Ph 623 - March 31st

- Digital Prelab due tomorrow
- Exam II next Tuesday
- HW 9 due ~~nex~~ Thursday, April 9
  - Available on course website
  - Good practice for exam, however!

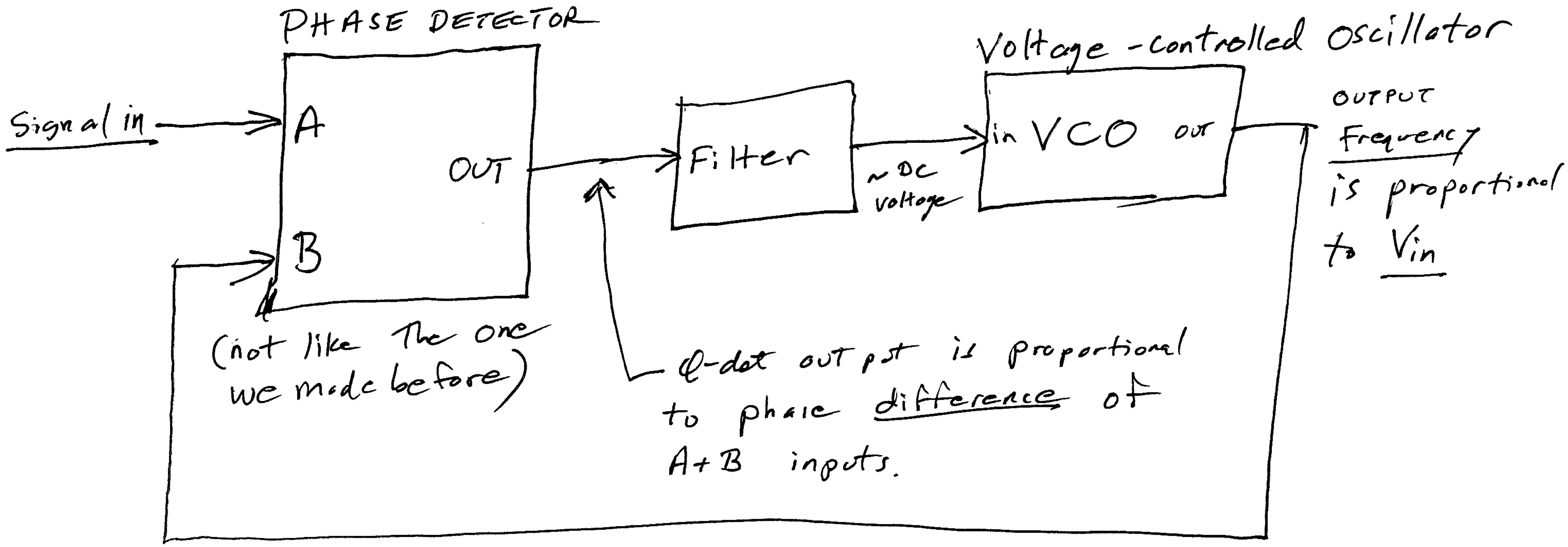
Today:

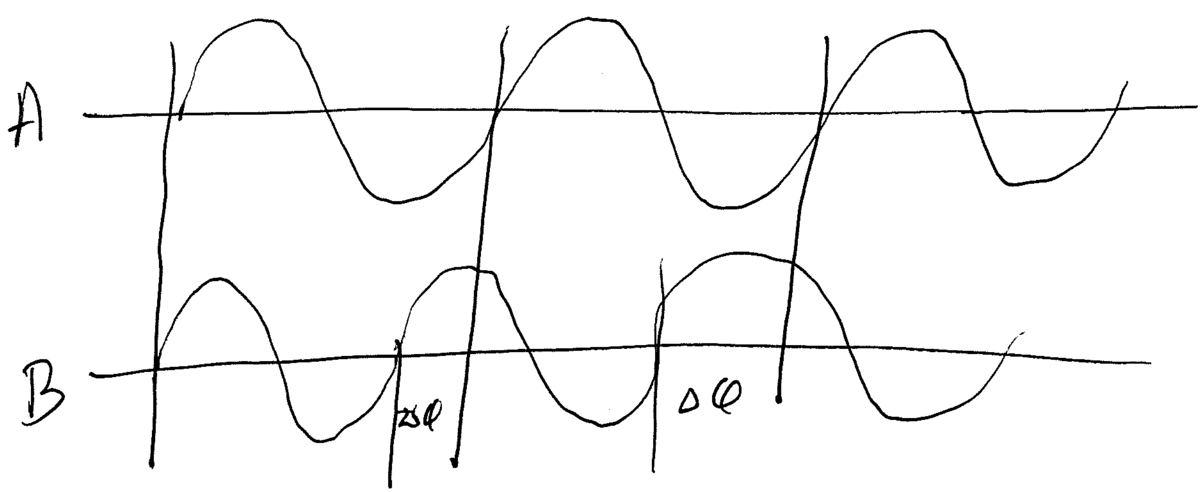
Phase-locked Loops (Read 13.13)

Problems they can solve:

1. How do you identify the tones the telephone pushbuttons make?
2. How do you generate a 2 GHz clock for your computer from a 10 MHz crystal reference?
3. How do you know when to look at the bits in a digital data stream from a satellite? ("Clock regeneration")
4. How do you make a digital "Frequency synthesizer" where you put in a number and get an output at that many Hz? (It needs to be referenced to a crystal oscillator or atomic clock frequency standard.) – There's one in every radio reciver these days.
5. How do you lock a laser to a fixed difference from another laser?

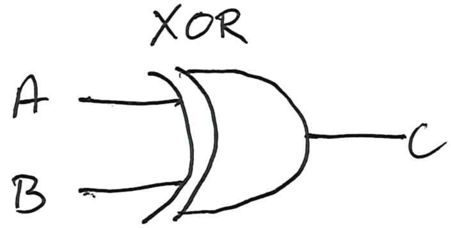
Phase-locked Loop is a feedback loop.

