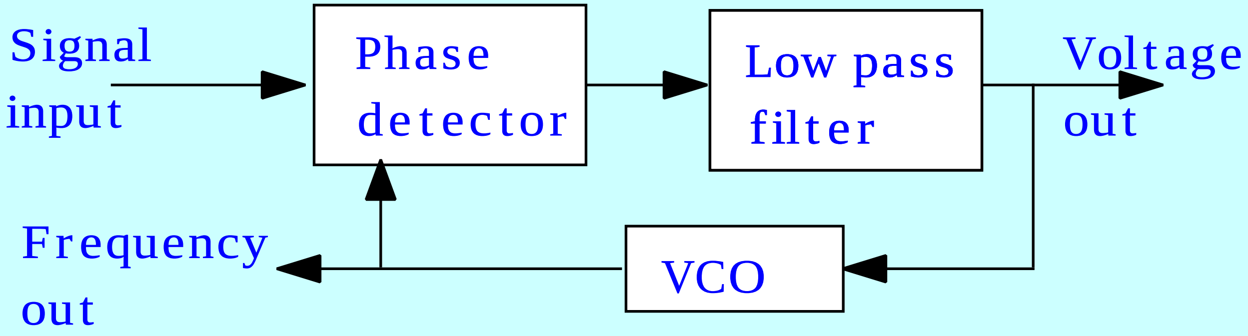
Phase Locked Loops - PLL

•frequency selective feedback system

wide use in FM detectors, stereo demodulators, tone decoders, frequency synthesisers, frequency synchronisation,...



•Voltage Controlled Oscillator

in feedback loop

reference oscillation, with frequency dependent on DC voltage

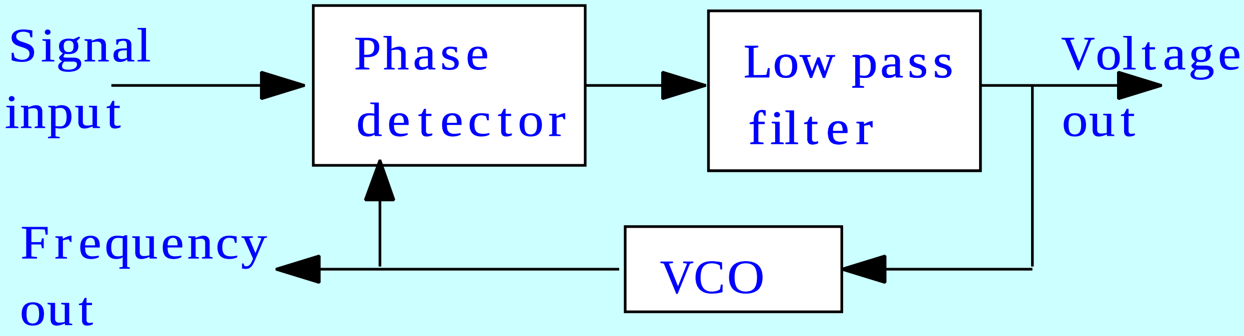
•Phase detector

compares periodic input signal with output of VCO and adjusts in response

•Low pass filter

generates correction voltage from phase detector output

PLL operation



- No signal present

  error voltage = 0

  VCO "free runs" at f_0

- Apply periodic signal at f_s

  $f_s \approx f_0$

  phase comparison with VCO generates error voltage...

