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Electronics II - INEL 4202 - Fall 2001 - Prof. Manuel Toledo
Solutions to Exam 3

1. For the 741 circuit estimate the d.c. operating point current in the collector of Q_1 in the event that $\pm 10V$ supplies are used. Also, find the input resistance seen by a differential source connected between the bases of Q_1 and Q_2. (15 pts. each)

   ANSWER:

$$I_{ref} = \frac{20V - 1.4V}{39k\Omega} = 477\mu A$$

$$I_{C10} = \frac{V_T}{R_M} ln\left(\frac{I_{ref}}{I_{C10}}\right) = 5\mu A ln\left(\frac{477\mu A}{I_{C10}}\right)$$

   Let an initial guess for I_{C10} be $100\mu A$. After a few iterations, above equation converges to $I_{C10} = 16.8\mu A$. As we saw in our lectures,

$$I_{C1} \approx \frac{I_{C10}}{2} = 8.4\mu A$$

   From lectures,

$$R_{in} = 4r_\pi = 4 \times \beta \times \frac{V_T}{I_{C1}} = 4 \times 200 \times \frac{25mV}{8.4\mu A} = 2.4M\Omega$$

2. Consider the design of the second stage of the 741. What value of R_9 would be needed to reduce the current I_{C16} to $9.5\mu V$? Assume that the circuit is using $\pm 15V$ power supplies, and that the $I_{C13B} = 550\mu A$. (20 pts.)

   ANSWER:

$$I_{C16} \approx I_{E16} = I_{R_9} + I_{B17} = \frac{V_{E16}}{R_9} + I_{B17}$$

$$I_{B17} = \frac{I_{E17}}{\beta_N + 1} = \frac{550\mu A}{201} = 2.75\mu A$$

$$v_{BE_{17}} = V_T ln\left(\frac{I_{C17}}{I_S}\right) = 25mV ln\left(\frac{550\mu A}{10^{-14}A}\right) = 0.62V$$

$$V_{E16} = V_{BE_{17}} + I_{E17} \times 100\Omega = 0.675V$$

$$9.5\mu A = \frac{0.675V}{R_9} + 2.75\mu A$$

   Finally,

$$R_9 = \frac{0.675V}{9.5\mu A - 2.75\mu A} = 100k\Omega$$

3. (a) Utilizing a reference current of $100\mu A$, design a Widlar current source to provide an output current of $10\mu A$. Let the BJTs have $v_{BE} = 0.7V$ at 1-mA current, and assume β to be very high. (20 pts)

   ANSWER:

$$R_M = \frac{V_T}{I_O} ln\left(\frac{I_{ref}}{I_O}\right) = \frac{25mV}{10\mu A} ln\left(\frac{100\mu A}{10\mu A}\right) = 5756\Omega$$

   (b) For the source designed in (a), assume $\beta = 200$ and $V_A = 100V$. Find the value of the output resistance, and find the change in output current corresponding to a 5V change in output voltage. (15 pts each)

   ANSWER:

$$r_O = \frac{V_A}{I_O} = \frac{100V}{10\mu A} = 10M\Omega$$

$$R_O = r_O\left(1 + g_m R_M\right) = 10M\Omega\left(1 + \frac{10\mu A}{25mV} \times 5756\Omega\right) = 33M\Omega$$

$$\Delta I_O = \frac{5V}{33M\Omega} = 0.15\mu A$$

   or about 1.5%.

NOTE: A COPY OF FIGURE 10.1 FROM SEDRA AND SMITH WAS INCLUDED WITH THE EXAM