ECE 3510 Phase-Locked Loops

Phase-Locked Loops are a bit of a distraction right here, but we need to cover them for next lab. (6 & 7)

Need parts and breadboard for this lab. PLL IC is expensive and prone to static & handling damage.

See lab 6 handout PAY ATTENTION to warnings in the lab.

Modulation

AM = Amplitude Modulation

\[ x_{\text{mod}}(t) \to \text{multiplier} \to \text{AM signal out} \]

\[ \cos(\omega_c t) \]

"carrier", \( \omega_c \) is the "carrier frequency"

Demodulation

A simple rectifier circuit

Returns the modulation signal

And a coupling capacitor can remove the DC

FM = Frequency Modulation

\[ x_{\text{mod}}(t) \to \text{VCO} \to \text{FM signal out} \]

Voltage-Controlled Oscillator

\( \omega_c \) is the carrier frequency and is the output when \( x_{\text{mod}} = 0 \)

\( \omega_c + k_{\text{VCO}} \cdot x_{\text{mod}}(t) \) is the output frequency

So if: \( \cos(\omega_c t) \) is the carrier, I guess \( \cos(\omega_c + k_{\text{VCO}} \cdot x_{\text{mod}}(t)) \cdot t \) must be the output... WRONG!

\[ \theta(t) = \int \omega \, dt \] is the REAL relationship between \( \theta \) and \( \omega \), unmodulated.

\[ = \omega \cdot t \] for the unmodulated (steady-state sinusoid) case

so if you want to modulate the frequency:

\[ \theta(t) = \int (\omega_c + k_{\text{VCO}} \cdot x_{\text{mod}}(t)) \, dt = \omega \cdot t + \int k_{\text{VCO}} \cdot x_{\text{mod}}(t) \, dt \]

And, the VCO becomes

\[ \frac{k_{\text{VCO}}}{s} \]

if you just care about \( \theta(t) \) and not the carrier

PM = Phase Modulation
One way to demodulate FM is with a Phase-Locked-Loop.

To analyze the Phase-Locked-Loop (PLL).

The same loop if you only care about what happens to $\theta(t)$

$G(s) = k_{pd}\frac{k_{vco}}{s}C(s) = \frac{k_{pll}}{s}C(s)$ where $k_{pll} = k_{pd}k_{vco}$

Closed-loop: $H(s) = \frac{\frac{k_{pll}}{s}C(s)}{1 + \frac{k_{pll}}{s}C(s)} = \frac{k_{pll}C(s)}{s + k_{pll}C(s)}$

At first glance, that filter, $C(s)$, doesn't look necessary, but many phase detectors don't put out a nice DC.

Our phase detector in the lab is a good example:

For filter, $C(s)$, design, see Bodson, section 4.5.4 and PLL labs.

Your challenge in the lab will be to get a good demodulation and a stable system.

PLLs can also be used for frequency synthesis and motor speed control, etc.