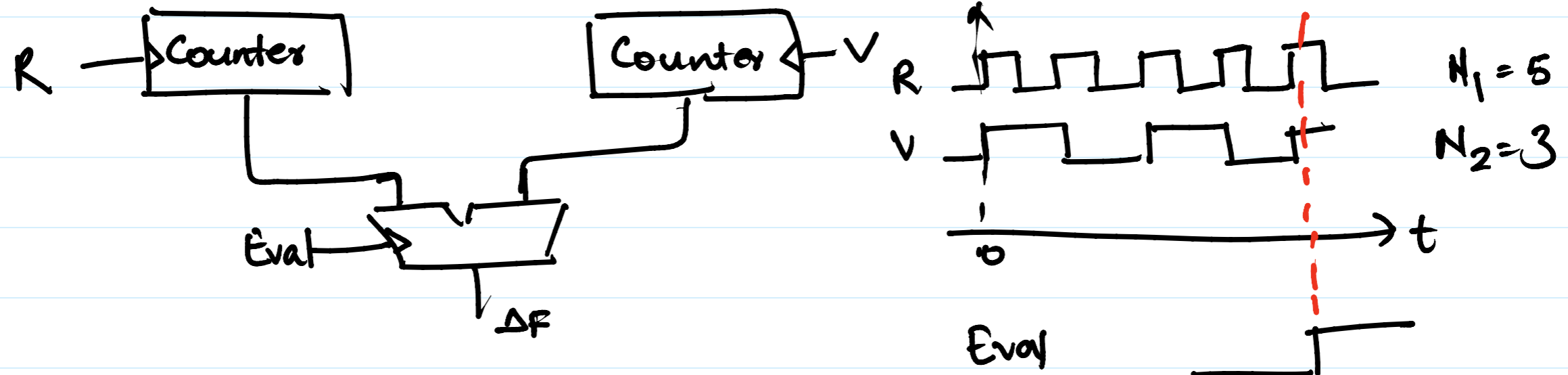
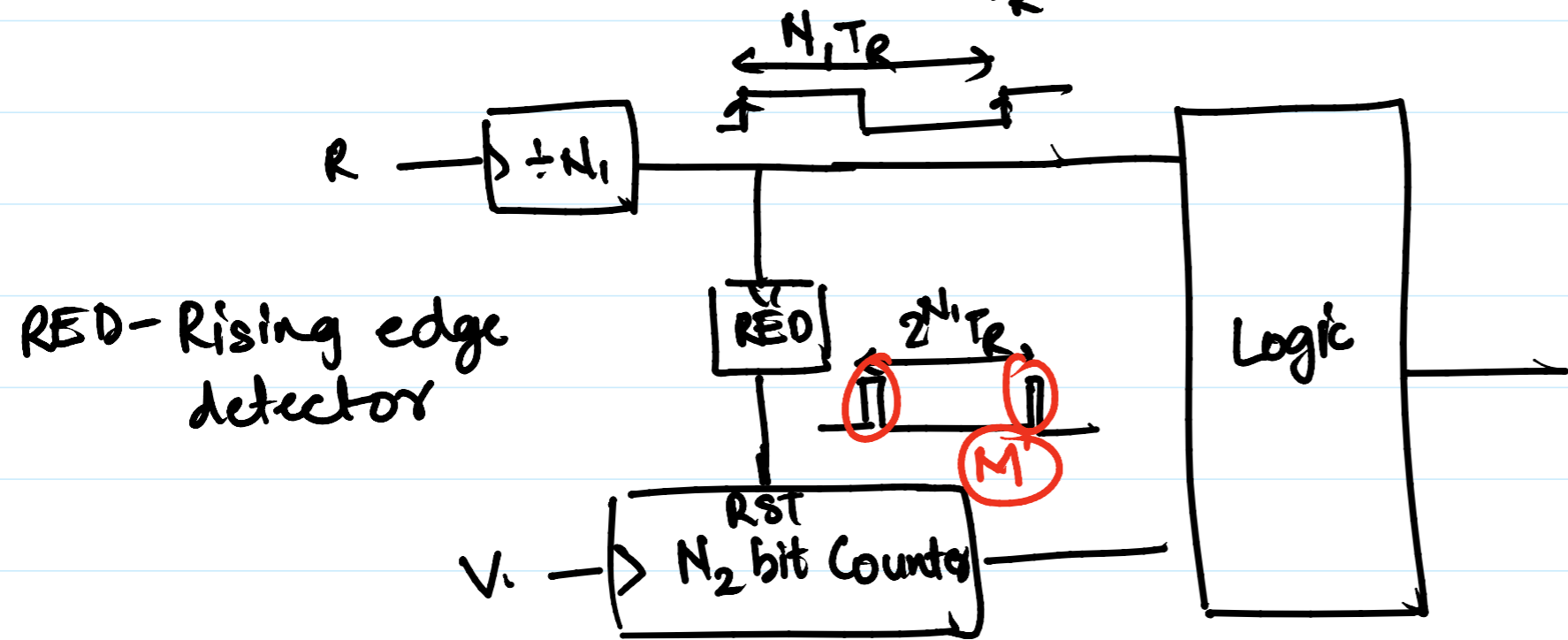


