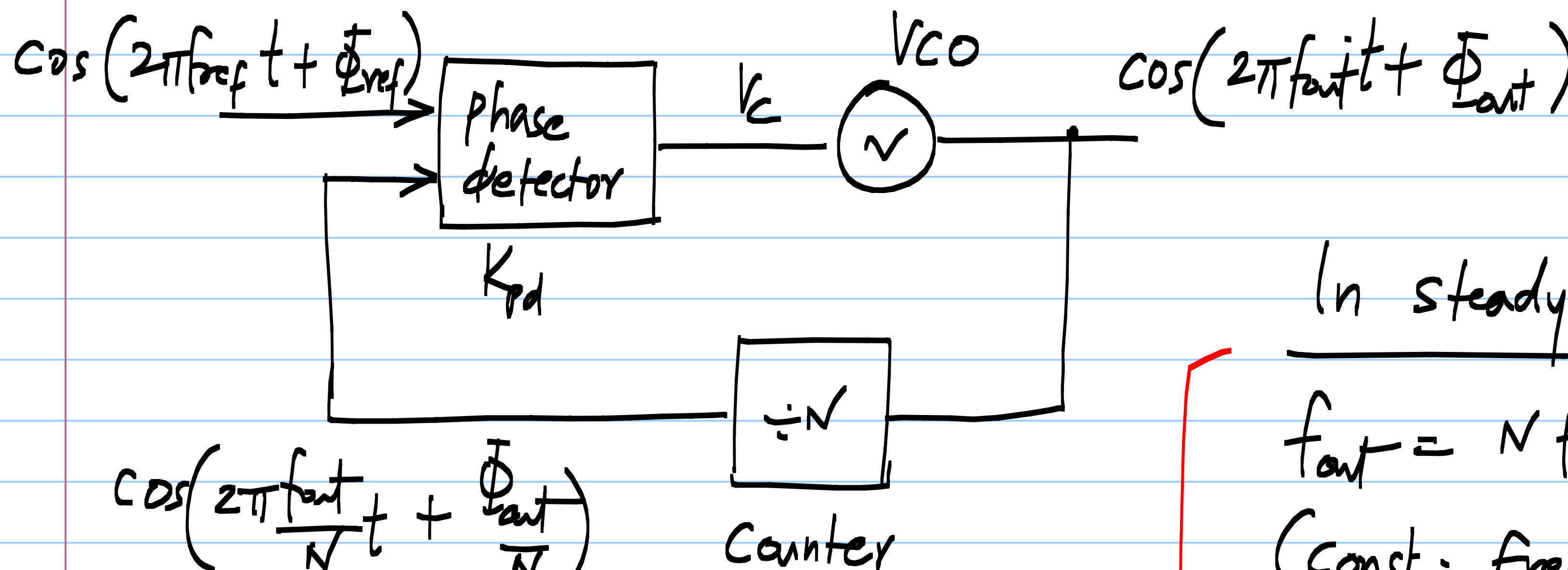
Lecture 46 : Phase locked loop → Type I PLL



$$\cos\left(2\pi \frac{f_{out}}{N} t + \frac{\Phi_{out}}{N}\right)$$

$$K_{vco} \cdot V_c + f_o = f_{out} = N f_{ref} \text{ (freq. divider)}$$

In steady state:

$f_{out} = N f_{ref}$

(const. f_{ref})

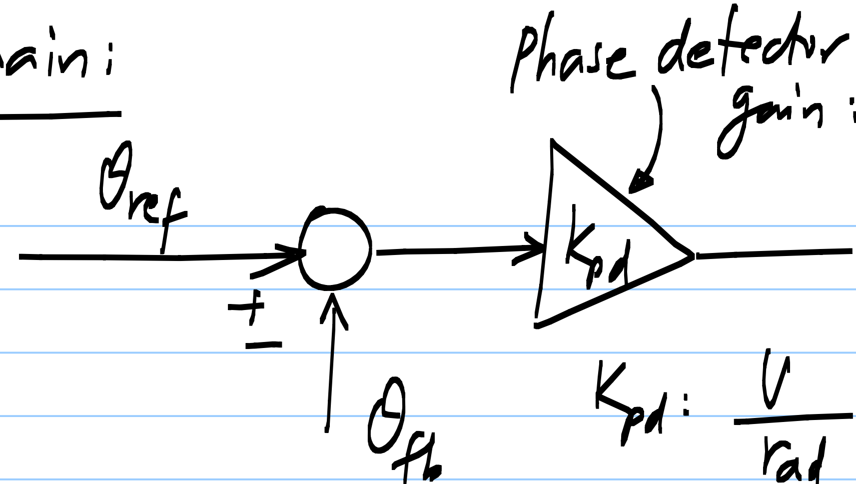
$$V_c = K_{pd}\left(\Phi_{ref} - \frac{\Phi_{out}}{N}\right)$$

$$= \frac{N f_{ref} - f_o}{K_{vco}}$$

"operating point"