  ...which forces VCO to synchronise with f_s

  PLL "locks" onto input frequency

  VCO frequency identical to input frequency, but with phase difference

- If input frequency varies slowly, PLL will remain locked

  will track input frequency

  eg input clock with jitter (phase noise), PLL will "clean up" clock

  FM radio: audio signal much lower frequency than carrier

  voltage output will follow audio

Phase sensitive detection

- Mix input and reference signals

  $V \sim \sin\omega_0 t.\sin\omega_s t$

  produces two components

  $f \sim 2f_0$

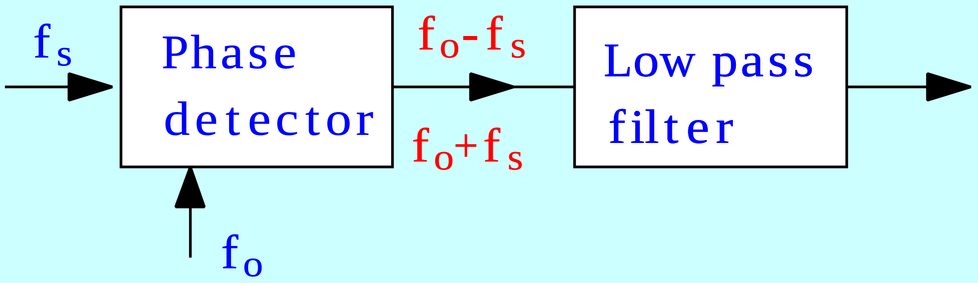
  $f = \Delta f$ ie low frequency

