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
  \( V \sim \sin \omega_0 t \cdot \sin \omega_s t \)
  produces two components
  \( f \sim 2f_0 \)
  \( f = \Delta f \) ie low frequency

• Pass though low pass filter
  \( \tau >> 1/f \)
  produces error voltage

• Actual method different

\( V_{\text{error}} = A \cos \phi \)

\( \cos \phi \) dependence not ideal for real applications
Improved phase detector

- Transform sine wave to square wave

\[ V_{\text{ref}} = \frac{(v_{\text{max}} - v_{\text{min}})}{2} \]

or input may already be pulsed

\[ V_{\text{out}} = V_{\text{ref}} \pm v_{\text{out}} \]

VCO output
signal after comparator
product

\[ V_s \]
Voltage Controlled Oscillator (VCO)

- Ideal VCO behaviour

- Moderate frequency example
  - nMOS = switch

![VCO Circuit Diagram]

\[ V_{\text{in}} \to 2R \to R \to +V_S \to \text{Vout} \]

\[ f = f_0 + V_{\text{in}} \]

\[ V_{\text{out}} \]
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 \( \tau \))
  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

- **AM detection**
  If input is sinusoidal, then PLL can demodulate signal from carrier

Also used in Frequency-shift keying - where mark/space ratio changes, not f.
PLL applications (ii)

- Frequency synchronisation and signal conditioning
  - A poor oscillator can be locked to good reference signal - e.g., colour TV
  - Remove out-of-range interference, i.e., phase jitter

- Synchronisation for control
  - E.g., motor speed - required for many applications
  - E.g., 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 $\Delta f$

• Tone or carrier detection
  simply detect if a given frequency is present with magnitude above threshold
  useful eg in stereo decoders, modem