

Laboratory 8

Lock-in amplifier¹

Prior to the lab,

- Understand the circuit (Figure 1). Download from the blog and read the spec sheets for the comparator and the quadrant multiplier.
- Draw how to connect the components of this circuit on protoboard picture (Figure 4) . This approach helps in assembling your circuit when you get to the lab.

The goals in this laboratory session are:

- (1) Assemble a lock-in amplifier
- (2) Test this instrument
- (3) Understand how a lock-in amplifier works

Introduction

In this experiment, you will construct a simple lock-in-amplifier and characterize its properties. This is the most complicated circuit that you are going to make in this course but it should also be fun because you are going to make real albeit simple instrument. While you construct the various parts of the lock-in amplifier, make sure that each circuit part behaves as expected. Feel free to use Microcap if you are unsure about the expected output of each part

Components and Equipment Needed

1. Comparator (AD790)
2. Quadrant multiplier (AD835)
3. Resistors
4. Capacitors
5. Oscilloscope
6. Function generator
7. Microcap

A. Circuit overview

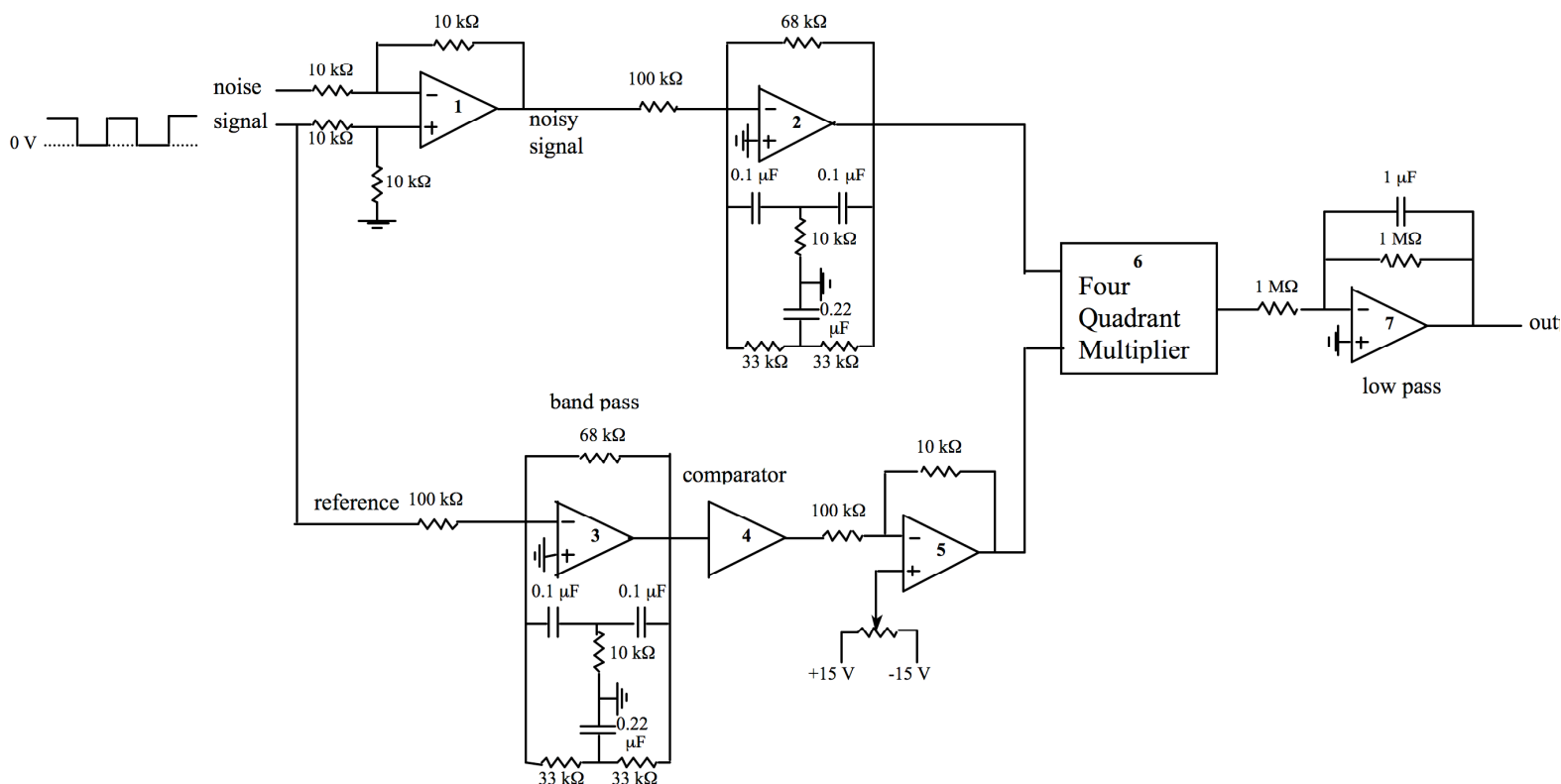
Instead of using a random noise source, this experiment uses the sine wave from a function generator as the noise signal. This allows you to assess more easily the effect of the signal frequency and amplitude of the noise on the output of the lock-in-amplifier.

