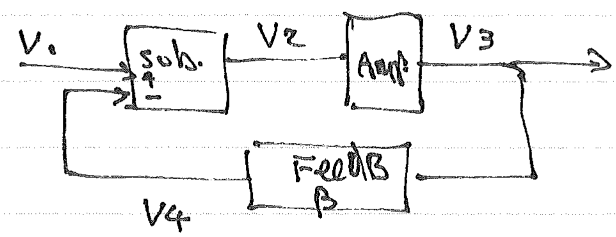
PLL notes

PLL → Feedback oscilator

- Amplification
- positive feedback (regenerative – correct phase & freq.)
- freq. determination (changes freq.) has a natural freq.
- Source

Loopback system

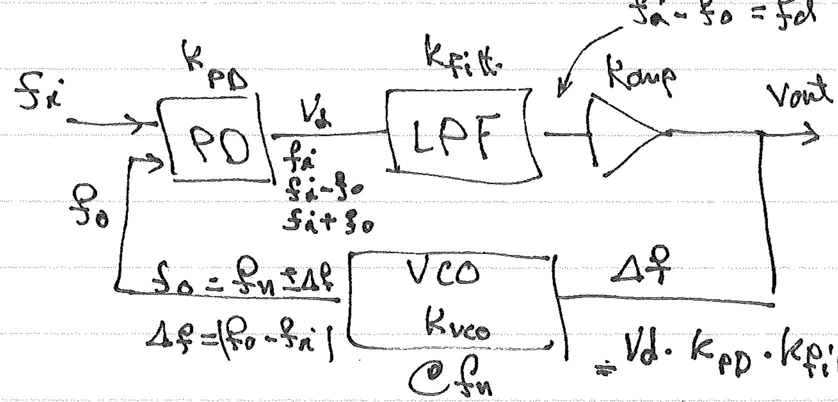


$$\frac{V_{out}}{V_{in}} = \frac{V_3}{V_{in}} = \frac{A_{ol}}{1+\beta A_{ol}}$$

$= A_{cl}$ ← Closed Loop Gain

$A_{ol} = V_3/V_2$

$V_4 = \beta V_3$



integrated.

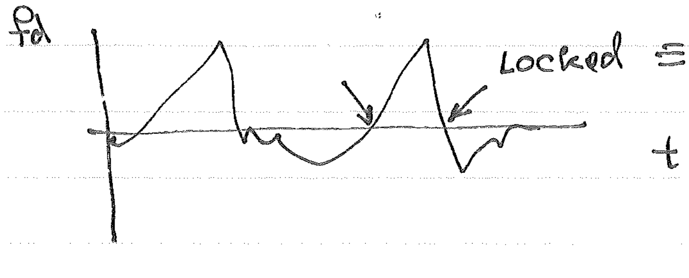
$= V_d \cdot K_{PD} \cdot K_{filter} \cdot K_{am} = V_d \cdot K_{oL}$

$=$ Vout (DC biased)

what it does:

→ Lock to freq.

→ Generate a voltage eq. to θ_e



Locked ≡ Freq. Aquisition

Zero beat

Locked $f_i = f_o$

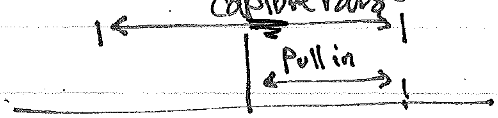
Aquisition time (Pull-in time) $\Delta t \rightarrow f_i = f_o$

natural freq

capture range unlocked → locked (Aqu. range)

Lock range locked → unlock (tracking range)

Pullin range

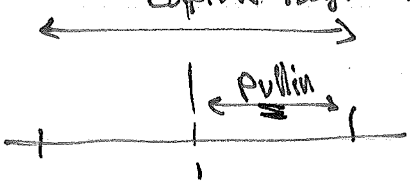


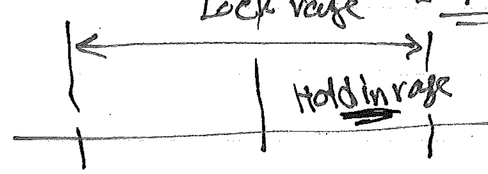
Example $f_n = 100 MHZ$

Pull-in range = 1 percent of f_n → ~~100~~ MHZ

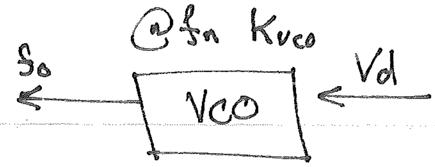
hold in range = 2 percent of f_m → 102 MHZ

