2I_D = \frac{1}{2} k' \frac{W}{L} (V_{OV})^2 = \frac{1}{2}(3m)(0.3)^2$

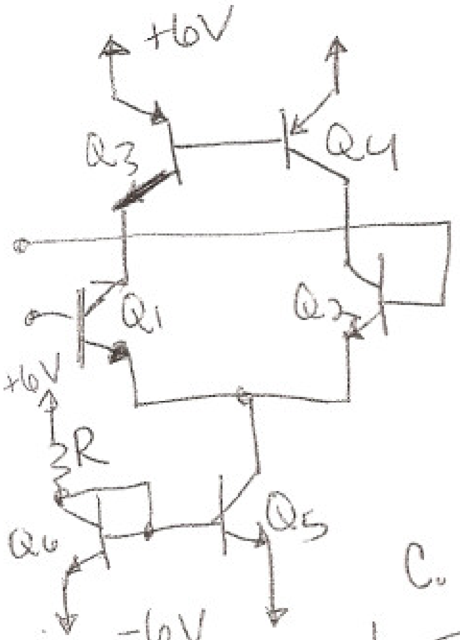
$\boxed{I = 135\mu A}$

4. Refer to Fig. 7.32(a)

$$G_m = \frac{I/2}{V_T} = 4mA/V$$

$$I = \boxed{0.2mA}$$

$$R = \frac{6-(-6)-V_{BE}}{I} = \frac{11.3}{.2m} = 56.5k\Omega$$



a. $R_{id} = (\beta+1)2r_e$

$$r_e = \frac{V_T}{I/2} = \frac{25m}{0.1m} = 250$$

$$R_{id} = \boxed{50.5k}$$

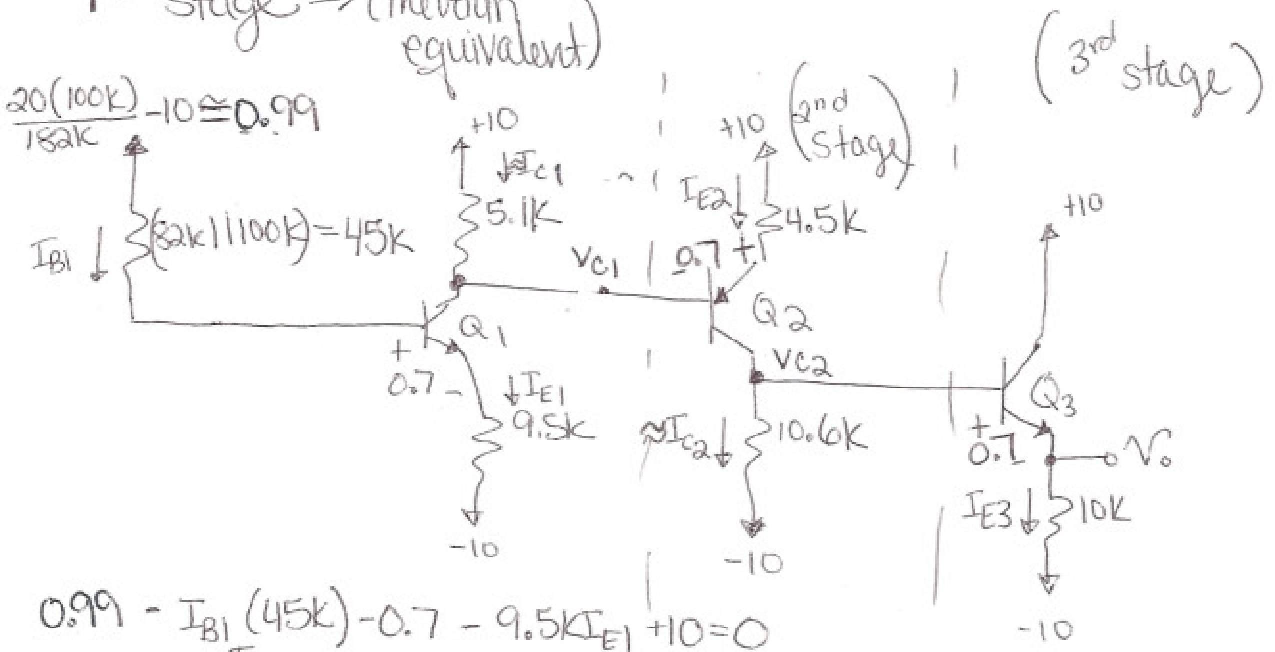
b. $R_o = \frac{r_o}{2} = \frac{V_A}{2I_c} = \frac{80}{2(0.1m)} = \boxed{400K}$

c. $A_d = g_m R_o = 4m(400K) = \boxed{1{,}600 V/V}$

d. $I_B = \frac{I/2}{(\beta+1)} = \frac{0.2m/2}{101} \cong \boxed{1\mu A}$

5. DC Analysis:

1st stage ⇒ (Thevenin equivalent)



