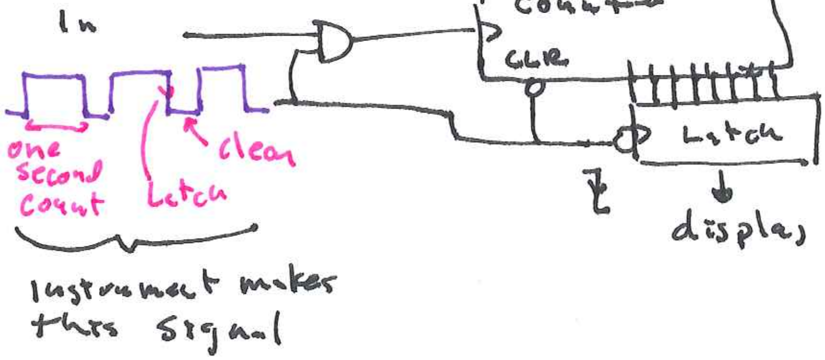
Frequency meters & Period meters share same basic design

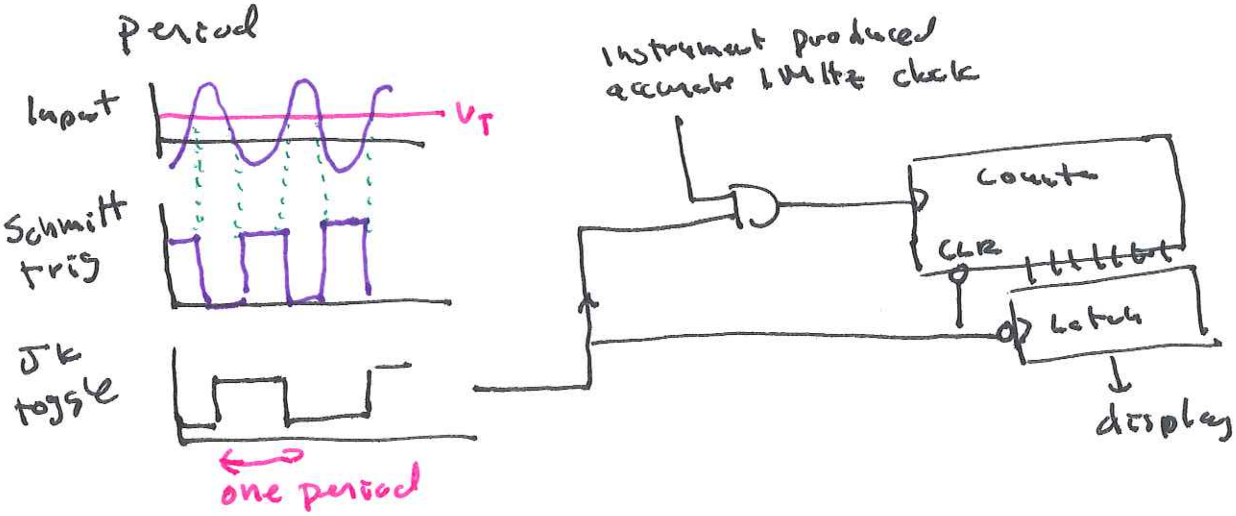
Frequency:



Counter counts (starting at zero) while signal High; ⊥ latches that final count; ⊔ clears to restart count

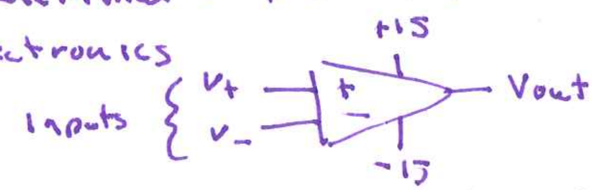
AND is gate thru which pulses arrive

Period



Digital to Analog Converters (DAC)

→ start with OpAmp ("Operational Amplifier") which will star in Analog Electronics

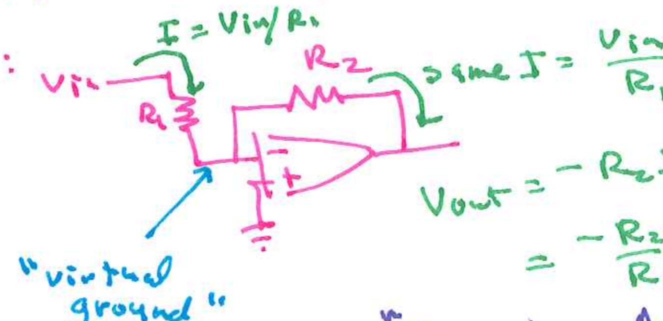


OpAmp Rules:

V_+ & V_- do not eat current

$V_+ \approx V_-$ if operating correctly as $V_{out} = 10^7 (V_+ - V_-)$ but V_{out} limited to its supplies: ±15 V so V_+ is within a few parts-per-million of V_-

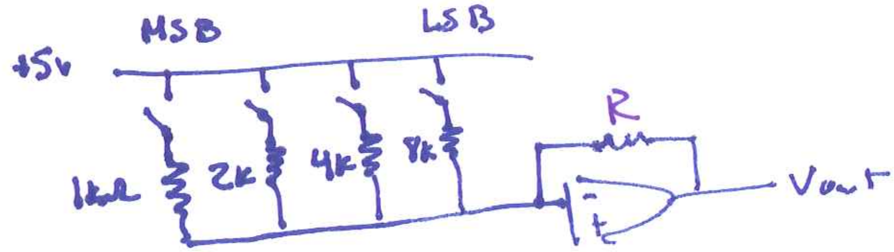
Basic Circuit:



$$V_{out} = -R_2 I = -\frac{R_2}{R_1} V_{in}$$

"Inverting Amplifier"

Basic DAC circuit:



the (in this case) 4 bit binary number closes or opens switches to +5V. If closed the current $\frac{5V}{R}$ flows towards virtual ground and then around thru R producing $V_{out} = -R I_{total}$

$$I_{total} = \frac{5V}{1k\Omega}\left(D + \frac{1}{2}C + \frac{1}{4}B + \frac{1}{8}A\right)$$

Note: TTL controlled "switches" = CMOS transmission gate aka analog switch

Note2: Not perfect switch – few Ω resistance; may not be bipolar

Note3: This circuit has problems as precision resistors are expensive

Note: Example: CD audio is stereo (2 channels) of 16 bits @ 44.1 kHz
ie 64K → 15 ppm accurate resistor required

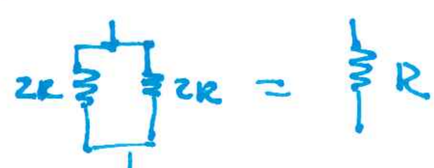
Tricky solution – use lots of resistors that are identical but not of any precise value.

R-2R ladder:

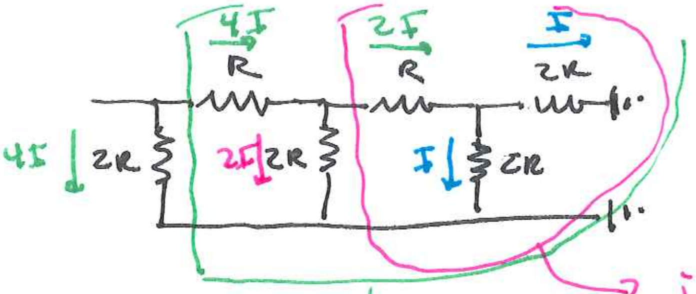
use:

2 1R resistors in series

starting point:



as $\frac{(2R)(2R)}{(2R)+(2R)} = R$



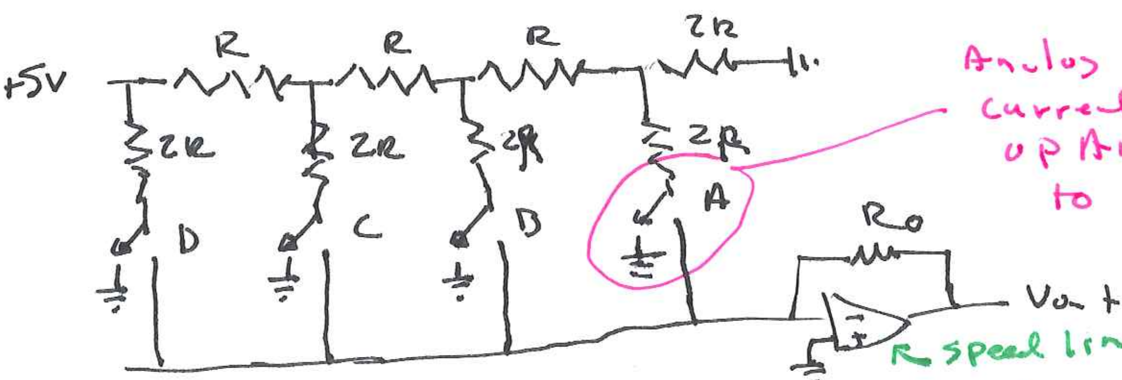
I: same volts same 2R ⇒ same current

2I: current in = current out

(pink) is equivalent to 2R so 2I going right must mean 2I goes down

(green) is equivalent to 2R so 4I going right must mean 4I goes down

Result: A system that produces currents exactly $2^N I$ from identical but not precise Rs. (Note: exact value of I will dependent on R, thus the proportional constant between (digital in) & (voltage out) is not accurately known, but the proportionality between (digital in) & (voltage out) should be accurate — ie Fit between (voltage out) & (digital in) should be accurately linear but the slope is only approximately set.

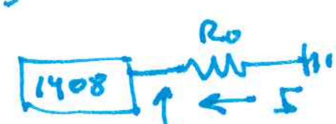


Analog switch direct current to ground or op Amp according to value of digit

↖ speed limited only by Op Amp

Note: Ro sets the overall scale of the output voltage and it is often an external component.