Counter based frequency detector



$$\text{Freq. Error} = \frac{\Delta F}{f_R} \times 10^6 \text{ ppm}$$



RED - Rising edge detector

$$MT_V = N_1 T_R, \quad N_1 \text{ is frequency divider}$$

$$N_1 = 10$$

$$N_1 = 1000$$

$$10 T_R = P T_V$$

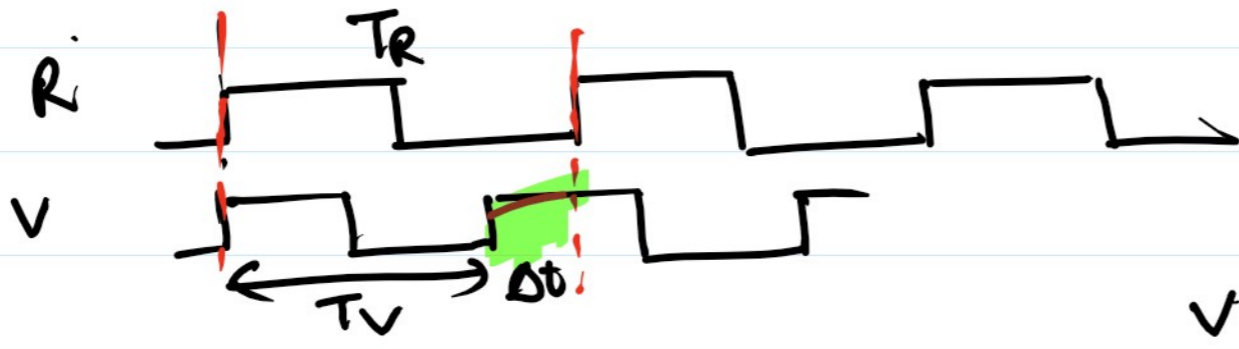
$$1000 T_R = Q T_V$$