- pass though low pass filter

  $\tau \gg 1/f$

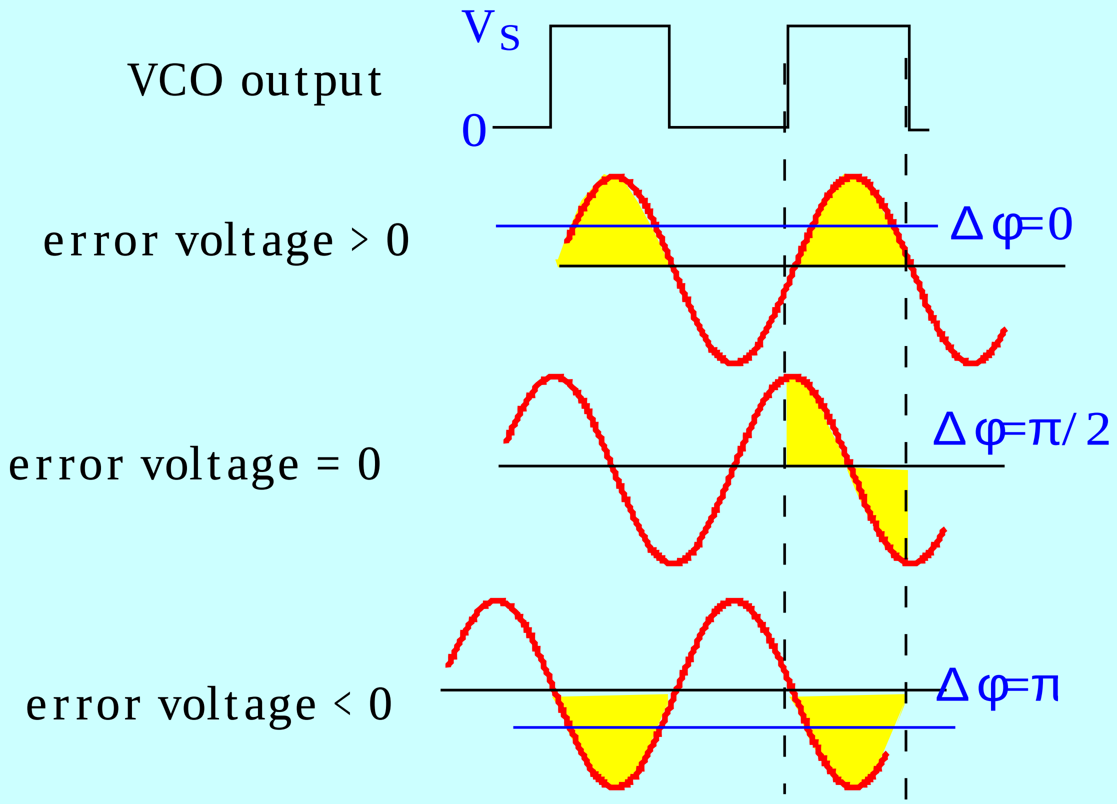
  produces error voltage

- actual method different →



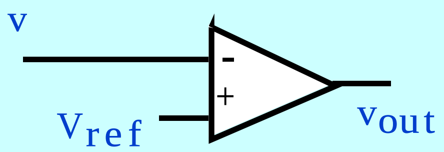
$V_{error} = A\cos\varphi$

cosφ dependence not ideal for real applications



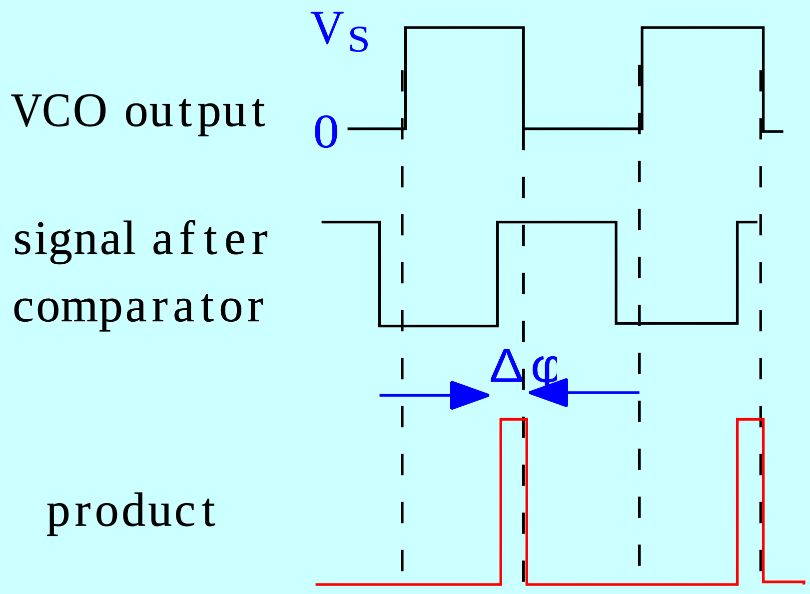
Improved phase detector

- Transform sine wave to square wave



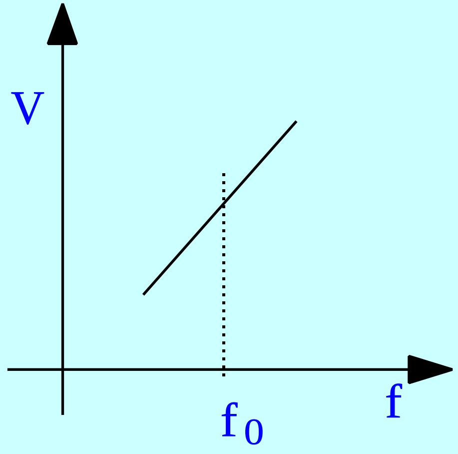
$V_{ref} = (v_{max} - v_{min})/2$

or input may already be pulsed



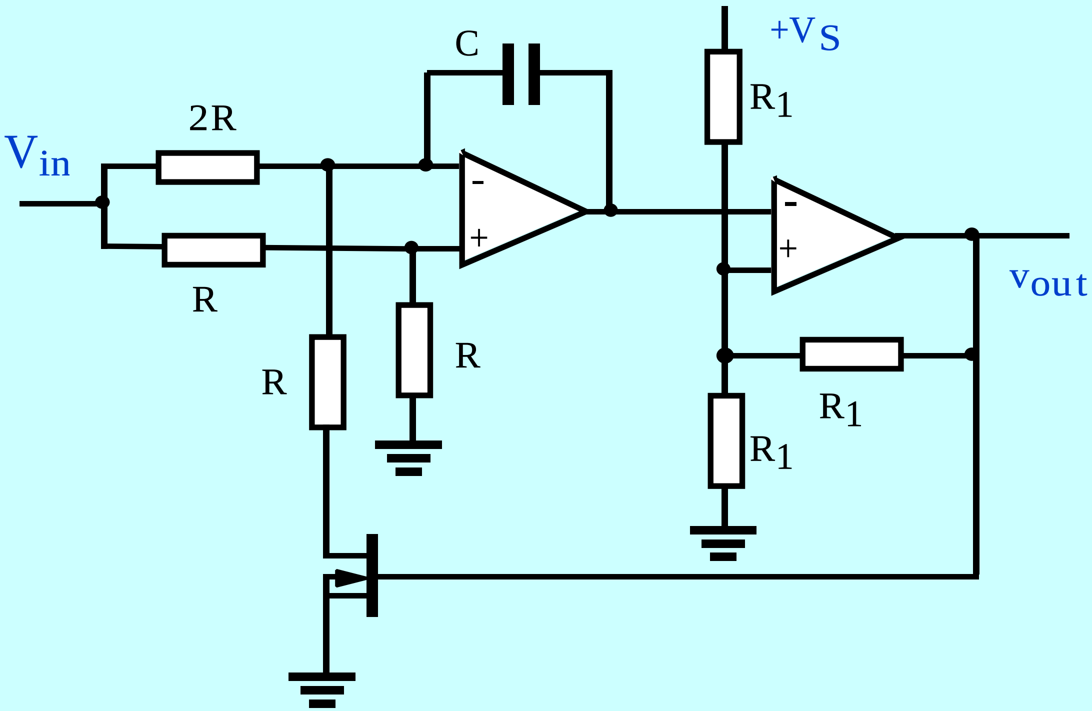
Voltage Controlled Oscillator VCO

•ideal VCO behaviour



•moderate frequency example

