Project Proposal: Phase Sensitive Detection

(How dark is dark)

1. Introduction to PSD

Phase Sensitive Detection (PSD), commonly referred to as a lock-in amplifier, is a technique used to extract signals with a known carrier wave from an extremely noisy environment. It is particularly useful in applications where the signal of interest is weak compared to the background noise. The PSD technique achieves this by multiplying the input signal with a reference signal of the same frequency and then applying a low-pass filter to extract the desired signal component.

2. Theory Behind PSD

The core principle of PSD relies on synchronous detection, where the incoming signal is mixed with a reference signal that has the same frequency but a well-defined phase relationship. This process shifts the frequency of the desired signal down to DC while unwanted noise, which is typically at different frequencies, gets shifted away and is removed by the low-pass filter.

The key components of a PSD system include:

- **Phase Shifter (All-Pass Filter):** Adjusts the phase of the reference signal to match the signal of interest.
- **Switch-Based Phase Sensitive Detector:** Utilizes analog switches controlled by a square wave signal derived from the reference.
- **Low-Pass Filter:** Removes high-frequency components, leaving only the DC component proportional to the amplitude of the original signal.

The mathematical expression governing PSD is: $V_{OUT} = V_{in} \cos(\theta)$ where θ is the phase difference between the input signal and the reference.

3. Applications

One of the critical applications of PSD is in precision **photodetection**, as highlighted in the "How Dark is Dark" document.

Lock-in amplifiers enable the measurement of signals with amplitudes much smaller than the noise floor by isolating the signal component correlated with a modulated reference.

4. Experimental Procedure

The experiment aims to construct and analyze a PSD system through a series of circuit implementations:

Session 1: Studying the Lock-in Amplifier Blocks

- **Buffer (741-based voltage follower):** Provides impedance matching.

- **Phase Shifter:** Implements an all-pass filter to adjust the reference signal phase.
- **Switch Driving Circuit:** Generates complementary square wave signals to control the phase-sensitive detector.
- **Switch-Based Phase Sensitive Detector:** Utilizes the CD4066 quad analog switch for demodulation.
- **Low-Pass Filter:** Extracts the DC component corresponding to the original signal amplitude.

Phase Shifter Implementation

1. Connect the phase shifter circuit.
2. Apply a 1Vp-p, 1kHz sinusoidal input signal.
3. Observe and record the output phase shift for different potentiometer settings (0°, 45°, 90°, 135°, and 180°).

Switch-Based PSD Implementation

1. Connect the phase-sensitive detector circuit.
2. Drive the switches using complementary square waves.
3. Observe and measure the output voltage (Vpsd) for different phase shifts (0°, 90°, 180°).

Low-Pass Filter Implementation

1. Connect the LPF circuit and apply a test signal.
2. Measure and plot the frequency response.
3. Integrate the LPF with the PSD output and record the final output voltages for different phase angles.

5. Expected Outcomes

- **Phase Shifter:** The phase shift should match theoretical calculations.
- **Switch-Based PSD:** The demodulated output should be proportional to the input amplitude.
- **Low-Pass Filter:** The extracted DC component should correspond to the phase difference.

6. Conclusion

This experiment demonstrates the fundamental working of Phase Sensitive Detection and its application in noise reduction and precision measurement. The results obtained will be compared with theoretical values to validate the effectiveness of PSD in signal conditioning.