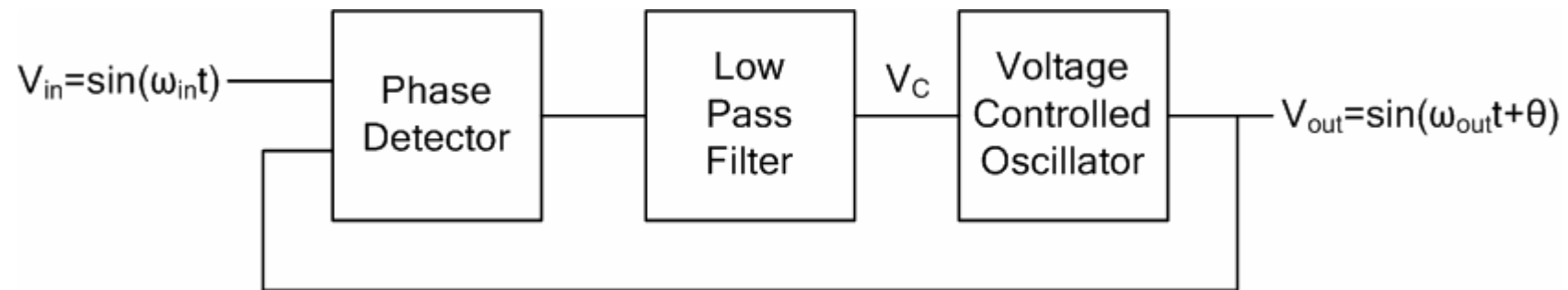


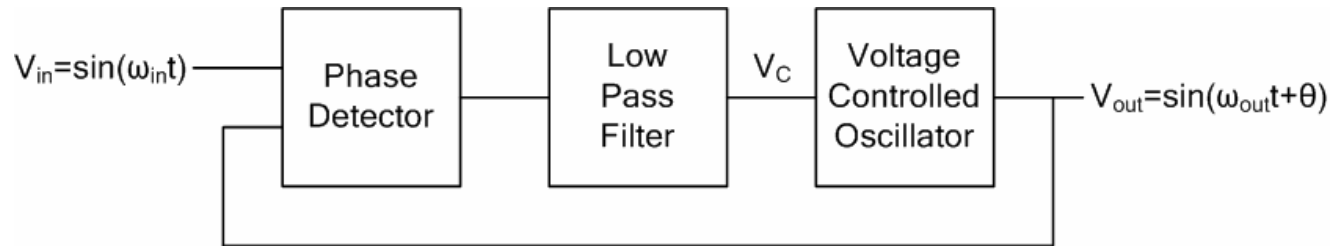
Lect. 22: PLL

PLL (Phase-Locked Loop): A closed-loop feedback system that synchronizes output signal with input signal in frequency and phase.

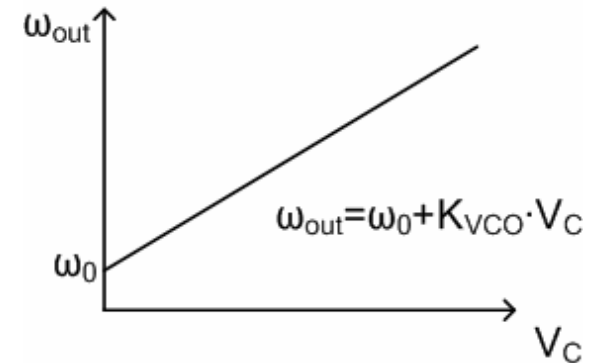
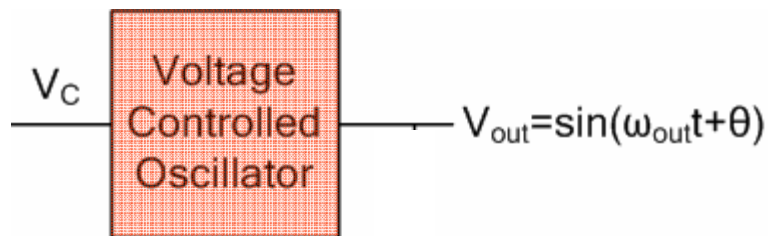


→ Frequency locking of input and output ($\omega_{in} = \omega_{out}$)
with constant phase difference (θ)

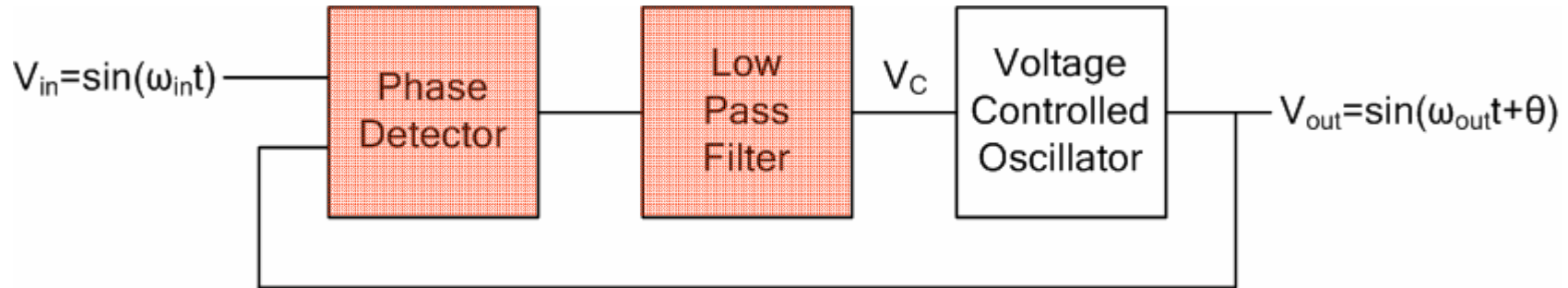
Lect. 22: PLL



VCO (Voltage Controlled Oscillator): Frequency-tunable oscillator, i.e., its output frequency is a function of a control voltage (V_C)



