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

\[ V_{\text{error}} > 0 \]

\[ \Delta \phi = 0 \]

\[ error \text{ voltage} \]

\[ V_{\text{error}} = 0 \]

\[ \Delta \phi = \pi/2 \]

\[ V_{\text{error}} < 0 \]

\[ \Delta \phi = \pi \]
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
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 $\tau$)
  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
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

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Phase detector

Low pass filter

encoder

motor

reference frequency

feedback frequency

error voltage

voltage

encoder

reference frequency
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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 e.g. in stereo decoders, modem