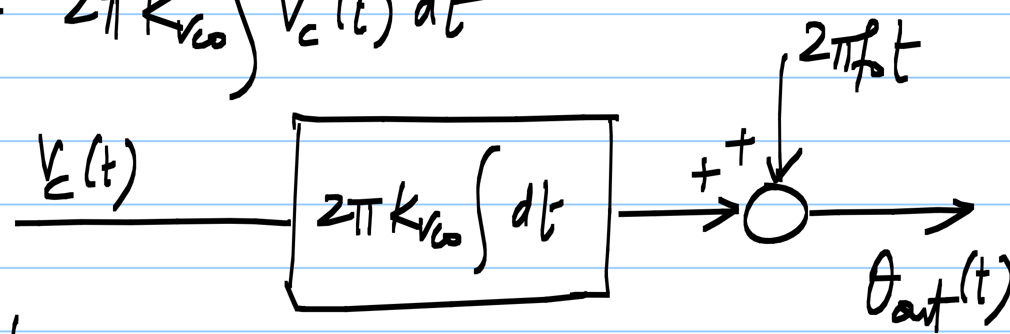
Model in the phase domain:

Phase detector:

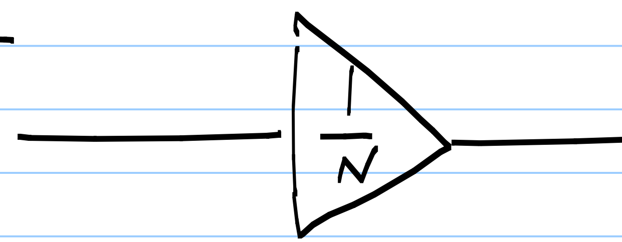


K_{pd}: $\frac{V}{rad}$

VCO: $\theta_{out} = 2\pi f_o t + 2\pi K_{vco} \int v_c(t)\, dt$



Freq. divider: $\theta_{fb} = \frac{\theta_{out}}{N}$

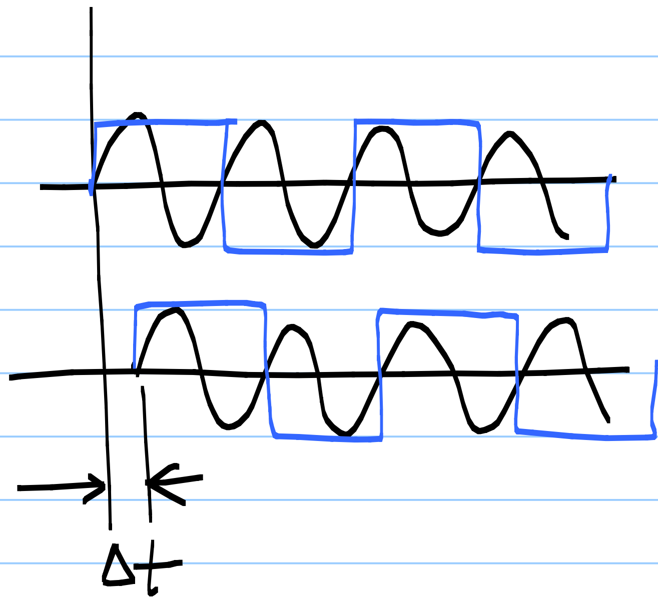


Nagendra Krishnapura, Dept. of EE
Indian Institute of Technology, Madras

θ_{out} → $\div N$ → θ_{fb}

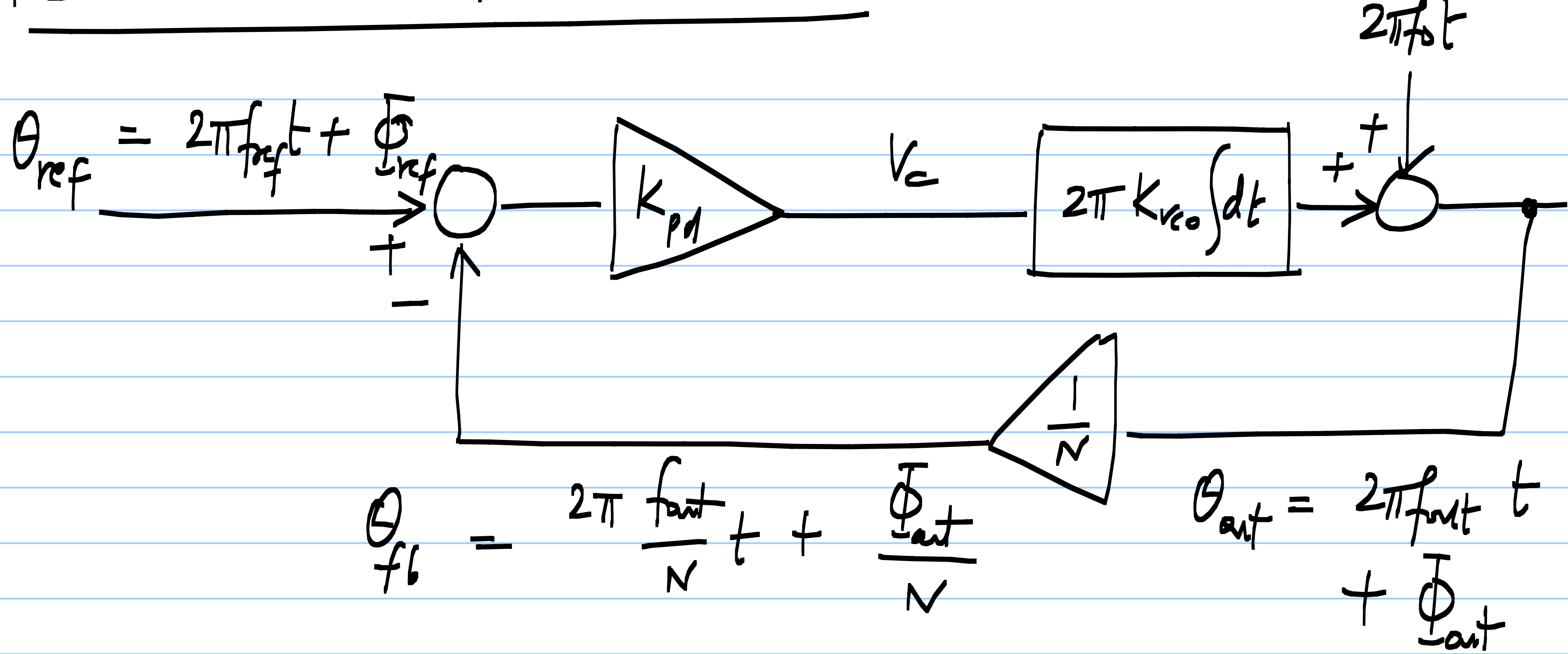
$$\theta_{out} = 2\pi f_{out} t + \Phi_{out}$$

