EE230-02 RFIC II
Fall 2018

Lecture 17: Phase-Locked Loops 2

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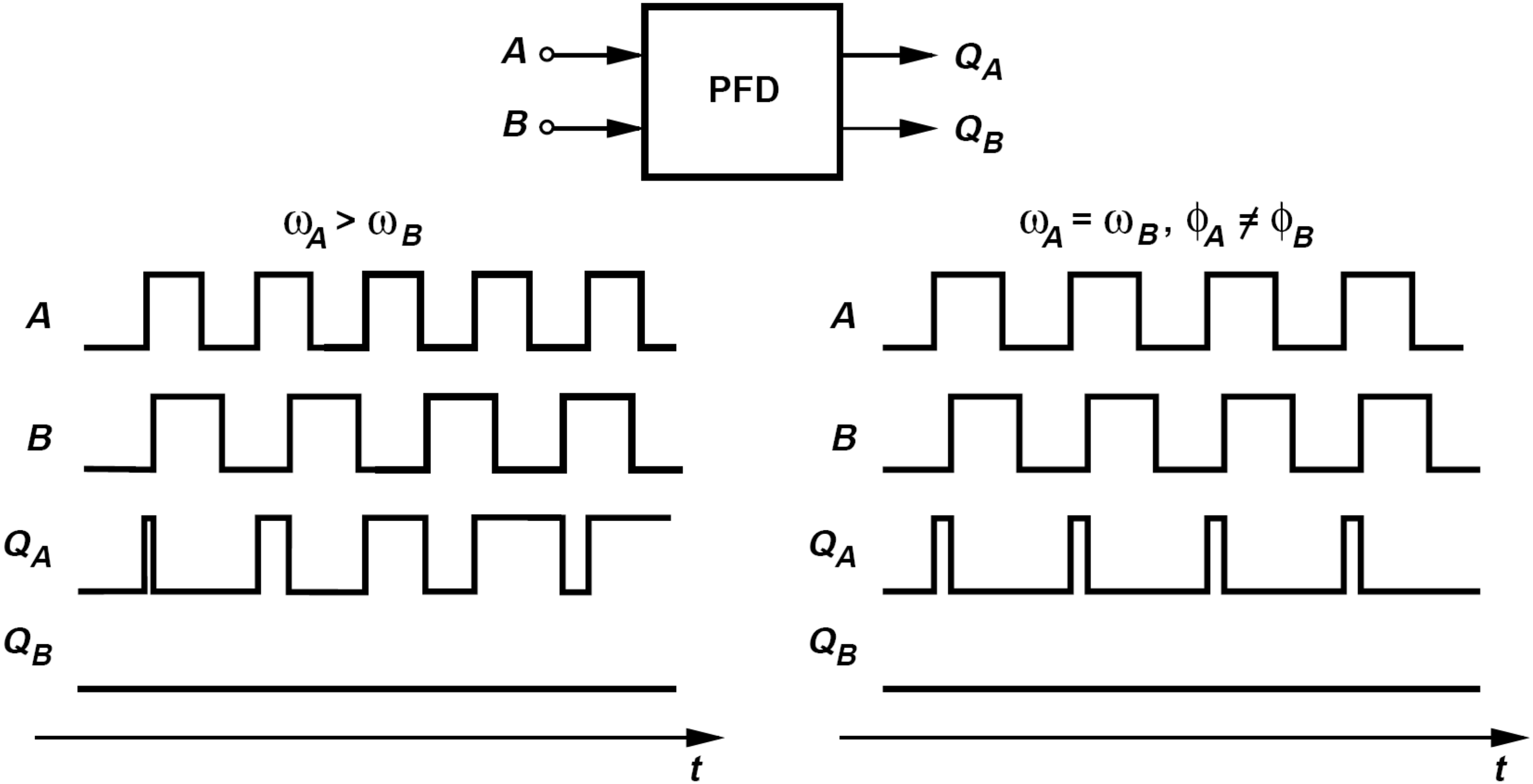
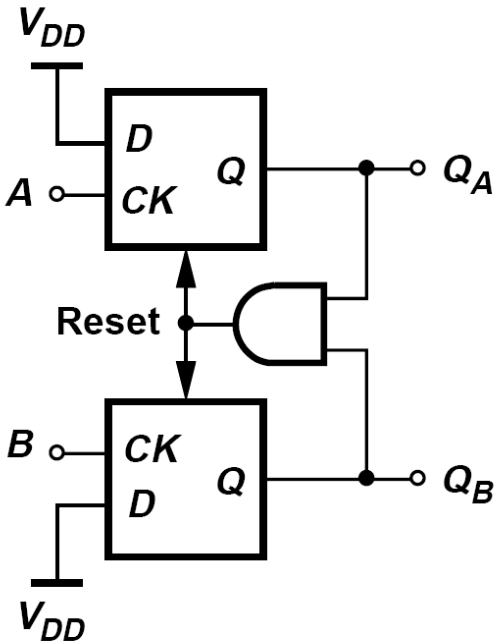
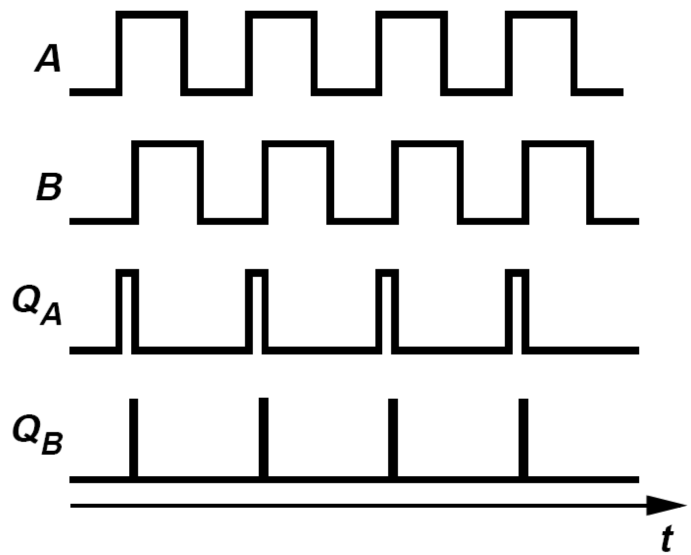
Type-II PLLs: Phase/Frequency Detectors

