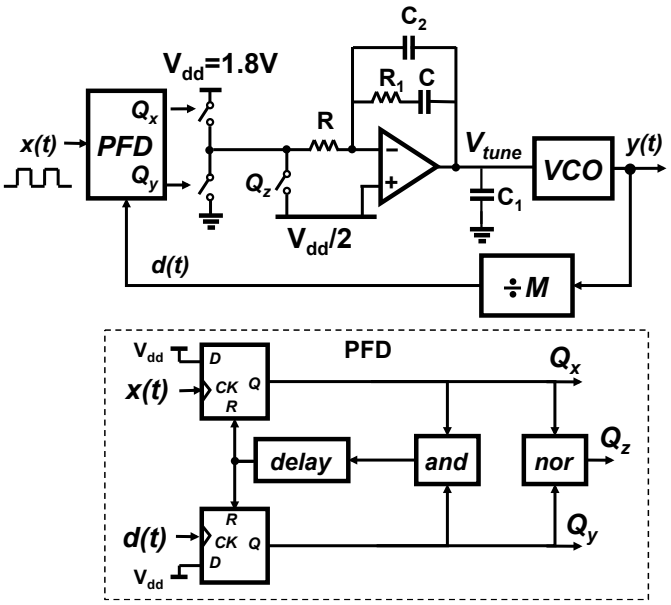
Tutorial T4

T4.1 The PLL in the figure embeds the PFD in the inset, where the block "delay" introduces a delay of 0.5 ns. The switches have infinite resistance (when off) and 10 Ω (when on). The reference clock $x(t)$ has 50 MHz frequency. The frequency-division factor is M = 55 and the VCO frequency varies in the range between 2650 and 2850 MHz, sweeping the V_{tune} from 0 to V_{dd} = 1.8 V. Let the capacitors be C_1 = 100 pF and the resistor R_1 = 100 Ω.



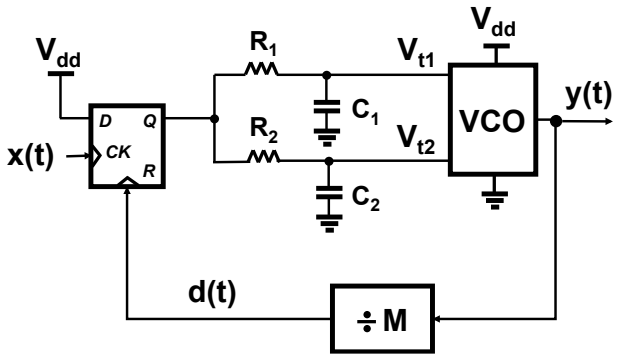
a. Assuming an ideal Op-Amp (with infinite gain and bandwidth), set the value of R and C to get two complex dominant (closed-loop) poles at 100 kHz located at 45 degree on the Gauss plane.

b. If the resistance of the switch driven by Q_X is 15 Ω (when on), set the minimum value of C_2, to get the level of the spur at 50 MHz in the spectrum of $y(t)$ lower than -80 dBc.

c. Assuming all the switches with resistance 10 Ω (when on), but an offset voltage of 100 mV for the Op-Amp, can the loop lock? If yes, what is the value of the output frequency, the delay between $x(t)$ and $d(t)$ at steady state, the reference-spur level?

[Solution: a. R = 195 Ω, C = 22.5 nF; b. I_{OS} = -0.92 mA, t_e = 105 ps, C_2 = 154 pF; c. I_L = 0.49 mA, t_ϵ = 2.2 ns, SFDR = -32.8 dBc]

T4.2. Let V_{dd} = 1.8V, R_1 = 1 kΩ, C_1 = 300 pF, R_2 = 10 kΩ, C_2 = 120 nF, $x(t)$ a 10-MHz periodic signal and M = 135. The D flip-flop has rails 0 and V_{dd}, and synchronous reset (clock samples data even when reset is "1"). The VCO has two tuning voltages V_{t1} and V_{t2}, which varies linearly VCO frequency, and a free-running frequency of f_{fr} = 1200 MHz at V_{t1} = V_{t2} = 0.



a. After deriving the continuous-time phase model of the system, compute the VCO tuning frequency ranges through control voltages V_{t1} and V_{t2} (when varied from 0 to V_{dd}) to set the unity-gain bandwidth of loop gain equal to 100 kHz and phase margin equal to 60 degrees.

b. What is the value of V_{t1} and V_{t2} at steady state? Calculate the delay relationship between $x(t)$ and $d(t)$ in seconds at steady state.

c. Do you expect any reference spur? If so, compute the level of the spurious tone in the spectrum of $y(t)$ in dBc.

[Solutions: a. τ = 4.65 μs, Δf_{VCO1} = 80 MHz, Δf_{VCO2} = 22.0 GHz; b. V_{t1} = V_{t2} = 12.2 mV, t_ϵ = 0.68 ns; c. SFDR = -50 dBc]