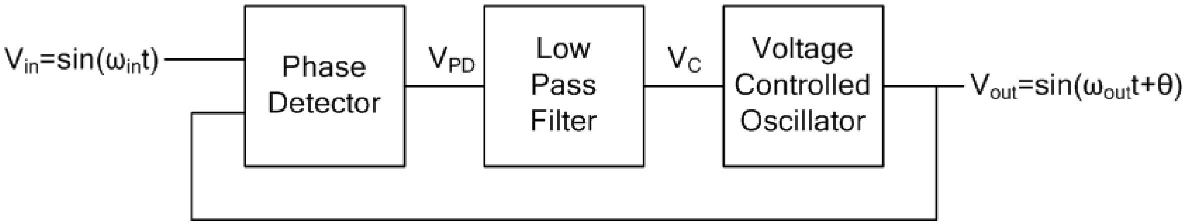
Lect. 27: Charge-Pump PLL



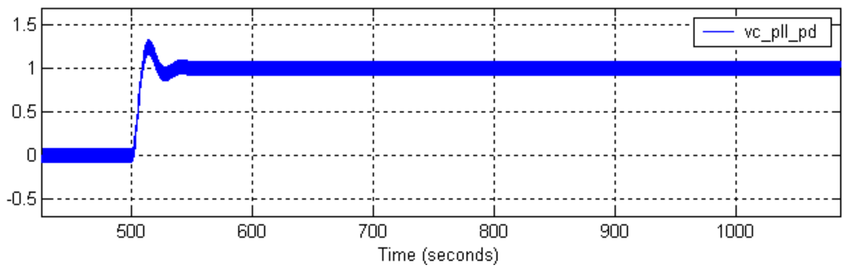
$$H(s) = \frac{K_{PD} K_{VCO} \omega_p}{s^2 + \omega_p s + K_{PD} K_{VCO} \omega_p}$$

This type of PLL has very narrow locking range

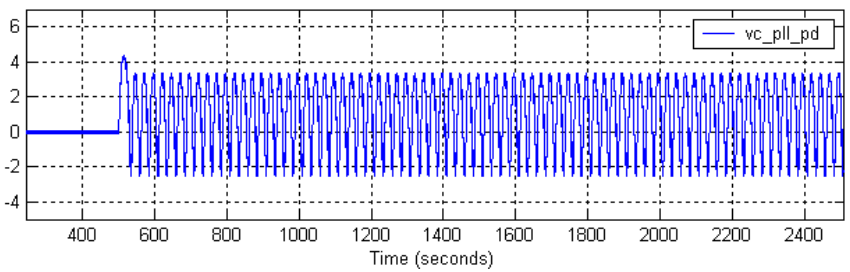
Step response simulation:

$$f_{in} = 1Hz,\ K_{PD} = 5V/rad,\ K_{VCO} = 2\pi \times 0.01 rad/s/V,\ and\ f_p = 0.032Hz$$

$\Delta f_{in} = 0.01Hz$



$\Delta f = 0.05Hz$



Lect. 27: Charge-Pump PLL

Limitation is due to narrow linear phase detection range

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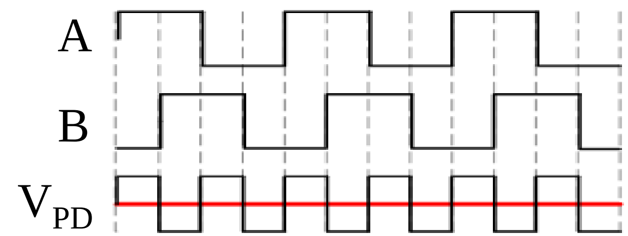
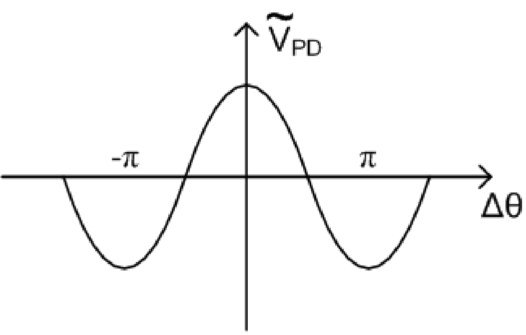
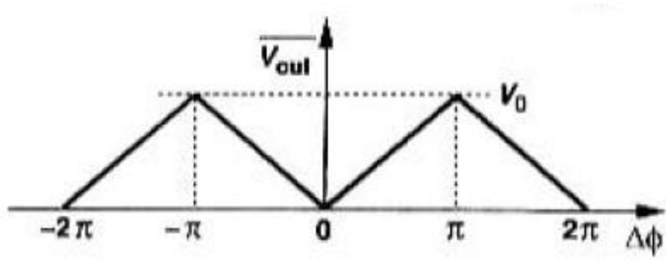
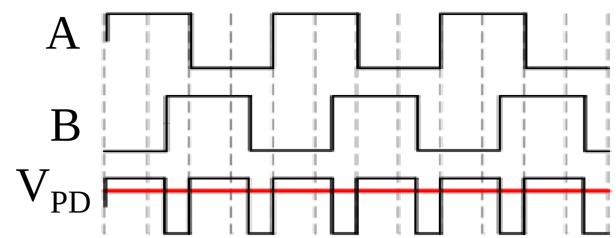


