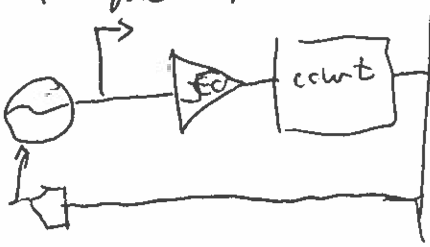
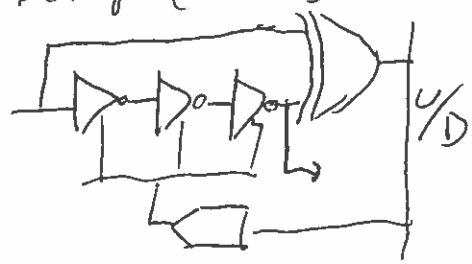
What are they	Basic Model	Phase as a Signal	Implementing	Control & Jitter
- Brainstorm clock replication - Vs. DLL & FLL	- PD - CP - LF - VCO - Linearization (of a very nonlinear thing)	- $\phi = \frac{\partial \omega}{\partial t}$ - accumulation - pictures of controlling ϕ w/ f	- mult PD - XOR PD - J/K PD - Ring osc. - LC osc. - divider	- PLL as filter - N and loop gain

- How do we make a clock? ⟶ oscillators
- If we have a clock, how do we replicate it? ⟶ PLL

Frequency (FLL)



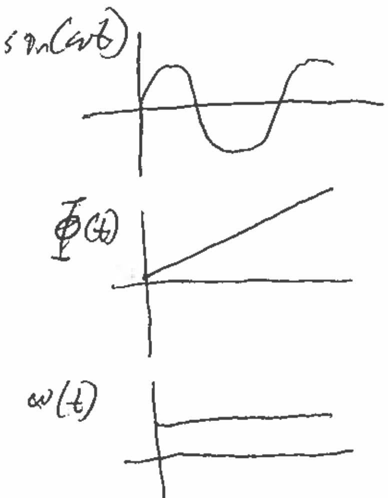
Delay (DLL)



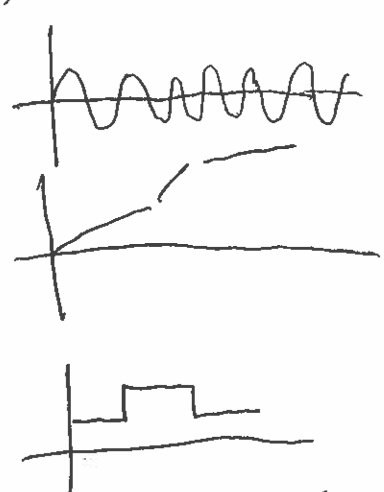
But we want phase & freq locked simultaneously

- Do so w/ a PLL ... many possible implementations (highly digital)
  ... interesting b/c linear models work in v. non-linear

- Big trick: control ϕ as a variable
  - Interpret $\sin(\omega(t)t)$ as $\sin(\Phi(t))$



simple example



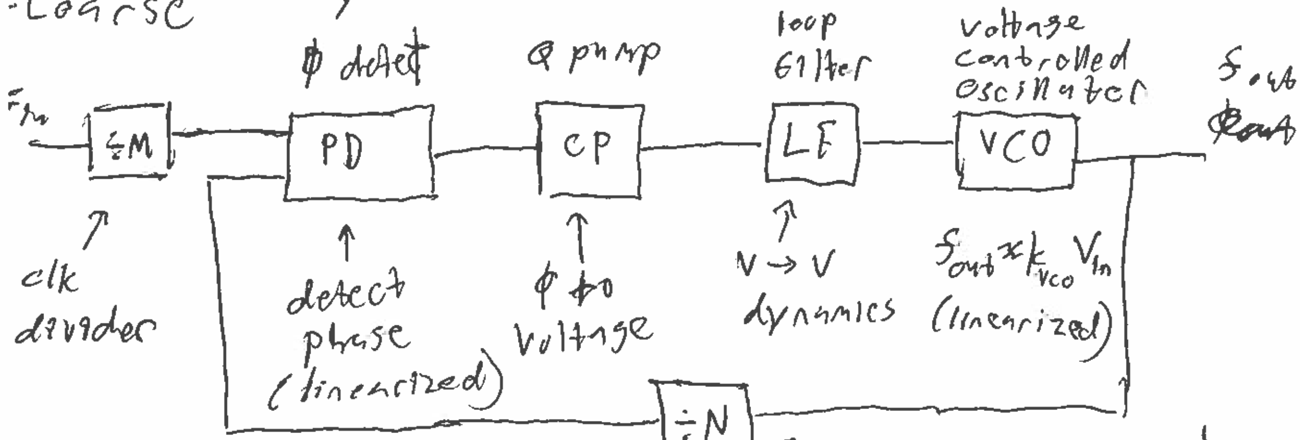
FSK example

Back & forth to ω:

$$\Phi(t) = \int \omega(t)\,dt$$

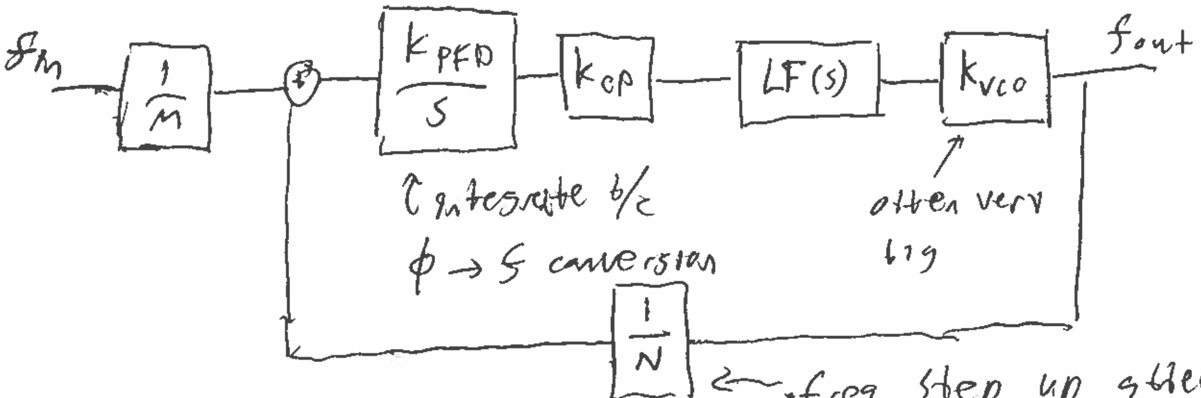
$$\omega(t) = \frac{d\Phi(t)}{dt} + \phi_0$$

· Coarse way to make it:



← frequency gain! cool!

Lends itself to a linear model

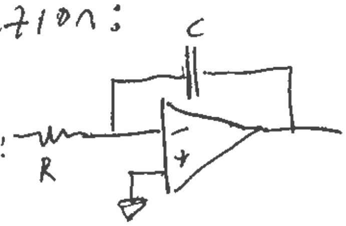


← · freq step up affects loop gain

· Big BW & stability implications (eg: can it respond to input noise) cleanup/filter

Implementation:

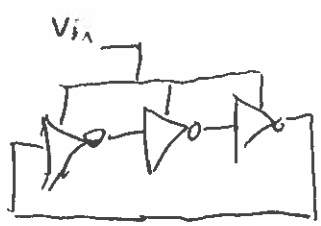
Loop filter:



· Voltage to voltage, we know that

· Often GBW sensitive

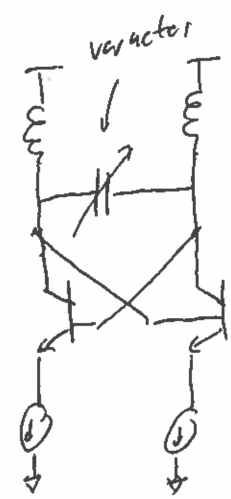
VCO:



- big k_{vco}
- non-linear
- noisy (jitter)

- quad. out
- easy to build

Ring Oscillator

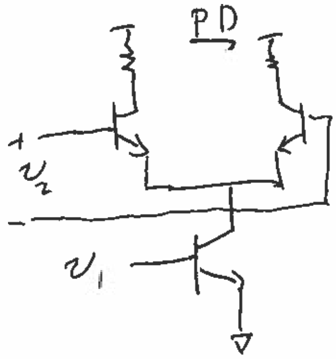
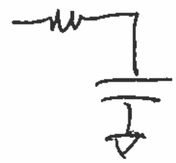
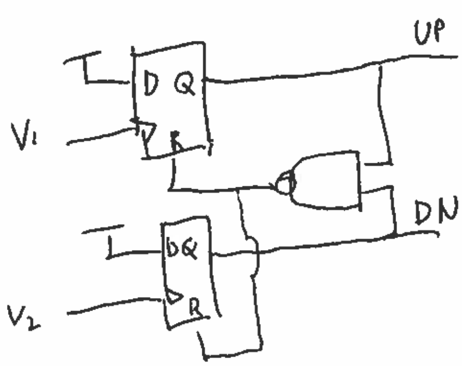
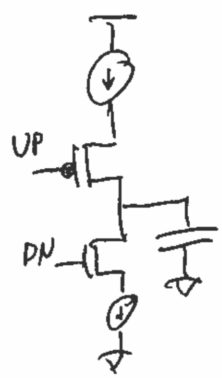


· LC tank filters φ noise

· power hog & touchy

· Varactors hard

PD + CP:

	PD	CP	editorial
Analog multiplier		none	$v_o = V_1 \sin(\omega t+\phi) \cdot V_2 \sin(\omega t)$ ≈ — touchy in a lot of ways —
XOR	 pulse width ≈ $\Delta\phi$	 make into avg. value	— slow b/c LPF — ripple — no direction info
JK Flop			— commonly used — prone to mismatch

Divider:

Just use a digital counter