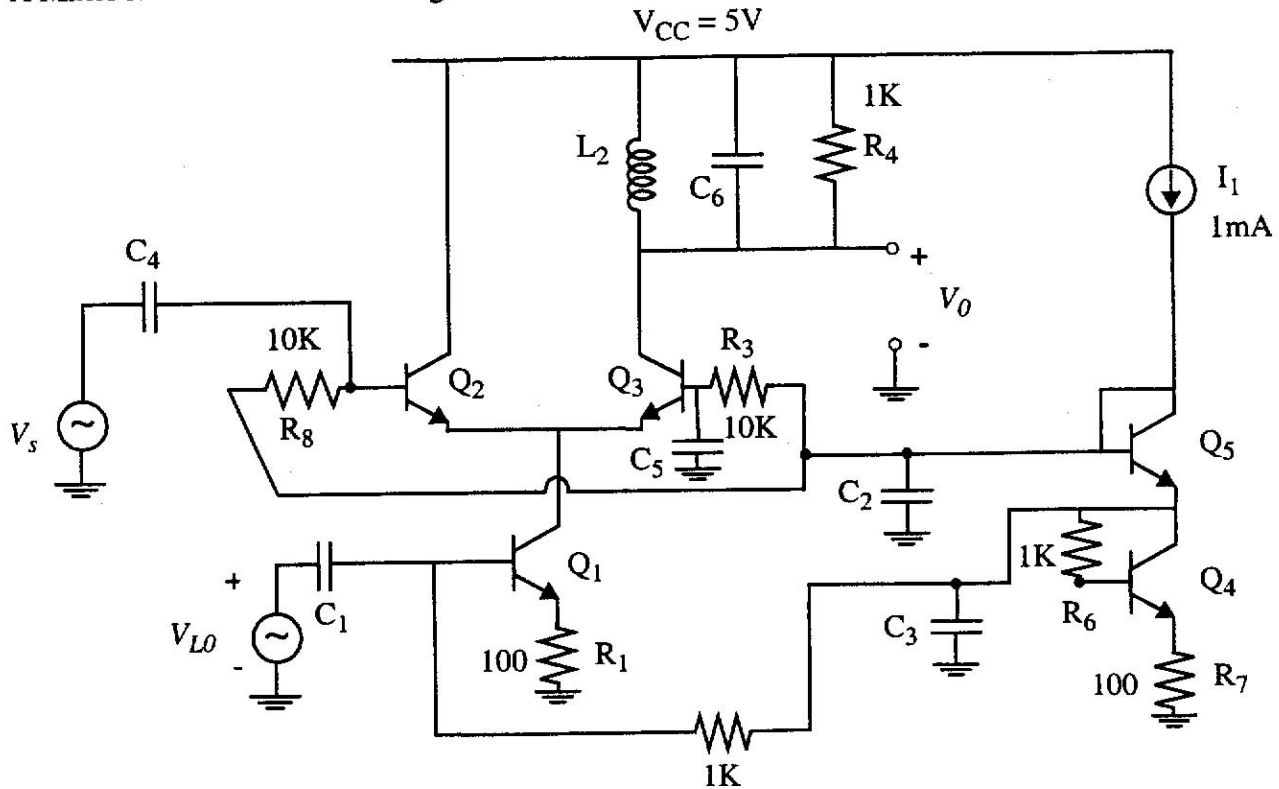


2.) (17 points)

A Mixer is shown below. Mixing occurs when the current in the differential pair is pumped by  $Q_1$ .



$V_{LO}$  is a local oscillator voltage with frequency 110 MHz and zero-peak amplitude of 60 mV.  $C_1$ ,  $C_2$ ,  $C_3$ ,  $C_4$  and  $C_5$  are large capacitors. The IF tank  $L_2 - C_6 - R_4$  has  $Q = 20$  and is tuned to 10 MHz. Device data:  $\beta = 100$ ,  $V_A = \infty$ ,  $r_b = 0$

