2.) (17 points)

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

$V_{CC} = 5\, \text{V}$

$V_L0$ 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: $\beta = 100$, $V_A = \infty$, $rb = 0$

(a) Calculate the IF output voltage $V_0$ if a signal input at $V_S$ has frequency 100 MHz and rms amplitude of 1 mV.

(b) 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.

(c) What is the input impedance seen by $V_S$?

(d) 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:
\[
\frac{I_{C3}}{I_{C1}} = \frac{1}{2} + \frac{1}{4} \frac{qV_S}{kT} - \frac{1}{48} \left(\frac{qV_S}{kT}\right)^3 + \ldots
\]

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

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

The Fourier Series of a square wave is

\[I = \frac{A}{2} + \frac{2A}{\pi} \left(\cos \omega t + \frac{1}{3} \cos 3\omega t + \frac{1}{5} \cos 5\omega t + \ldots\right)\]
(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).