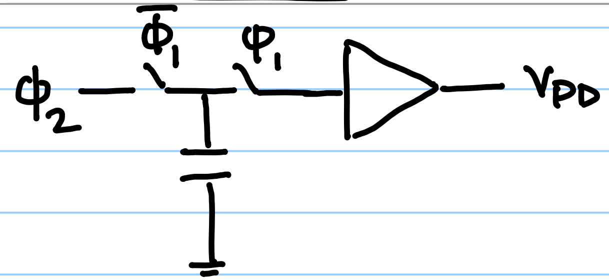
Lecture # 12

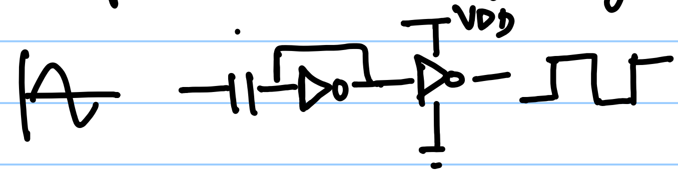


Ref. → PLL → o/p

✓ ϕ_1 : square wave signal — Ref., o/p

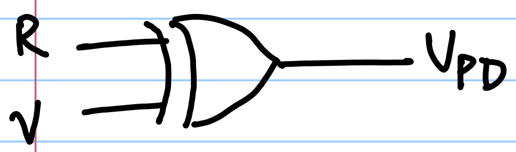
ϕ_2 : sinusoidal signal — Ref, o/p

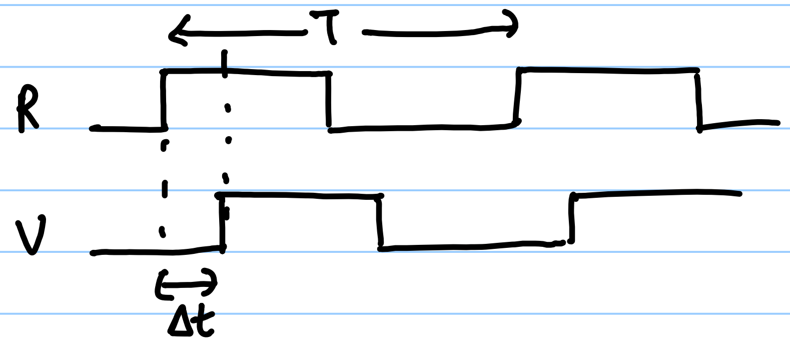
- o/p signal $f_{out} \geq f_{ref}$
- f_{out} as sinusoidal signal
- Ref. is a low freq. signal



