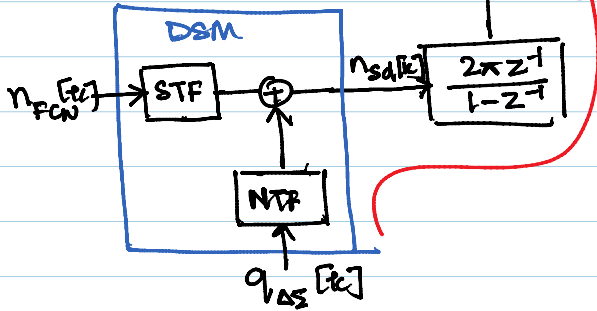
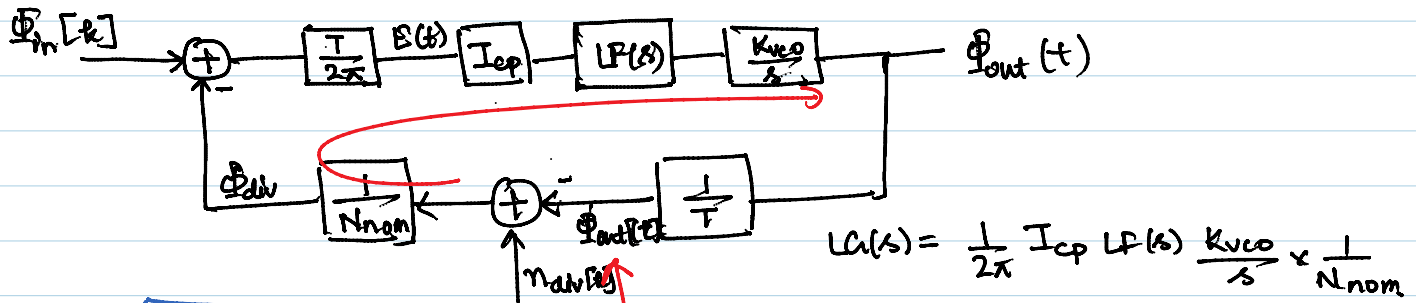


Frac-N PLL



$$f_{out} = N_{nom} f_{ref} = (N + \alpha) f_{ref}$$

$$0 < \alpha < 1$$



$$y(z) = STF(z) n_{frac}(z) + NTF(z) q_{\Delta\Sigma}(z)$$

$$\frac{n_{div}(z)}{q_{\Delta\Sigma}(z)} = \underbrace{NTF(z)} \cdot \frac{2\pi z^{-1}}{1-z^{-1}}$$

DT-CT: $|Y(f)|^2 = \frac{1}{T} |H(f)|^2 S_x(e^{j2\pi fT})$

$$|\Phi_{out}(f)|^2 = \frac{1}{T} |q_{\Delta\Sigma}(z)|^2 |NTF(z)|^2 \left| \frac{2\pi z^{-1}}{1-z^{-1}} \right|^2 \times \left| \frac{T \times L_{vco}(s)}{1+L_{vco}(s)} \right|^2$$

$S_x(e^{j2\pi fT})$

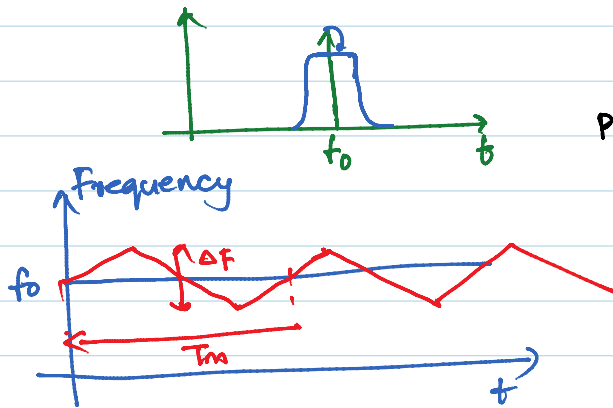
$$= T \left| \frac{L_{vco}(s)}{1+L_{vco}(s)} \right|^2 |q_{\Delta\Sigma}(e^{j2\pi fT})|^2 \times \underbrace{|(1-z^{-1})^{-m}|^2}_{\text{NTF of } m^{\text{th}} \text{ order } \Delta\Sigma \text{ modulator}} \frac{4\pi^2 |z^{-2}|}{|(1-z^{-1})|^2}$$

$$= 4\pi^2 T \left| \frac{L_{vco}(s)}{1+L_{vco}(s)} \right|^2 |q_{\Delta\Sigma}(e^{j2\pi fT})|^2 \times \underbrace{(1-z^{-1})^{-2(m+1)}}_{\Rightarrow \left[4 \sin^2 \left(\frac{\pi f}{f_{ref}} \right) \right]^{m+1}}$$

$$1-z^{-1} = 1 - e^{-j2\pi fT} = 1 - \cos(2\pi fT) + j \sin(2\pi fT)$$

$$|1-z^{-1}|^2 = 2(1 - \cos(2\pi fT)) = 4 \sin^2(\pi fT)$$

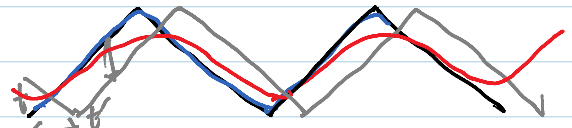
For spread-spectrum clocking \rightarrow Vary $n_{fcw}[k]$ to frac-N PLL