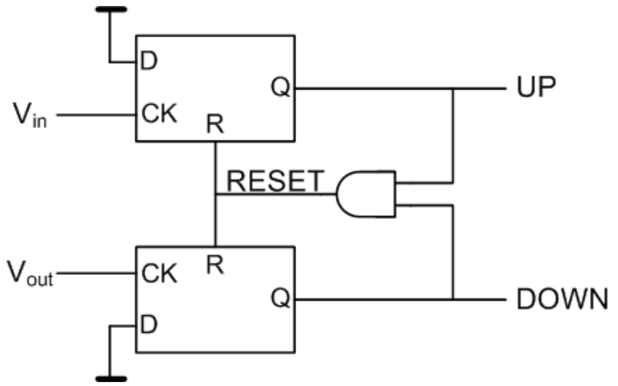


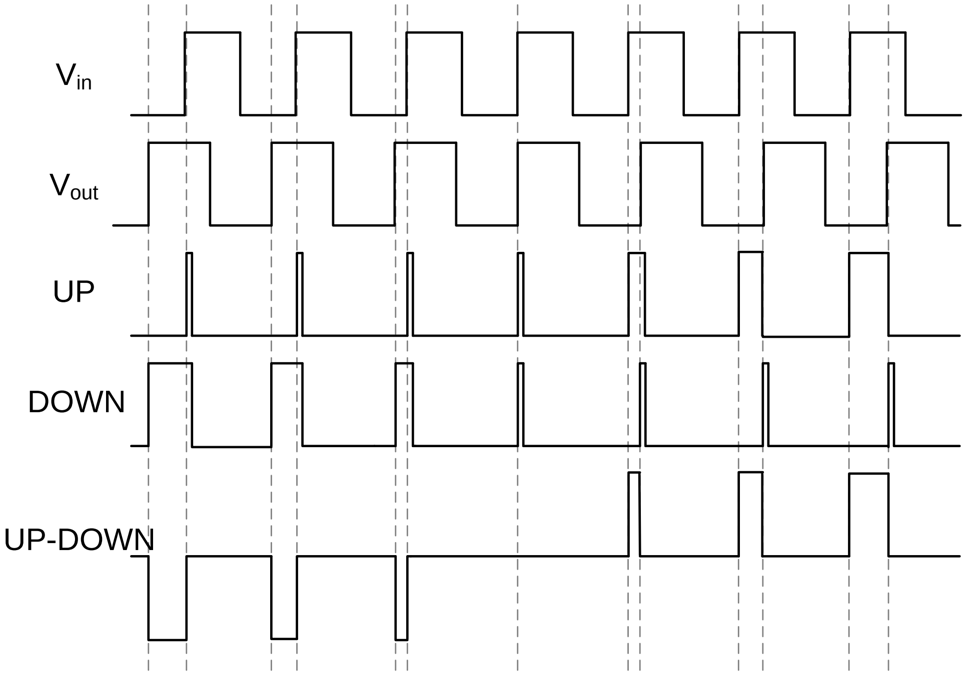




Lect. 27: Charge-Pump PLL

Wider range phase detection?

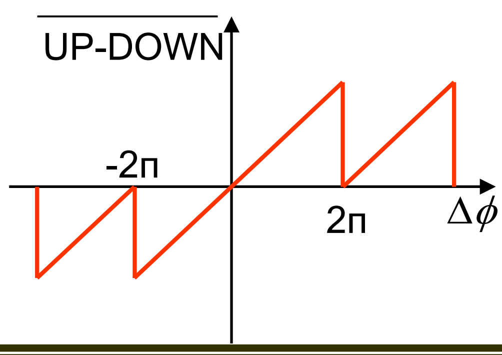




D Flip-flop:

Q becomes D at the rising clock edge
Q resets when R is HIGH

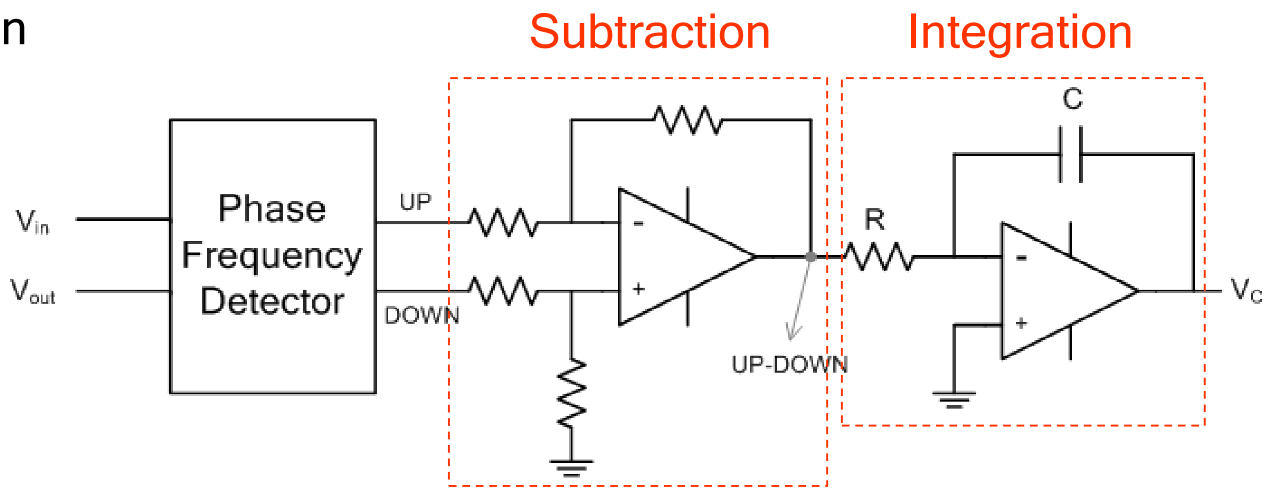
➔ Phase and Frequency Detector (PFD)



