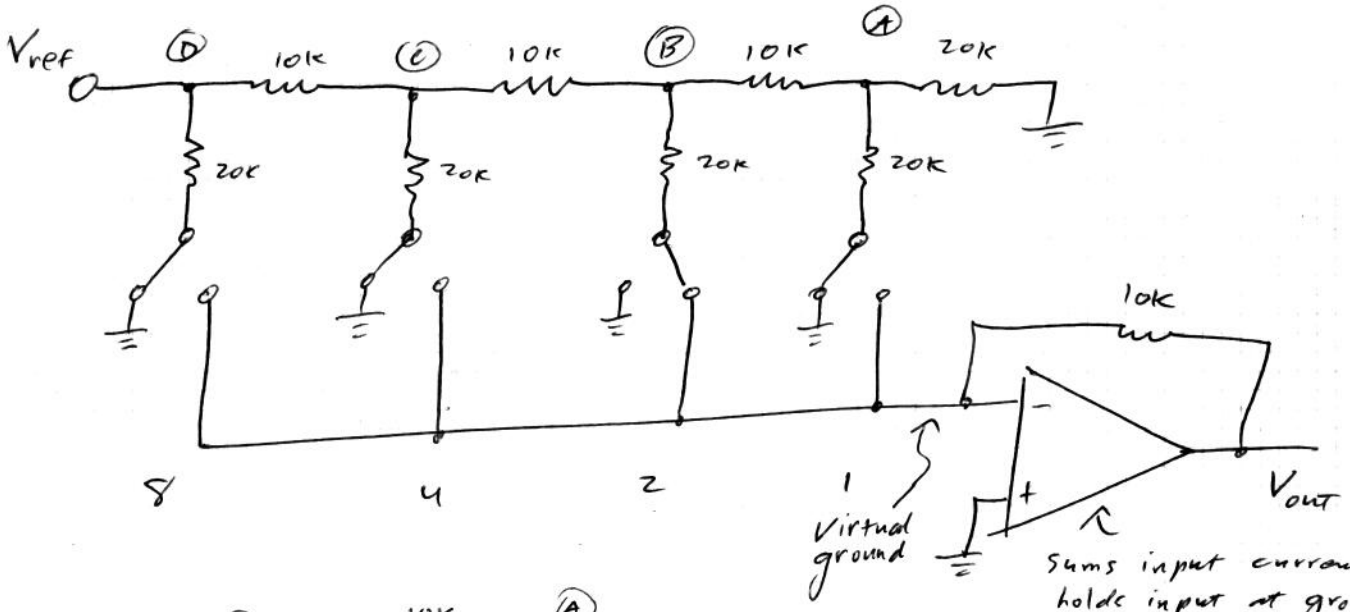
D/A and A/D conversion

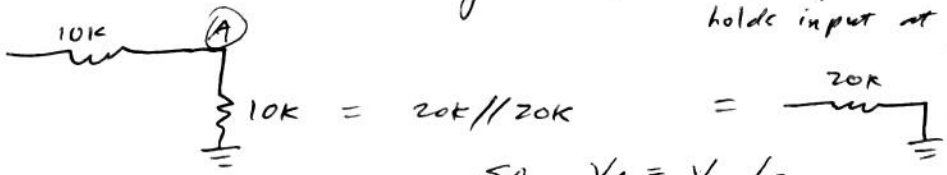
How to get back and forth?

DAC is easy in principle. Use digitally-controlled analog switches to switch a resistor ladder.

Usual approach is R-2R ladder:

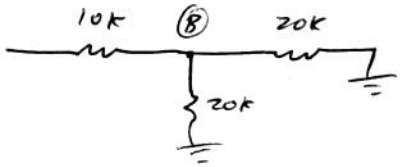


100K at (A):



So $V_A = V_B / 2$

So at (B):

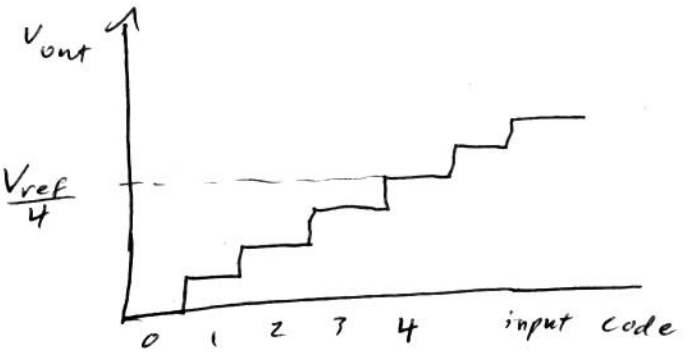


just like (A)!