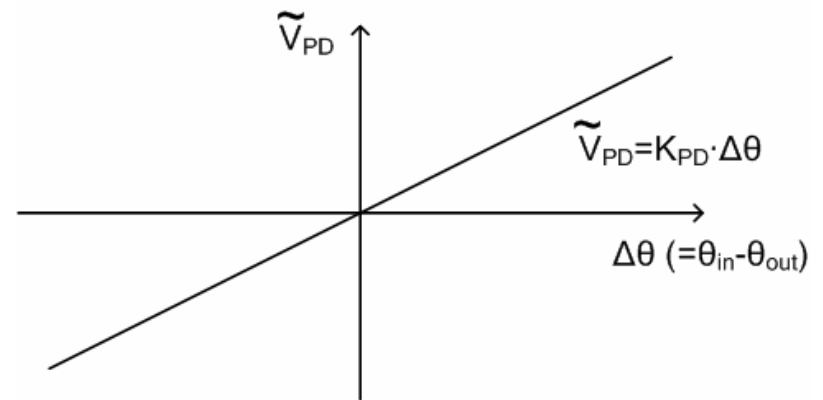
Lect. 22: PLL



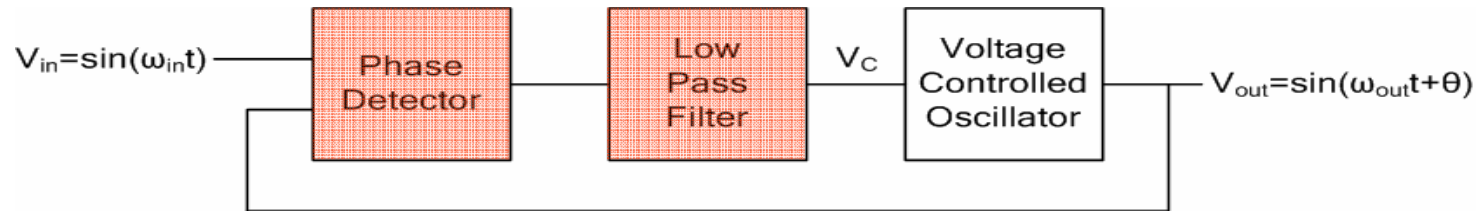
PD (Phase Detector): Compares phases of input and output signal and converts the phase difference to voltage signal

LPF (Low Pass Filter): Takes an average level of PD's output voltage signal

Average of PD's output voltage (\tilde{V}_{PD}) is a linear function of the difference of two input phases



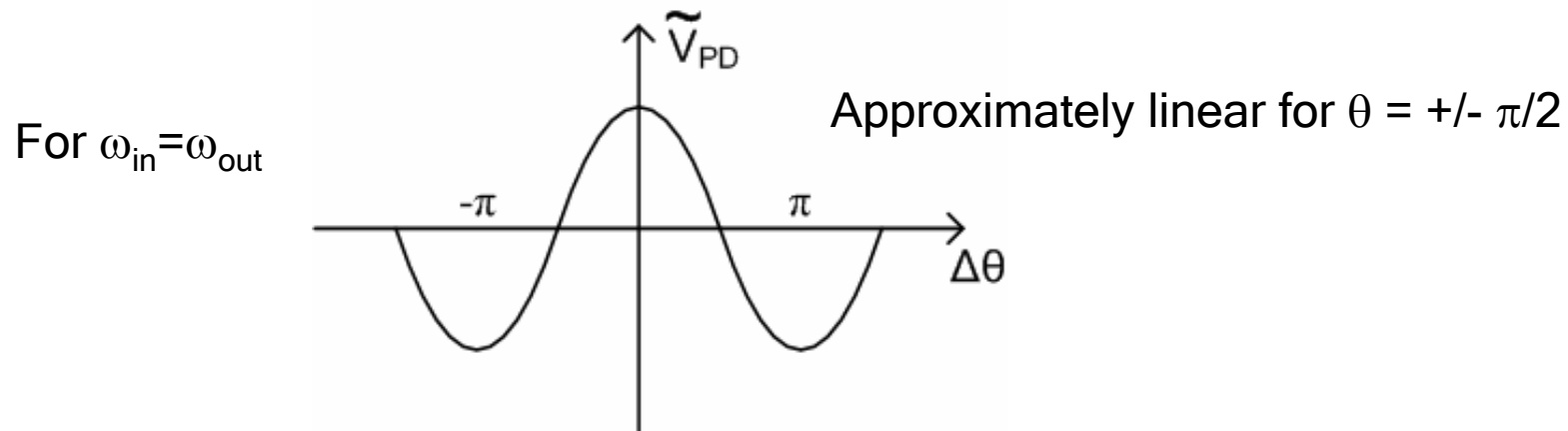
Lect. 22: PLL



PD can be realized with a multiplier

$$\sin(\omega_{in} t) \sin(\omega_{out} t + \Delta\theta) = \frac{1}{2} \left\{ \cos[(\omega_{in} - \omega_{out})t - \Delta\theta] - \cos[(\omega_{in} + \omega_{out})t + \Delta\theta] \right\}$$