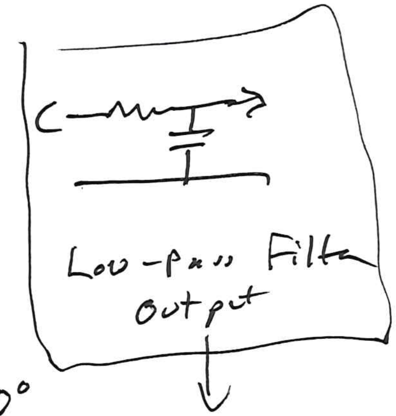


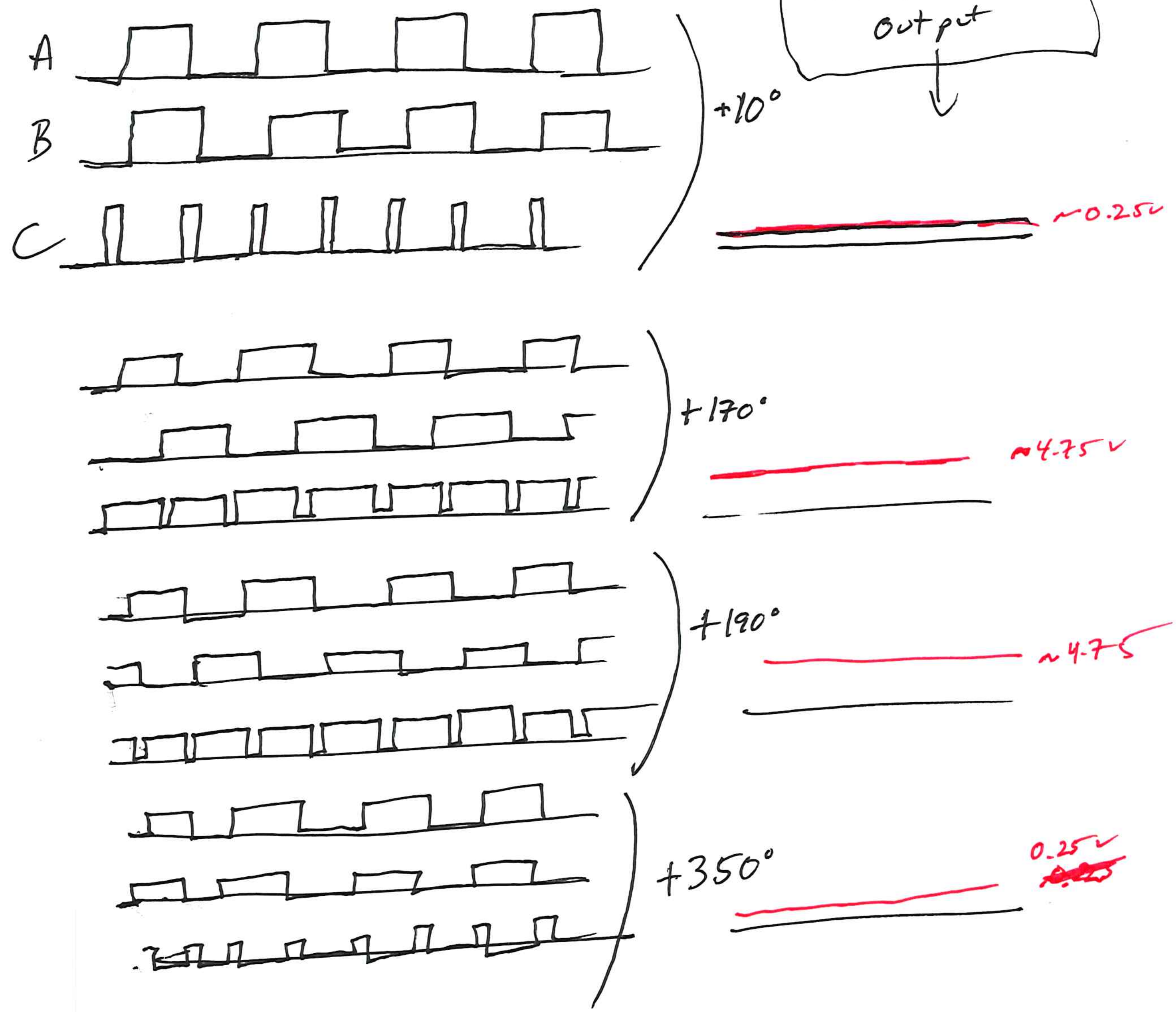


Phase difference $\Delta\varphi$ is integral of Frequency difference

Type I Phase Detector

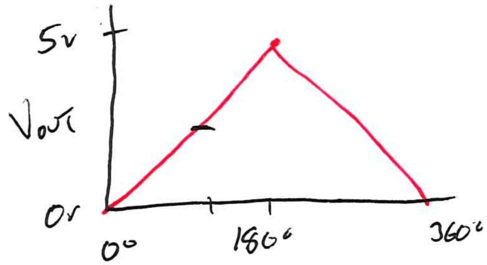




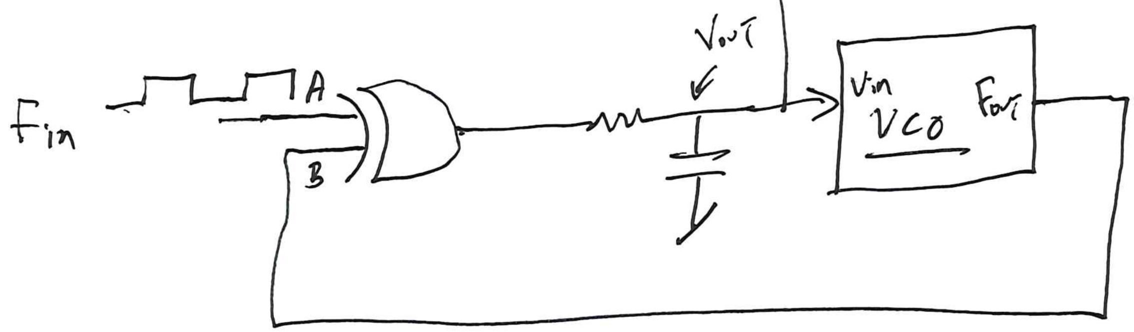


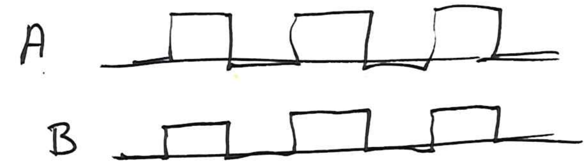
Transfer Function

Δφ → Vout from Filter



→ $V_{OUT} \propto F_{in}$ when loop is "locked"