Ex: $T_V = 2 T_R \Rightarrow P = 5$

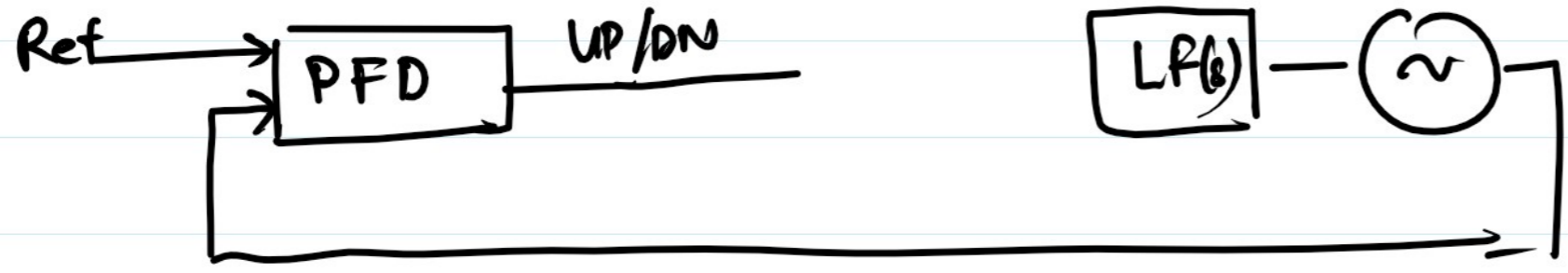
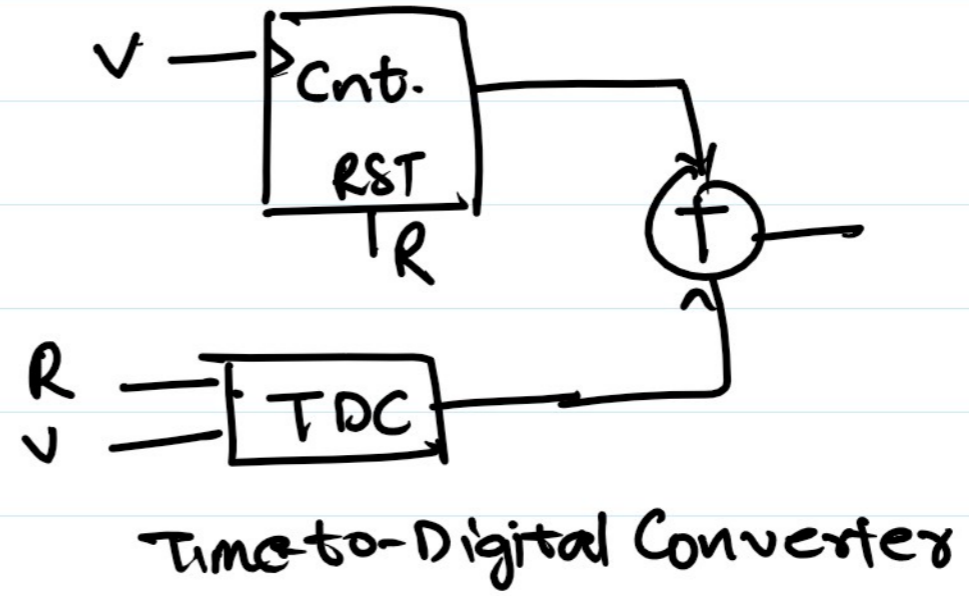
$$Q = 500$$

$$T_V = 2.05 T_R \Rightarrow P = 2$$

$$Q = \frac{2000}{41 \cdot 2.05}$$



$T_R = T_V + \Delta t$
 Counter measures only T_V

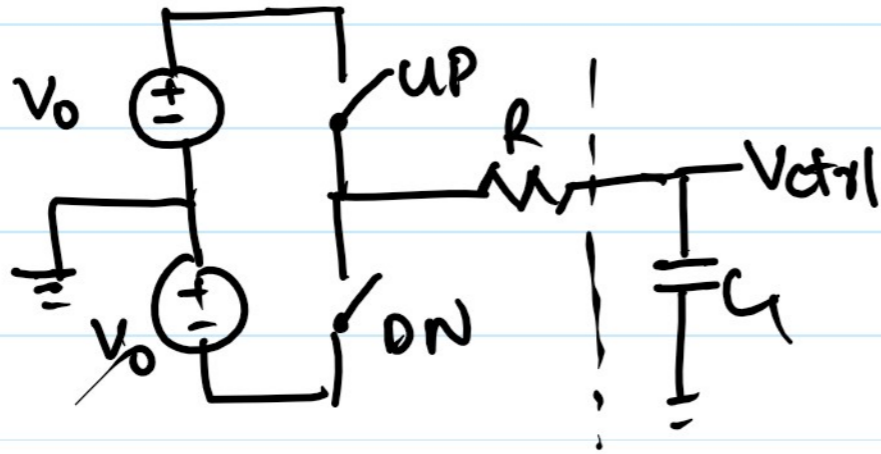


UP/DN - Pulse width modulated signals.