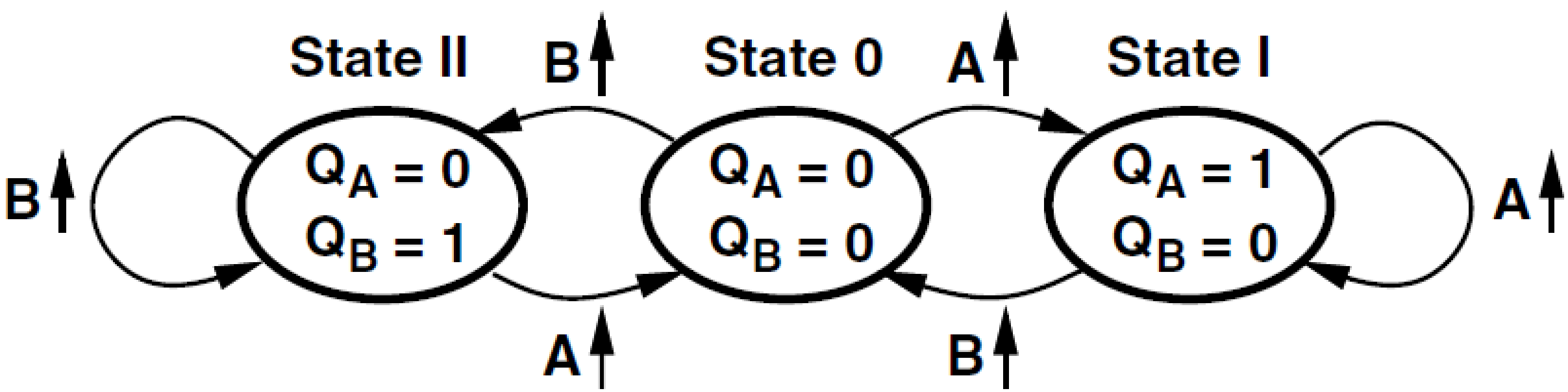


- A rising edge on *A* yields a rising edge on Q_A (if Q_A is low)
- A rising edge on *B* resets Q_A (if Q_A is high)
- The circuit is symmetric with respect to *A* and *B* (and Q_A and Q_B)