nMOS = switch



PLL operation

- For phase locking, require $f_s \approx f_0$

  => sensitive to finite range of frequencies

- Capture range

  frequency range over which PLL can lock on signal

- Lock range

  frequency range over which PLL can track input variation

- Role of low pass filter - decreasing bandwidth (increasing τ)

  slows capture process, increases time to lock

  decreases capture range

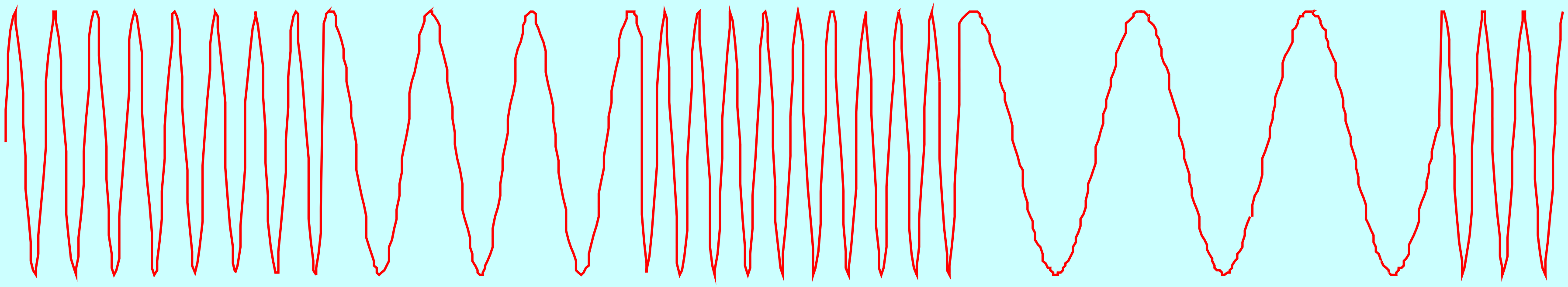
  once locked, greater immunity to high frequency interference

  transient response to sudden changes in frequency within capture range becomes underdamped

PLL applications (i)