Find ~~fo~~ capture range
Lock range



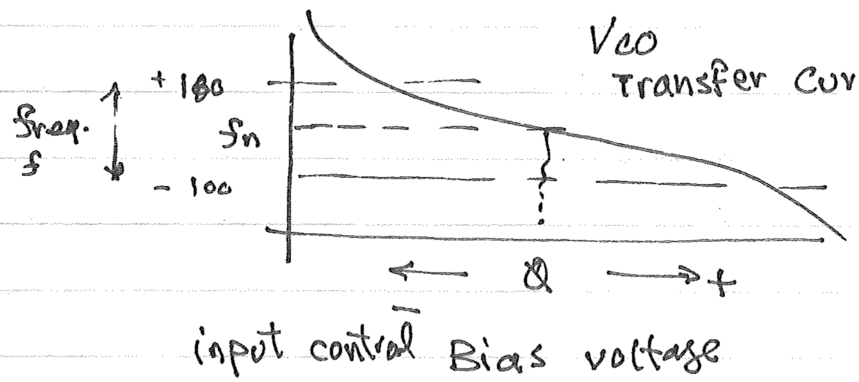


VCO

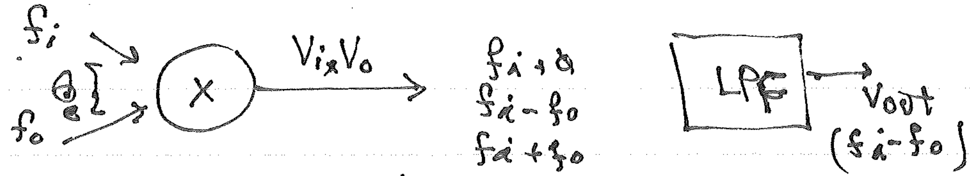


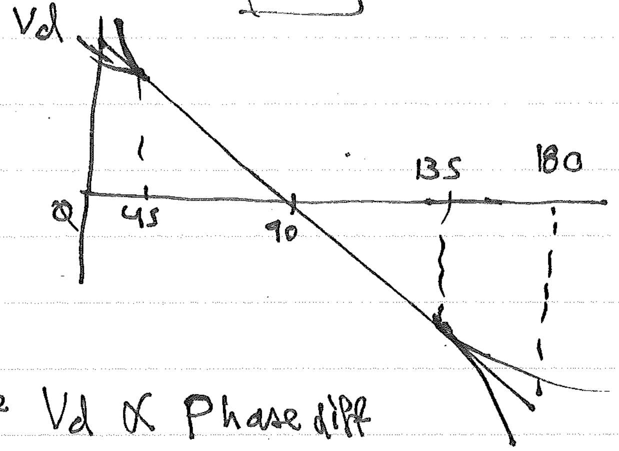
$$K_{VCO} \ (Hz/V) = \text{Transfer function} = \frac{\text{output}}{\text{Input}} = \frac{\Delta f}{\Delta V}$$ ← change in input freq.

Vco Transfer curve (symmetric)