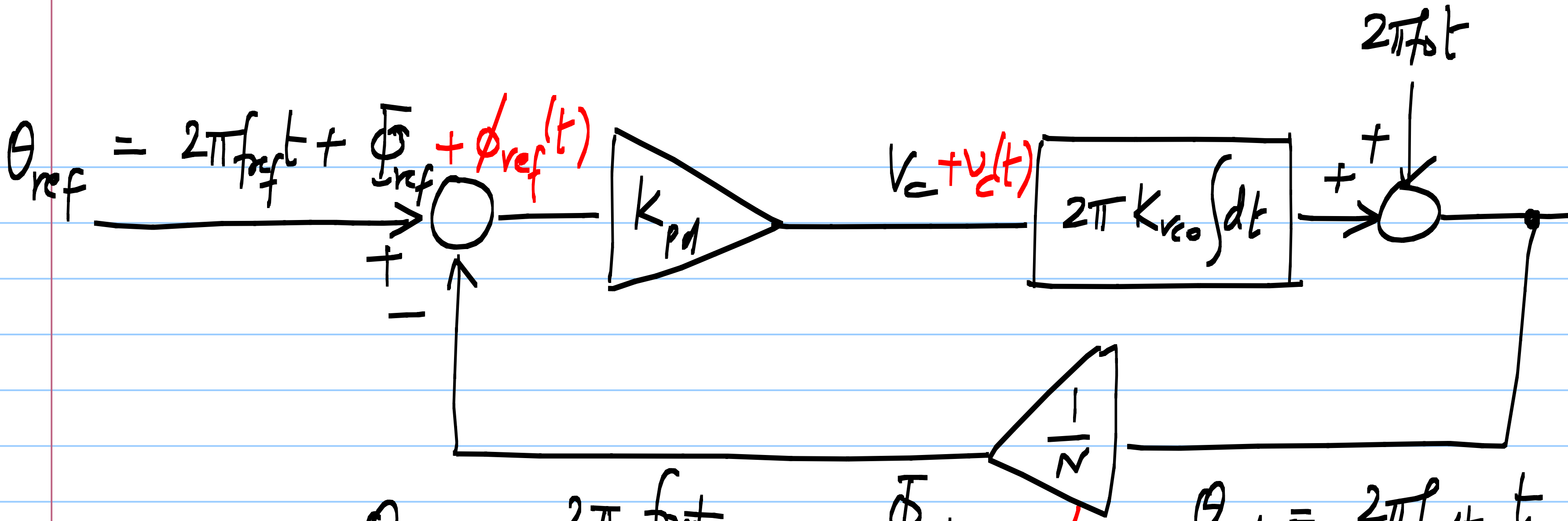
$$\theta_{fb} = 2\pi \frac{f_{out}}{N} t + \frac{\Phi_{out}}{N}$$