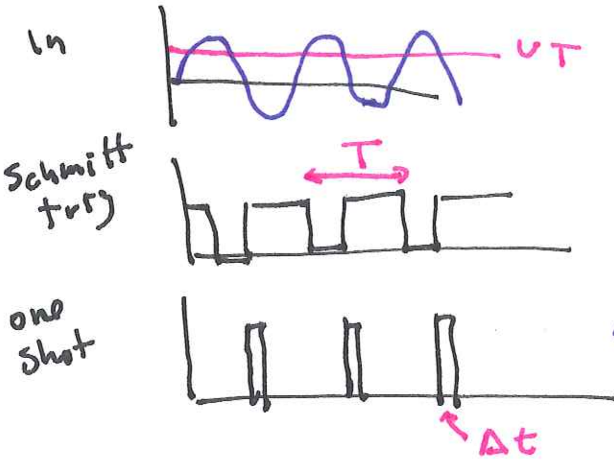
"Multiplying DAC" — 1408



$V_o = -I R_o$

Other Digital → Analog conversions

frequency → voltage

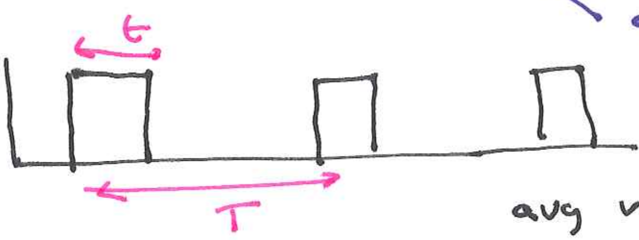


← avg voltage out $= +5V \frac{\Delta t}{T}$

$= +5V \, \Delta t \, f$

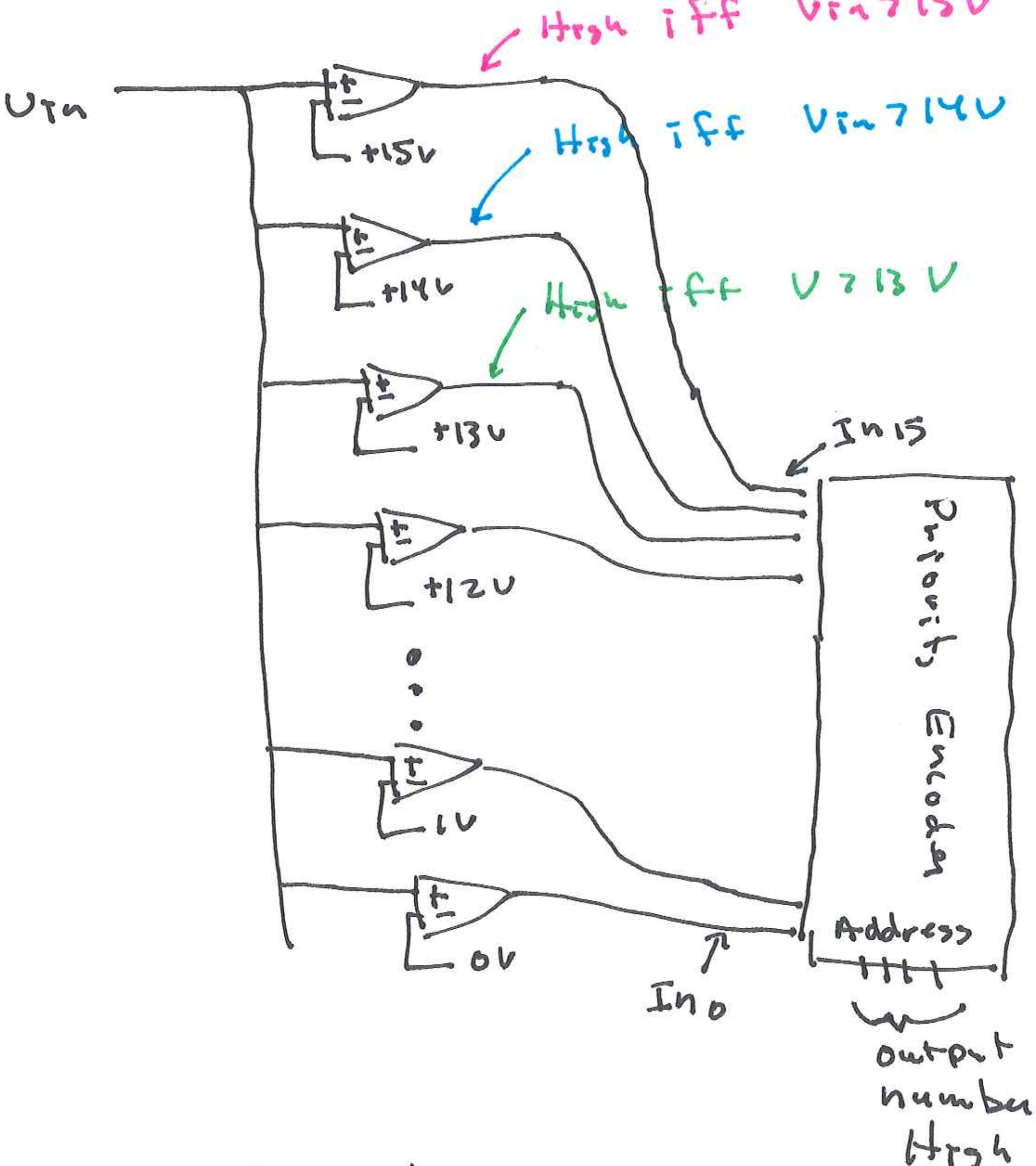
Pulse width modulation – fixed frequency; time High varies

↖ a not uncommon way to transmit signal



avg voltage out $= +5V \frac{t}{T}$

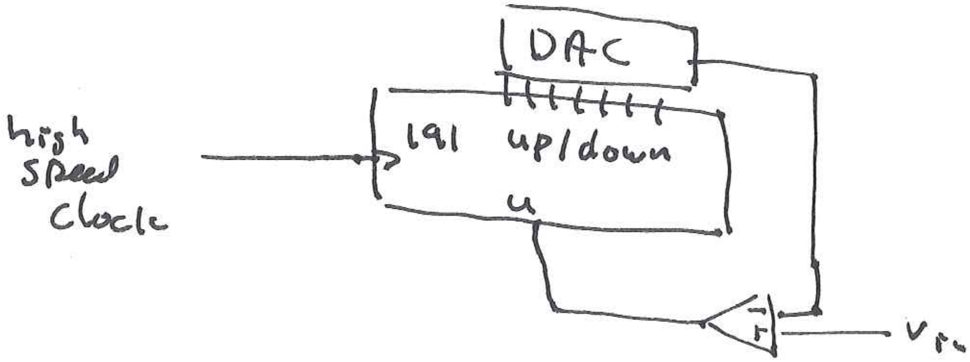
Analog to Digital Conversion (ADC)



"Flash ADC" in Digital Scopes

→ another bit doubles the price.

slower but less expensive: use feedback & control



if the DACs output is below Vin, count up
if DACs output above Vin; count down
The value in the counter is the binary value of Vin