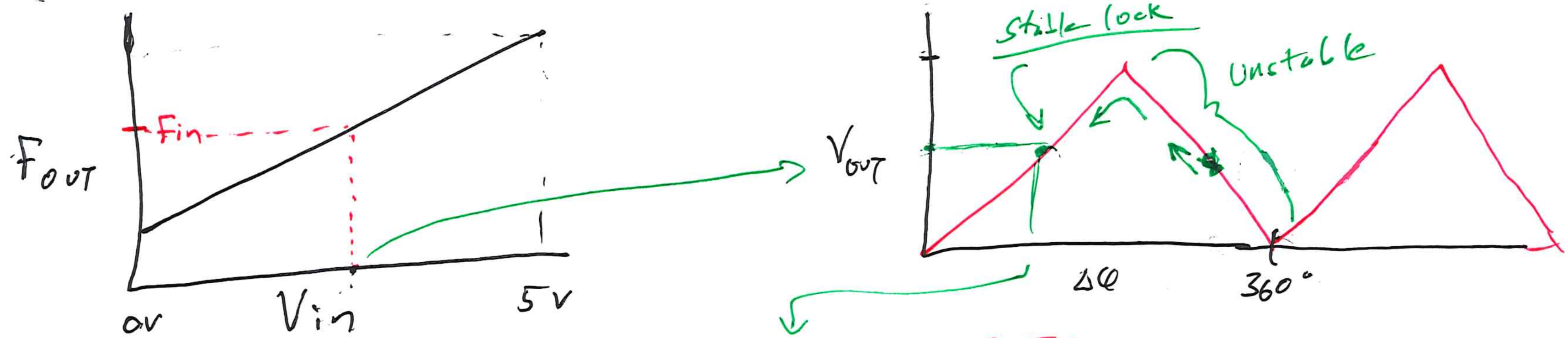




$B < A \longrightarrow \Delta\phi \uparrow$

$B > A \longrightarrow \Delta\phi \downarrow$

VCO Transfer Function



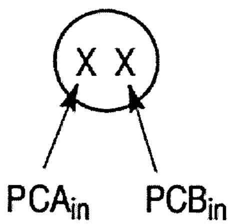
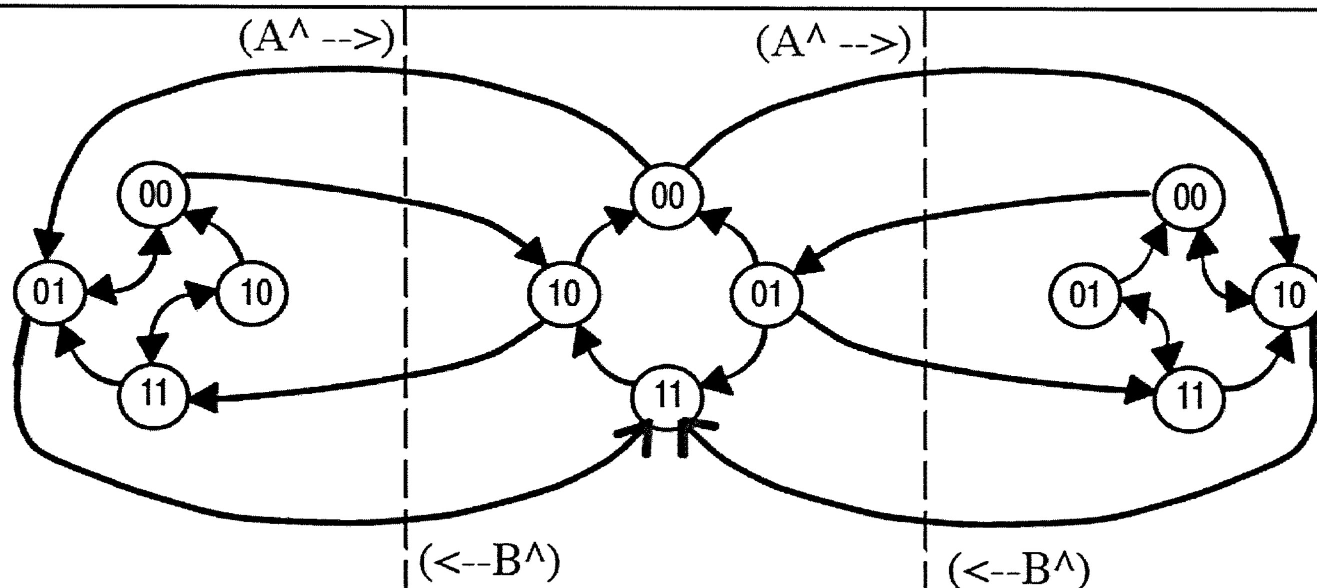
↑ will stop at ~ 90° Δφ → 2.5v

Type I

→ Stabilizes ("Locks") with a $\Delta\phi = 0° \rightarrow 180°$

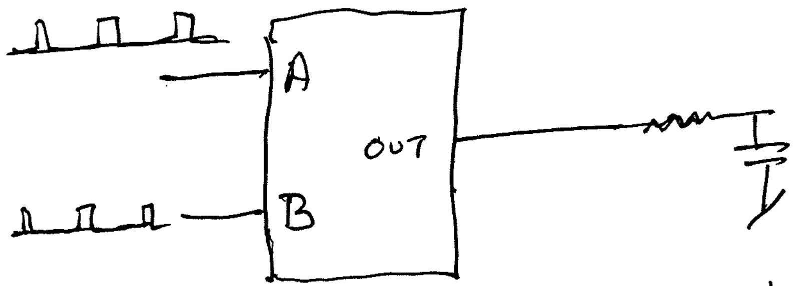
→ Requires square wave input on A and B.