PFD: Logical Implementation

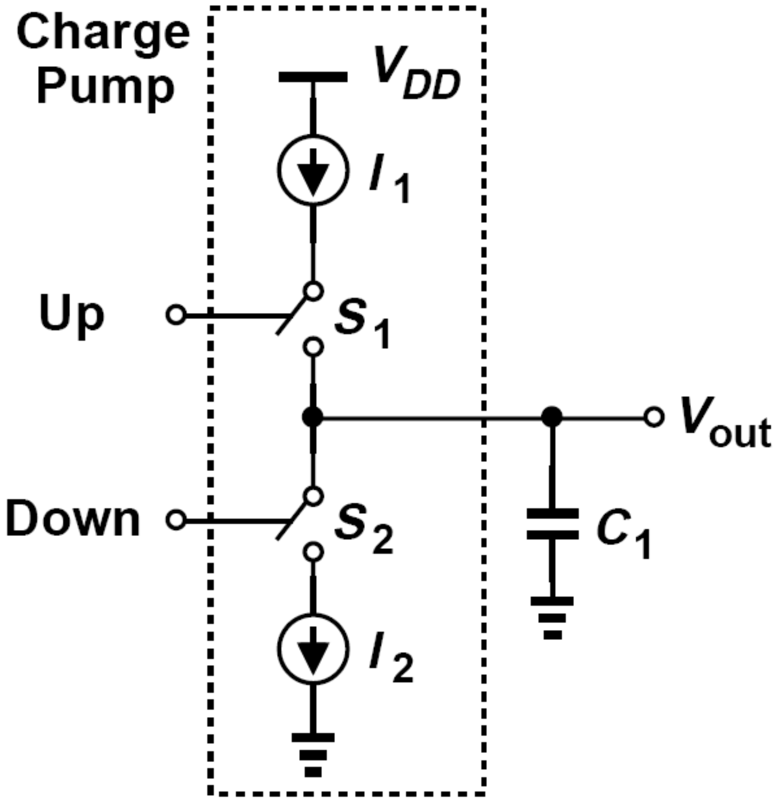




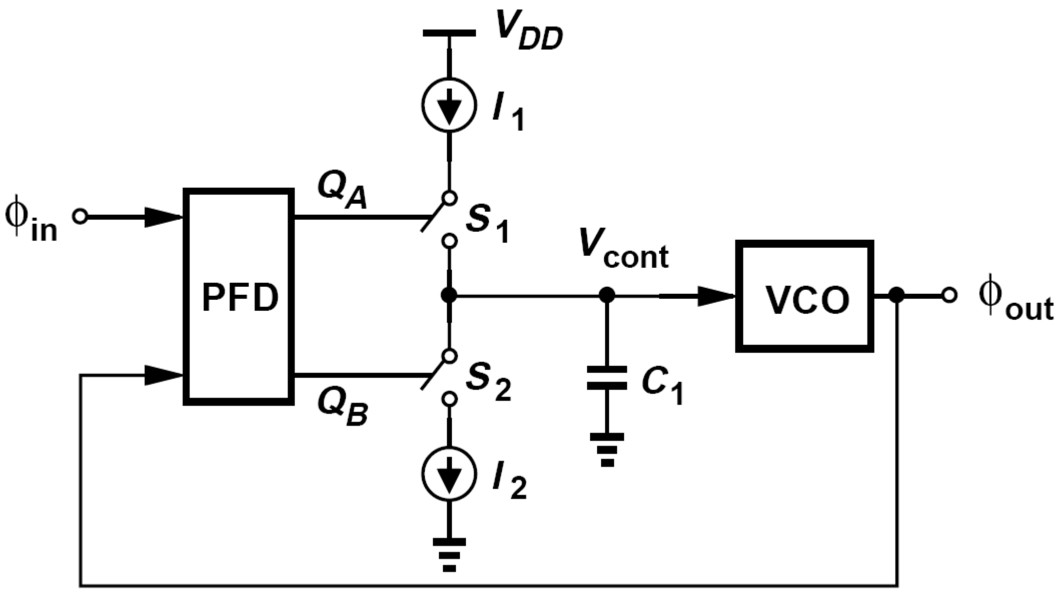


Charge Pumps: an Overview

- Switches S_1 and S_2 are controlled by the inputs "UP" and "Down"
- A pulse on Up for ΔT on S_1 makes V_{out} goes up by $\Delta T \cdot I_1/C_1$
- A pulse on Down yields a drop in V_{out}.