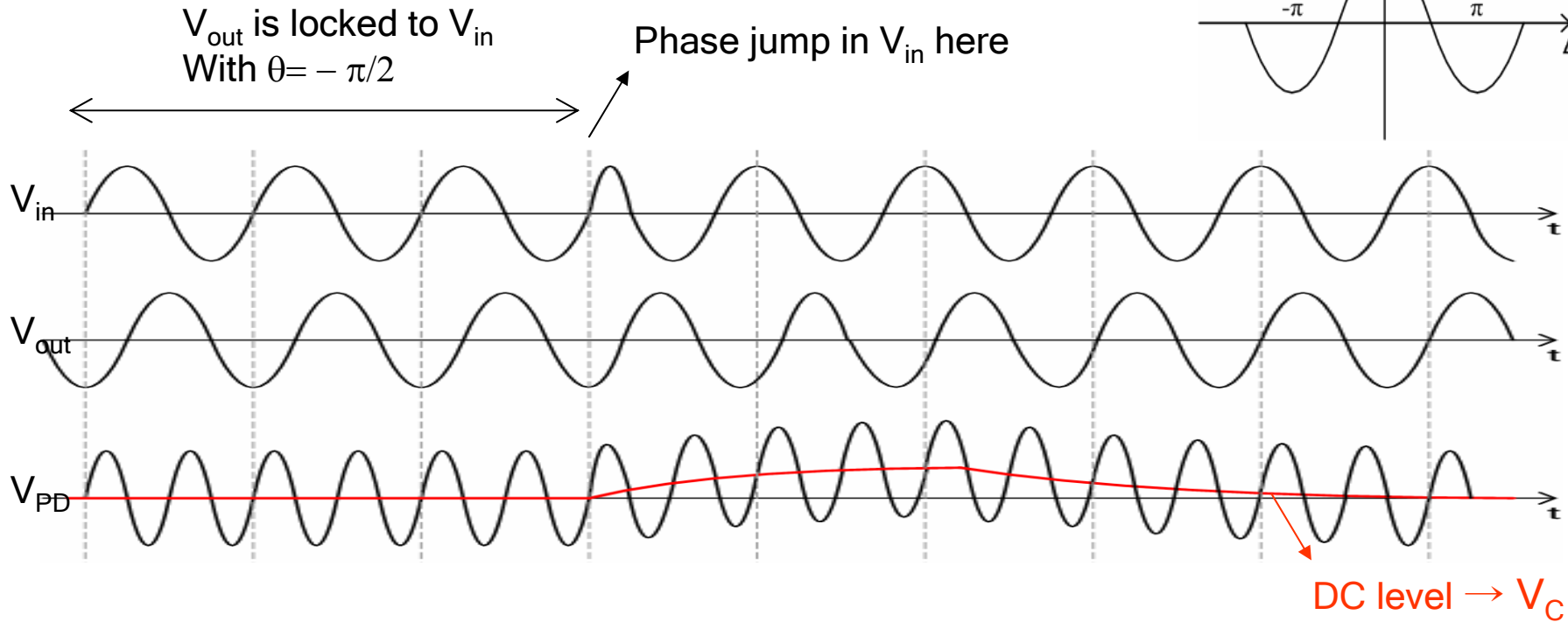
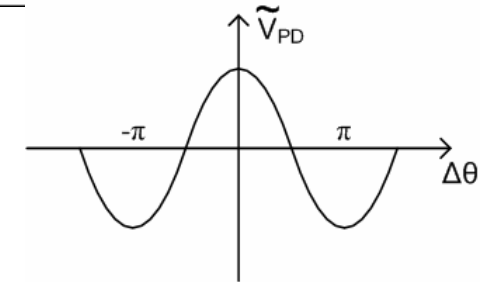
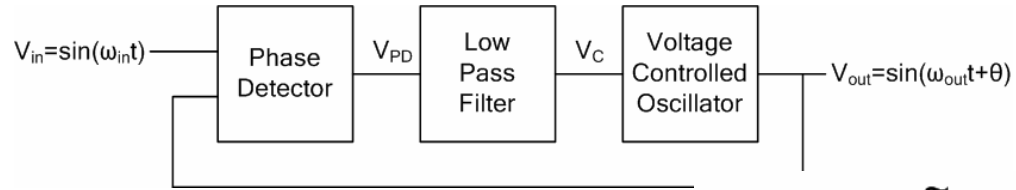
Filtered out by LPF