$$\frac{\Delta t}{T_{fb}} = \frac{1}{2} \cdot \frac{\Delta t}{T_{out}}$$

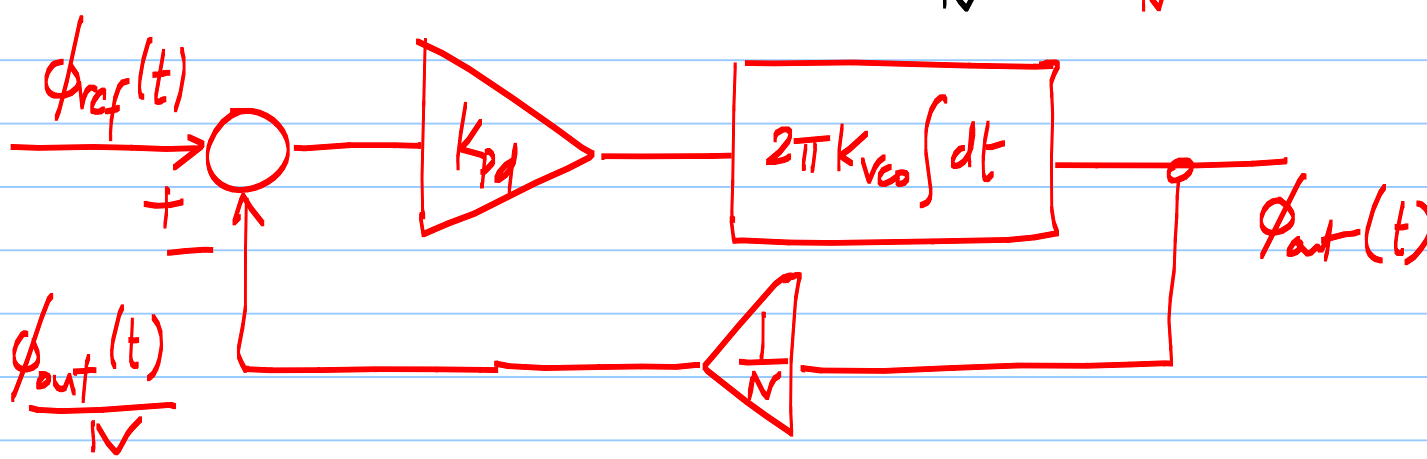
PLL in the phase domain :

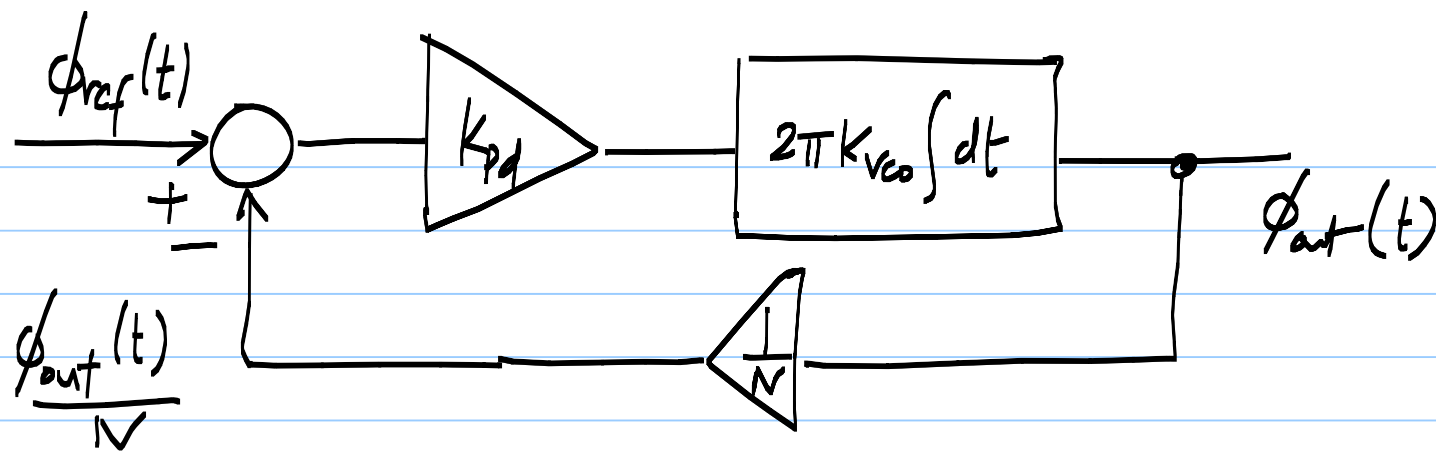




$$\theta_{fb} = 2\pi \frac{f_{out}}{N} t + \frac{\Phi_{out}}{N} + \frac{\phi_{out}(t)}{N}$$