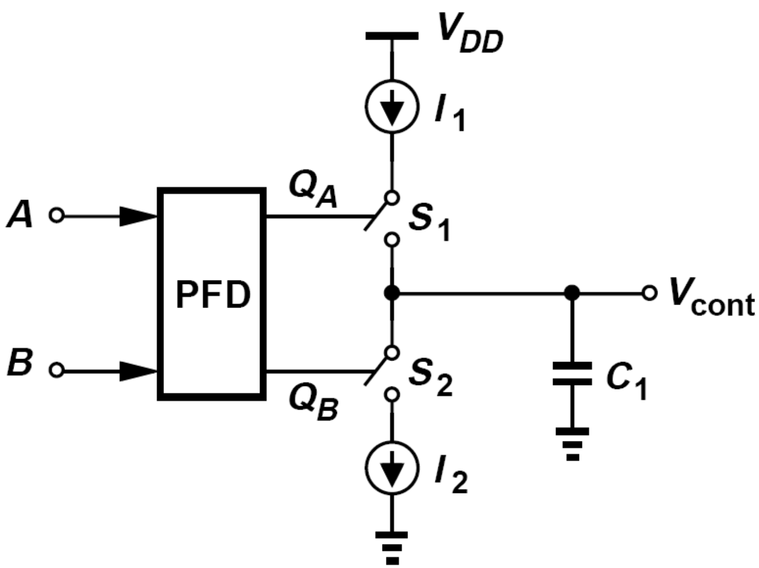
Charge Pump PLLs: First Attempt

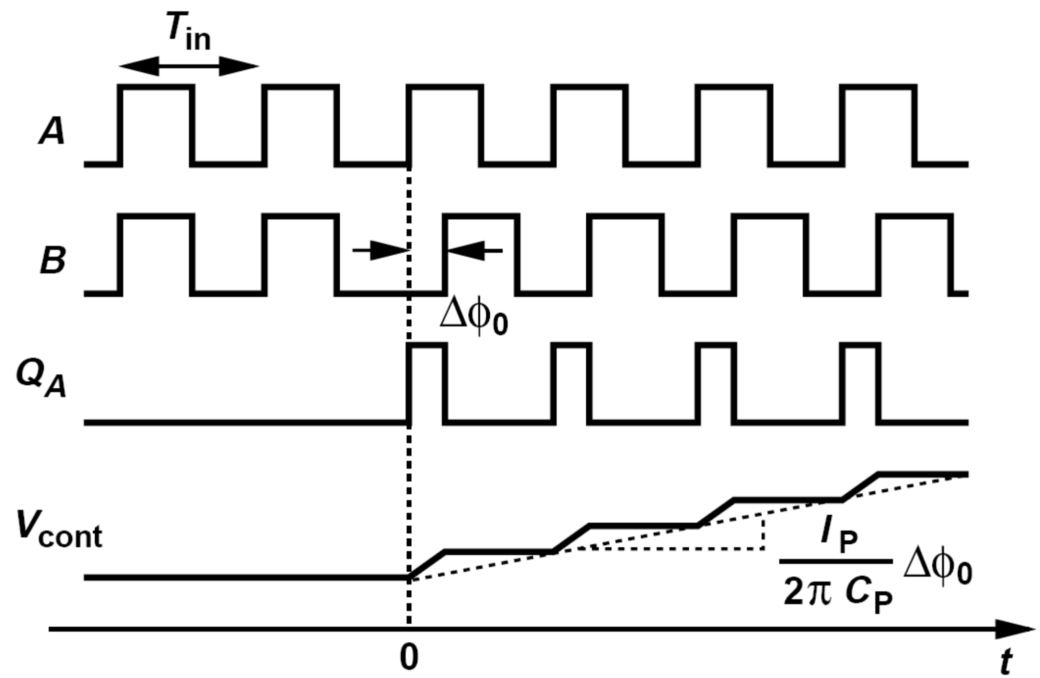


$$H(s) = \frac{\dfrac{I_p}{2\pi C_1 s} \cdot \dfrac{K_{VCO}}{s}}{1 + \dfrac{I_p}{2\pi C_1 s} \cdot \dfrac{K_{VCO}}{s}} = \frac{I_p K_{VCO}}{2\pi C_1 s^2 + I_p K_{VCO}}.$$

- Ideally forces the input phase error to zero because a