Type II

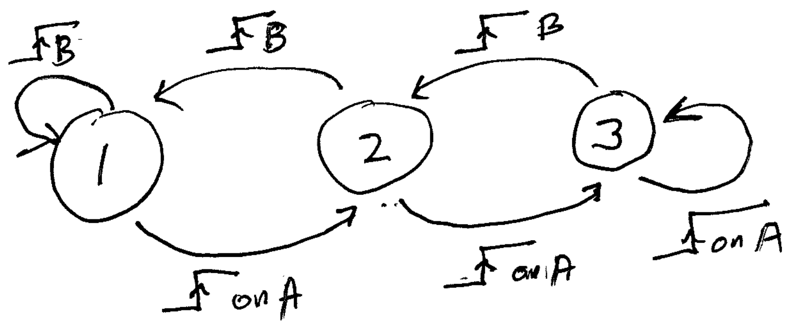
<table>
<tr><td></td><td colspan="3">PHASE COMPARATOR 2 (Edge-triggered)</td></tr>
<tr><td>Input Stage

</td><td colspan="3">
</td></tr>
<tr><td>PC2$_{out}$</td><td>0</td><td>3–State
Output Disconnected</td><td>1</td></tr>
<tr><td>LD (Lock Detect)</td><td>0</td><td>1</td><td>0</td></tr>
</table>

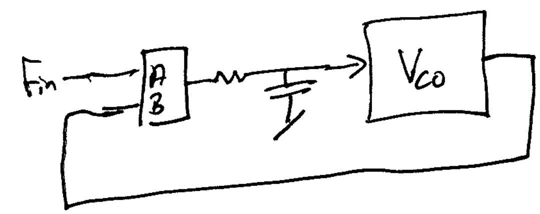
Type II Φ-det

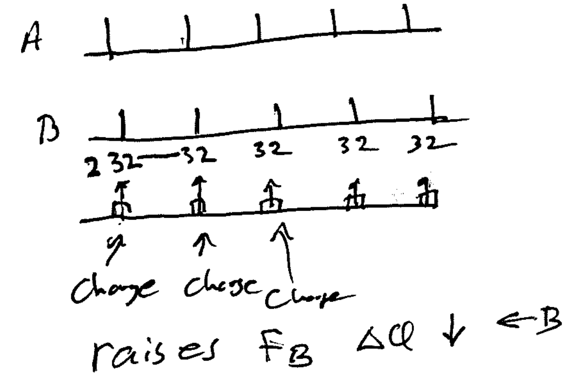
Consult MC14046B Data Sheet From website



Easiest to Think of as State Machine



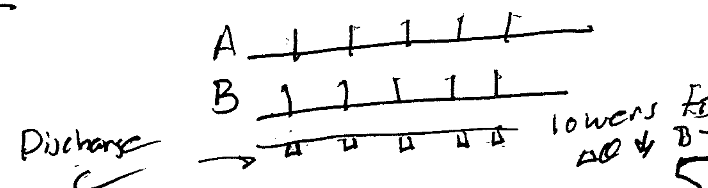




① ⇒ OUTPUT is LOW

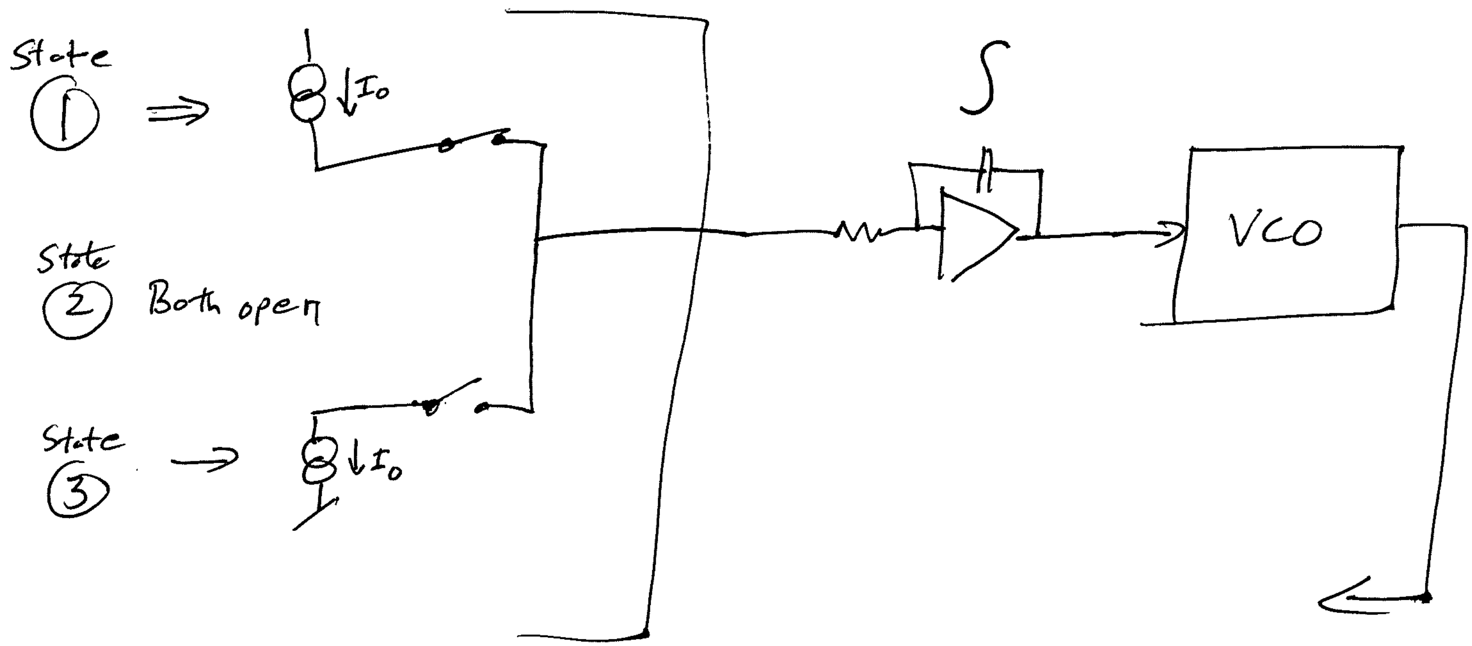
② ⇒ OUTPUT High Impedance (open circuit)

