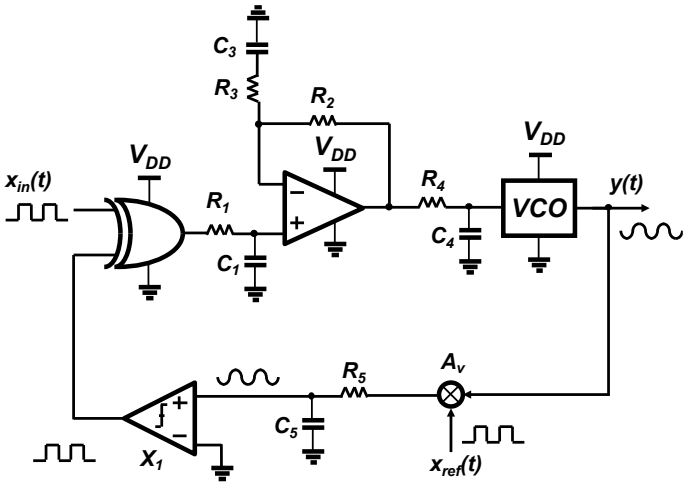
RF Circuit Design **Prof. Salvatore Levantino**

Available time: 120 minutes Jul. 22, 2021

Problem #1

Let R_1=10kΩ, R_3=R_4=R_5=1kΩ, C_1=100nF, C_3=10nF, C_4=2nF, C_5=200pF, V_{dd} = 1.8V. The signals $x_{in}(t)$ and the $x_{ref}(t)$ are 50%- duty-cycle square-waves with 1.5MHz and 21.5MHz frequency, respectively. The VCO has 1V output amplitude and linear tuning range centered at 20MHz with 500kHz span over the 0-V_{dd} range of V_{tune}. Let the OpAmp be ideal, and the mixer conversion gain be A_v=0.5. The block X_1 acts as a level-shifting comparator, convertin eg a sinusoid to a 0-V_{dd} square-wave.



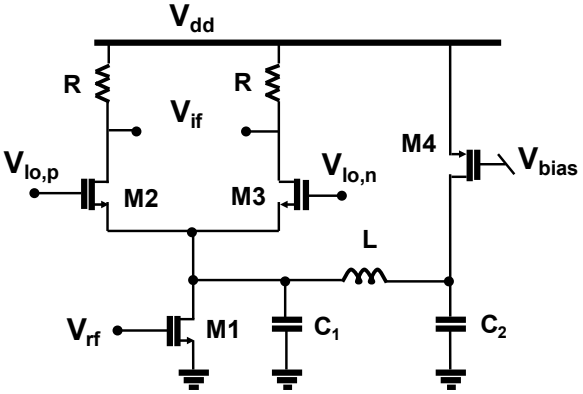
a) Derive the **continuous-time model** of the system and write the expression of the **loop gain**.

b) Calculate ***R*2** that sets the unity-gain frequency to 8kHz and evaluate the **phase margin** in degrees.

c) What are the **frequencies of the main spurs** in the spectrum of $y(t)$? Calculate the **level (in dBc)** of the two main spurs at the output.

Problem #2

In the mixer in figure, let $V_{lo,p}(t)$ and $V_{lo,n}(t)$ be out-of-phase 5GHz sinusoids with dc voltage of 1V and zero-peak amplitude of 0.1V. Let $V_{rf}(t)$ be a 5GHz sinusoid modulated with 1MHz bandwidth and with 0.6V dc value. Let V_{dd} = 1.4V, V_{bias} = 0.7V, R = 500Ω, C_1 = 300fF. For the FETs: $|V_t|$ = 0.3V, $1/2\mu_n C_{ox}$ = 200μA/V^2, μ_p/μ_n = 0.5, (γ/α) = 0.8, $(W/L)_{M1}$ = 222, $(W/L)_{M2,3}$ = 128, $(W/L)_{M4}$ = 188.



a) Neglecting L and C_2 (i.e. L = 0, C_2 = 0) but considering C_1, calculate the value of the **conversion gain (in dB)** of the mixer (from RF to IF), and the **noise figure (in dB)** with respect to an input impedance of 50Ω **(**calculate first the contribution of each noise source).

b) Considering now L = 3.38nH and C_2 = 10pF, calculate the new values for the **conversion gain** and the **noise figure (**calculate first the contribution of each noise source).

c) Let us assume the M2-M3 pair has an input-referred offset voltage of 10 mV. Calculate the value of the **output differential voltage at DC** (using the abrupt-switching approximation). Through what mechanism can this offset voltage degrade the **SNR at the output of the mixer in a zero-IF receiver in the presence of interferers**? (Justify your answer and quantify the impact of the offset voltage on the output SNR).