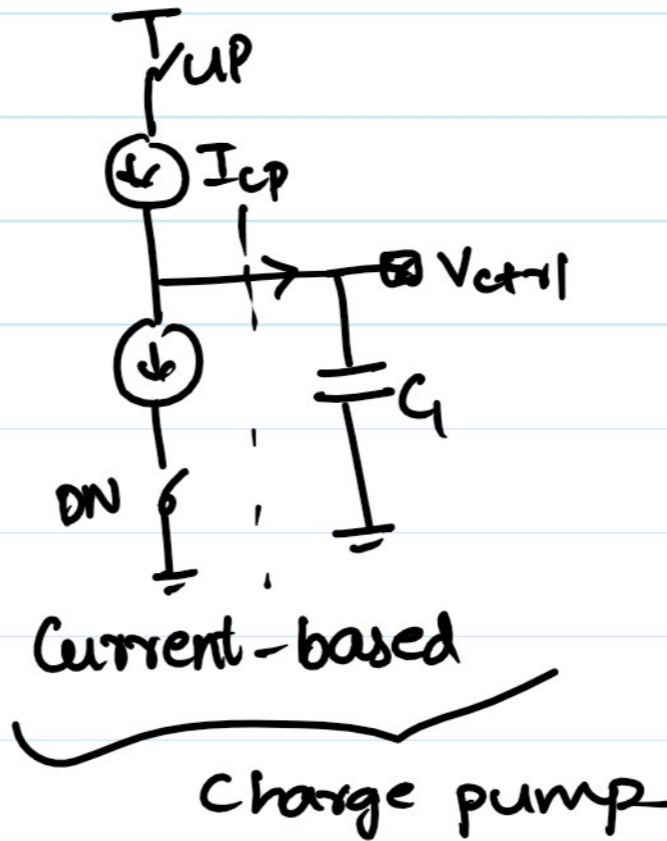




PFD O/P \rightarrow Voltage/Current

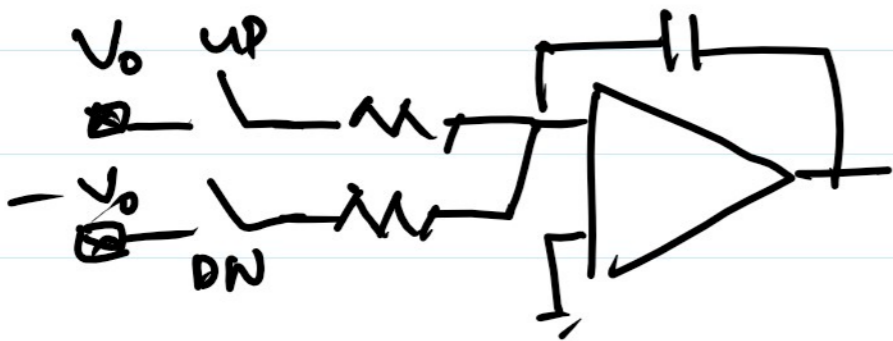


Voltage-based

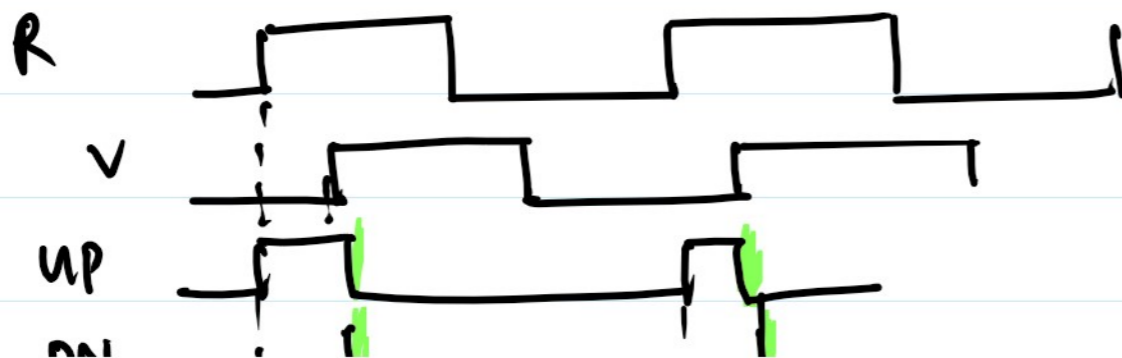


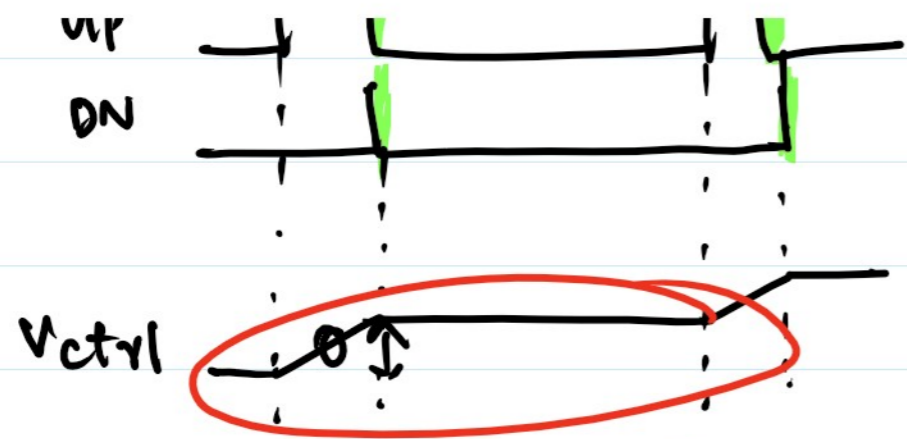
Current-based

Charge pump



Charge-pump based PLL



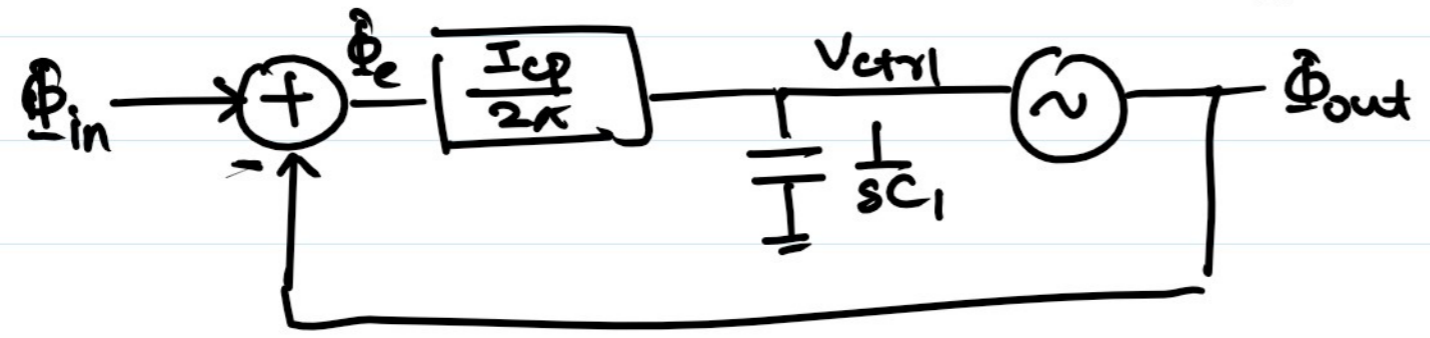


$$\Delta V_{ctrl} = \frac{I_{cp} \cdot \Delta t}{C_1} ; \quad V_c = \frac{1}{C} \int i \cdot dt$$

$$= \frac{I_{cp}}{C_1} \frac{\Phi_e}{2\pi} \cdot T_R$$

$$= \left(\frac{I_{cp}}{2\pi} \right) \times \Phi_e \times \frac{T_R}{C_1} = \Phi_e \times \underbrace{\left(\frac{I_{cp}}{2\pi} \right)}_{\text{up phase error}} \times \frac{T_R}{C_1}$$

