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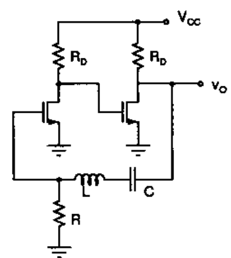
NAME: KEY STUDENT NO.:

University of Puerto Rico
Electrical and Computer Engineering Department
INEL 4202 - Electronics II - Exam 4 - Prof. M. Toledo
25 POINTS EACH PROBLEM - BE CLEAR OR LOOSE POINTS

1. The sketch below shows a sinusoidal oscillator. The transistor transconductance is g_m.
   (a) Find an expression for the frequency of oscillation, ω_r, in terms of C, and L.
   (b) Apply Barkhausen amplitude criterion to find an expression, in terms of g_m, C, R and R_D, that the circuit gain should satisfy for sustained oscillations.



(a)

Let $X_L \equiv \omega L$

$X_C \equiv -\dfrac{1}{\omega C}$

Then

$$\beta = \frac{R}{R + j(X_L + X_C)}$$

$$Z_\beta = R + j(X_L + X_C)$$

and $$Z_D = R_D \| Z_\beta = \frac{R_D\left[R + j(X_L + X_C)\right]}{R_D + R + j(X_L + X_C)}$$

$$\text{gain} = g_m^2 R_D Z_D = g_m^2 R_D^2 \frac{R + j(X_L + X_C)}{R_D + R + j(X_L + X_C)}$$

$$\beta \times \text{gain} = g_m^2 R_D^2 \frac{R}{R_D + R + j(X_L + X_C)}$$

Since numerator is real, denominator should also be real (phase criterion). Thus $X_L = -X_C = \omega L = \dfrac{1}{\omega C} \Rightarrow \boxed{\omega_r = \dfrac{1}{\sqrt{LC}}}$

(b) at $\omega = \omega_r$

$$\boxed{A_v \beta = g_m^2 R_D^2 \frac{R}{R_D + R} \geq 1}$$

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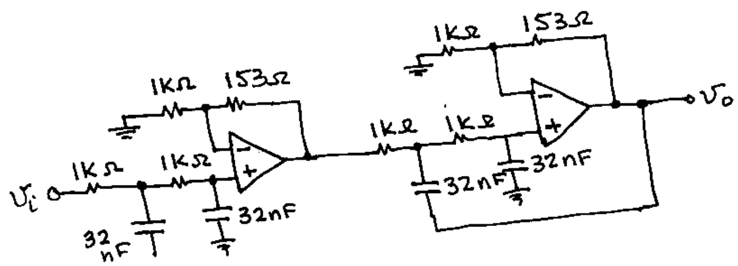
3. Design a low-pass, foyrth order Butterworth filter with a cutoff frequency of 5000Hz. Use cascaded Sallen-Key and first order stages, as needed. The filter's d.c. gain should be 0dB. $B_4(s) = (s^2 + 0.765s + 1)(s^2 + 1.847s + 1)$.

$\frac{1}{RC} = 2\pi \times 5K$ → Set $R = 1k\Omega$; $C = 31.8nF \simeq 32nF$

We need two Sallen-Key stages

stage 1: $3 - A_v = 0.765 \Rightarrow 1 + \frac{R_2}{R_1} = 2.235$; Select $R_1 = 1k$, $R_2 = 1235\,\Omega$

stage 2: $3 - A_v = 1.847 \Rightarrow R_2/R_1 = 0.153$; Select $R_1 = 1k$, $R_2 = 153\,\Omega$



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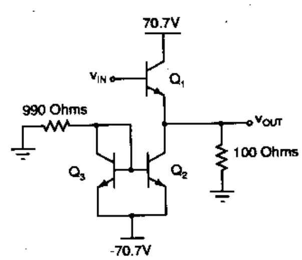
2. In the sketch shown below, the area of transistor Q_2 is 10 times the area of transistor Q_3. Find the efficiency of the amplifier if the peak output voltage is maintained at $\frac{1}{2}V_{CC}$. Determine he required power rating for Q_1 if this output voltage level is always maintained.



$P_{DC} = \frac{2V_{CC}^2}{R_L} = \frac{2(5000)}{100} = 100W$ ← (this neglects power dissipated in 990Ω & Q_3)

$P_{Load} = \frac{(\frac{1}{2}V_{CC})^2}{2R_L} = \frac{1}{8}\frac{V_{CC}^2}{R_L} = \frac{1}{8}\frac{5000}{100} = 6.25\ W$

$\therefore \eta = \frac{6.25W}{100W} \times 100\% = \boxed{6.25\%}$

$P_{C.S.} = P_{DQ_2} = (70.7)(I_{EE})$

$I_{EE} = 10\ \frac{70.7 - 0.7V}{990\Omega} = 0.707A \Rightarrow P_{C.S.} \cong 50W$

$P_{DQ_1} = 100W - 50W - 6.25W = \boxed{43.75\ W}$

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If we take into account the energy dissipated in the 990Ω resistor and Q_3, then

$P_{DC} = 100W + (70.7mA)^2(990\Omega) + (70.7mA)(0.7V)$
$\cong 105W$

and $\eta = \frac{6.25W}{105W} \times 100\% = \boxed{5.95\%}$