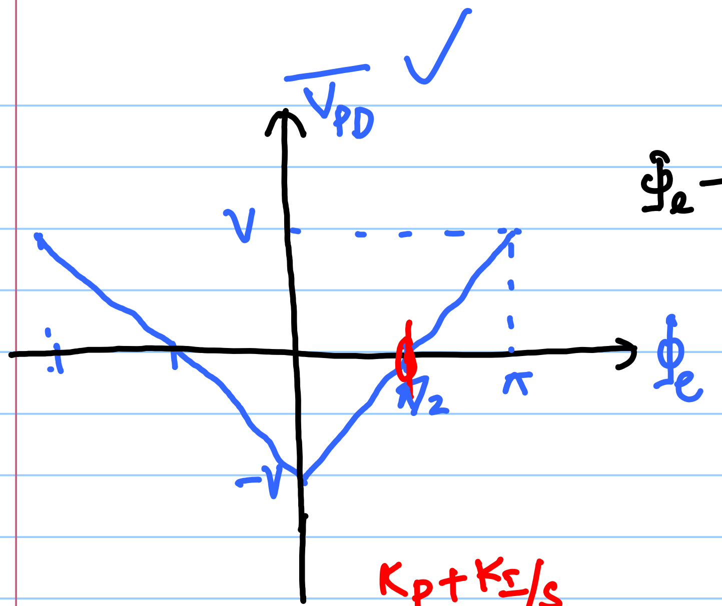
Digital PD

1. E-XOR based PD

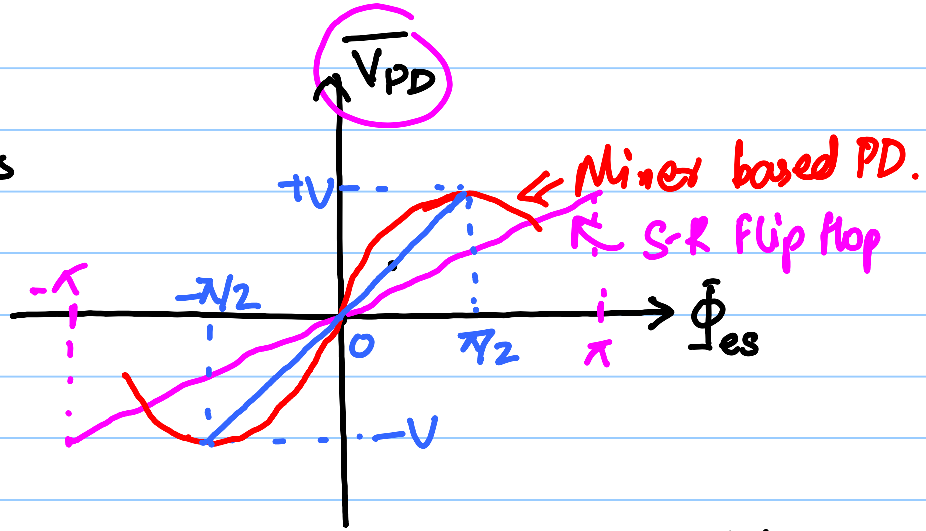


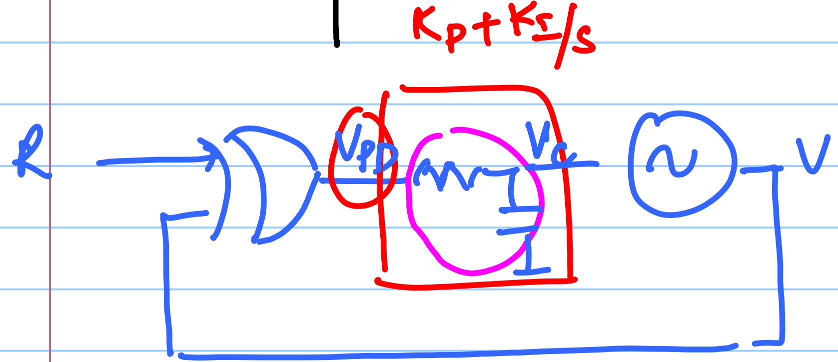


$$\overline{V_{PD}} = V\left(\frac{2\Phi_e}{\pi} - 1\right)$$



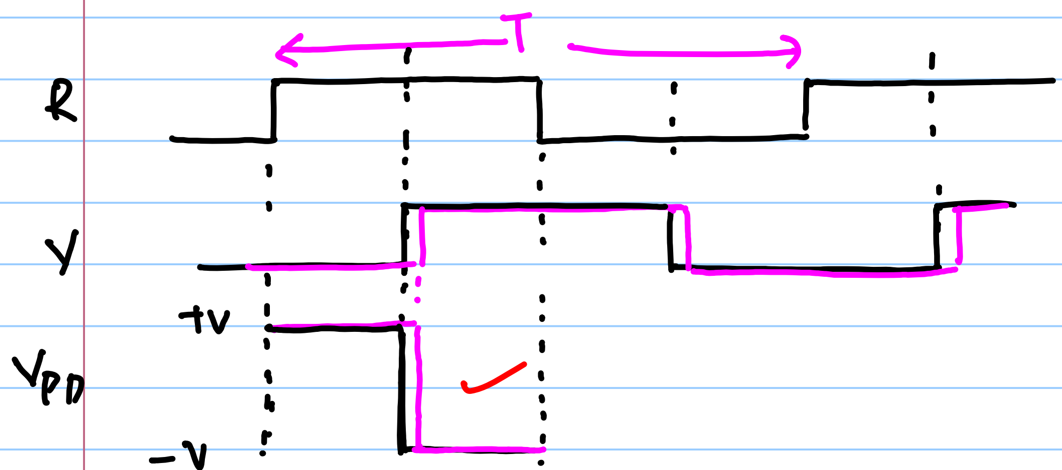
$\Phi_e \to \Phi_{es}$

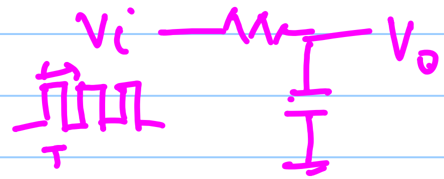


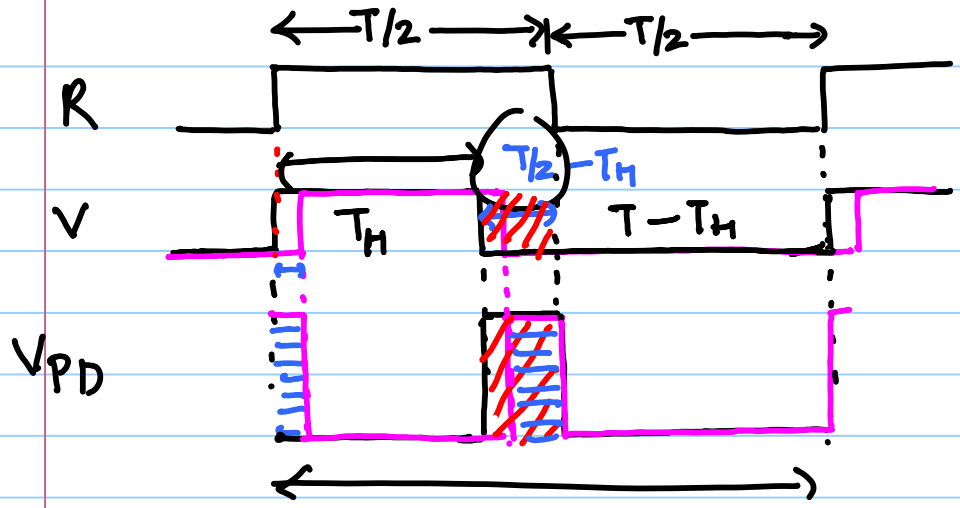


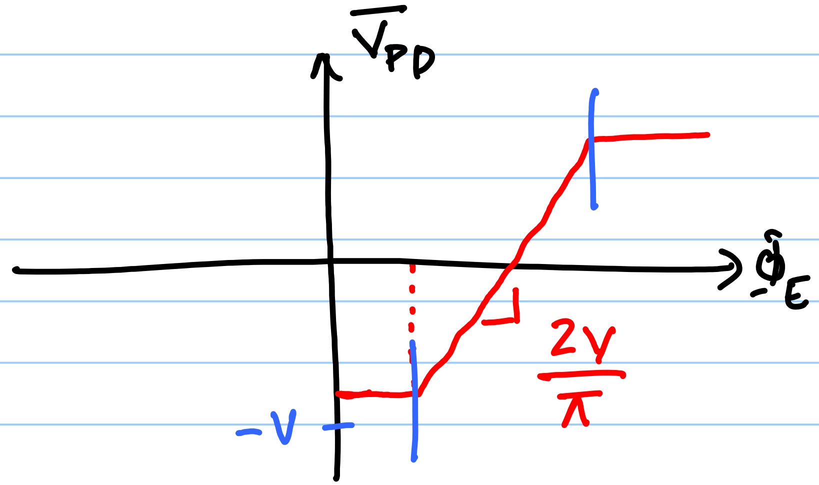
- Linear range $\left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$

- $K_{PD} = \frac{2V}{\pi} = \frac{\partial \overline{V_{PD}}}{d\Phi_e}$









Duty Cycles, $D = \frac{T_H}{T}$

$$\overline{V_{PD}} = \frac{T_H \times -V + \frac{T}{2} \times (-V) + \left(\frac{T}{2} - T_H\right) \times +V}{T}$$

$$= \frac{V}{T}\left(\left(\frac{T}{2} - T_H\right) - \left(\frac{T}{2} + T_H\right)\right)$$

