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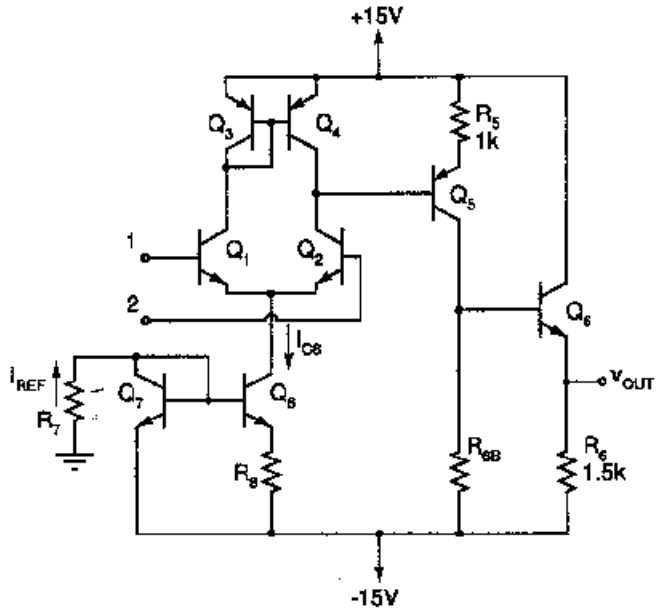
Electronics II - INEL 4202 - SPRING 2002 - Exam 3A - Prof. Manuel Toledo
THIS EXAM CONTAINS 15 BONUS POINTS - WORK CLEARLY OR LOOSE POINTS

The transistors in the amplifier shown below have $\beta = 100$. Base currents can be neglected in your analysis. **Assume that Q_5 is biased such that $I_{C5} = \frac{\beta}{\beta+2} I_{C8}$.**



1. Assuming $R_7 = 72k\Omega$, $R_{6B} = 10k\Omega$, $R_8 = 0$, $V_A = 100V$ and that the area of Q_8 equals 5 times the area of Q_7, 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, neglecting the resistance seen into the collector of Q_5. (25 points)

   (d) v_{OUT} when $v_1 = v_2 = 0$. (15 points)

-lave 3A

① First find the opp. point currents

$$I_{REF} = \frac{14.3}{72k\Omega} \approx 0.2\,mA \Rightarrow I_{C8} = 5 \times .2mA = 1mA$$

$$I_{C2} = 0.5mA \Rightarrow g_{m2} = \frac{0.5mA}{25mV} = \frac{1}{50}\ A/V$$

$$I_{C5} = \frac{100}{102} \times 1mA = 0.98mA \Rightarrow g_{m5} = 0.0392\ A/V$$

$$V_{C5} = 10K \times I_{C5} - 15 = -5.2\,V$$

$$I_{C6} = \frac{-5.2 - .7\beta - (-15)}{1.5k\Omega} = 6.07\,mA$$

$$g_{m6} = 0.243\ A/V$$

$$r_{o2} = r_{o4} \approx \frac{V_A}{I_{C2}} = \frac{100V}{.5mA} = 200k\Omega$$

$$R_{in\,base5} = r_{\pi 5} + 101K = \frac{100}{.0392} + 101k = 103.55k\Omega$$

$$\frac{V_{C2}}{V_1 - V_2} = g_{m2}\left(r_{o2} \| r_{o4} \| R_{in\,base5}\right)$$

$$= \left(\frac{1}{50}\frac{A}{V}\right)\left(100K \| 103.55K\right) = +1017.4\ V/V$$

$$\frac{V_{C5}}{V_{C2}} = \frac{-g_{m5} R_{C5}}{1 + g_{m5} R_5}$$

$$R_{C5} = 10K\Omega \| \left(\frac{100}{.243} + 101 \times 1.5K\right) \approx 152k\Omega \| 10K$$

$$= 9382\Omega$$

$$\frac{V_{C5}}{V_{C2}} = \frac{-.0392 \times 9382}{1 + .0392 \times 1000} = -9.15\ V/V$$

$$\frac{V_{e6}}{V_{c5}} = \frac{+g_{m6} R_6}{1+g_{m6} R_6} = \frac{.243 \times 1500}{1+.243 \times 1500} = 0.997$$

$$A_d = \cdot 1017.4 \wedge (-9.15)(.997) = \boxed{-9283.7\ V/V}$$

(b) $R_{in} = 2r_{\pi 2} = 2 \frac{100}{1/50} \Omega = \boxed{10K\Omega}$

(c) $R_{out} = 1.5K \| \frac{r_{\pi 6} + R_{6B}}{101} = 1.5K \| \left(\frac{\frac{100}{.243} + 10K}{101} \right)$

$= \boxed{96.5\Omega}$

(d) $V_{out} = V_{c5} - .7 = -5.2V - 0.7V = \boxed{-5.9V}$