- FM demodulation

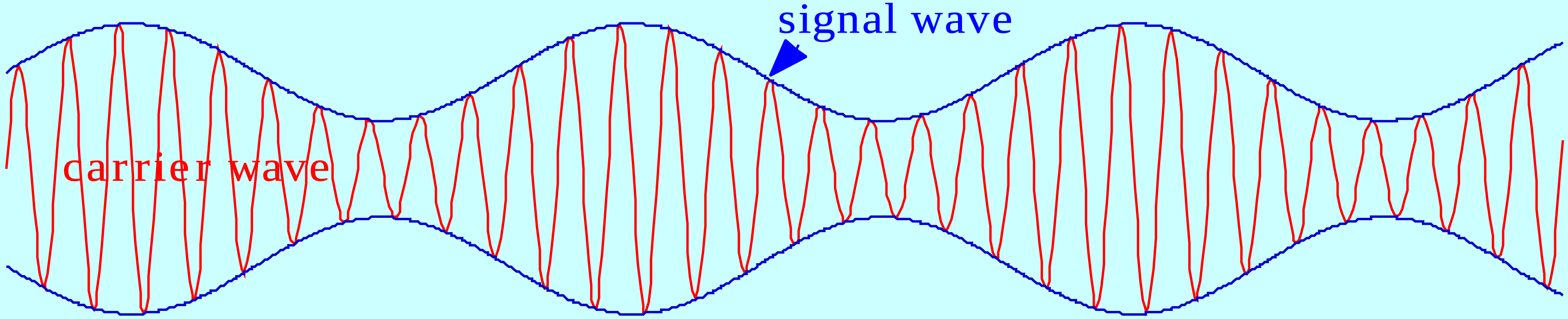
PLL tracks variation in frequency



also used in Frequency-shift keying - where mark/space ratio changes, not f

- AM detection

if input is sinusoidal, then PLL can demodulate signal from carrier



PLL applications (ii)

- Frequency synchronisation and signal conditioning

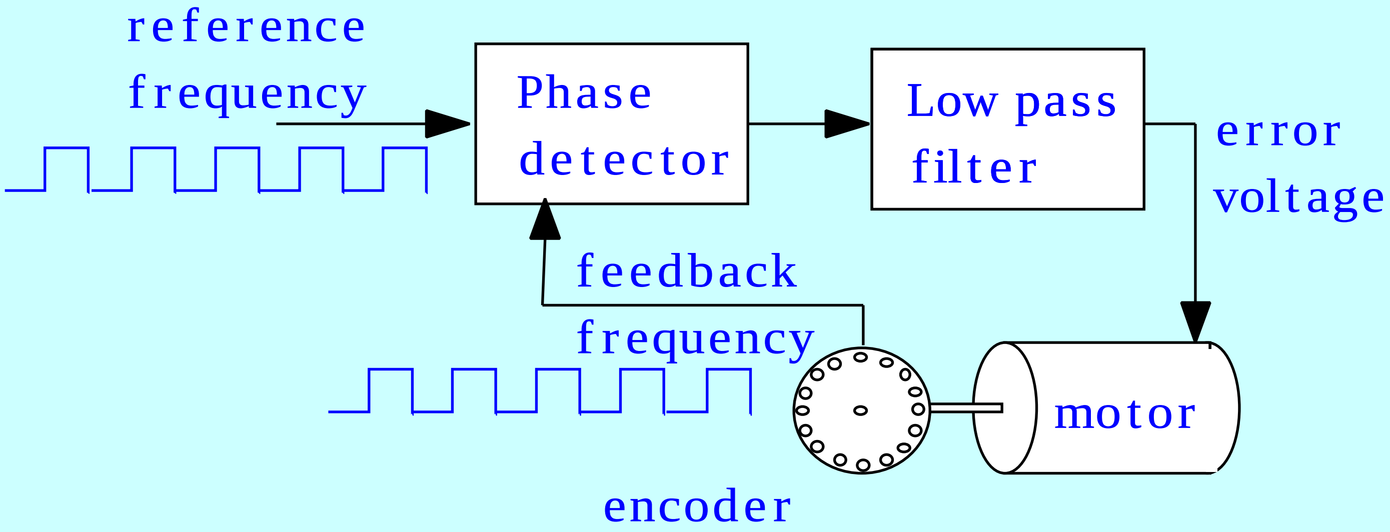
  a poor oscillator can be locked to good reference signal - eg colour TV

  remove out-of-range interference, ie phase jitter

- Synchronisation for control

  eg motor speed - required for many applications

  eg CD player



PLL applications (iii)

- Frequency synthesis

  multiply reference frequency by N, by dividing output in feedback loop

- Frequency translation

  by adjusting response to out of phase signal at input, can offset by small Δf

- Tone or carrier detection

  simply detect if a given frequency is present with magnitude above threshold

  useful eg in stereo decoders, modem