Phase Detection



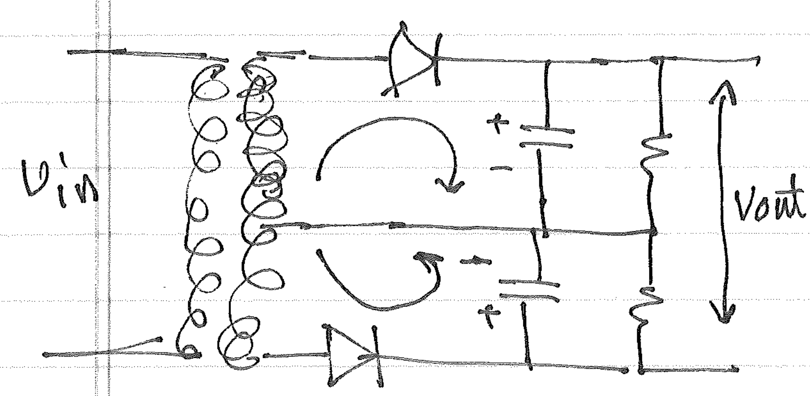


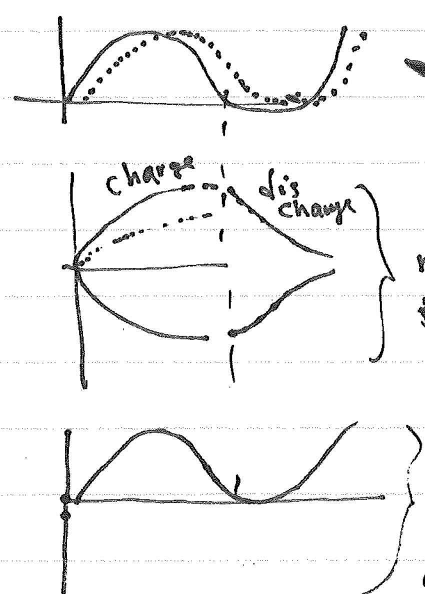
output voltage $V_d \propto$ Phase diff

$\theta_e = \theta_i - \theta_o$

$$\text{Transfer function} = \frac{\text{Output}}{\text{Input}} = \frac{V_d}{\theta_e} \left(V/\text{rad}\right) = K_{pd}$$

How do we convert phase diff to voltage?





net voltage is zero

when out of phase then Vout is diff.

PLL Terms

open loop Gain $= K_{op} = K_{PD} \cdot K_{filter} \cdot K_{amp} \cdot K_{VCO} = K_{opLG}$

$K_{PD} \equiv$ phase detector gain (V/rad)

$K_{filter} \equiv$ filter gain (V/V)

$K_{amp} \equiv$ (V/V)

$K_{VCO} \equiv$ ~~Hz/Volt~~ $\equiv Hz/Volt$

$$K_{LoopGain} \equiv V/rad \cdot (V/V)\,(V/V)\,\frac{Hz}{Volt} = Hz/rad$$

or

$$K_{LG} = \frac{Hz}{rad} = \frac{cycle}{rad\text{-}sec} \cdot \frac{rad\ 2\pi}{cycle} = 2\pi K_{LD}\ rad/sec$$

$K_{V(dB)} = ~~20\log~~\ 20\log K_V$

Example P. 99

$f_n = 200\,kHz$

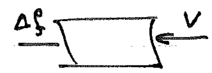
$f_i = 210\,kHz$

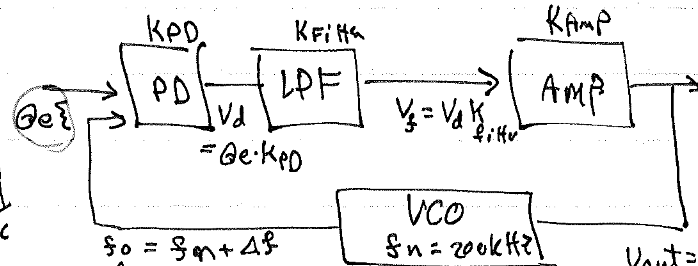
$K_{PD} = 0.2\ V/rad$

$K_{Filter} = 1$

$K_{amp} = 5$

$K_{vco} = 20\ kHz/V$





$f_o = f_n + \Delta f$

$\Delta f = V_{out} \cdot K_{vco}$ K_{vco} $V_{out} = V_d K_{fil} \cdot K_{Amp}$

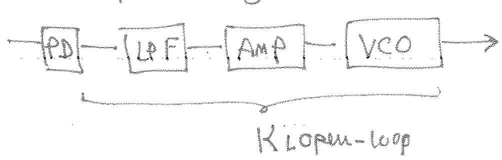
$= \theta_e\, K_{PD} \cdot K_{filter} \cdot K_{Amp} \cdot K_{vco}$

$= \theta_e \cdot K_{openloop} \quad \left(rad \cdot \frac{Hz}{rad} \right)$

Find the following

- open loop gain (Hz/rad) & rad/sec
- change in VCO for Δf
- PLL output voltage (V_{out})
- phase detector output voltage (V_d)
- phase static error (θ_e)
- Hold-in range (Δf_{max})

note : open loop gain :