Lect. 22: PLL

Phase tracking of PLL

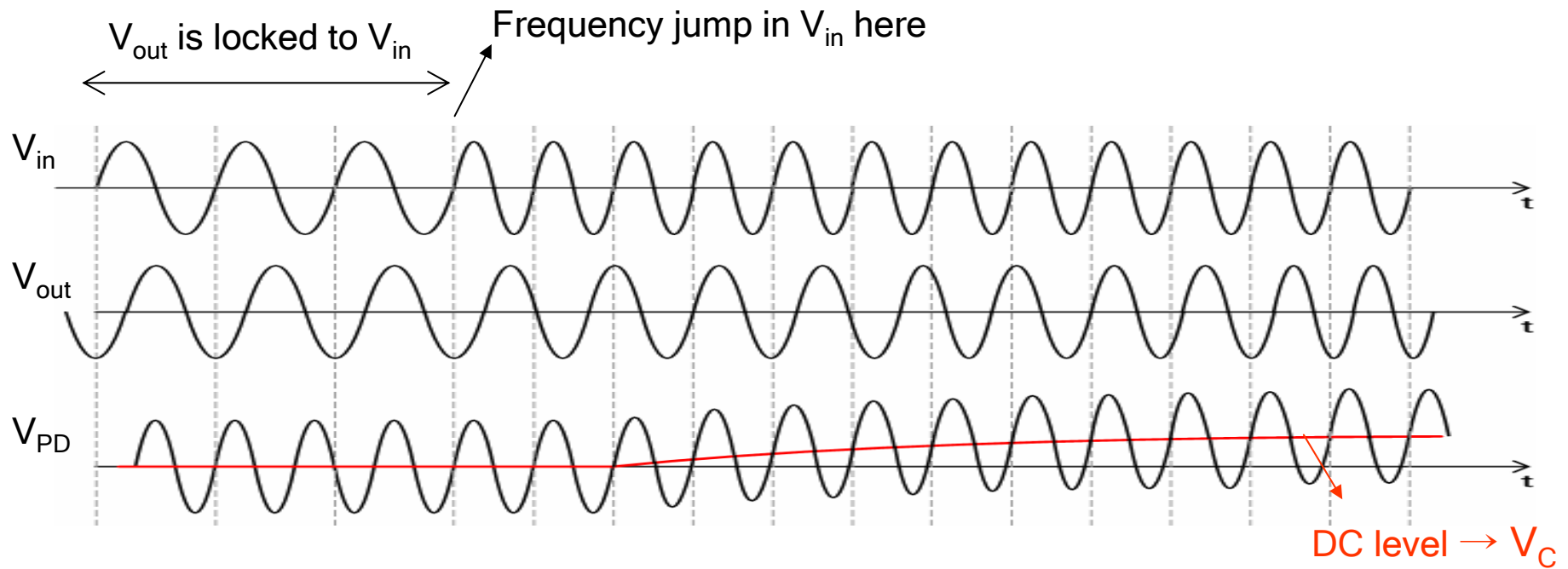
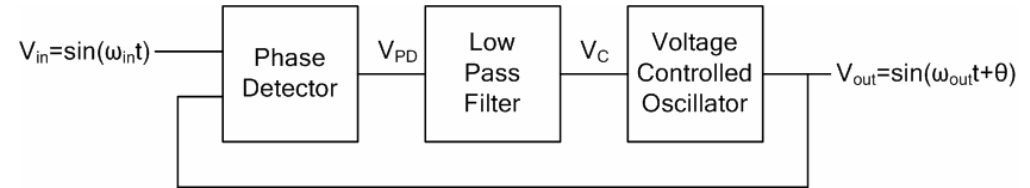
$$\omega_{in} = \omega_{out}$$