So $V_B = V_C / 2$

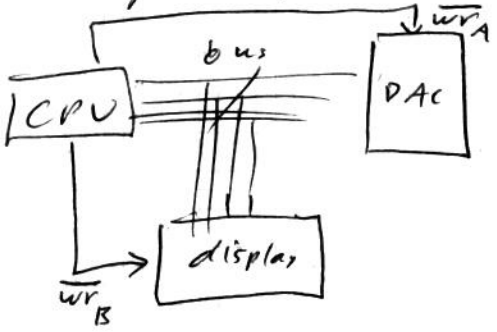
Thus regardless of switch settings, $V_D = 2V_C = 4V_B = 8V_A$

Now all we do is switch the current into an op amp. As shown, V_B is switched in with a gain of $\frac{1}{2}$, so $V_{out} = \frac{1}{8} V_{ref}$. Switch (D) gives $\frac{1}{2} V_{ref}$, etc.



← watch spec's -- integral & diff'l linearity, monotonicity. ← vital if feedback !!

Many DAC's have a resistor ladder with current outputs; used directly or with op amps. Often has input latches as well -- allows shared data lines:



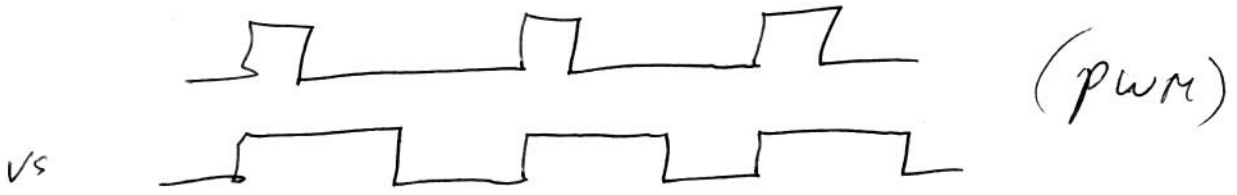
example: DAC0831, only $3 to $4.

For microcontrollers, MCP4822 has fast SPI serial interface — 2x12 bits in 8-pin package for ~$3.

Used for generating waveforms, controlling instruments, heaters, --- ad infinitum.

6-18 bit converters can be had on chips.

There's also another approach -- <u>averaging</u> DAC. Switch system on & off with varying duty cycle --

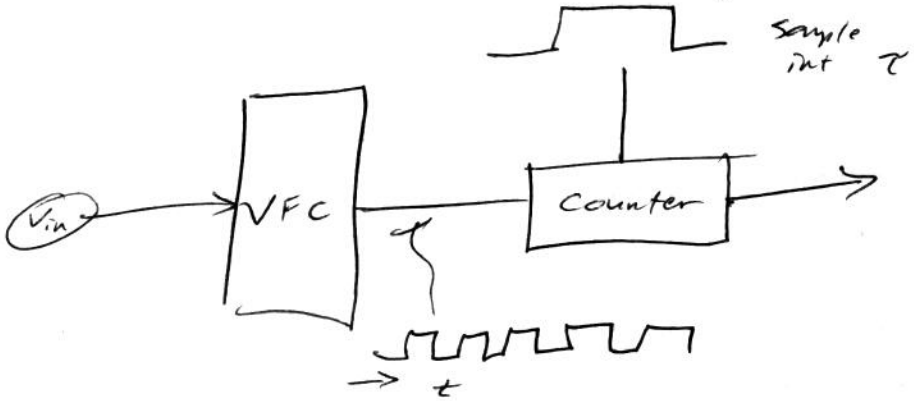


Allows good control of slow systems (e.g. room heat.) Can even average pulse train with an RC filter, but not as common.

ADC's:

Many methods.

