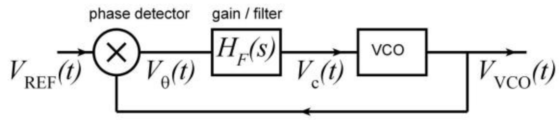
ECE 145C/218C first problem set: PLLS

Problem 1: The PLL uses a mixer with a 10 dBm signal power at the LO port from the VCO. The signal power at $V_{REF}(t)$ is 0 dBm. The mixer attenuation is 7 dB.



If $V_{REF}(t) = V_R \cos(\omega_{LO} t + \theta)$ and $V_{VCO}(t) = V_{VCO} \sin(\omega_{LO} t)$, with V_R and V_{VCO} determined from the parameters given above, neglecting the term at frequency $2\omega_{LO}$, give the value of the DC voltage $V_\theta(\theta)$.

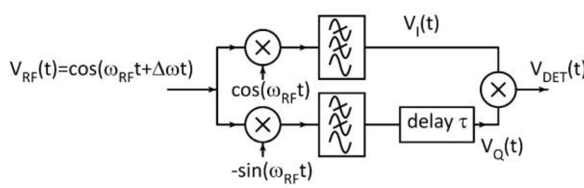
Problem 2: Continuing with the same PLL. The VCO has $\omega_{\text{VCO}}(t) = \omega_0 + K_{VCO} V_C(t)$ with $\omega_0 / 2\pi$ = 915 MHz and $K_{VCO} / 2\pi$ = 100 MHz/Volt. Defining $H_F(s) = (1 + s\tau_z) / s\tau_i$, find τ_z and τ_i such that the PLL loop bandwidth is 1 MHz and the zero frequency is 1/2 the loop bandwidth.

Problem 3: Continuing with the same PLL, what is the loop phase margin ? Please draw the circuit diagram of an op-amp integrator for $H_F(s)$ giving all resistance and capacitance values.

Problem 4: If we were to reduce the signal power of $V_{REF}(t)$ to -10 dBm, what would the loop bandwidth become?

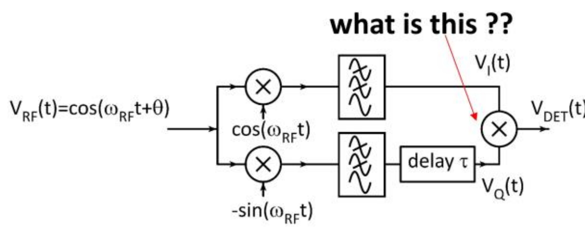
Problem 5: Returning the signal power of $V_{REF}(t)$ to 0 dBm, Approximately what is the frequency range which we would expect the PLL to acquire lock ?

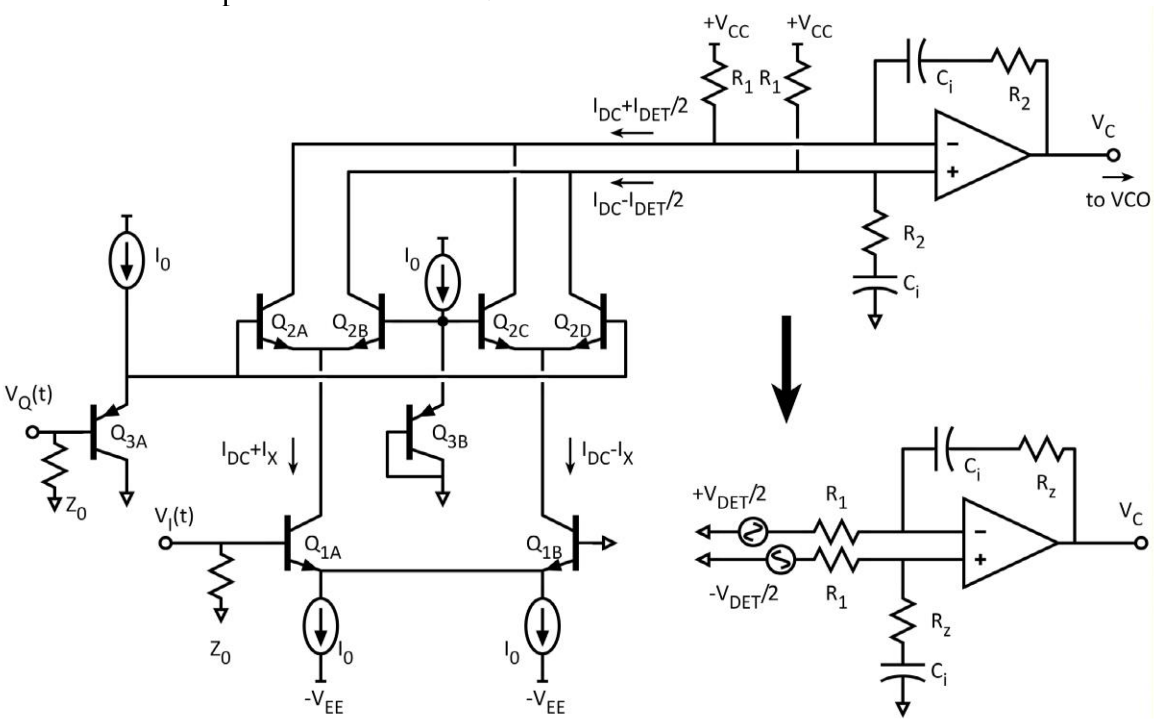
Problem 6: The signal power at $V_{RF}(t)$ is 0 dBm at the input to both mixers. The local oscillator power for both mixes is ten dBm. The mixer attenuation is 7 dB. Other parameters are as in the previous problems