Lect. 22: PLL

Frequency tracking of PLL

$$\omega_{in} \neq \omega_{out}$$

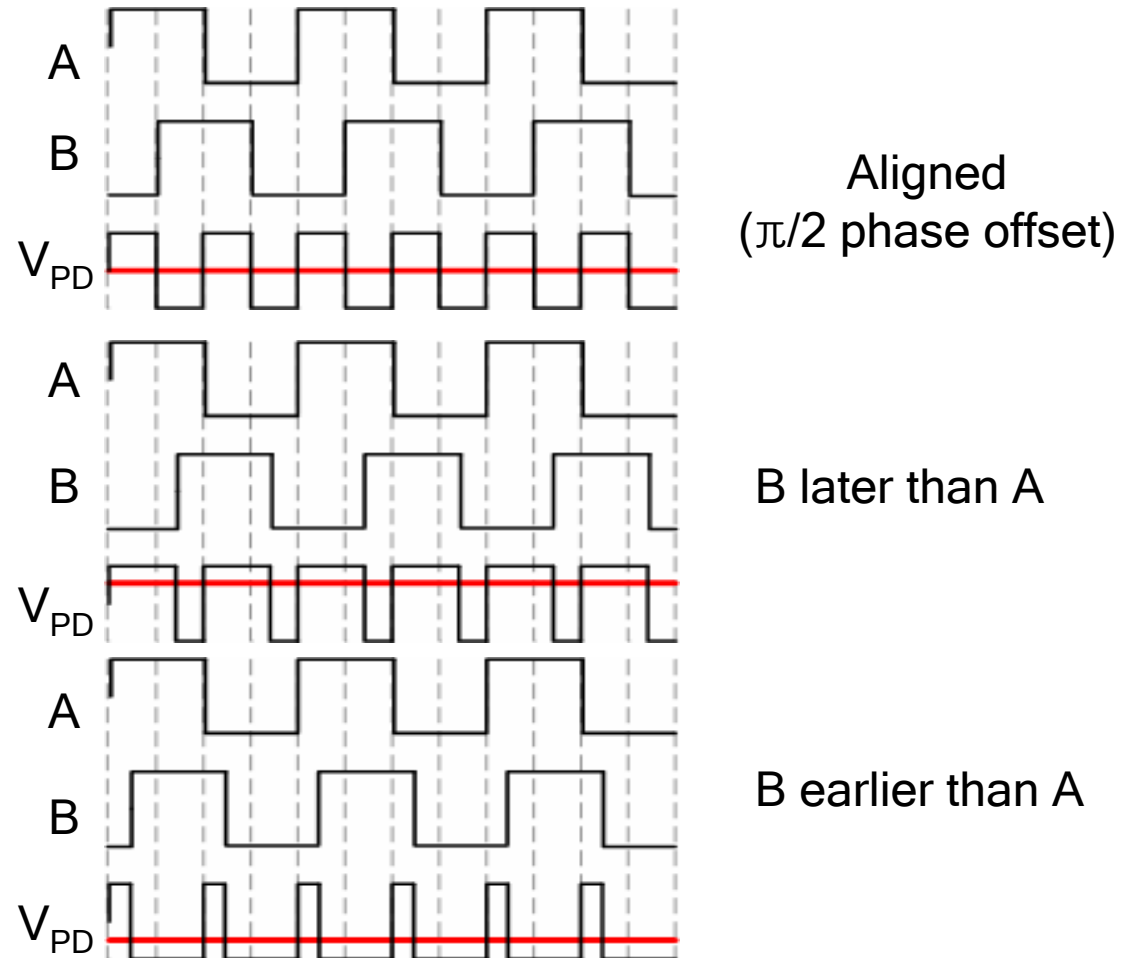


Lect. 22: PLL

XOR gate can be used as PD for digital signals



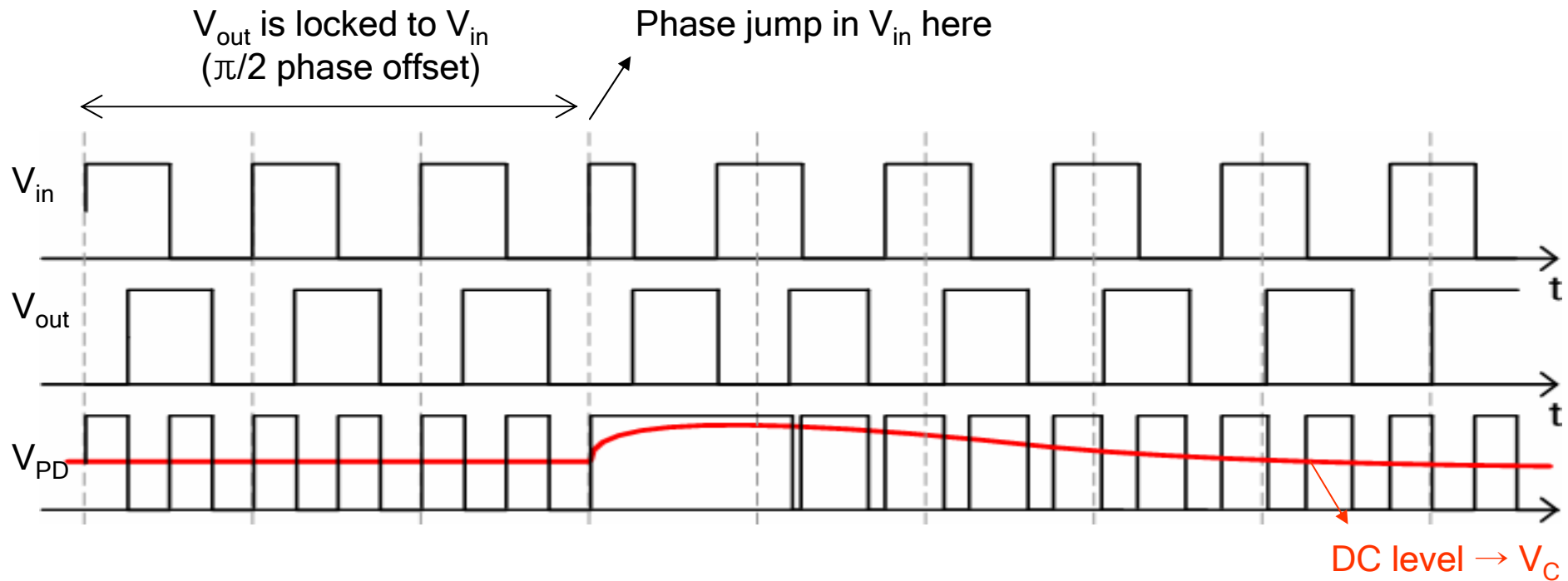
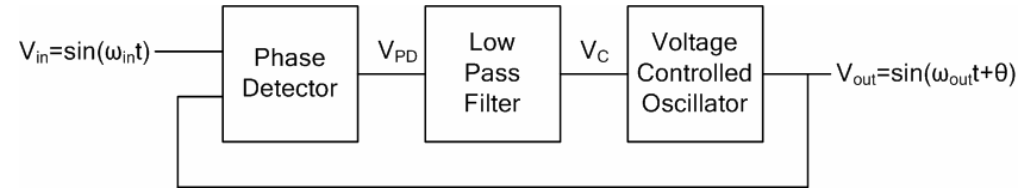
A	B	V_{PD}
0	0	0
0	1	1
1	0	1
1	1	0