③ ⇒ OUTPUT is HIGH



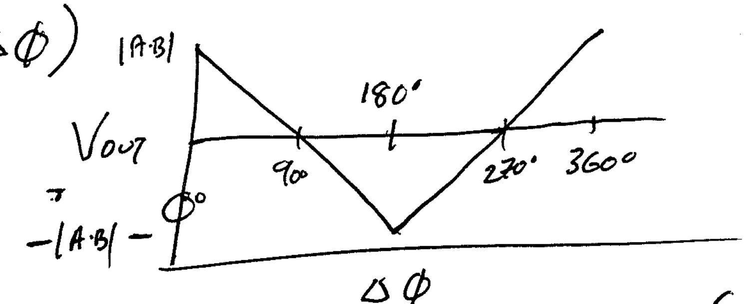
1. Always Locks with $\Delta\phi = 0°$
2. Duty cycle doesn't matter → only sees ↑ (more sensitive to noise on Fin)

COULD also make type II with current Sources:



Type I can also use an analog multiplier

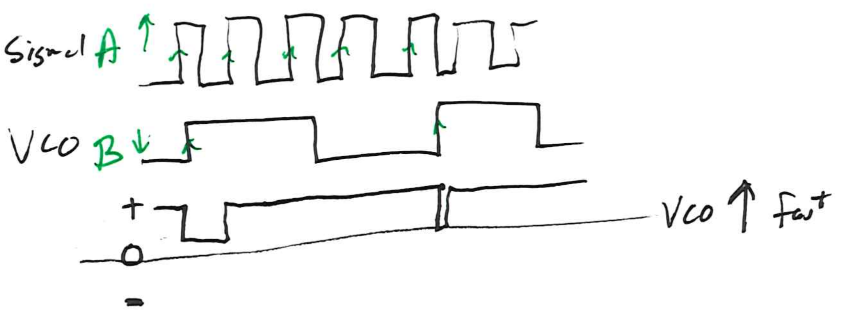
This is like our old phase detector, where the Signal is input A + phase reference is input B. When $F_A \equiv F_B$, after low-pass filter (to remove A+B) Get (A−B) ≐ zero F or D.C. * $\cos(\Delta\phi)$

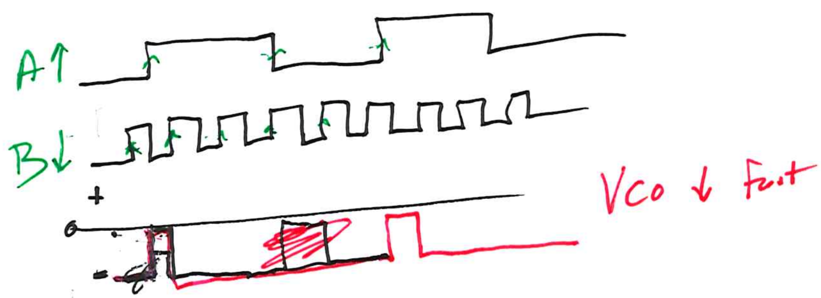


IF it is very linear + B has amplitude ≡ 1.000, then this is same as our lock-in circuit.

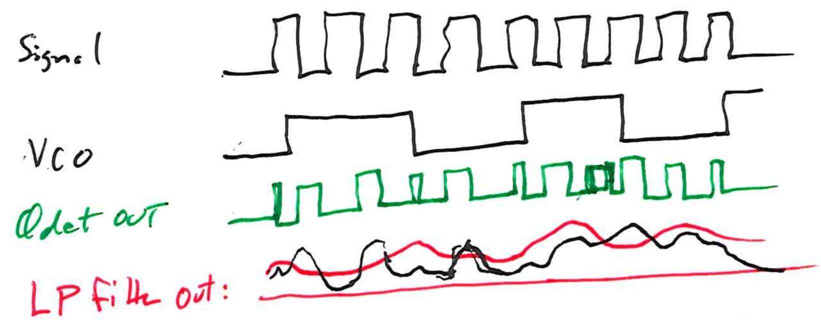
"Capture"

Easy with type II:





Pretty wild with Type I:



Capture is complicated function of Filter response.

> "Capture range" ≡ range of signal frequencies where initially unlocked signal will be locked to.

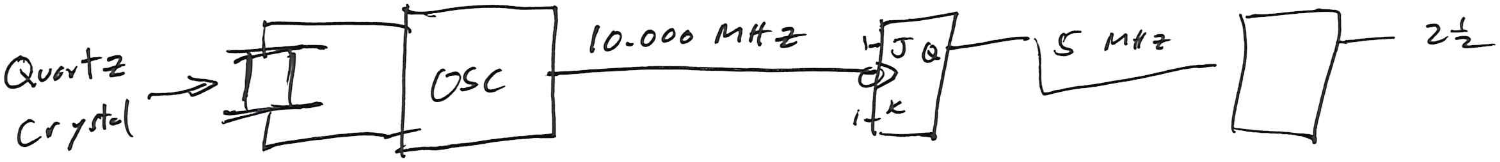
> "lock range" ≡ range of signal frequencies where VCO will follow once it is locked.