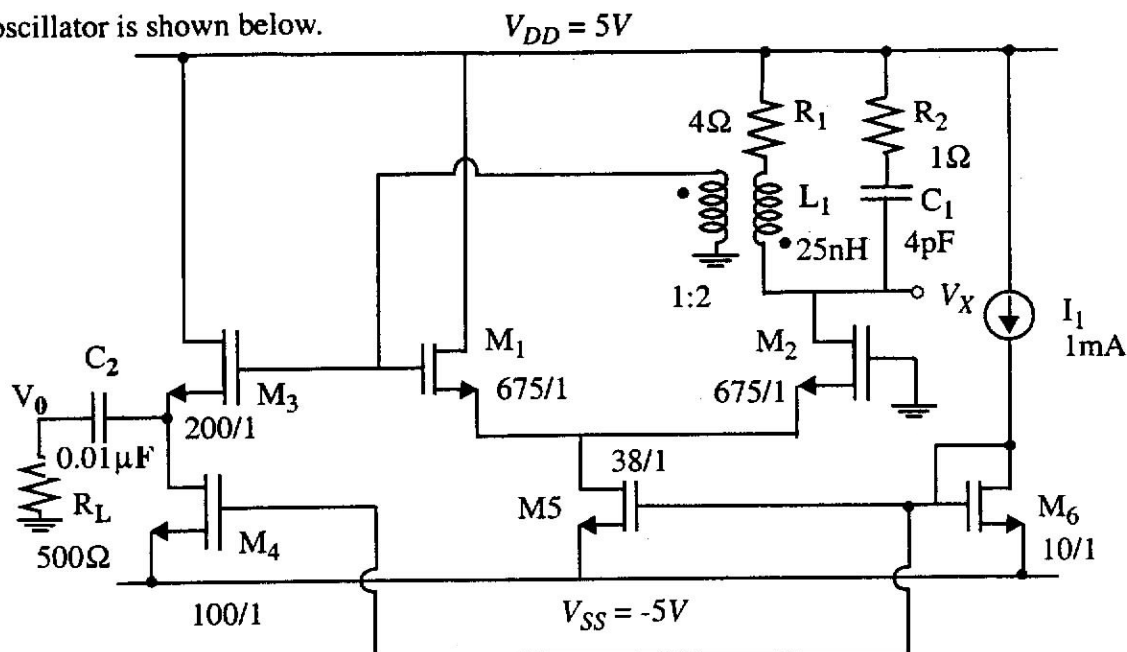
- Calculate the IF output voltage  $V_0$  if a signal input at  $V_S$  has frequency 100 MHz and rms amplitude of 1 mV.
- Harmonics in  $I_{C1}$  will cause harmonic mixing. Calculate the 10 MHz IF output voltage at  $V_0$  produced by an input signal at  $V_S$  at 210 MHz and rms amplitude 0.1 mV.
- What is the input impedance seen by  $V_S$ ?
- Nonlinearity in  $Q_2 - Q_3$  will cause intermodulation. Calculate the 10 MHz IF output voltage at  $V_0$  produced by two inputs at  $V_S$  with amplitude 10 mV rms each and frequencies of 101 MHz and 102 MHz.

Data for the differential pair:

$$\frac{I_{C3}}{I_{C1}} = \frac{1}{2} + \frac{1}{4} \frac{qV_S}{kT} - \frac{1}{48} \left( \frac{qV_S}{kT} \right)^3 + \dots$$

3) (17 points)

An oscillator is shown below.

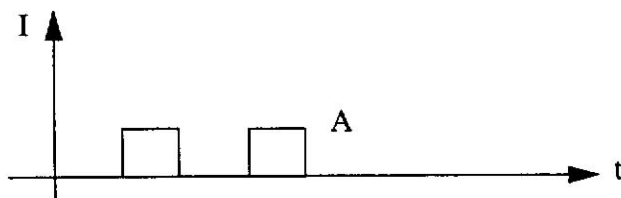


Device data:  $I_0 = \frac{\mu C_{ox}}{2} \times \frac{W}{L} (V_{GS} - V_t)^2$

Neglect body effect

$\mu C_{ox} = 100 \times 10^{-6} \text{ A/V}, V_t = 0.7\text{V}, \lambda = 0$

The Fourier Series of a square wave is



$$I = \frac{A}{2} + \frac{2A}{\pi} \left( \cos \omega t + \frac{1}{3} \cos 3\omega t + \frac{1}{5} \cos 5\omega t + \dots \right)$$

- (a) Calculate the oscillation frequency and amplitude of the signal at  $V_x$  and  $V_0$ . Assume the differential pair is driven to a square wave in steady state.
- (b) Calculate the initial loop gain.
- (c) Calculate  $HD_3$  at  $V_x$  and  $HD_2$  at  $V_0$  in dB.
- (d) If the transformer has  $-45^\circ$  excess phase, recalculate (a), (b), and (c).