$$K_{pd, cp} = \frac{I_{cp}}{2\pi}$$



$$V_{ctrl}(s) = \frac{I_{cp}}{2\pi} \frac{1}{sC_1} \Phi_e(s)$$

$$V_{ctrl}(s) \Big| = \frac{I_{cp}}{2\pi} \frac{1}{s} \times \frac{\Delta \Phi}{c}$$

$$I_{cp} \Delta t = Q_1$$

$$\left(\frac{\Delta t I_{cp}}{T} \right) \times T = Q_1$$

$$V_{ctn1}(s) |_{\hat{\Phi}_e(s) = \frac{\Delta\hat{\Phi}}{s}} = \frac{I_{cp}}{2\pi} \frac{1}{sC_1} \approx \frac{\Delta\Phi}{s}$$

$$= \frac{I_{cp}}{2\pi} \frac{\Delta\Phi}{C_1} \frac{1}{s^2}$$

$$V_{ctn1}(t) = \frac{I_{cp}}{2\pi} \frac{\Delta\Phi}{C_1} \textcircled{t} \cdot T_R$$

$$\hat{\Phi}_e = 2\pi \cdot \frac{\Delta t}{T}$$

$$\Rightarrow Q_1 = \left(\frac{I_{cp}}{2\pi} \times \hat{\Phi}_e \right) \times T$$