Type I: Capture range: Depends on filter; lock range = range of VCO

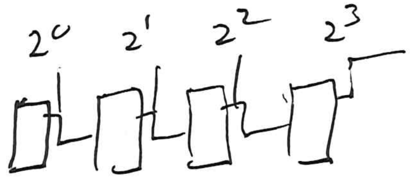
Type II: Capture range = lock range = range of VCO

Applications

Frequency Multiplier? Easy to make divider:

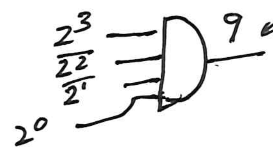


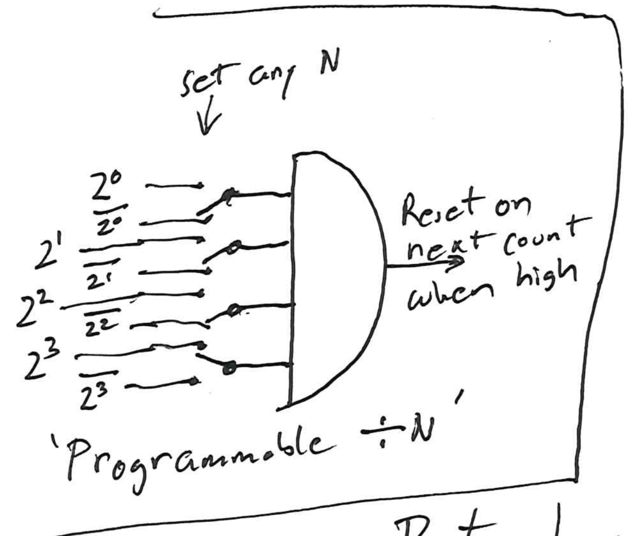
$\div 2^N$ easy



CAN U $\div 10$

CLK ↓





CAN MAKE $\div N$

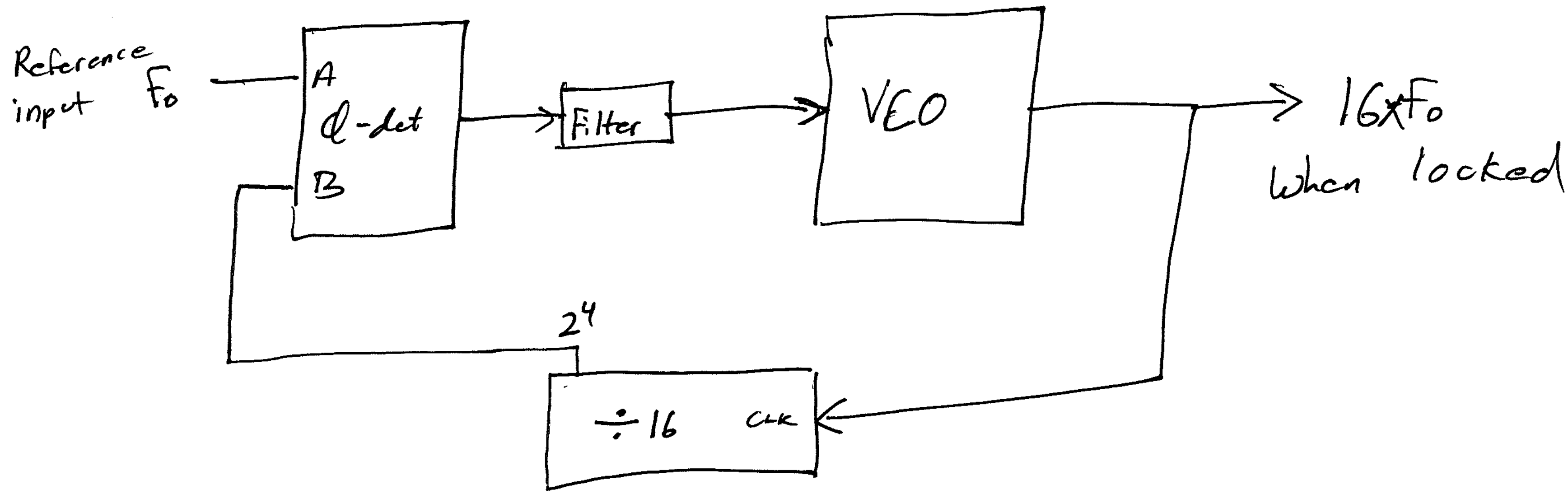
2^3

If we need a square output, double f_o and add one more toggle

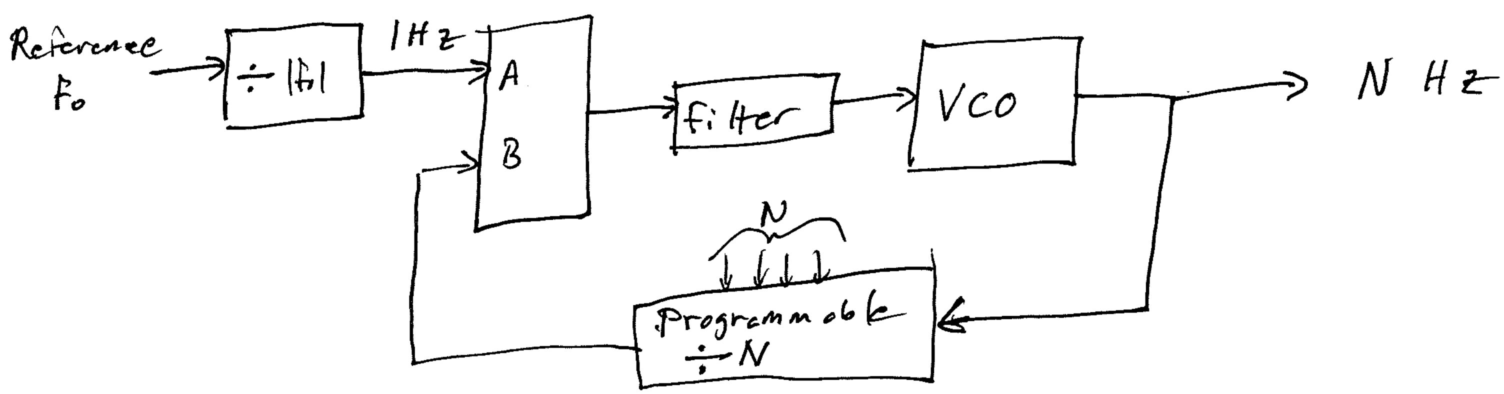
But how to get 2 GHz from 10 MHz?