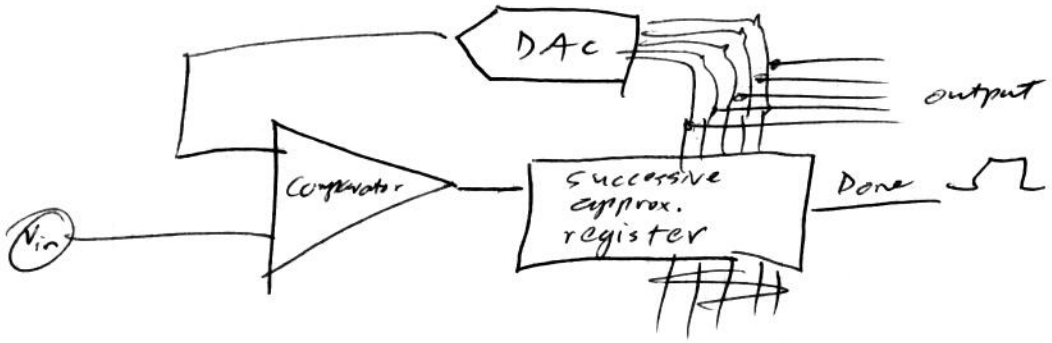
1) One simple & oft-neglected one is:

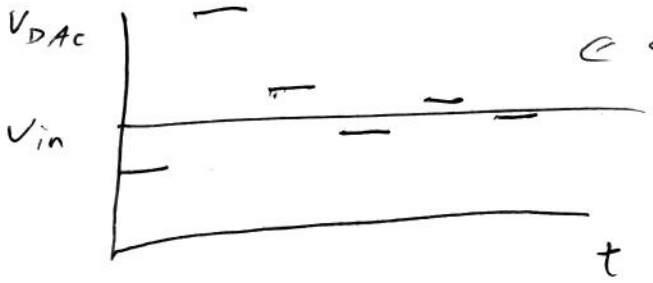


good for $\tau \gtrsim 1$ ms

Easy to build with full control over integration period.