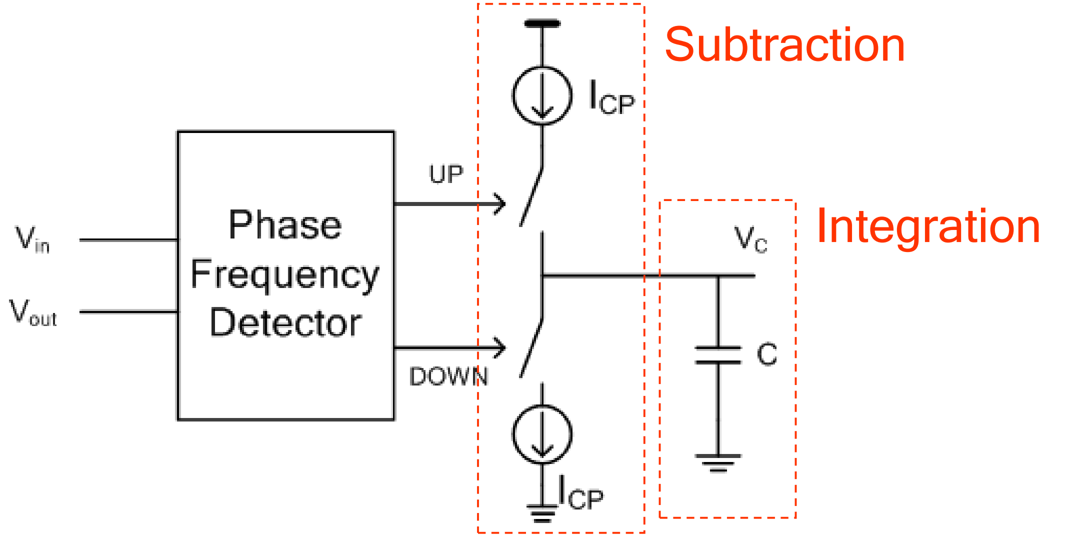
Lect. 27: Charge-Pump PLL

Subtraction and integration

Voltage mode
using OP amplifiers

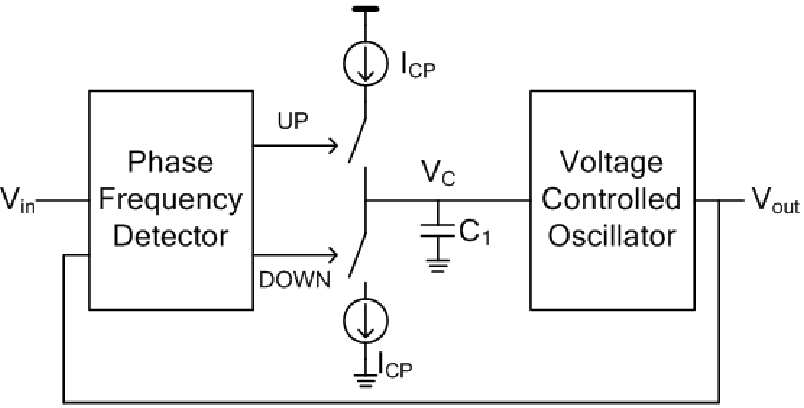


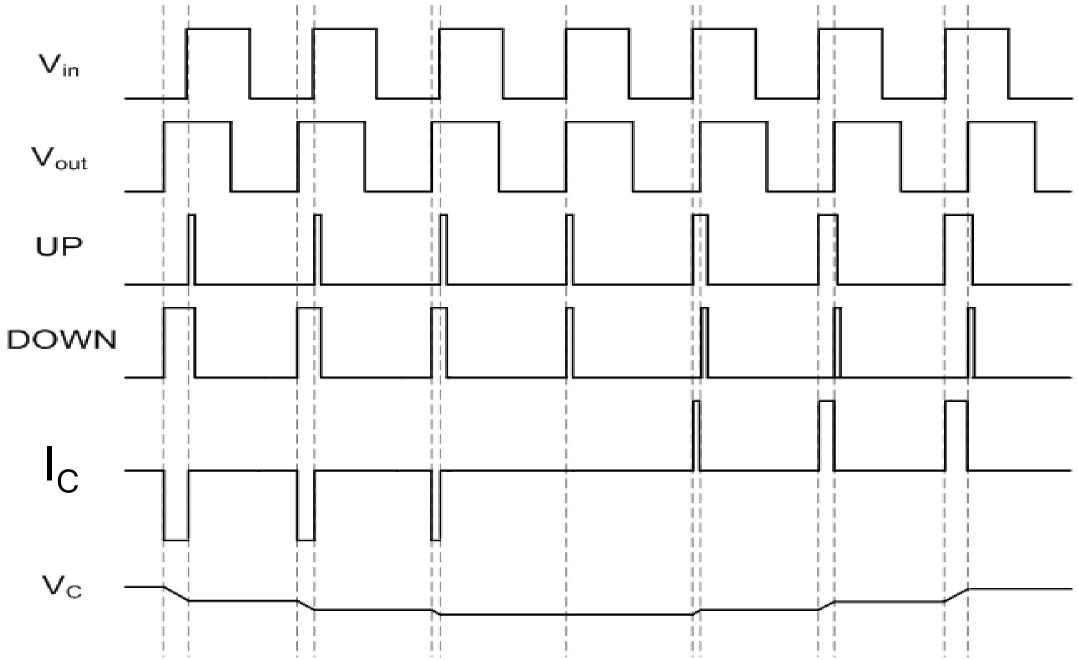
Current mode
using charge pump