The manufacturer's specification of the voltage controlled oscillator indicates that it might oscillate at any frequency between (don't use these #s for the lab project: check the data sheets instead) 800 MHz and 1 GHz. You want to set the delay to be as large a value as possible to give the strongest possible frequency difference detection, But you don't want the frequency difference detector to give you the wrong sign of the voltage. Given this, what value of delay should you pick for a 915 MHz input signal $V_{RF}(t)$?

Problem 7: Parameters as in previous problems unless stated otherwise. We work with the Costas PDF, But we need to consider more carefully the design of the 3rd mixer. A suggested circuit design for this 3rd mixer is drawn below. For the NPN's, use the MRF901, MRF951, or Infineon-BFP181. For the PNPs, use the ONSEMI MMBTH81. transistors, and the current sources can be replaced with resistors.



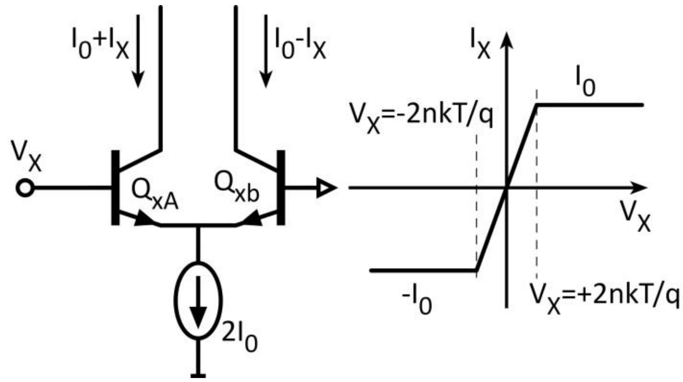


We cannot use transformer coupled mixers for the 3rd mixer because the signal frequencies will be below the low frequency cut off of the transformers. So we build a discrete Gilbert cell mixer, With the PNP transistors providing the appropriate level shifting. The output of the mixer is the Differential current I_{DET}; which drives the op amp integrator that implements $H_F(s)$. Thevenin-Norton transformations give the equivalent network in the lower inset, with $V_{DET} = I_{DET} R_1$ and $H_F(s) = (1 + s\tau_z)/s\tau_i$, with $\tau_i = R_1 C_i$ and $\tau_z = R_2 C_i$.

Start with $V_{RF}(t) = V_{RF}\cos(\omega_{RF} t + \theta)$. Given the known amplitude of V_{RF} and the known mixer losses, you can now calculate $V_I(t)$ and $V_Q(t)$ as a function of θ. To do this, *initially make the simplifying approximation that any differential pair has infinitely sharp switching characteristics.* That is to say, in any differential pair, 100% of the current is carried by the transistor with the greater V_{be}.

Given this, please calculate $V_{DET}(\theta)$ as a function of θ, and make a graph of the resulting quantity.

Problem 8: A linearized model of any of the differential pairs in the mixer is given to the right. Given this, calculate A slightly better approximation to $V_{DET}(\theta)$ as a function of θ, and make a graph of the resulting quantity.



Problem 9 (218C only): Given the above models of the differential pair can you compute the phase/frequency detector voltage V_{DET} as a function of differential frequency $\Delta\omega$?