2) successive approximations



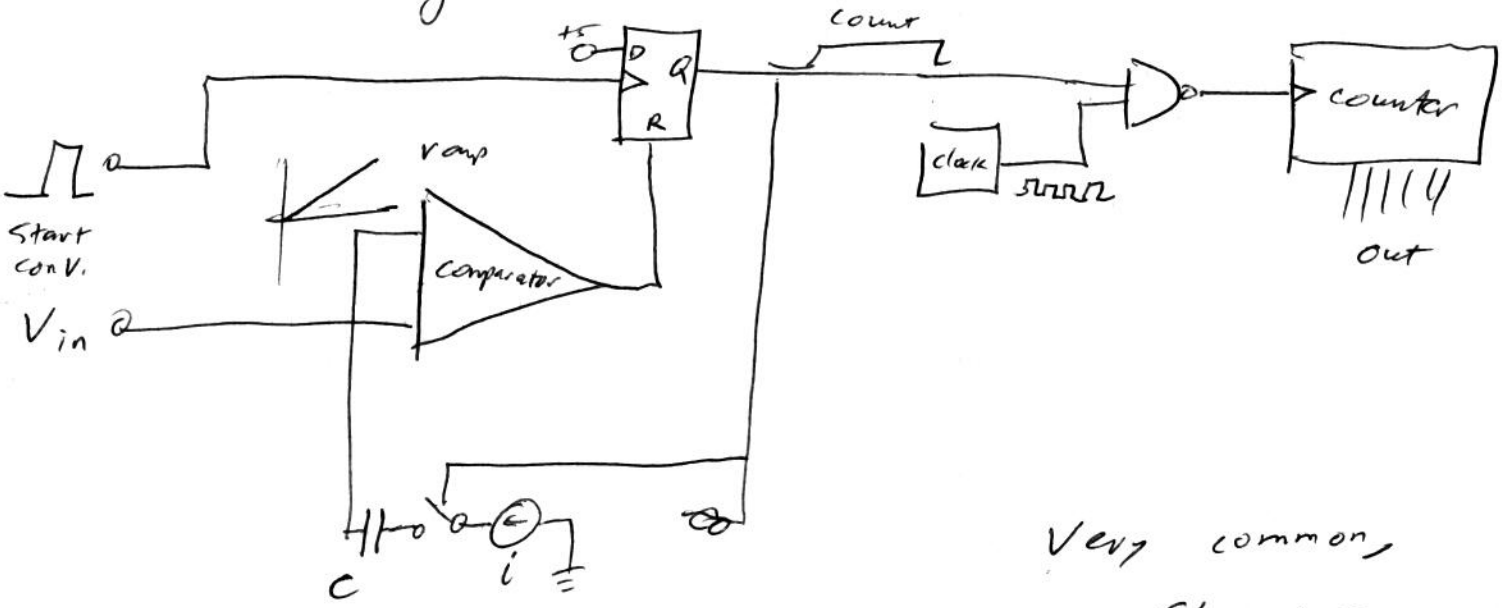


@ successive bifurcations

For n bits, need n DAC settling times

⇒ 1 μs to 50 μs typ.

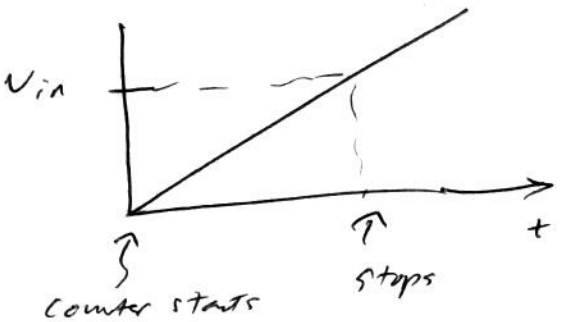
3) RC integration:



Very common,

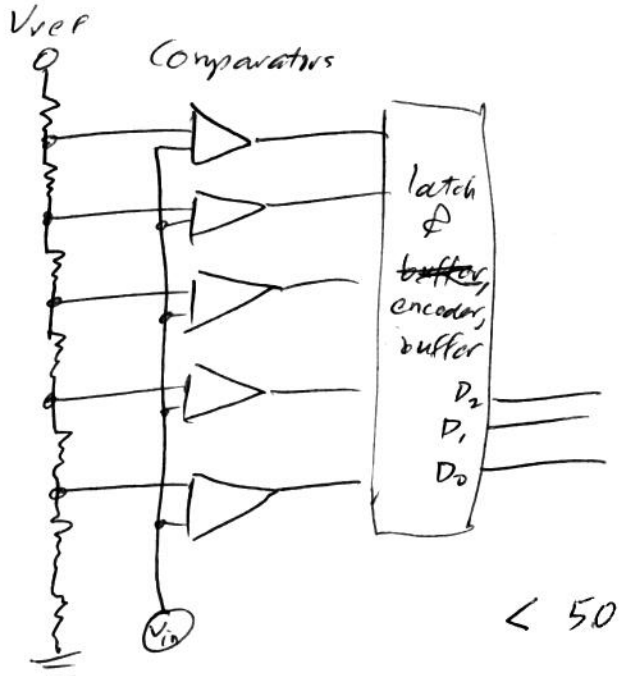
Slow but precise,

Always monotonic (like VFC)



"Dual slope" version works better. A more elaborate variation is the "delta sigma" converter, with digital averaging.