finite error would lead to an unbounded value for V_{cont}.
- Called Type-II PLL because its open-loop transfer function contains two poles at the origin

Transfer Function: Continuous-Time Approximation

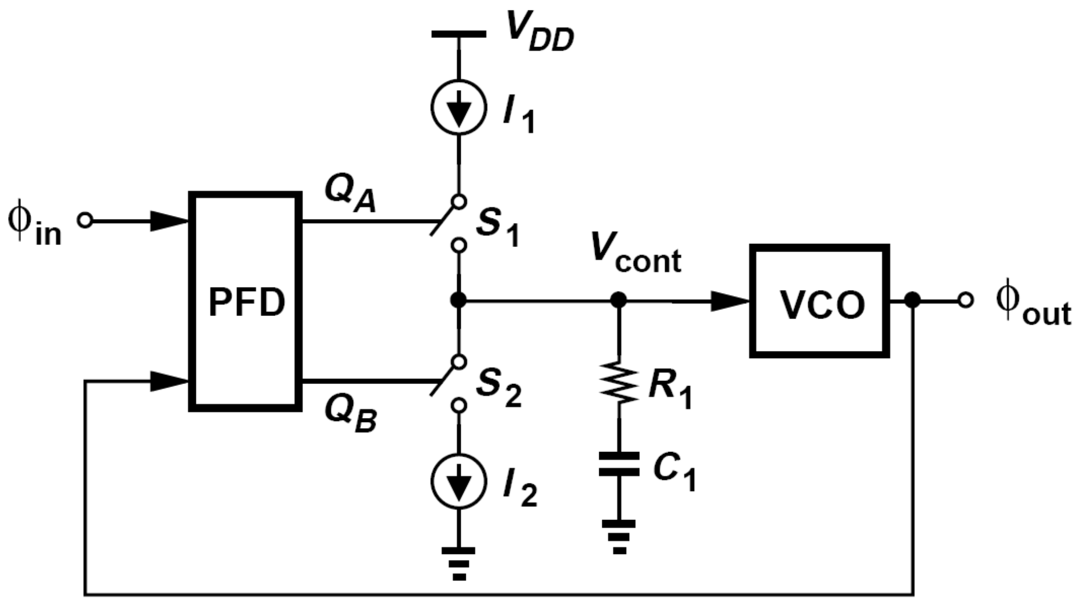




Approximate this waveform by a ramp --- as if the charge pump continuously injected current into C_1