Remember Op-amp circuits? Putting a function in a negative feedback loop → inverse function.

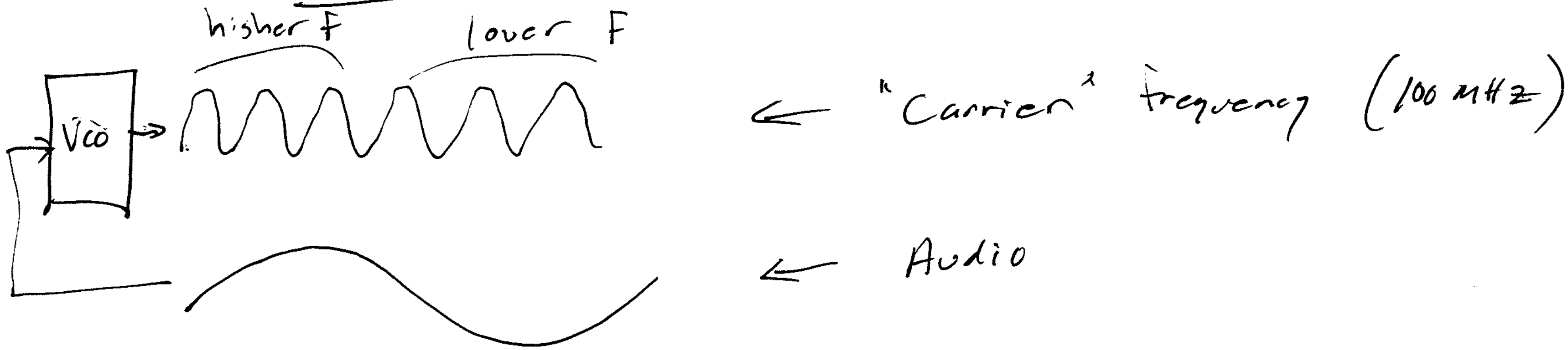
Frequency Multiplier

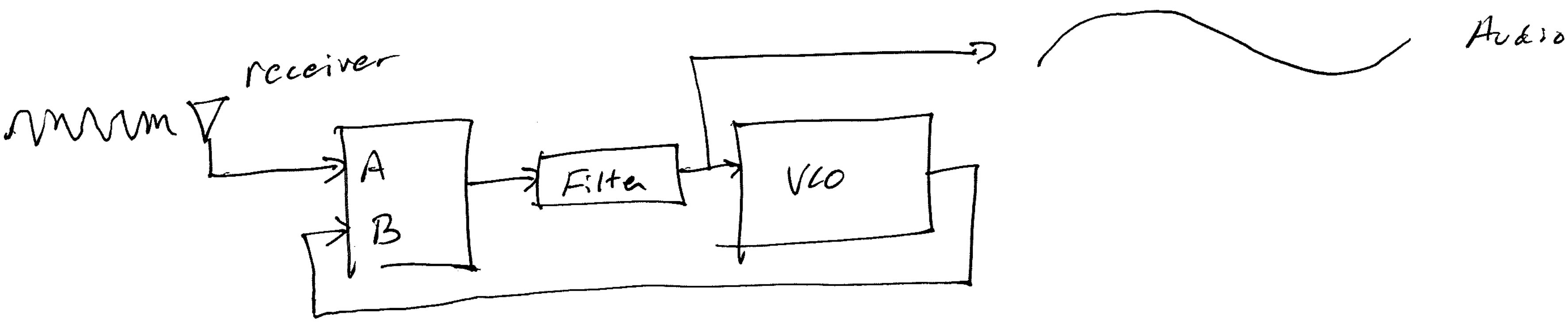


Frequency Synthesizer

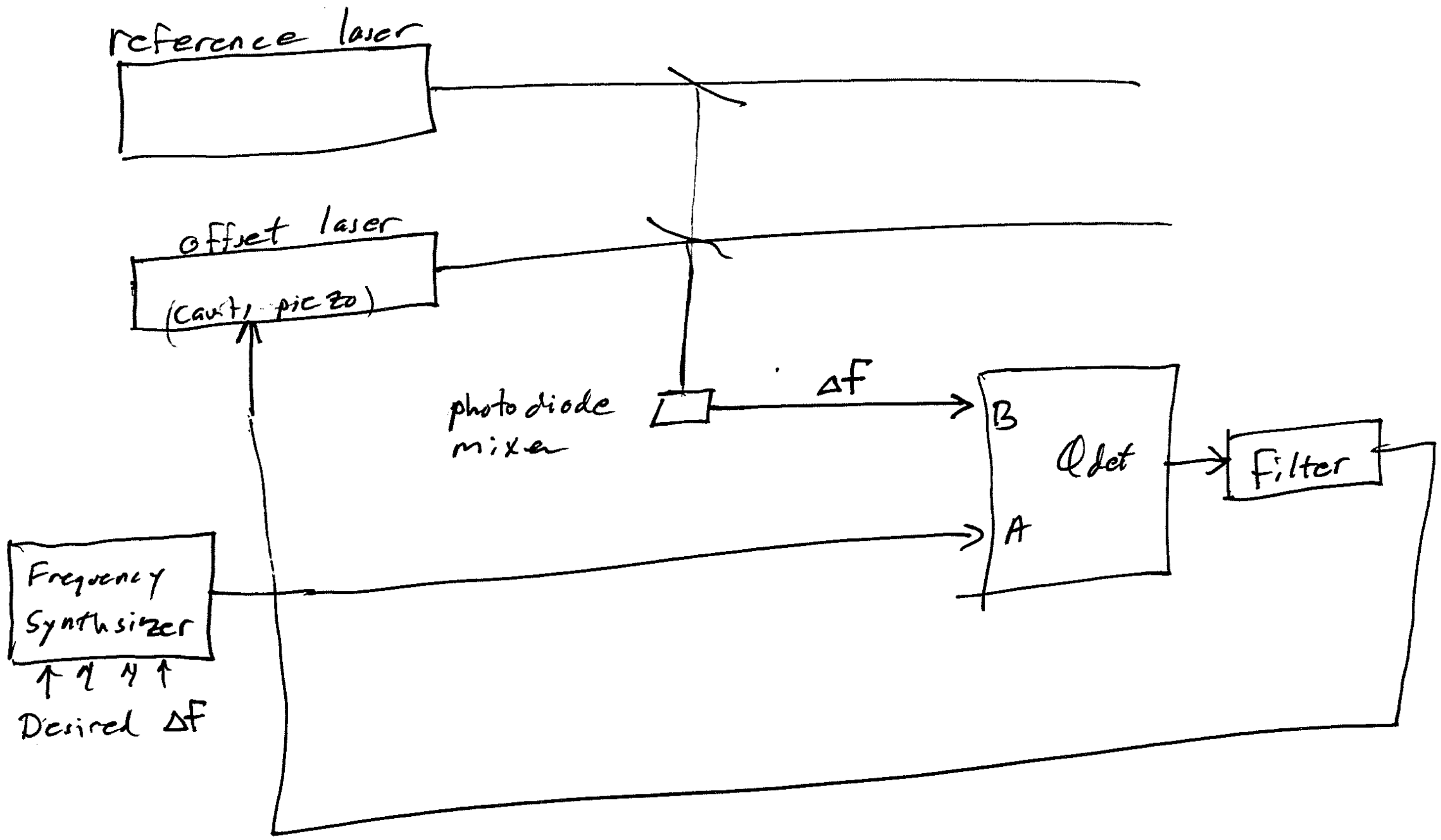