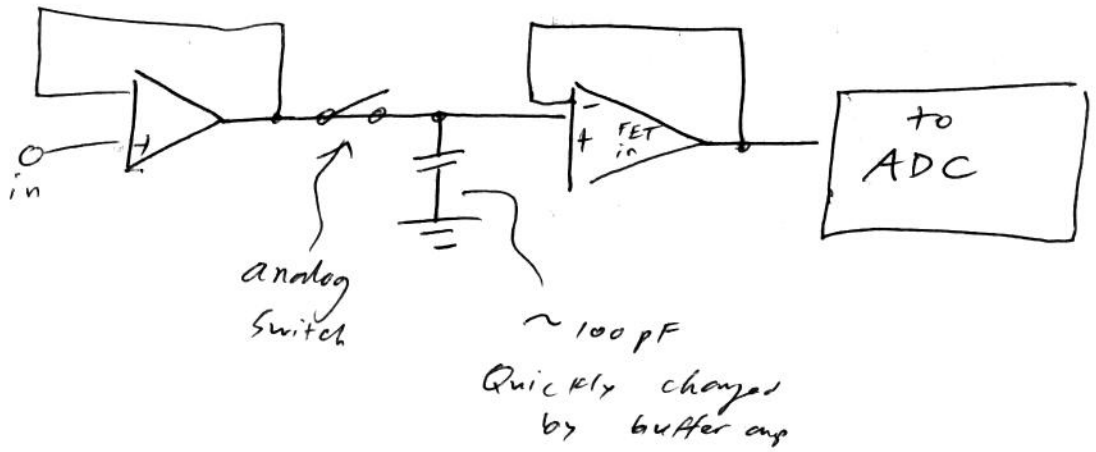
4) Direct "flash" conversion (digital scopes, etc.)

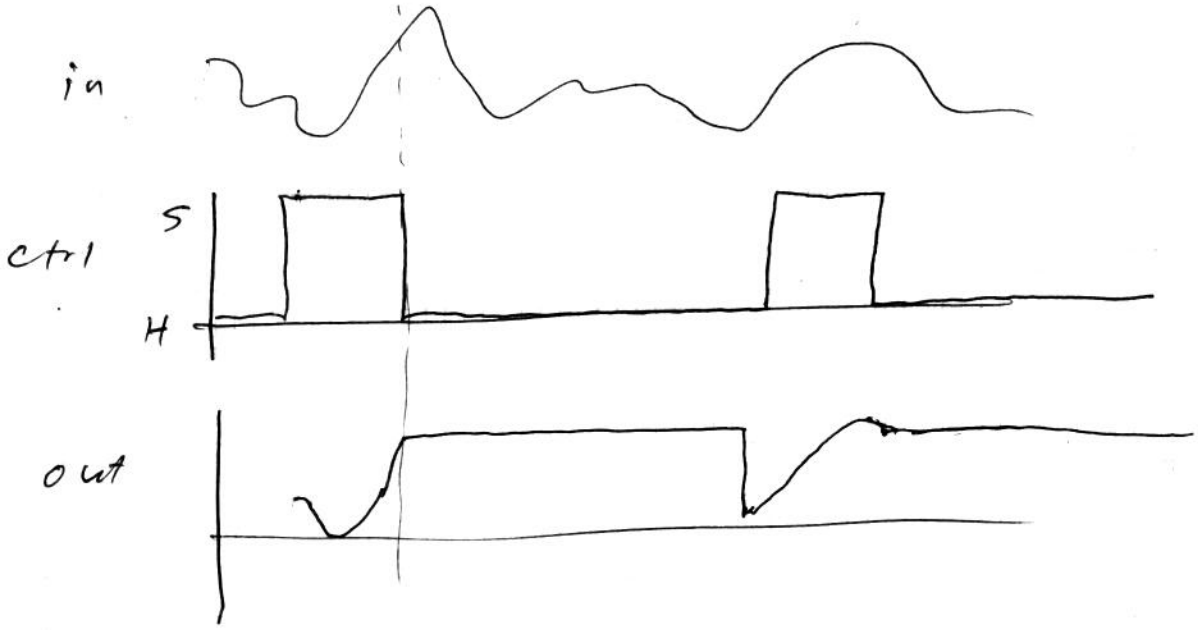


binary output.

< 50 psec is possible!