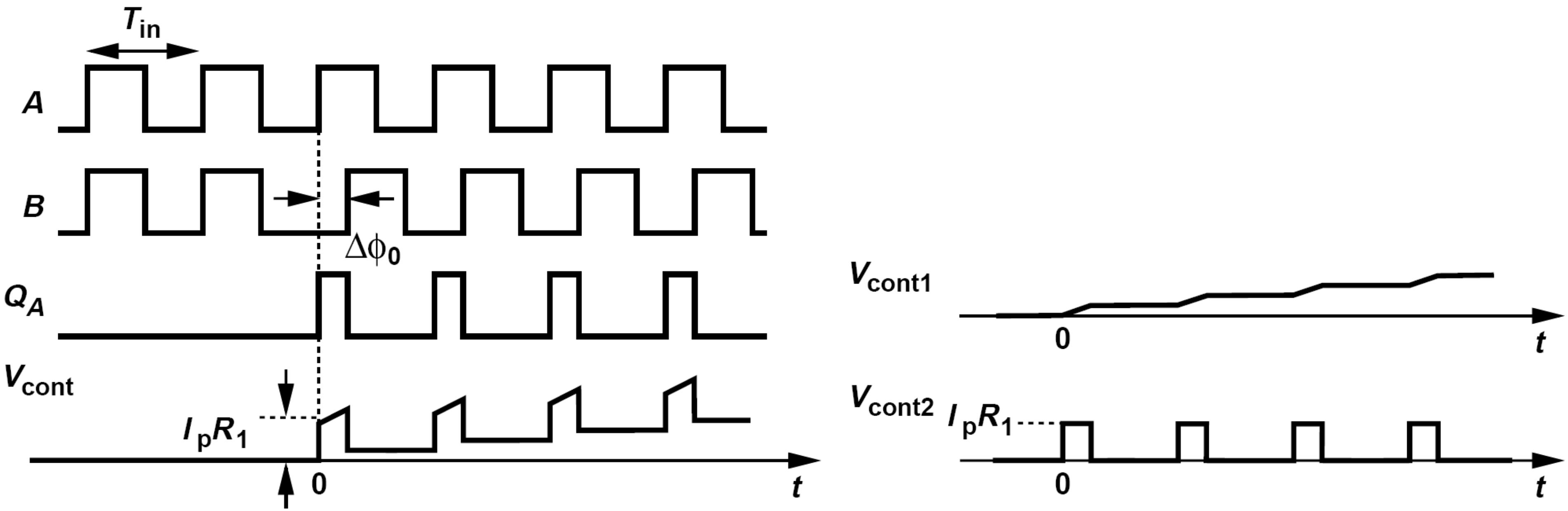
$$V_{cont}(t) \approx \frac{\Delta\phi_0}{2\pi}\frac{I_p}{C_1}tu(t) \quad \Longrightarrow \quad \frac{V_{cont}}{\Delta\phi}(s) = \frac{I_p}{2\pi C_1}\frac{1}{s}$$

Charge-Pump PLL



- If one of the integrators becomes lossy, the system can be stabilized.
- This can be accomplished by inserting a resistor in series with C_1. The resulting circuit is called a "Charge Pump PLL" (CPPLL)