FM demodulation





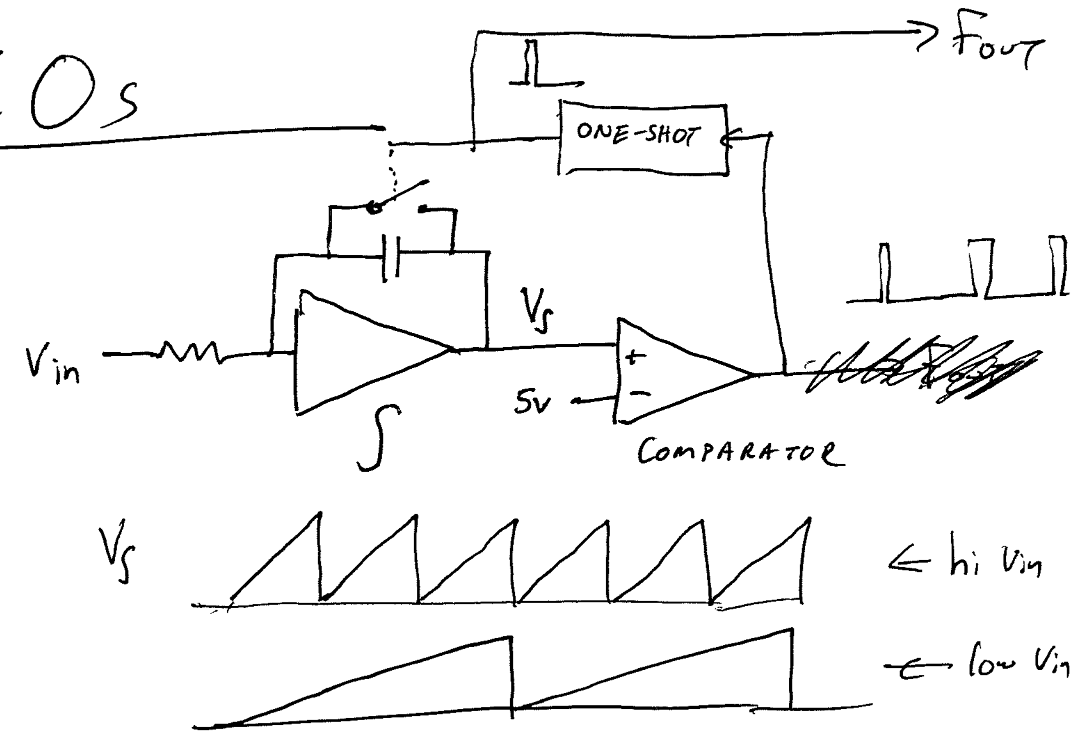
Laser offset lock



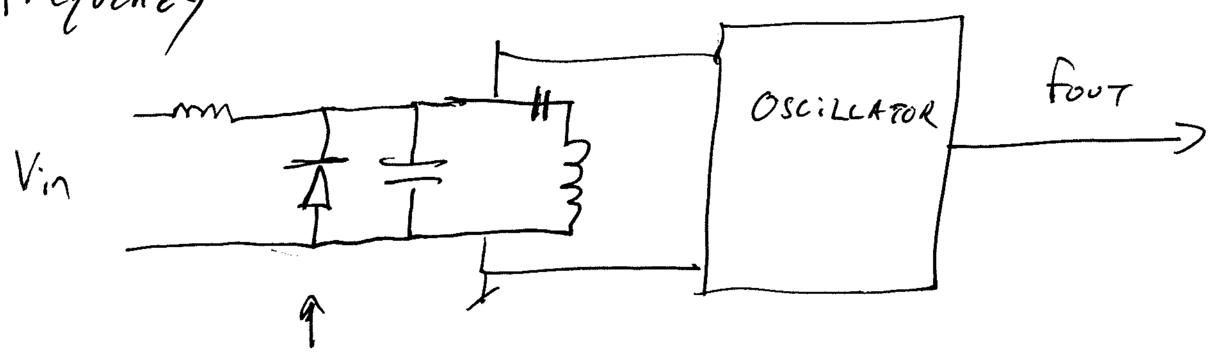
VCOs

low frequency

very linear



high frequency



"Varactor Diode"
reverse bias C depends on Vreverse

not so linear