$$= \frac{V}{T}\left(-\cancel{\frac{T}{2}} - 2T_H\right)$$

$$= -V\left(\frac{2T_H}{T}\right)$$

$$= -V\left(2D\right)$$

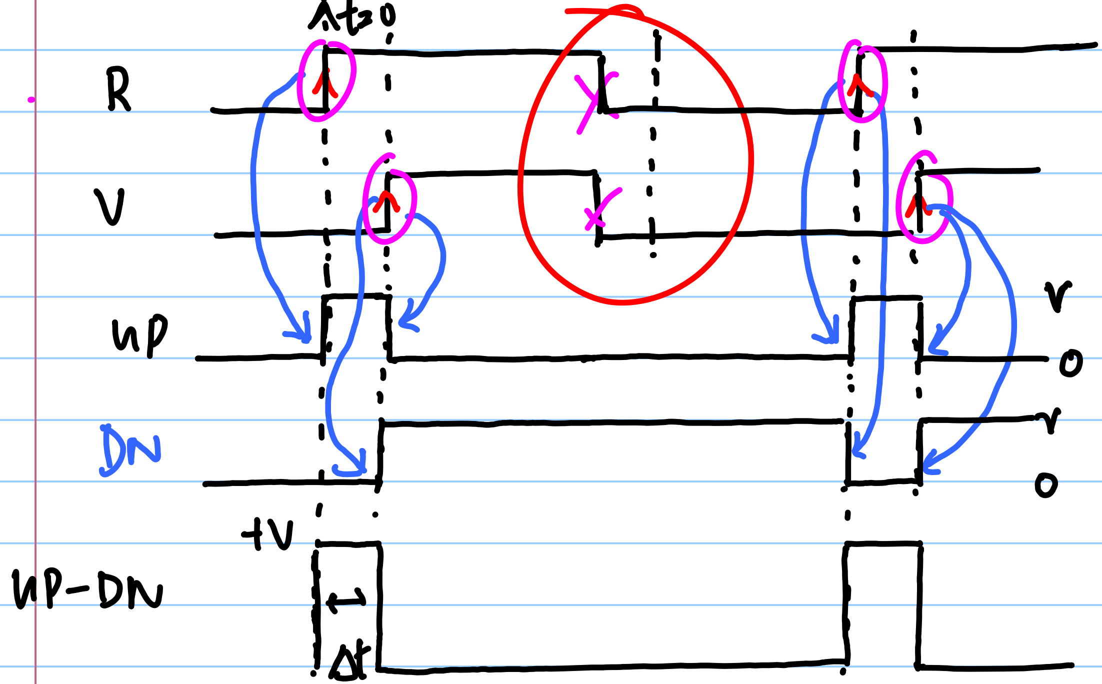
$$\Delta t > \frac{T}{2} - T_H$$

$$T \cdot \frac{\phi_e}{2\pi} > \frac{T}{2} - T_H$$

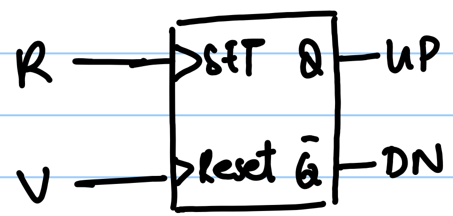
$$\phi_E > 2\pi\left(\frac{1}{2} - \frac{T_H}{T}\right)$$

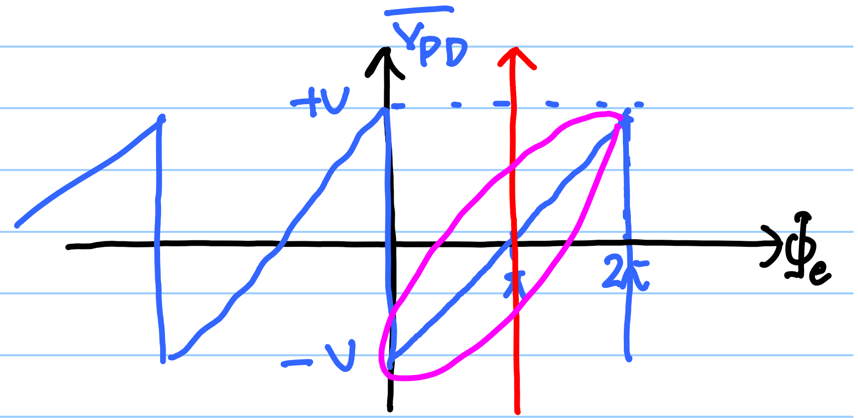
$$\phi_E = 2\pi \cdot \frac{\Delta t}{T}$$