Lect. 22: PLL

Phase tracking of PLL

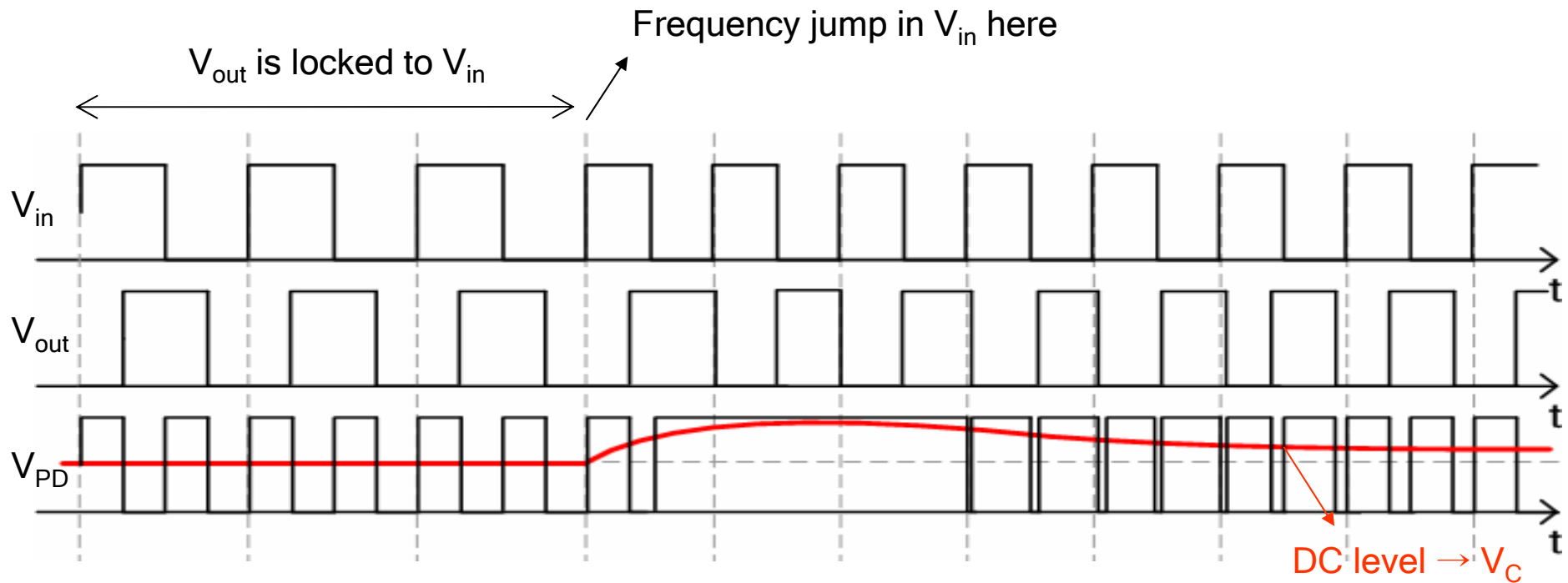
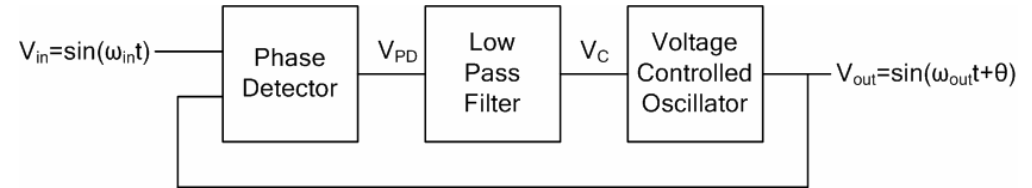
$$\omega_{in} = \omega_{out}$$