Solution

K_L openloop $= K_{PD} \cdot K_{filter} \cdot K_{Amp} \cdot K_{vco}$

$= 0.2\,V/rad \cdot 1 \cdot 5 \cdot 20\,kHz/V = \underline{20\ kHz/rad}$

a) or

$20\,\frac{kHz}{rad} = 20\,\frac{k\,cycles}{rad\text{-}sec} \cdot \frac{2\pi\,rad}{cycle} = \boxed{125.6\,k\,\frac{rad}{sec}}$ ← note rad/sec

$K_{openloop\,(rad/sec)\,dB} = 20\log(125.6\times10^3) = \underline{102\ dB}$

b) $\Delta f = f_i - f_n = 210\ kHz - 200\ kHz = \underline{10\ kHz}$

c) V_{out}: $V_{out} = V_d\, K_{filter} \cdot K_{amp}$

$K_{vco} = \frac{\Delta f}{V_{out}} \Rightarrow V_{out} = \frac{\Delta f}{K_{vco}} = \frac{10\,kHz}{20\,kHz/V} = \underline{0.5V}$

d) $V_d \cdot K_{filter} \cdot K_{Amp} = V_{out}$ → ~~$V_d = (0.5)(1)(5) =$~~

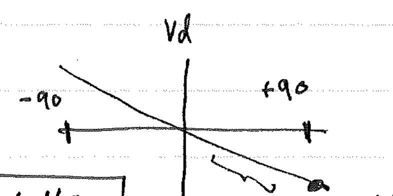
$V_d = \frac{V_{out}}{K_{filter} \cdot K_{amp}} = \frac{0.5}{5(1)} = \underline{(0.1)\,V}$

e) θ_e: $\Delta f = \theta_e K_{L_{OLG}}$ → $\theta_e = \frac{\Delta f\,(Hz)}{K_{L_{OLG}}\,(Hz/rad)} = \frac{10\,kHz}{20\,kHz/rad} = (0.5\ rad)$

→ 28.65 deg. — pay attention

note: this is diff. from steady state θ_e.

f) ~~Holding~~ Hold-in range (Δf_{max})



$(\pi/2\ rad) \cdot K_{L_{OLG}}\left(\frac{Hz}{rad}\right) = (\pi/2)(20\,kHz) = \boxed{31.4\,kHz}$

(Locked)

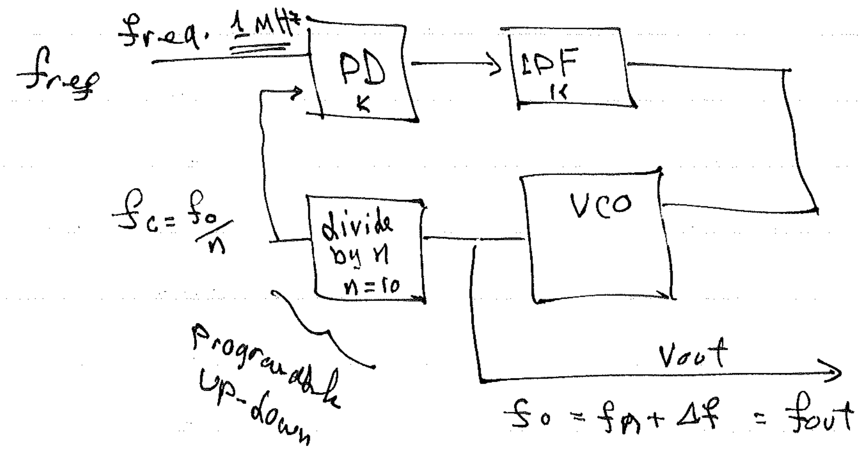
Away from the natural freq.

note   Lock range $= 2\Delta f_{max}$

Capture range (LPF) $= \dfrac{2\sqrt{\Delta f_{max}}}{RC\ (LPF)}$ ← Function of Filter

Lock range > capture range

Freq. synthesizer (single loop PLL) → freq. multiplier



$f_o = n\, f_{ref} = [1, 10]\, f_{ref}$

$= 1MHz$ to $10 MHz$

$$K_V = \frac{K_{PD} \cdot K_{LPF} \cdot K_{VCO}}{n}$$ Loop Gain