$$\theta_{out} = 2\pi f_{out} t + \Phi_{out} + \phi_{out}(t)$$

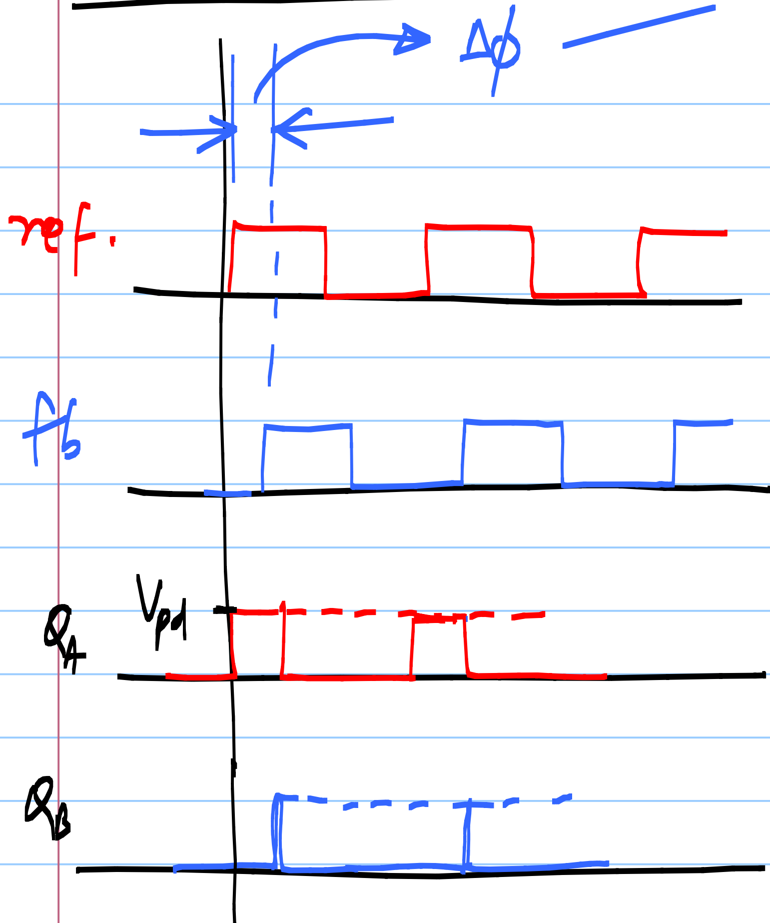




Incremental (linear) model of a PLL

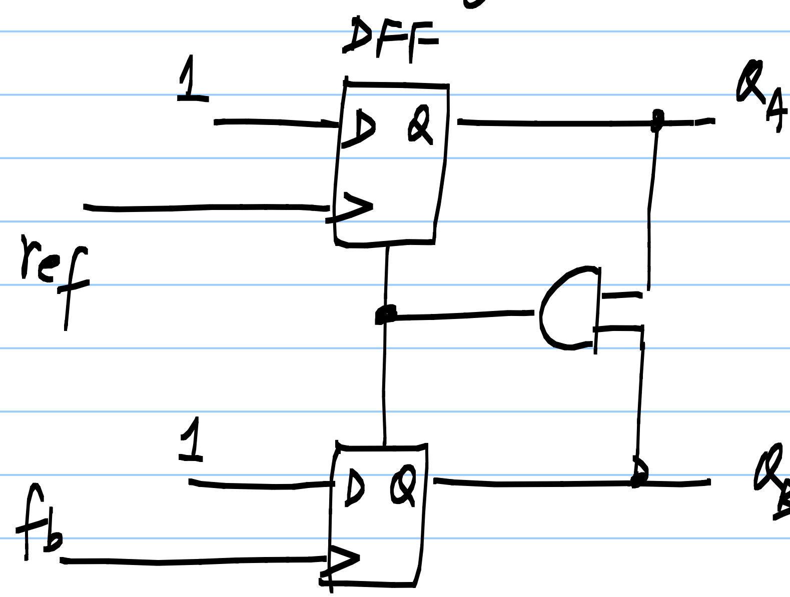
One integrator in the loop: Type-I PLL

Phase detector:

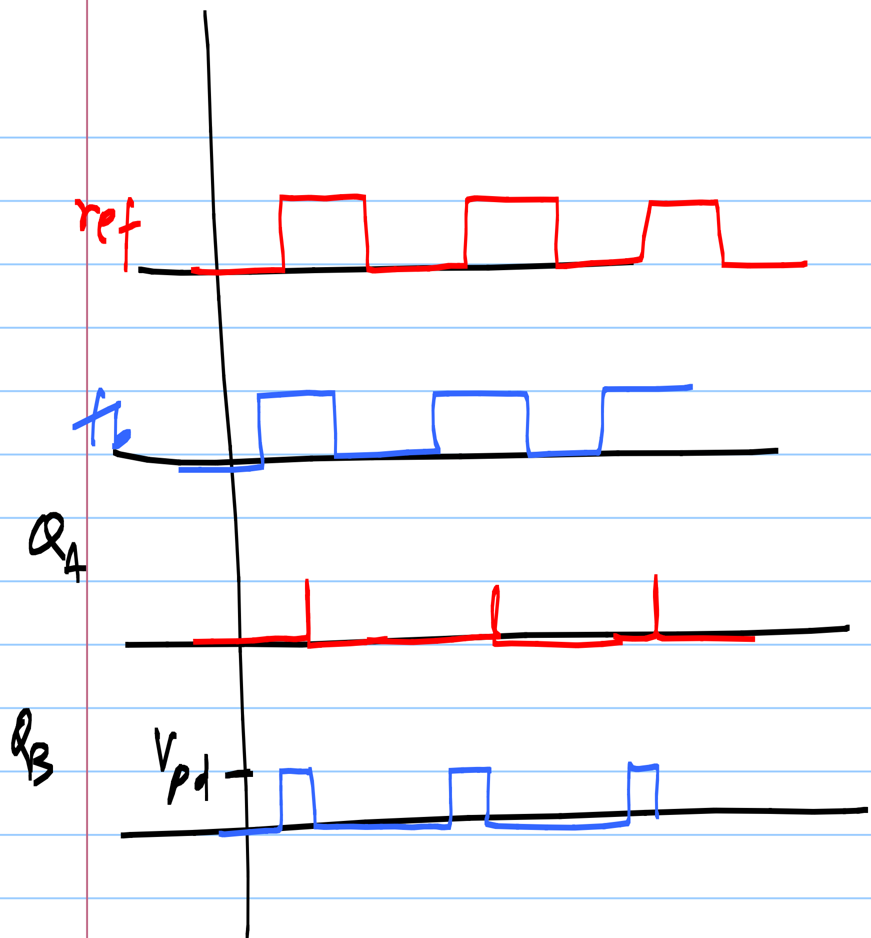


o/p must be proportional to $\Delta\phi$

* Must be sensitive only to the rising edges



Average value of $Q_A \propto \Delta\phi / 2\pi$



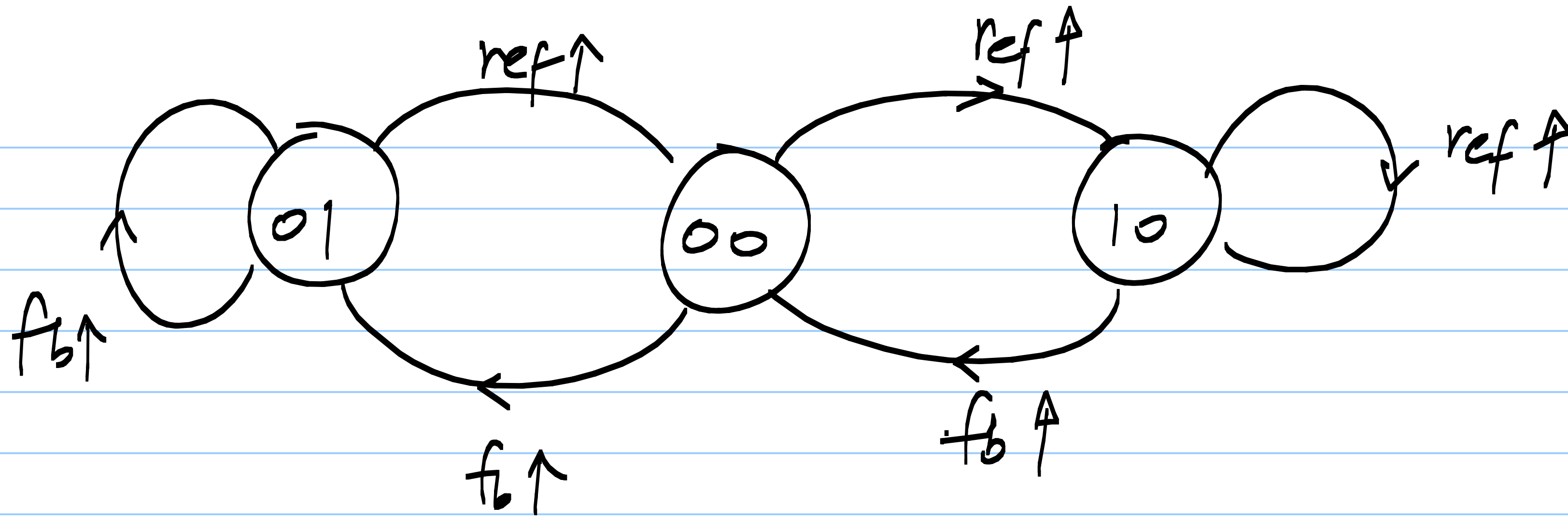
ref. lagging fb.

Average value of Q_B $\propto$ phase difference

average $(Q_A - Q_B)$:

$$\propto \frac{\Delta\phi}{2\pi}$$

$\Delta\phi$: amount by which ref. is leading fb.