Lect. 22: PLL

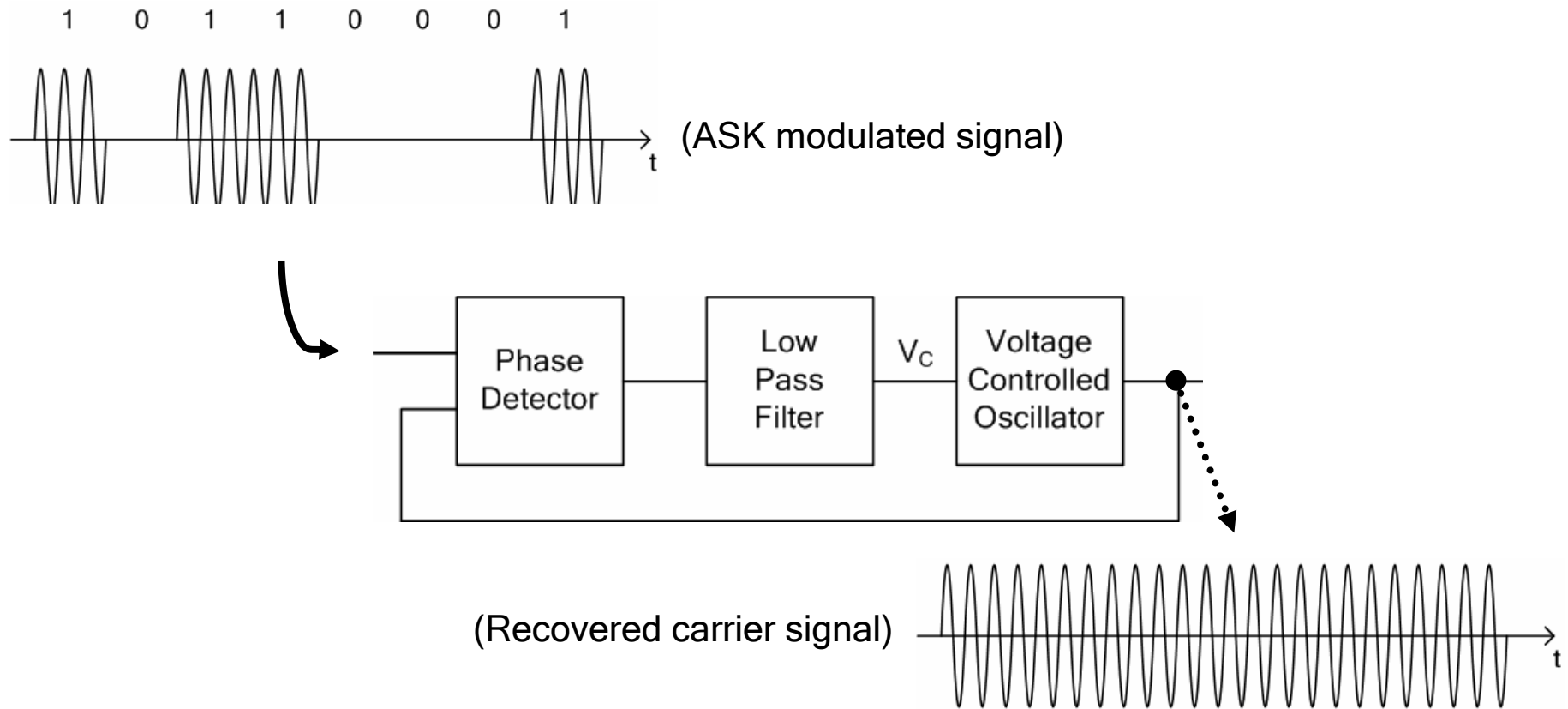
Frequency tracking of PLL

$$\omega_{in} \neq \omega_{out}$$



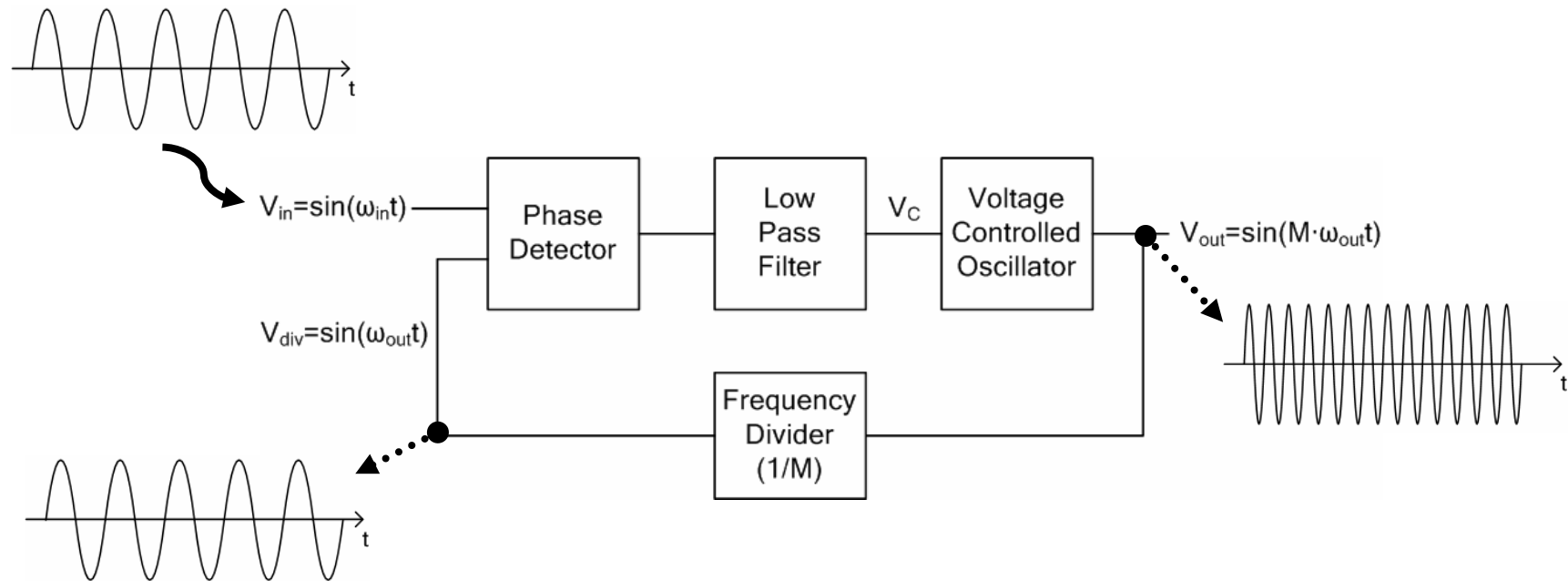
Lect. 22: PLL

Applications of PLL: Carrier Signal Recovery



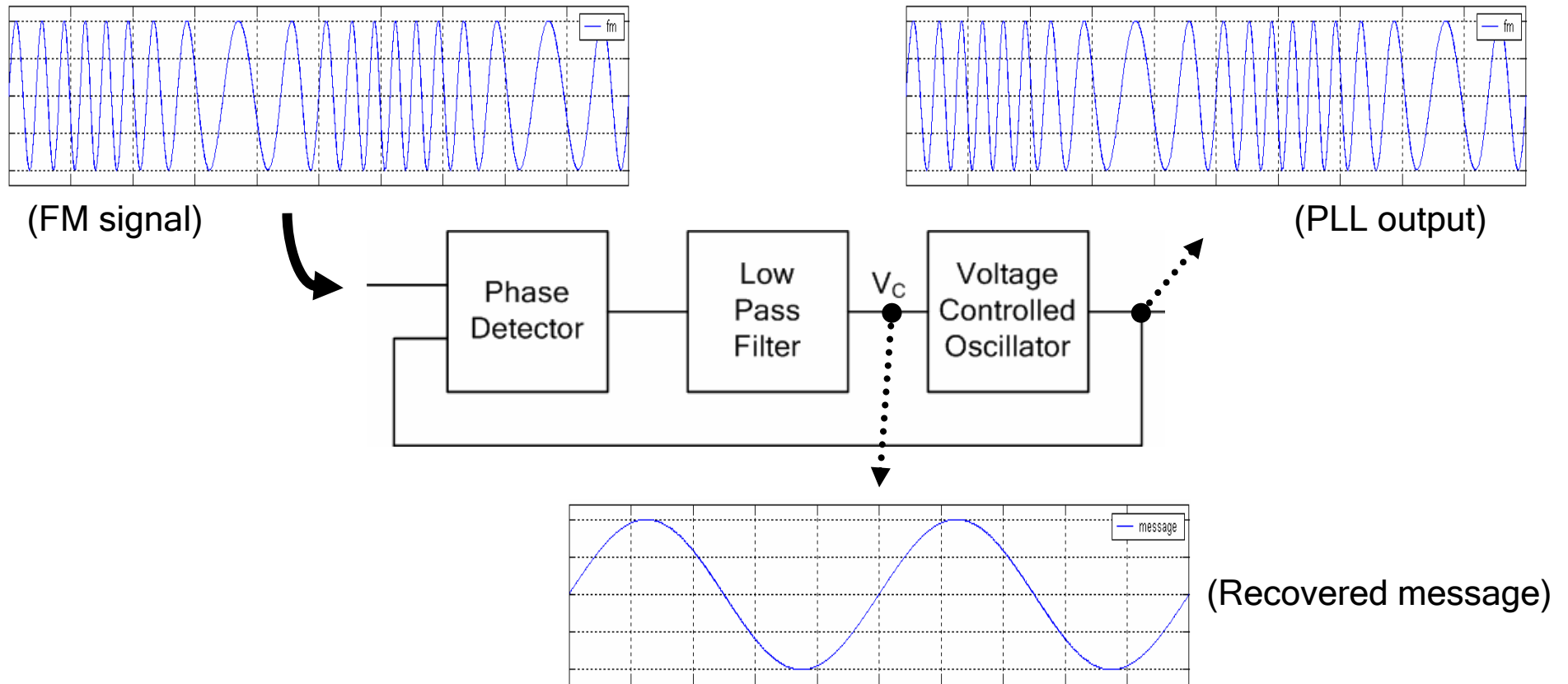
Lect. 22: PLL