2. 2-state Phase Detector



S-R Flip flop





$V_{PD} = UP - DN$

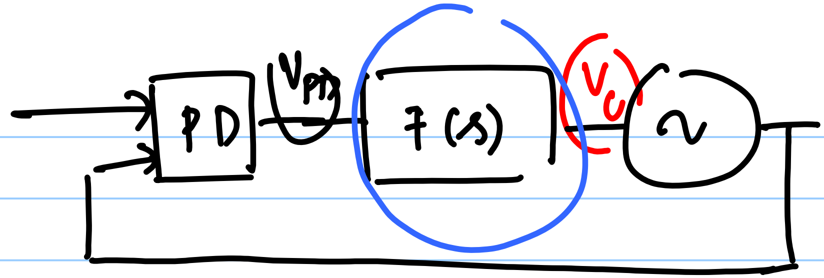
$$\overline{V_{PD}} = \overline{UP - DN} = \frac{\Delta t \cdot +V - (T - \Delta t)V}{T}$$

$$= \left(\frac{2 \cdot \Delta t - T}{T}\right) V$$

$$= \left(2 \cdot \frac{\Phi_e}{2\pi} - 1\right) V = \left(\frac{\Phi_e}{\pi} - 1\right) V$$

- Linear range. $[0, 2\pi]$
  $[-\pi, \pi]$

- Gain $K_{PD} = \frac{V}{\pi}$ v

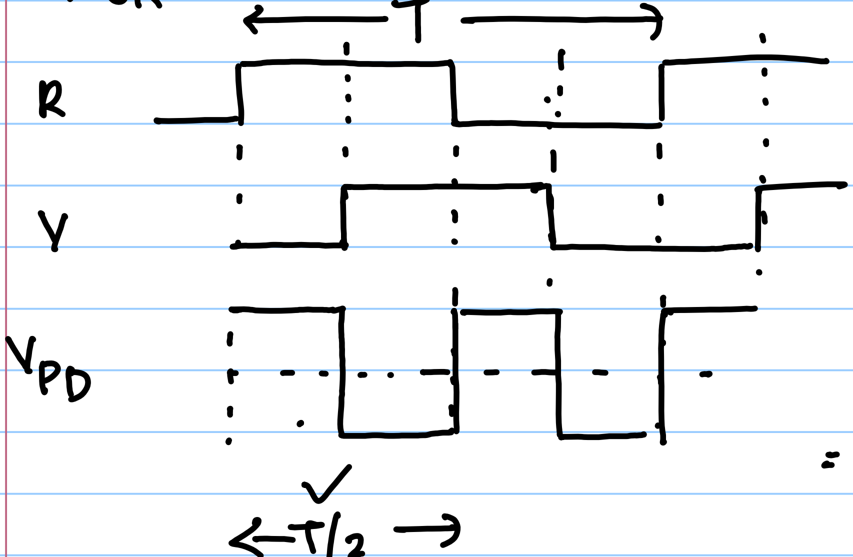


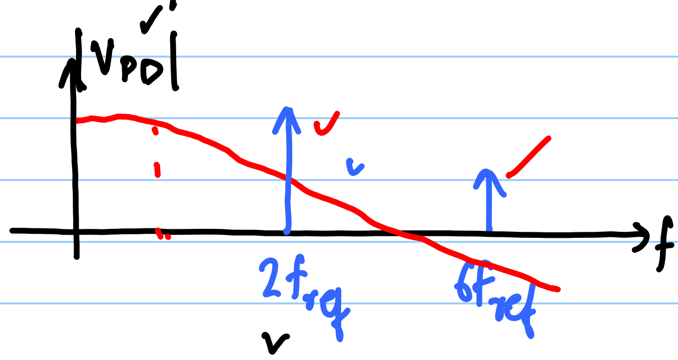
- Unity gain frequency (ω_{ugb}?)
- Phase Margin

