Phase Sensitive Detection(Lock-in-amplifier)

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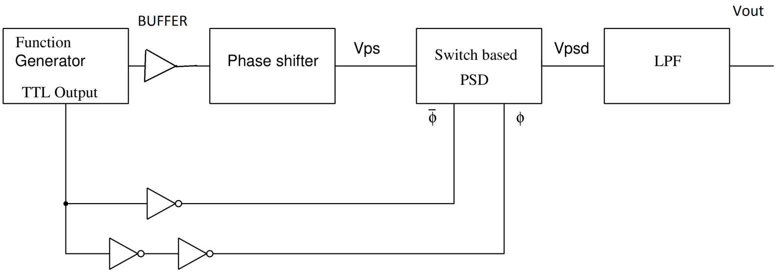
Before performing the experiment...

* Read the supporting document uploaded on moodle thoroughly to understand the motivation and principle of phase sensitive detection(also known as lock-in-amplifier).

* The overall block diagram has been modified for our lab experiment.



Session-1

In this session, we shall study the following blocks of the lock-in-amplifier.

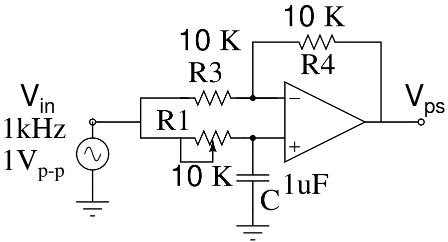
1. Buffer: 741 based voltage follower
2. Phase shifter
3. Switch driving circuit
4. Switch based phase sensitive detector
5. Low pass filter

- **Note: While making connections for individual blocks, please arrange them on your breadboard, as they appear in the block diagram.**
- **All the opamps used in the blocks use IC 741.**
- **Do not dismantle the connections of the blocks. All the blocks will be required for final testing.**

Phase shifter (also known as ALL PASS FILTER)

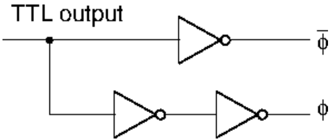
Analyze the circuit and justify how it works as a phase shifter and why it is called as all pass filter. Derive the transfer function of the phase shifter circuit.

1. Make the connections as shown in the circuit diagram.
2. Apply $1V_{p-p}$, 1kHz sinusoidal signal from CH1 of AFG.
3. Observe the output voltage of phase shifter V_{ps} with respect to the input signal V_{in}.
4. Vary the potentiometer R1 and observe how the phase difference between V_{in} and V_{ps} changes. Compare the observed phase difference with the theoretical value for phase angles, 0°, 45°, 90°, 135°, and 180°.



Switch driving circuit

* This circuit generates two complementary square wave signals.
* These are required to drive two pairs of analog switches in phase sensitive detector as control inputs. Make sure that the inverter IC is **74C04**, CMOS inverter to ensure 5V amplitude output signal.
* Use TTL output from your AFG as input to this circuit. This signal is internally synchronized with CH1 of the AFG and hence it is of same phase and frequency of that of CH1.
* Observe the two signals ϕ and $\overline{\phi}$ and verify that they are 180° apart.



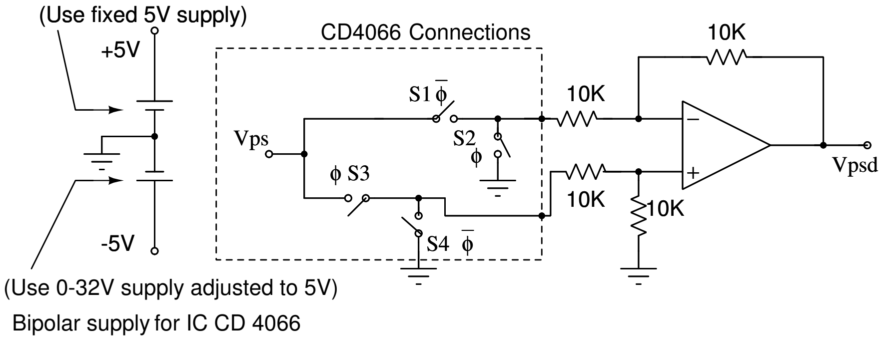
Switch based phase sensitive detection circuit-1

This is the heart of the lock in amplifier. In the lab experiment, we shall use IC CD4066 which is a quad analog bilateral switch. Please read the datasheet carefully.

1. The switches S1 and S4 are applied the control voltage $\overline{\phi}$ while, S2 and S3 are applied ϕ.
2. Since the input signal to be applied is bipolar, we need to use bipolar voltage supply (+/-5V) for the switch.
3. You need to derive this using a fixed 5V supply and the variable (0-32V) supply set to 5V.
4. Make the connections as shown in the circuit diagram.
5. Note that this circuit needs one bipolar supply (+/- 5V) for switch and another bipolar supply (+/-12V) for opamp. So be careful!
6. Connect the output of the phase shifter V_{ps} as input to the PSD circuit and drive the switches using ϕ and $\overline{\phi}$ signals.
7. Make sure that no ground node is left floating.