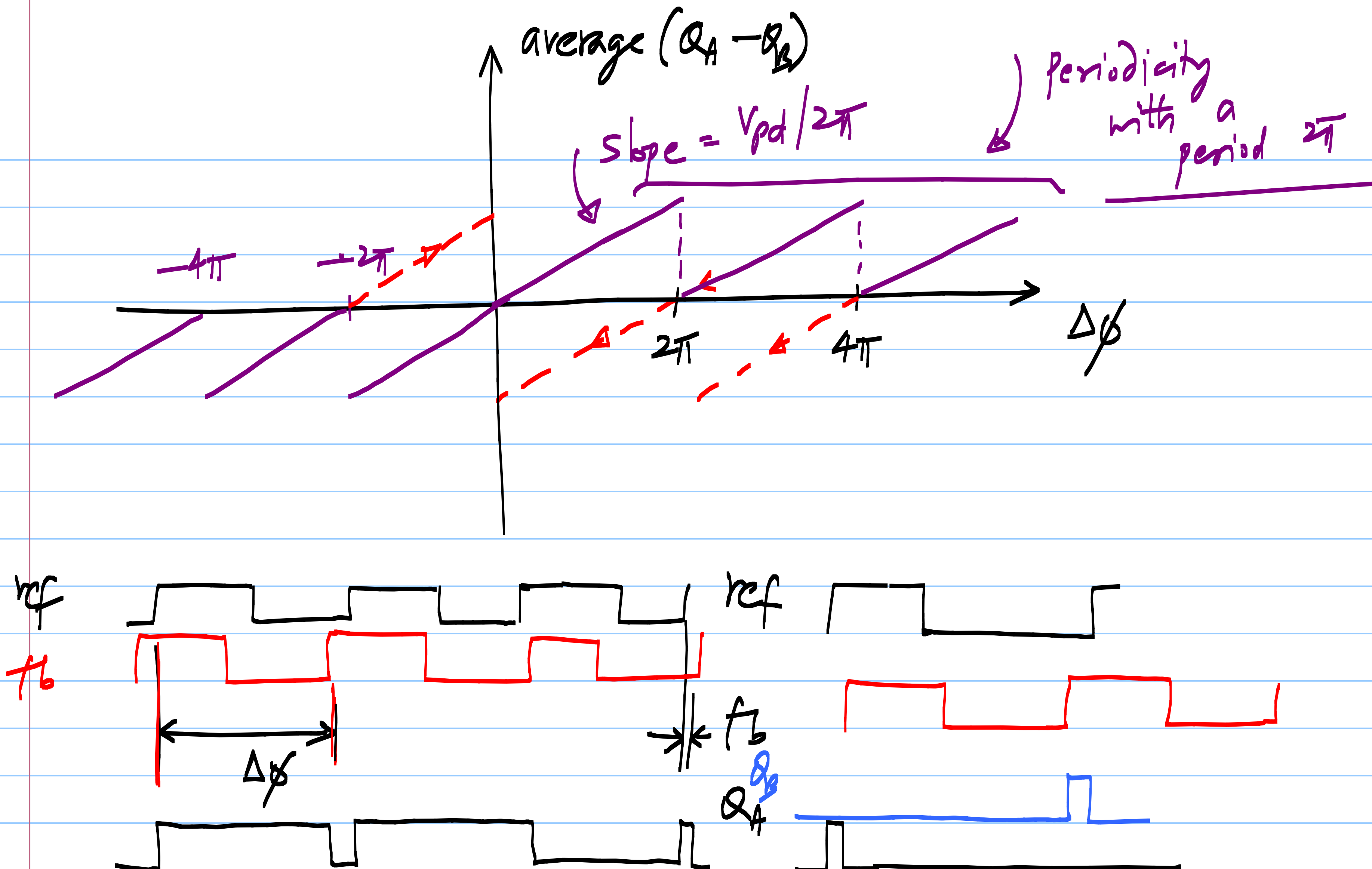


3-state phase detector.

State = $Q_A Q_B$

$Q_A - Q_B$: 3 values $\{-1, 0, 1\}$

$\text{average}(Q_A - Q_B)$: $\frac{\Delta\phi}{2\pi} \cdot V_{pd}$


average (QA − QB)
slope = Vpd/2π
periodicity with a period 2π
−4π
−2π
2π
4π
Δφ
ref
fb
Δφ
fb
ref
QB
QA

Operating point:

$$V_c = \frac{N f_{ref} - f_o}{K_{vco}} = K_{pd}\underbrace{\left(\Phi_{ref} - \frac{\Phi_{fb}}{N}\right)}_{\text{can be a maximum of } 2\pi}$$

$$\left|\phi_{ref} - \frac{\phi_{fb}}{N}\right| < 2\pi$$

$$\left|\frac{N f_{ref} - f_o}{K_{vco}}\right| < 2\pi \cdot K_{pd}$$

$$|N f_{ref} - f_o| < 2\pi K_{vco} \cdot K_{pd}$$

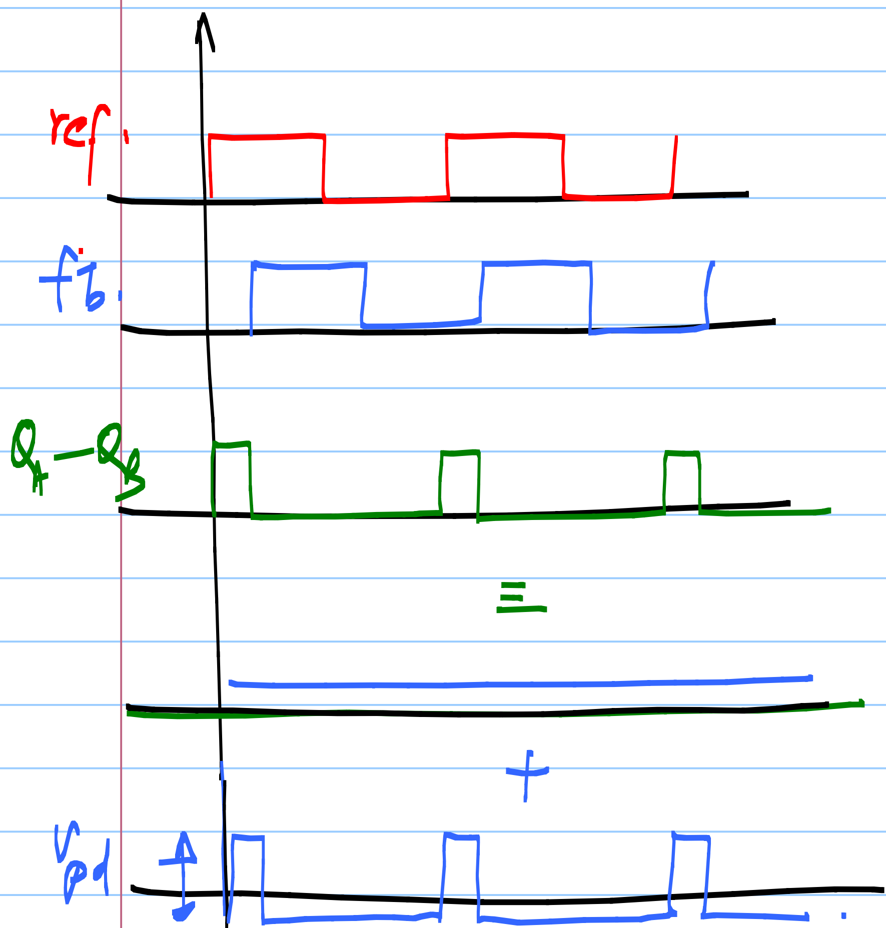
$$|f_{out} - f_o| < 2\pi K_{vco} \cdot K_{pd}$$