XOR — $2V/\pi$

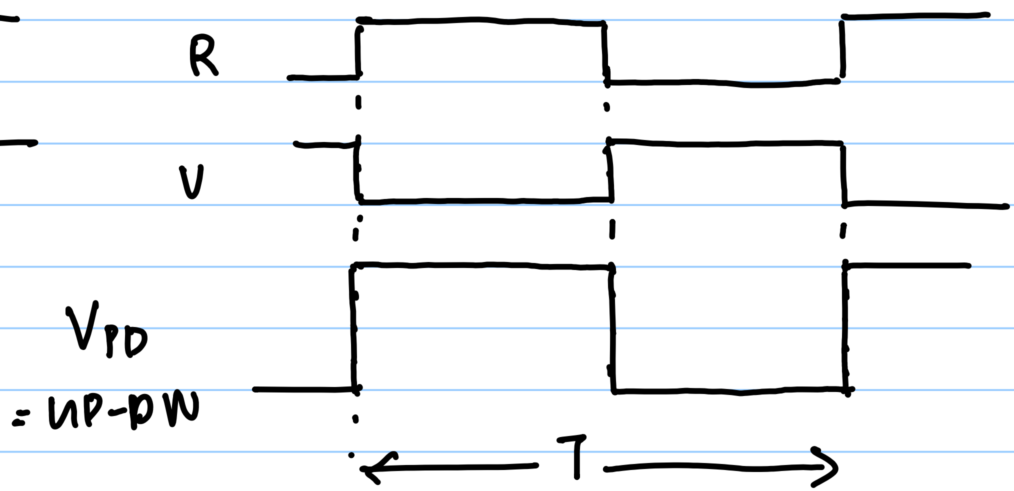
S-R flip flop — V/π

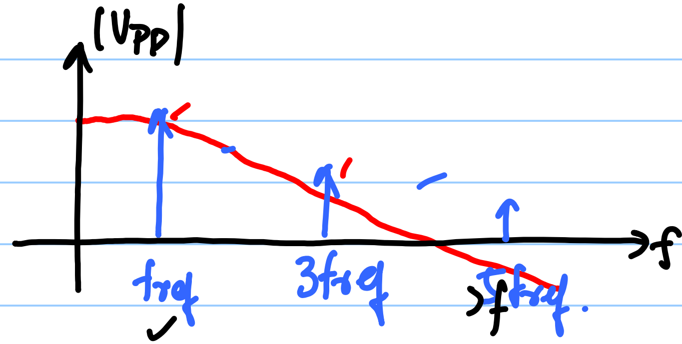
XOR





S-R flip flop





$$V_{out} = \sin\left(\omega_o \cdot t + \int K_{VCO} \cdot V_c \, dt\right)$$

$$= \sin\left(\omega_o t + K_{VCO} \int a_m \sin(m\omega_{ref} t)\, dt\right)$$

$$= \sin\left(\omega_o t - \underbrace{\frac{K_{VCO} a_m}{m\omega_{ref}}}_{\beta} \cos(m\omega_{ref} t)\right)$$

$$= \sin\left(\omega_o t - \beta \cos(m\omega_{ref} \cdot t)\right)$$

$$V_c = a_m \sin(m\omega_{ref} \cdot t)$$

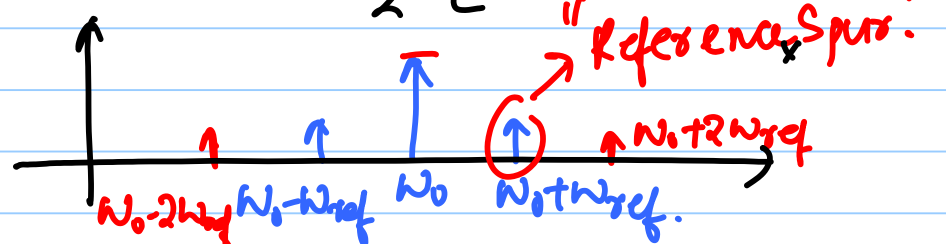
$$\beta = \frac{K_{VCO} \cdot a_m}{m\omega_{ref}}$$

$$\beta \approx 0$$

$$= \sin(\omega_o t) \cdot \cos\left(\underbrace{\beta \cdot \cos(m\omega_{ref} t)}_{1}\right) - \cos(\omega_o t) \cdot \sin\left(\beta \cos(m\omega_{ref} t)\right)$$

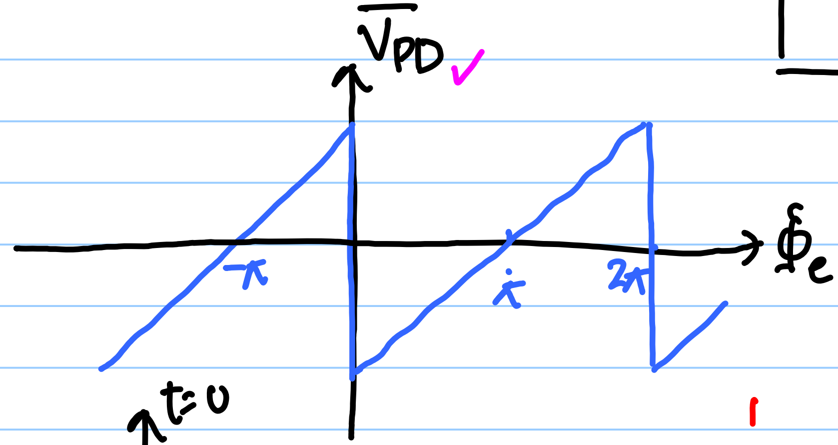
$$\approx \sin(\omega_o t) - \cos(\omega_o t) \cdot \beta \cos(m\omega_{ref} \cdot t)$$

