Electrical and Computer Engineering Department
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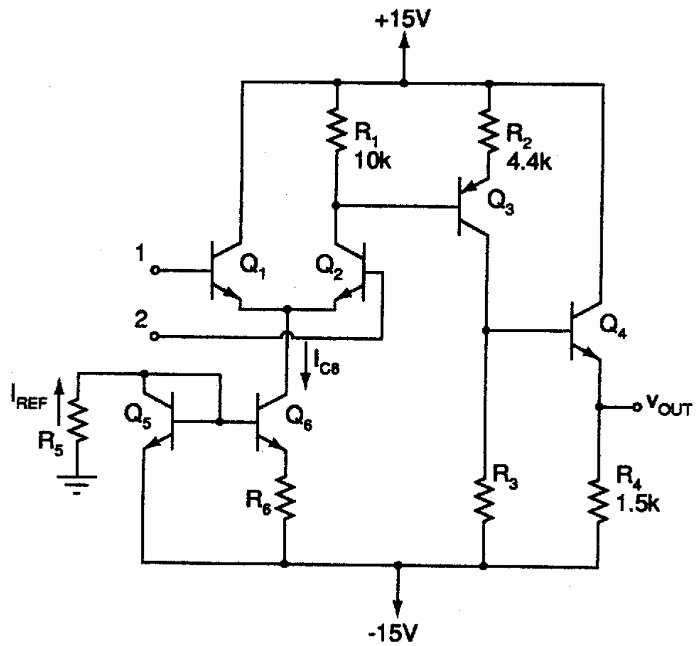
Electronics II - INEL 4202 - SPRING 2002 - Exam 3B - Prof. Manuel Toledo
THIS EXAM CONTAINS 15 BONUS POINTS - WORK CLEARLY OR LOOSE POINTS

The transistors in the amplifier shown below have $\beta = 100$. Base currents can be neglected in your analysis.



1. Assuming $R_5 = 50k\Omega$, $R_3 = 10k\Omega$, $R_6 = 0$, and that the area of Q_6 equals 5 times the area of Q_5, find:

   (a) the differential gain $A_d = \frac{v_{OUT}}{v_1 - v_2}$ (50 points)

   (b) the input resistance R_{in} seen by differential signals between terminals 1 and 2. (25 points)

   (c) the output resistance R_{out} at the output terminal. (25 points)

2. Assuming $I_{C6} = 1mA$, select R_3 so that $v_{OUT} \approx 0V$ when $v_1 = v_2 = 0V$. (15 points)

1.(a) To find the gain, we need to determine the bias currents.

$$I_{REF} = \frac{15-.7}{R_5} = \frac{14.3v}{50K} = 286\mu A$$

$$I_{C6} = 5 \times I_{REF} = 1.43 \text{ mA}.$$

$$I_{C_2} = \frac{1}{2} I_{C6} = 0.715 \text{ mA} \leftarrow$$

$$\therefore V_{C_2} = 15 - 10K(.715mA) = 7.85v$$

$$I_{C_3} = \frac{15V - (V_{C_2}+.7)}{4.4K\Omega} = \frac{15-(7.85+.7)}{4.4K} = 1.47 \text{ mA}$$

$$\therefore V_{B4} = -15 + (1.47mA)(R_3) = -15 + (1.47mA)(10K)$$

$$= -0.31V$$

$$I_{E4} = \frac{V_{B4} - .7 + 15}{1.5K} = 9.3 \text{ mA}$$

From this we can find the g_m's

$$g_{m_2} = \frac{.715mA}{25mV} = 0.0286 \text{ A/V}$$

$$g_{m_3} = \frac{1.47mA}{25mV} = 0.0588 \text{ A/V}$$

$$g_{m_4} = \frac{9.3mA}{25mV} = 0.372 \text{ A/V}$$

The load at the collector of Q_2 is

$$R_{C_2} = R_i // (r_{\pi 3} + (\beta+1)4.4K)$$

$$= 10K // \left[\frac{100(25)}{1.47} + 101 \times 4.4K\right] = 9.78K\Omega$$

$$\therefore \frac{v_{c2}}{v_1 - v_2} = +\frac{1}{2} g_{m_2} R_{C_2} = \frac{1}{2}(0.0286 A/V)(9.78K\Omega) = 140 \text{ V/V}$$

$$\frac{v_{c3}}{v_{c2}} = \frac{-g_{m3} R_{C3}}{1 + g_{m3} R_2}$$

$$R_{C3} = R_3 \,//\, (r_{\pi 4} + 101 \times 1.5k\Omega) = 10k \,//\, \left(\frac{100}{.372} + 151.5k\right)$$

$$= 10k \,//\, 151.8k\Omega = 9.38k\Omega$$

$$\frac{v_{c3}}{v_{c2}} = \frac{-.0588 \times 9.38k\Omega}{1 + .0588 \times 4.4k} = -2.12\, V/V$$

$$\frac{v_{e4}}{v_{c3}} = \frac{+g_{m4} R_4}{1 + g_{m4} R_4} = \frac{.372(1500)}{1 + .372 \times 1500} = 0.998$$

$$A_d = (+140 V/V)(-2.12 V/V)(.998 V/V) = \boxed{-296.3\, V/V}$$

(b) $R_{in} = 2 r_\pi = 2 \times \frac{100}{g_{m2}} = 2 \times \frac{100}{.0286 A/V} \doteq \boxed{7k\Omega}$

(c) $R_{out} = 1.5k \,//\, \frac{r_{\pi 4} + R_3}{101} = 1.5k \,//\, \frac{\frac{100}{.372} + 10k\Omega}{101} = \boxed{95.2\Omega}$

(2) if $I_{C6} = 1mA$, $I_{C2} = .5mA$, $V_{C2} = 10V$; $I_{C3} = \frac{15 - 10.7}{4.4k} = .98mA$

For $V_{out} = 0$, $V_{C3} = +0.7V$; $\therefore R_3 = \frac{15.7V}{.98mA} = \boxed{16k\Omega}$

(3) Widlar Current Source

$I_O R_M = V_T \ln\left(\frac{I_{REF}}{I_O}\right)$; $I_{REF} = 2mA \Rightarrow R_5 = \frac{14.3V}{2mA} = 7.15k\Omega$

$$R_C = \frac{25mV}{1mA} \ln(2) = 17.3\Omega$$