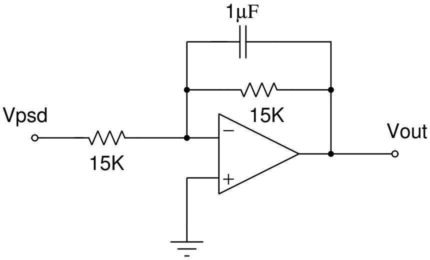
Switch based phase sensitive detection circuit-2

8. Set the phase shifter for 0° phase shift between the input signal and the TTL output..
9. Observe the V_{psd} with respect to ϕ.
10. Repeat for 90°, and 180° phase shift.
11. You should get the waveforms as shown in Appendix-2 for these phase angles.
12. Measure the average value of the output of the phase shifter V_{psd} in each of the three cases.



Low pass filter-1

* The output of the phase sensitive detector consists of a dc component and high frequency components.
* A low pass filter separates out the dc component and eliminates the harmonics.
* We shall use a first order LPF as shown in the figure.
* Derive the transfer function and the equation for cut-off frequency of the same.



Low pass filter-2

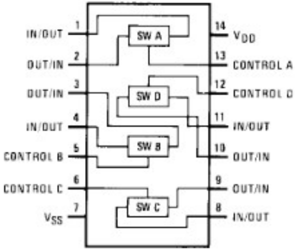
* Make the connections as shown in the circuit diagram. Apply $1V_{p-p}$ sinusoidal input signal.
* Measure the frequency response by varying the frequency from 1 Hz to 1kHz.
* Plot the frequency response and obtain the cut-off frequency. Compare it with the theoretical value.
* Now connect the output of PSD, V_{psd} as the input to LPF.
* Set the phase shift to 0° and measure the output of LPF.
* Repeat for 90° and 180°.
* Compare these values with the average values of V_{psd} measured in the last part.

What should you report

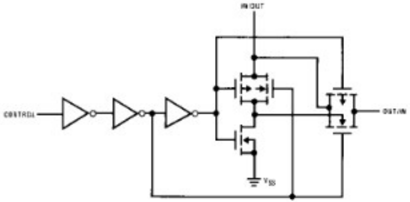
- All pass filter:
  - Tabulate the observed and calculated values of the phase angles mentioned.
- Switch based PSD:
  - Show the waveforms to your TA for three different phase angles mentioned.
  - Note the average values of the V_{psd} for these phase angles.
  - Take the pictures of the waveforms and save them for your reference.
- Low pass filter:
  - The frequency response
  - The cut off frequency of the filter
- The complete PSD:
  - The voltage V_{out} for the three phase angles

Appendix-1: IC Pin diagrams-1

Connection Diagram



Schematic Diagram



Appendix-1: IC Pin diagrams-2

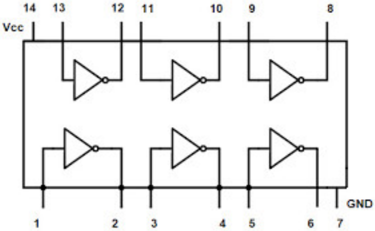


Figure: IC 7404

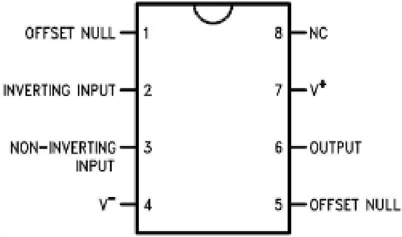
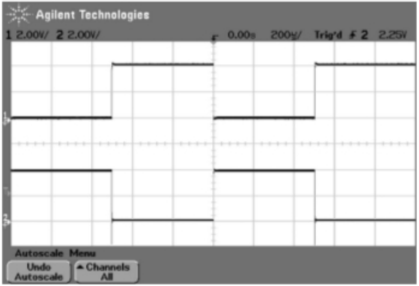
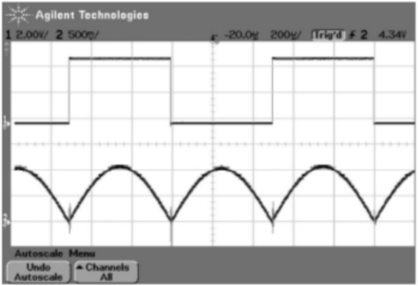


Figure: IC 741

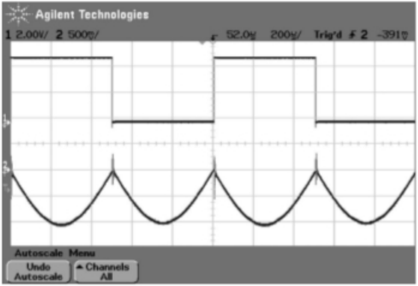
Appendix-2: Expected waveforms:The two reference signals



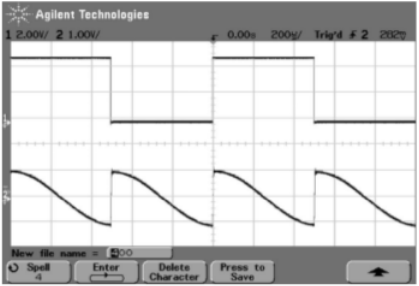
Appendix-2: Expected waveforms: 0° phase shift



Appendix-2: Expected waveforms: 180° phase shift



Appendix-2: Expected waveforms: 90° phase shift



Circuit Layout (DON'T DISASSEMBLE THE CIRCUIT !!!) You need the same for PSD Apps lab, next week