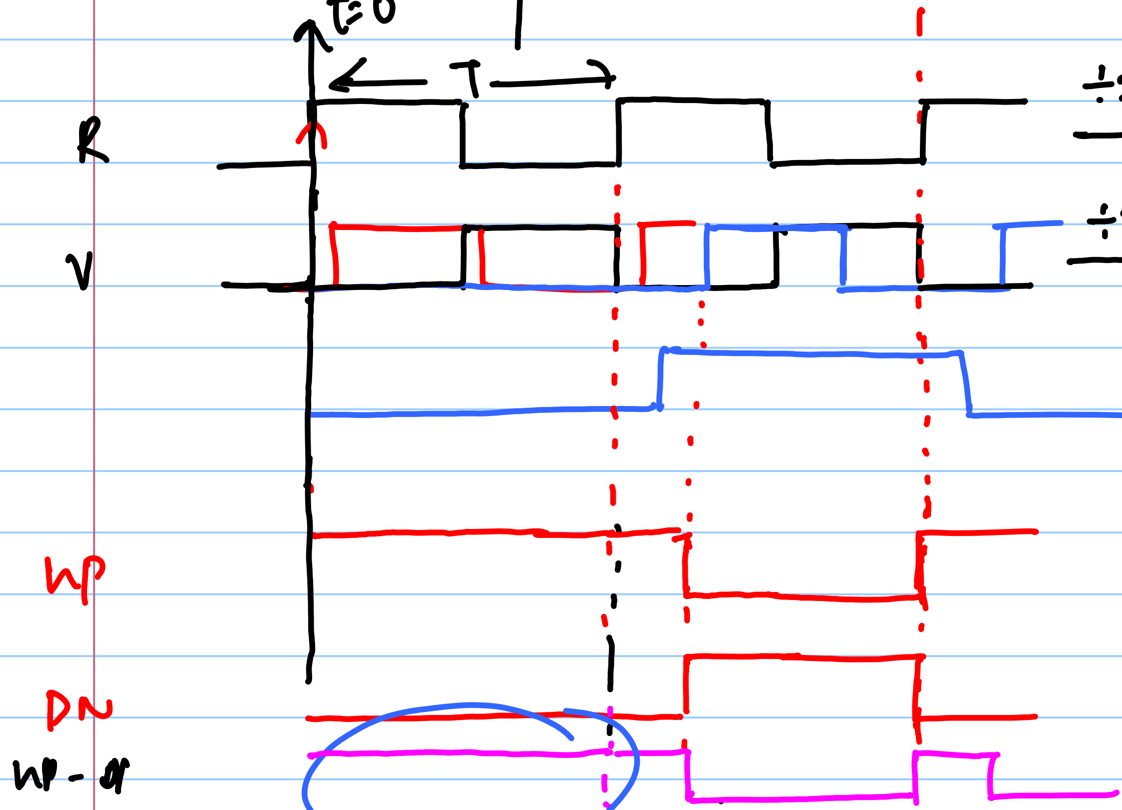
$$= \sin(\omega_o t) - \frac{\beta}{2}\left[\cos(\omega_o + m\omega_{ref} \cdot t) + \cos(\omega_o - m\omega_{ref} \cdot t)\right]$$



XOR

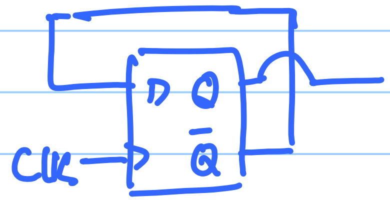
$m = 2, \quad \beta = \frac{K_{VCO} \cdot a_2}{2\omega_{ref}}$