$0.99 - I_{B1}(45k) - 0.7 - 9.5k I_{E1} + 10 = 0$

$I_{B1} = \frac{I_{E1}}{(\beta+1)}$

$10.99 - 0.7 = \left[9.5k + \frac{45k}{(\beta+1)}\right] I_{E1} \Rightarrow I_{E1} = \frac{10.29}{9.8k} = 1.05mA$

$I_{C1} = \alpha I_{E1} = \boxed{1.04mA}$

$V_{C1} \cong 10 - (1.04m)(5.1K) = 4.7V \Rightarrow V_{E2} = 4.7 + 0.7 = 5.4V$

$I_{E2} = \frac{10 - 5.4}{4.5k} = 1.02mA \Rightarrow I_{C2} = \boxed{1.01mA}$

$V_{C2} \approx I_{C2}(10.6K) - 10 = 0.7V$

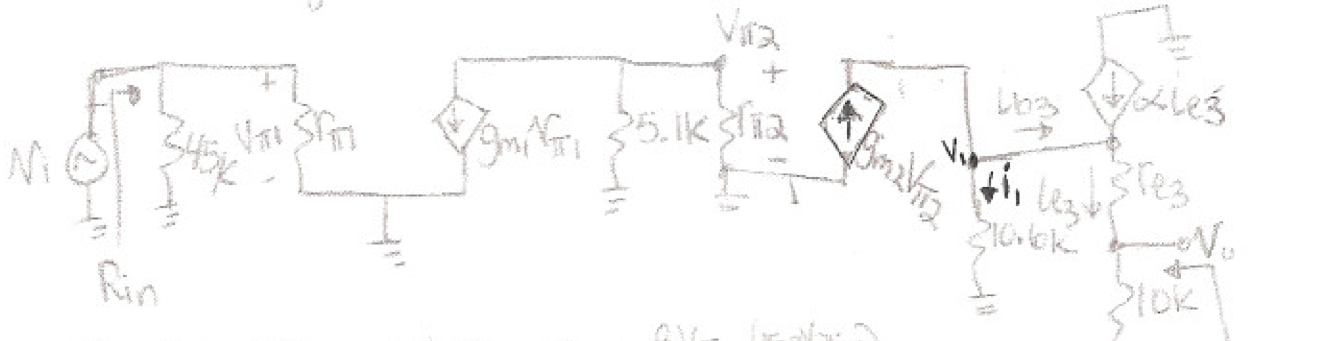
$V_{ooc} = V_{C2} - 0.7 = \boxed{0V}$ ← will vary up to 1 V. based on current value.

$I_{E3} = \frac{0-(-10)}{10K} = \boxed{1mA}$

Note: All transistors are operating at approximately $I_C \approx 1mA$

5. (cont.)

small-signal model (stage 1)



$R_{in} = 45k \parallel r_{\pi 1}$ where $r_{\pi 1} = \frac{\beta V_T}{I_{C1}} = \frac{(150)(25m)}{1.04m} = 3.6k\Omega$

$R_{in} \cong$ **3.3k Ω**

$R_{out} = 10k \parallel (r_{e3} + \frac{10.6k}{(\beta+1)}) \Rightarrow r_{e3} = \frac{V_T}{I_{E3}} = \frac{25m}{1m} = 25\Omega$

$R_{out} \cong$ **94 Ω**

$v_o = i_{e3} \cdot 10k$

$-i_{e3} + \alpha i_{e3} + g_{m2}v_{\pi 2} - i_1 = 0$

$i_1 = \frac{V_1}{10.6K} = \frac{(g_{m2}v_{\pi 2} + \alpha i_{e3})(10.6K \parallel (r_{e3}+10k))}{10.6K}$

$+(\alpha - 1)i_{e3} + g_{m2}v_{\pi 2} - \frac{g_{m2}v_{\pi 2}(10.6K \parallel (r_{e3}+10K))}{10.6K} - \frac{\alpha i_{e3}(10.6K \parallel (r_{e3}+10K))}{10.6K} = 0$

$i_{e3}(.49) = +20.8m\, v_{\pi 2}$

$i_{e3} = 42.4m\, v_{\pi 2}$

$v_{\pi 2} = -g_{m1}v_{\pi 1}(5.1k \parallel r_{\pi 2})$

$v_{\pi 1} = v_i$

$g_{m1} = \frac{I_{C1}}{V_T} = \frac{1.04m}{25m} = 41.6mA/V$

$g_{m2} = \frac{I_{C2}}{V_T} = \frac{1.01m}{25m} = 40.4mA/V$

$\frac{v_o}{v_i} = 10k[42.4m](-g_{m1}v_i(5.1k \parallel r_{\pi 2}))$

$r_{\pi 2} = \frac{\beta V_T}{I_{C2}} = 3713$

$\frac{v_o}{v_i} = (10k)(42.4m)(-89.4) =$ **37.9K V/V**