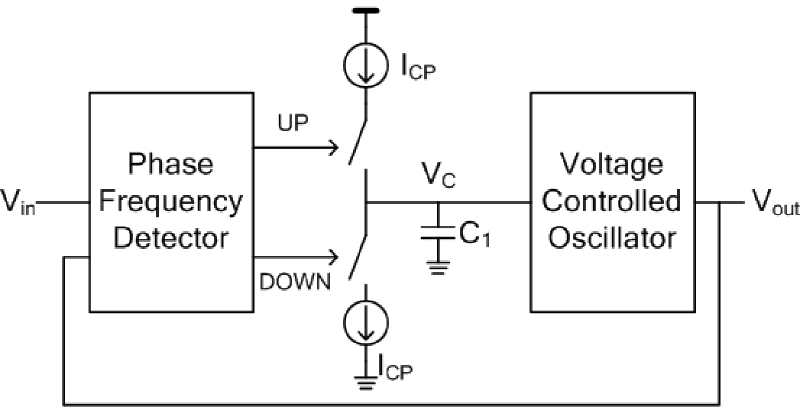
W.-Y. Choi

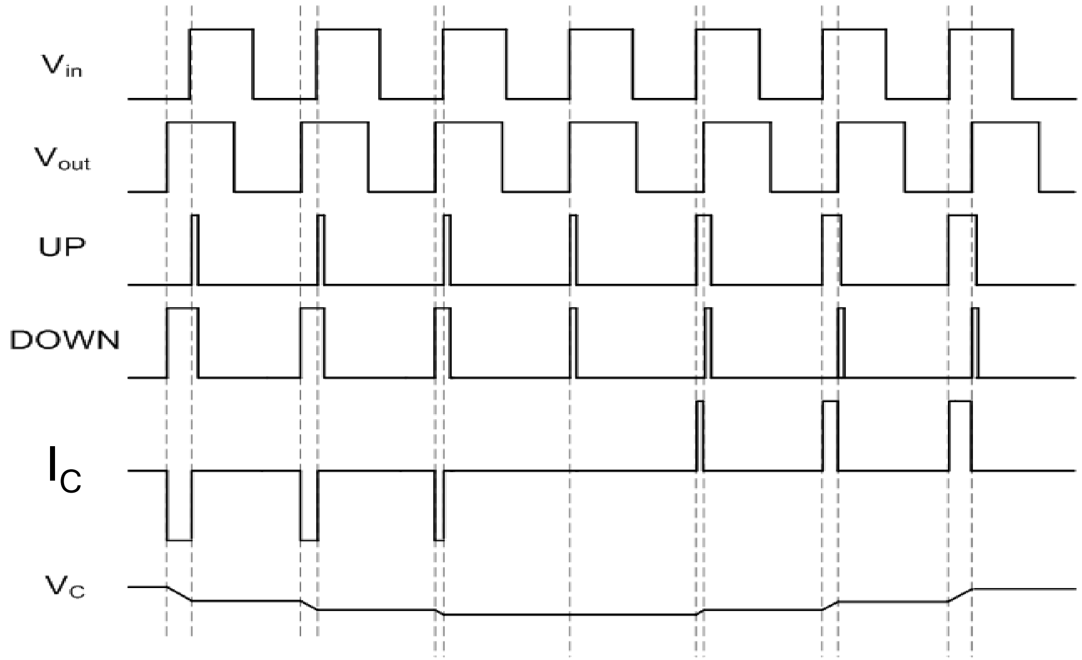
Charge Pump PLL



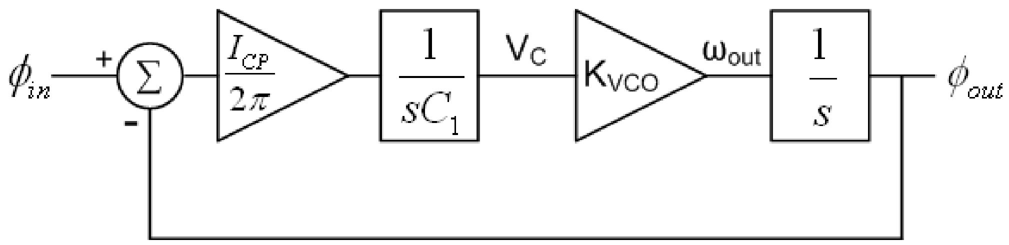


Lect. 27: Charge-Pump PLL

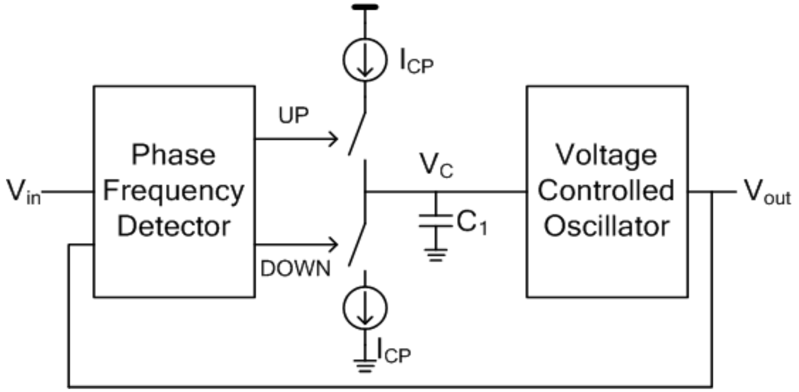


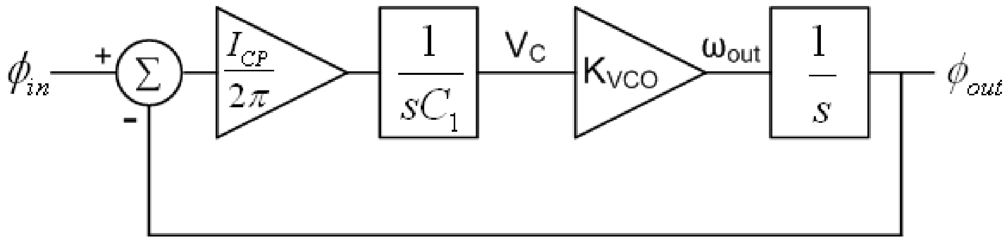