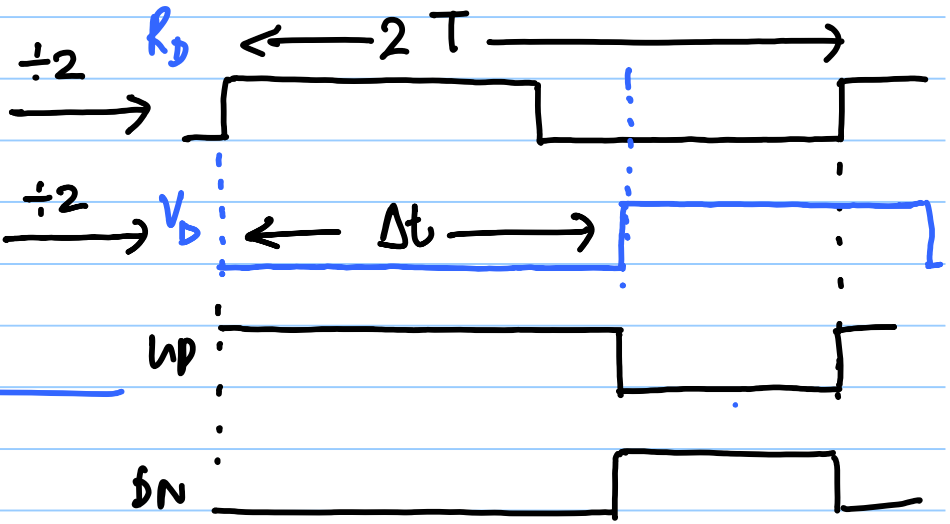




S-R

$m = 1, \quad \beta = \frac{K_{VCO} \cdot a_1}{\omega_{ref}}$

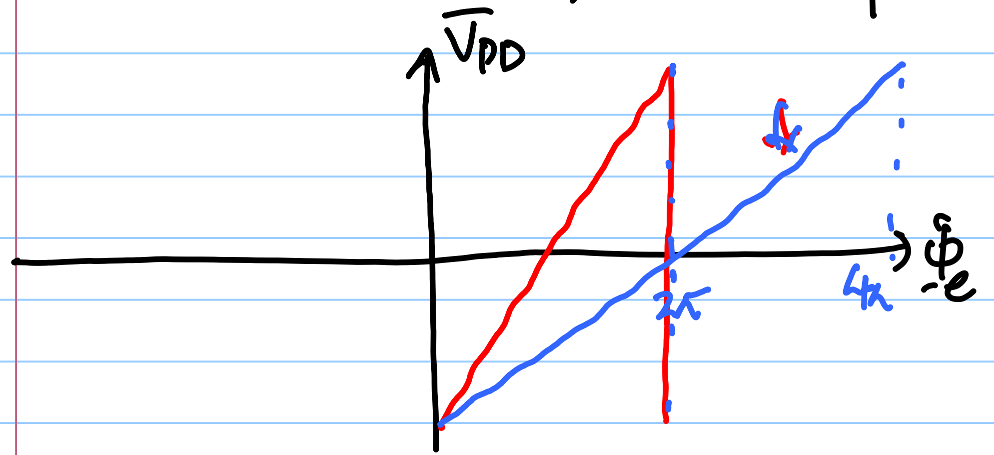




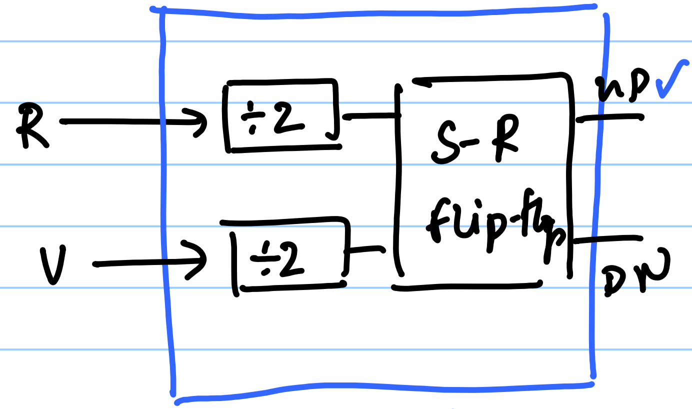
$$\overline{V_{up-dn}} = \frac{\Delta t \cdot V - (2T - \Delta t)V}{2T} = V\left(\frac{\phi_e}{\pi} - 1\right)$$

$$\overline{V_{PD}} = V\left(\frac{2 \cdot \Delta t}{2T} - 1\right)$$

$$= V\left(\frac{\phi_e}{2\pi} - 1\right)$$



$\phi_e : 2\pi \cdot \frac{\Delta t}{T}$



Modified PD

Range extension of PD.