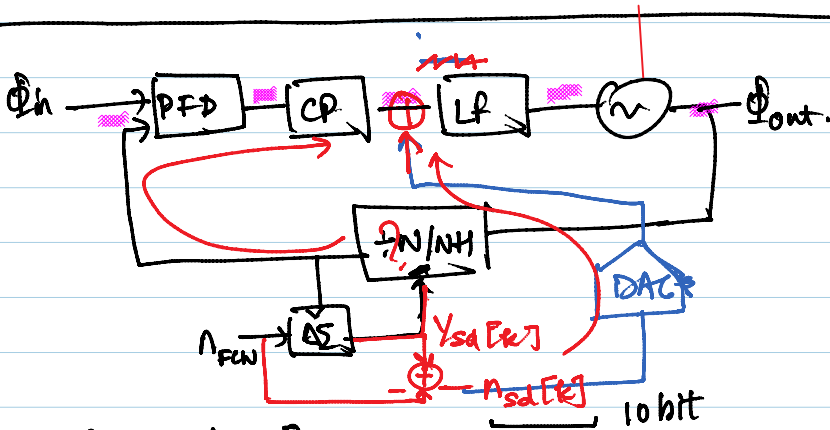
PLL BW = 1 MHz, $f_0 = 1.6 \text{ GHz}$, $\Delta F = \pm 200 \text{ MHz}$

$\Delta F = \pm 10 \text{ MHz}$, $T_m = 20 \text{ ns}$

$T_m = 20 \text{ ms}$

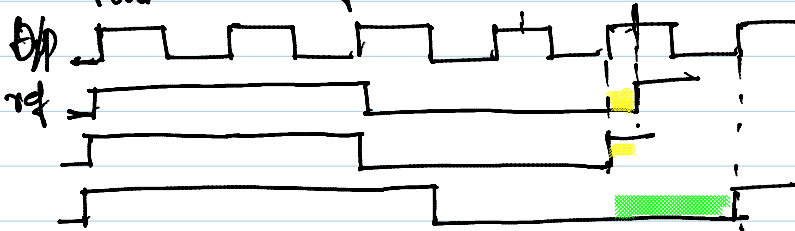


FMCW Radar - (Frequency Modulated Continuous Wave Radar)

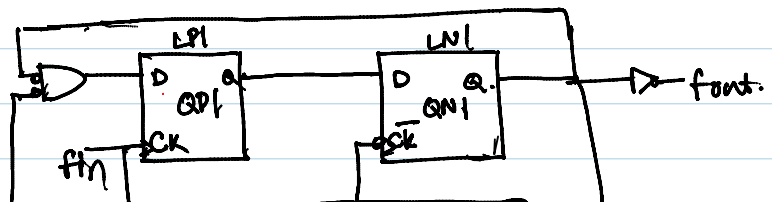
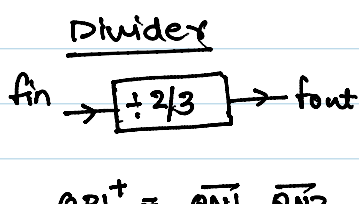


- $\sigma \Phi_{err} < 1 T_{vco}$ (200ps)
- Mismatch b/w analog & digital paths while cancelling quantization noise
- DAC non-linearity degrades final output jitter.

$F_{out} = N \cdot 25 F_{ref}$



- Calibration of gains along analog & digital path
- Replace PFD + CP w/ TDC ✓
- analog LF w/ digital loop filters

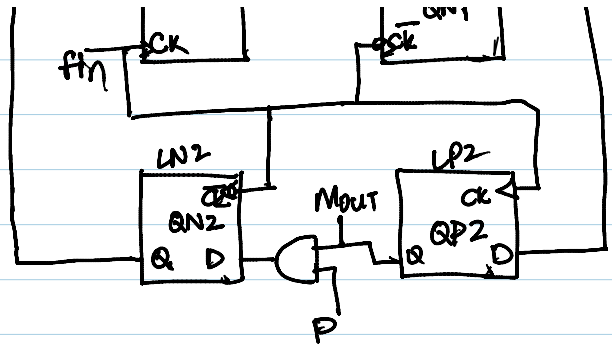


$$Q_{P1}^+ = \overline{Q_{N1}} \cdot \overline{Q_{N2}}$$

$$Q_{N1}^+ = Q_{P1}$$

$$Q_{P2}^+ = Q_{N1}$$

$$Q_{N2}^+ = Q_{P2} \cdot P$$



{ Q_{N1} Q_{N2}, Q_{P1} Q_{P2} }

10, 01