Computation of the Transfer Function



Approximate the pulse sequence by a step of height $(I_pR_1)[\Delta\Phi_0/(2\pi)]$:

$$V_{cont}(t) = \frac{\Delta\phi_0}{2\pi}\frac{I_p}{C_1}tu(t) + \frac{\Delta\phi_0}{2\pi}I_pR_1u(t)$$

$$\frac{V_{cont}}{\Delta\phi}(s) = \frac{I_p}{2\pi}\left(\frac{1}{C_1s} + R_1\right) \Rightarrow H(s) = \frac{\frac{I_pK_{VCO}}{2\pi C_1}(R_1C_1s+1)}{s^2 + \frac{I_p}{2\pi}K_{VCO}R_1s + \frac{I_p}{2\pi C_1}K_{VCO}}$$

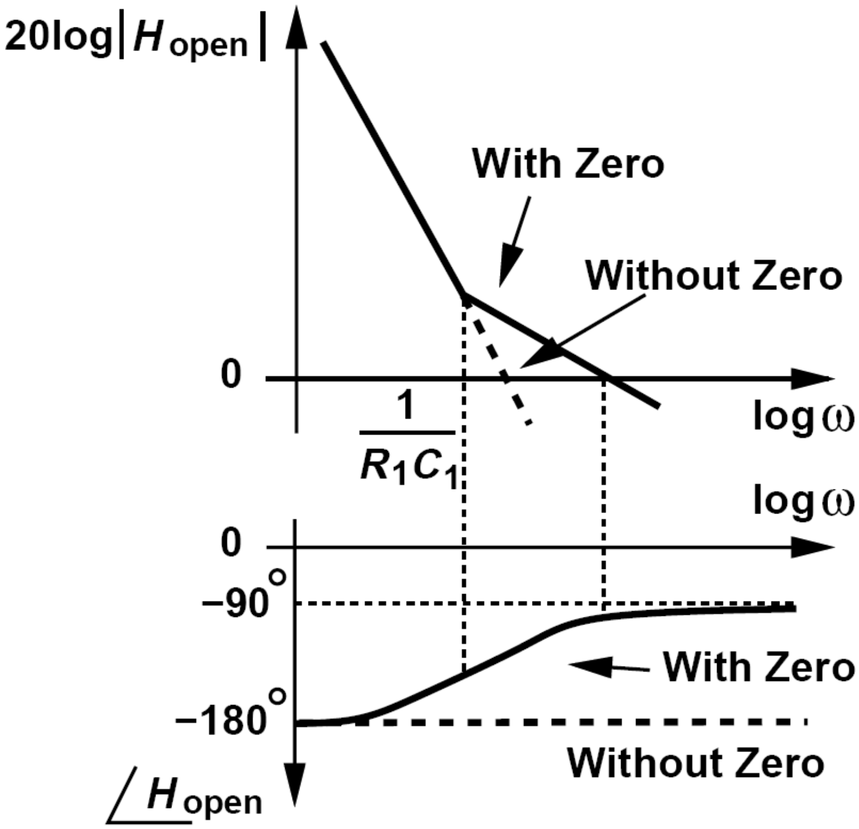
Stability of Charge-Pump PLL

Write the denominator as $s^2 + 2\zeta\omega_n s + \omega_n 2$

$$\zeta = \frac{R_1}{2}\sqrt{\frac{I_p C_1 K_{VCO}}{2\pi}}$$

$$\omega_n = \sqrt{\frac{I_p K_{VCO}}{2\pi C_1}}.$$

- As C_1 increases, so does ζ --- a trend opposite of that observed in type-I PLL: trade-off between stability and ripple amplitude thus removed.



Closed-loop poles are given by

$$\omega_{p1,2} = [-\zeta \pm \sqrt{\zeta^2 - 1}]\omega_n$$

A closed-loop zero at $-\omega_n / 2\zeta$

$$\frac{V_{cont}}{\Delta\phi}(s) = \frac{I_p}{2\pi}\left(\frac{R_1 C_1 s + 1}{C_1 s}\right)$$