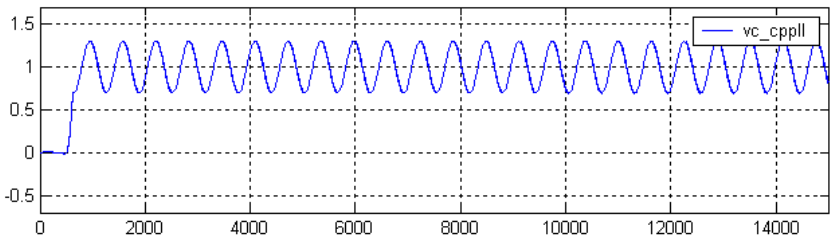
Linear continuous-time model for charge-pump PLL

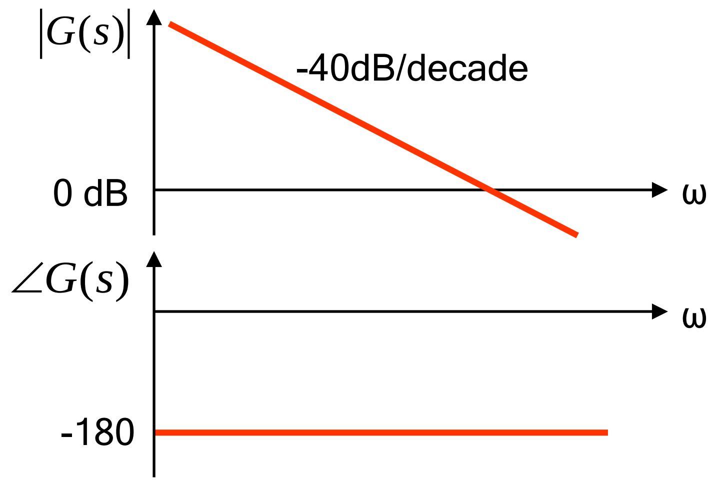


Lect. 27: Charge-Pump PLL







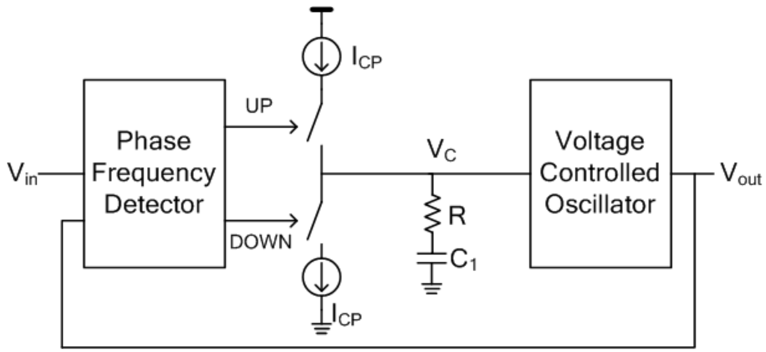


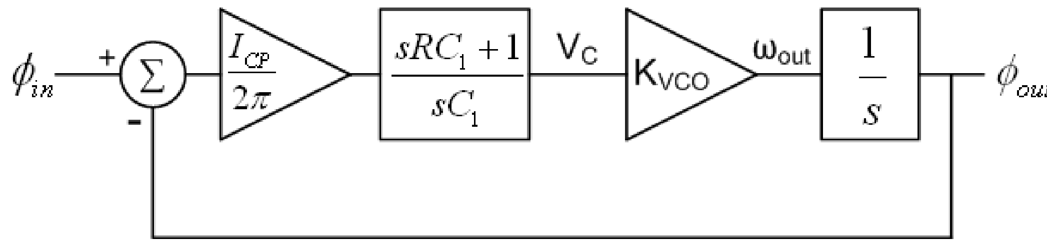
Open loop gain:

$$G(s) = \frac{1}{2\pi} I_{CP} K_{VCO} \frac{1}{s^2 C_1}$$

No phase margin → Unstable

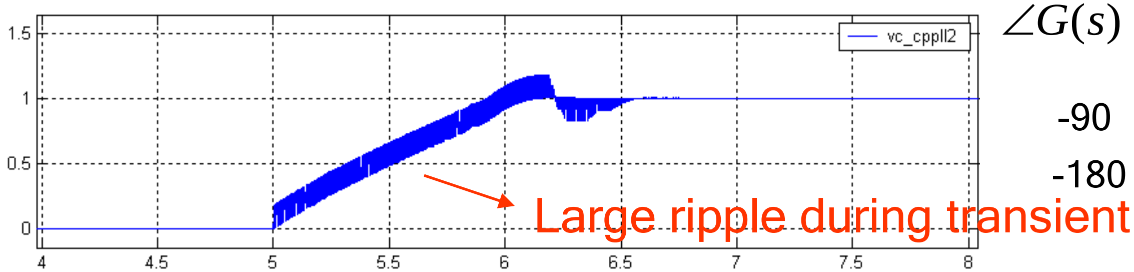
Lect. 27: Charge-Pump PLL

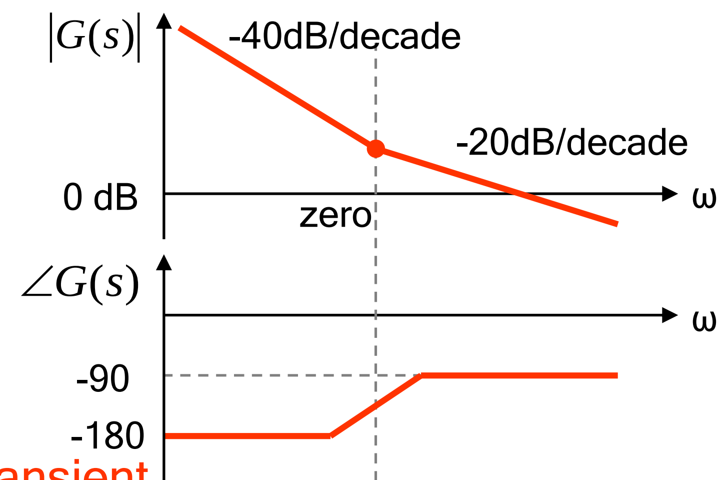




Open loop gain:

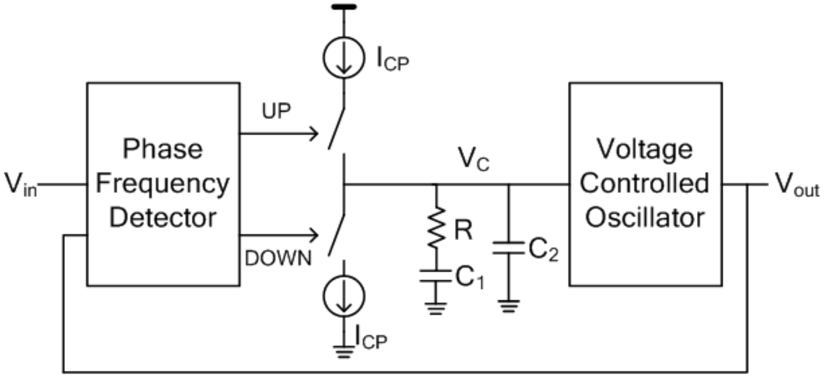
$$G(s) = \frac{1}{2\pi} I_{CP} K_{VCO} \frac{sRC_1 + 1}{s^2 C_1}$$

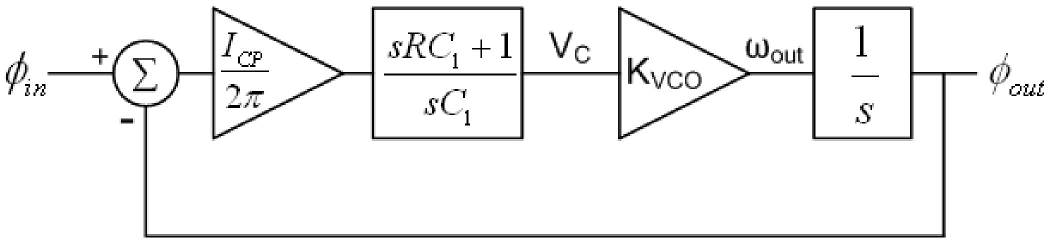




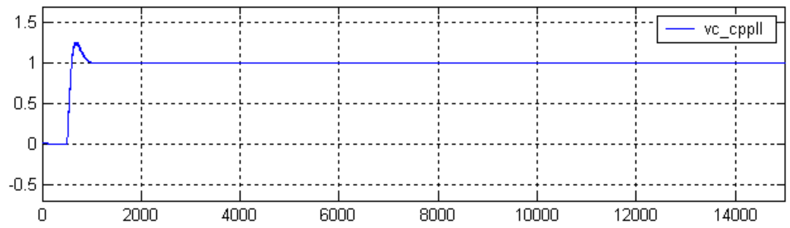
Lect. 27: Charge-Pump PLL

Charge Pump PLL





➔Ripple reduction with small C_2 ($\approx C_1/10$)