Applications of PLL: Frequency Synthesis



Lect. 22: PLL

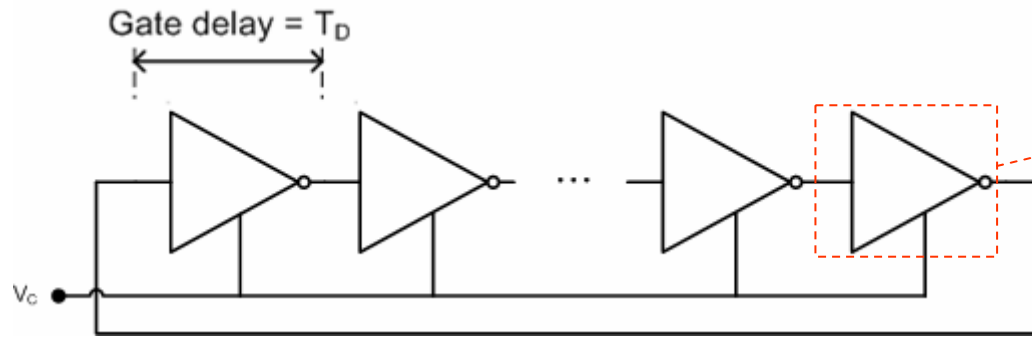
Applications of PLL: Frequency Demodulation



Lect. 22: PLL

Building Blocks: VCO

→ Ring-oscillator (Odd-stage chain of inverters)



$$T = 2nT_D \quad f = \frac{1}{T} = \frac{1}{2nT_D}$$