f_o: free running frequency

$f_{out} - f_o$: deviation from the free-running frequency

Lock range of the type-I PLL

3-state phase detector:

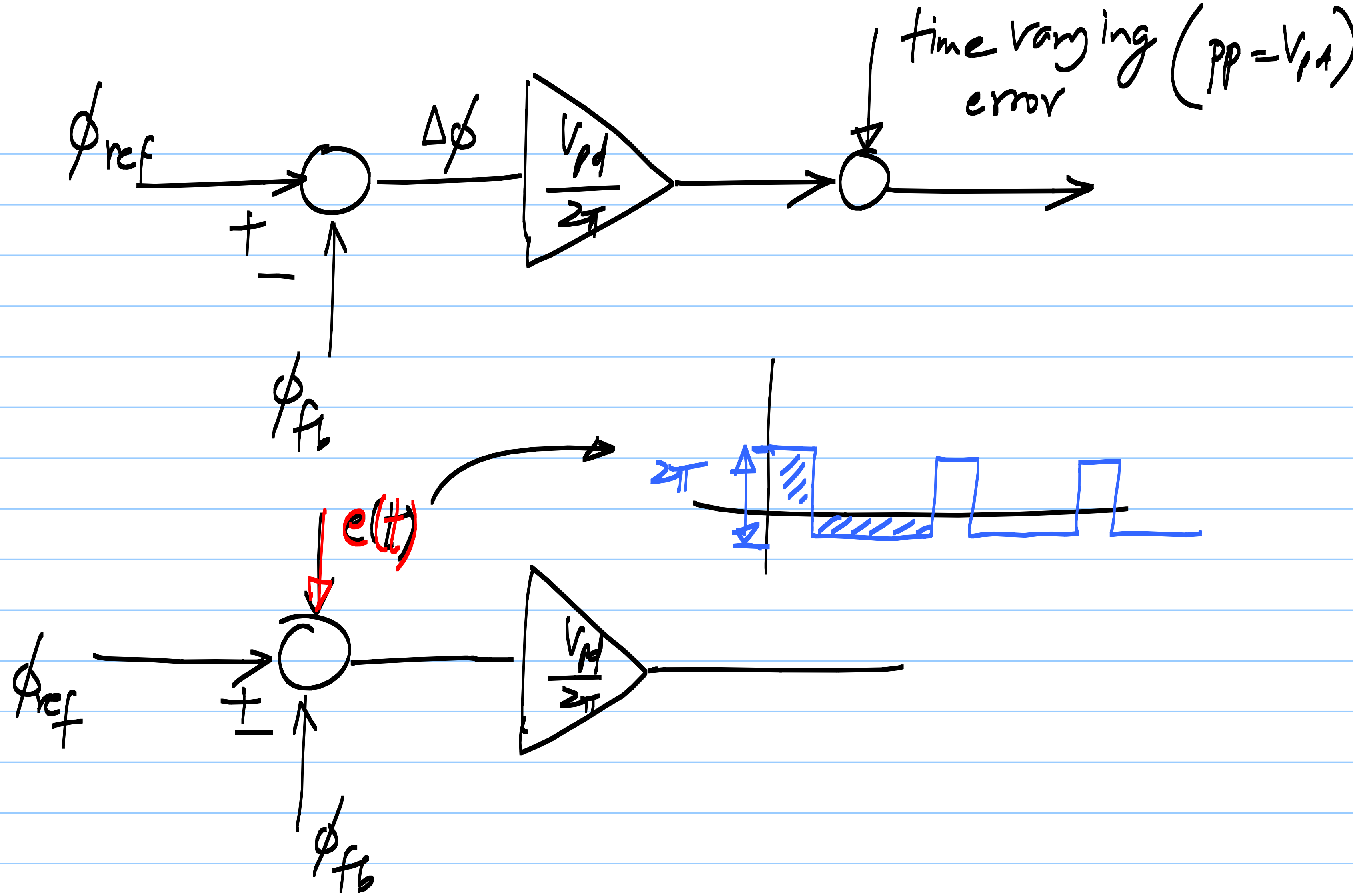


* Average output of $V_{pd} \cdot \frac{\Delta\phi}{2\pi}$

$$K_{pd} = \left(\frac{V_{pd}}{2\pi}\right)$$

average $= K_{pd} \cdot \Delta\phi$

$e(t)$: periodic error with zero average



time varying error (pp = Vpd)
φref
Δφ
Vpd / 2π
φfb
e(t)
2π