Open loop gain:

Simplification as 2nd-order system

$$G(s) \sim \frac{1}{2\pi} I_{CP} K_{VCO} \frac{sRC_1 + 1}{s^2 C_1}$$

Lect. 27: Charge-Pump PLL

$$G(s) = \frac{1}{2\pi} I_{CP} K_{VCO} \frac{sRC_1 + 1}{s^2 C_1}$$

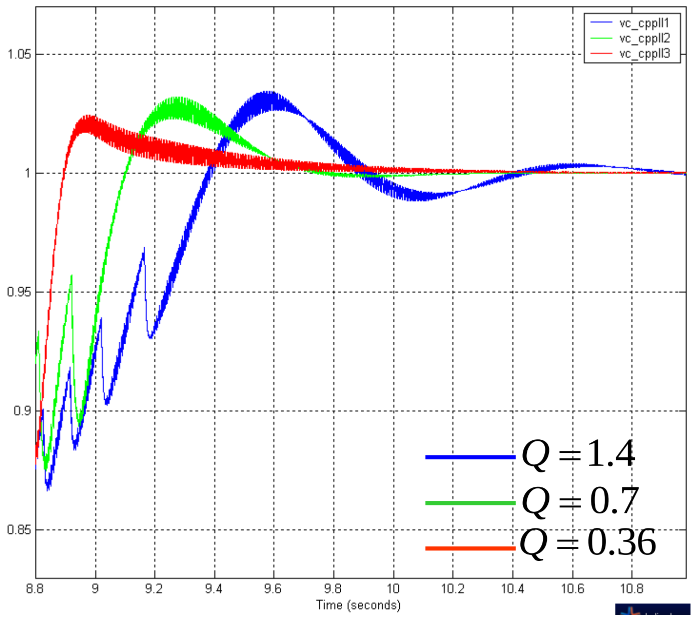
Closed loop transfer function

$$H(s) = \frac{\frac{I_{CP}}{2\pi C_1} K_{VCO} (RC_1 s + 1)}{s^2 + \frac{I_{CP}}{2\pi} K_{VCO} R s + \frac{I_{CP}}{2\pi C_1} K_{VCO}}$$

$$\omega_0 = \sqrt{\frac{I_{CP} K_{VCO}}{2\pi C_1}} \qquad Q = \frac{1}{R\sqrt{I_{CP} C_1 K_{VCO}}}$$

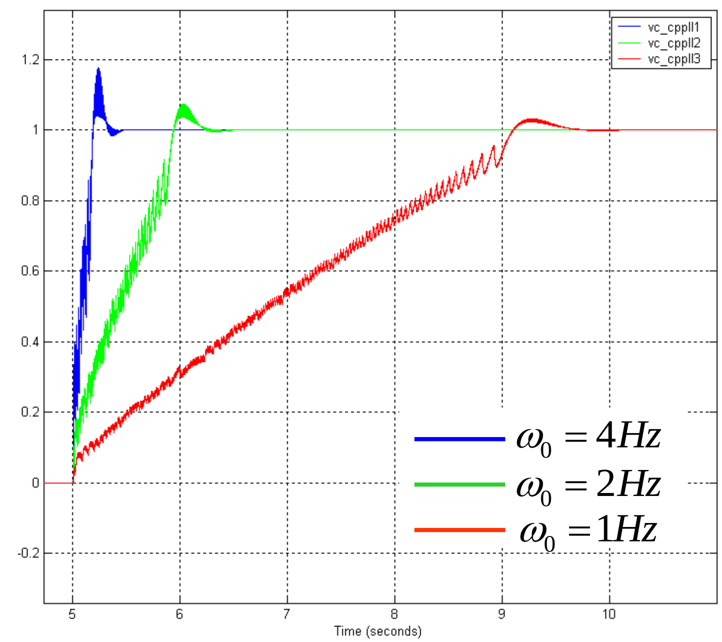
Lect. 27: Charge-Pump PLL

$$f_{in} = 200Hz$$
$$I_{CP} = 100\mu A$$
$$K_{VCO} = 2\pi \times 100 rad/s/V$$
$$f_0 = 1Hz$$



(Q dependence)

$$f_{in} = 200Hz$$
$$I_{CP} = 100\mu A$$
$$K_{VCO} = 2\pi \times 100 rad/s/V$$
$$Q = 0.7$$



(ω_0 dependence)

Step response simulations

➔ Optimization for desired performance!