Sample & Hold amplifier





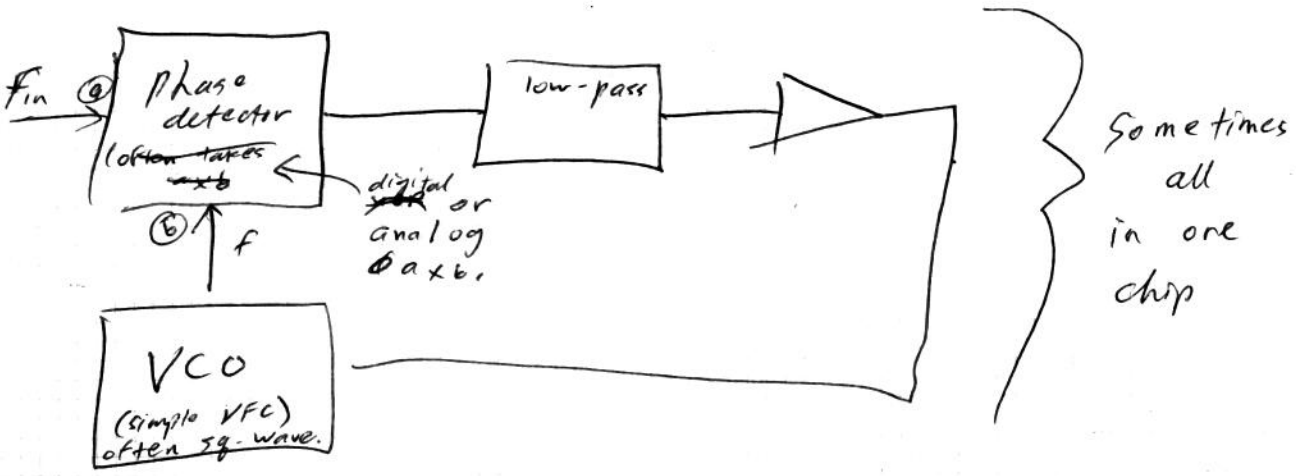
This waveform is <u>undersampled</u>.

<u>Droops</u> is caused by I_{IC_2}, $I = C\frac{dV}{dt}$.
(Bigger C takes longer to charge.)

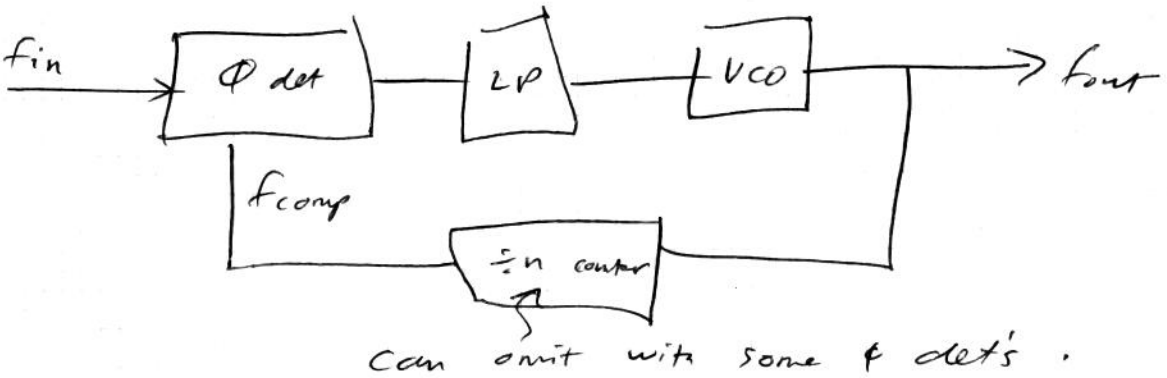
PLL's

another digital-analog hybrid.

- AM & FM de-modulators
- freq. synthesis
- harmonic generation
- synchronization of noisy signals

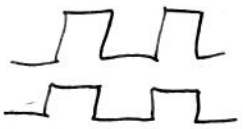


Standard use is n th harmonic lock



See texts and web for lots more.

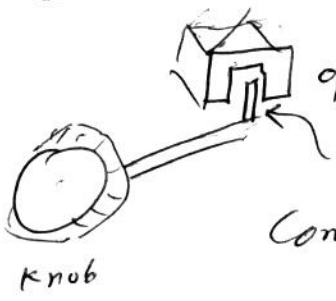
Simplest Φ det is an XOR gate



out of Φ always ~~false~~ ~~true~~ true ~~false~~ } take time average to get ΔΦ.

Finally, it's worth mentioning mechanical ADC's --

Example: shaft encoders: alternative to pot. + 8-bit ADC:



Commonly get ≥ 256 pulses/revolution in commercial units.

Some elaborate encoding schemes can be used to get µrad control of rotation in motor driven applications --- replaces old stepper or synch. schemes.

Used in most new 'scopes, other good µp-controlled instruments.