The signal is a square wave with a voltage minimum at 0 V. Such a signal would be obtained after chopping of a real continuous signal. For example, light emitted by a cell could be chopped with a chopper wheel right before it falls onto a photodiode, which converts it into a chopped electrical signal. The noise and the signal are added together with an op-amp circuit.

¹ This laboratory experiment was prepared by Jun Dai and Hao Luo, University of Minnesota.

This experiment does not use a separate source for the reference signal but use the signal output also as the reference signal. The reference signal is amplified and band-pass filtered, and then converted to a square wave with a comparator. An additional op-amp adds a bias to the comparator output to give a square-wave signal with a time

Figure 1. Lock-in amplifier circuit



average of 0 V. This output is then multiplied with the amplified and tuned signal using a four quadrant multiplier. In the final step, the signal goes through an op-amp low-pass filter.

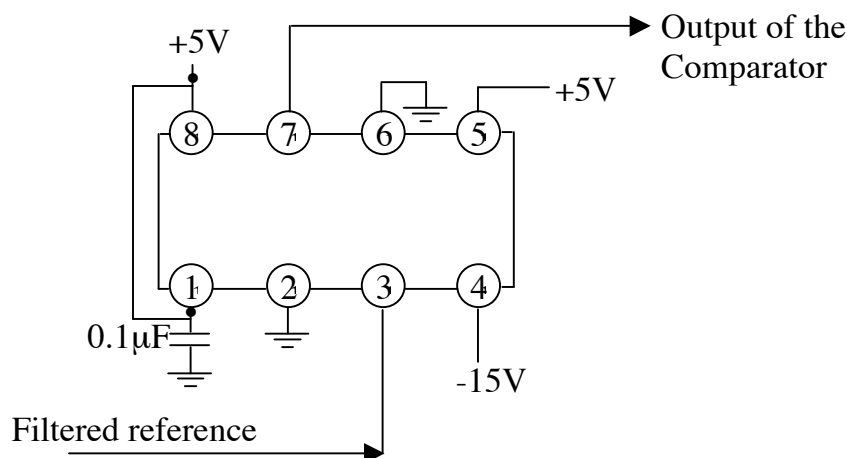
B. Circuit assembly

Procedure

1. Assemble the differential input amplifier (**Op amp 1**). The expected output is a "noisy signal" resulting from adding the outputs from two function generators.
2. Assemble the two band-pass filters based on a twin-T filter (**Op amp 2 and Op amp 3**).
3. Determine the resonance frequency of each band-pass filter.
4. Determine the frequency dependence of the output of the band-pass filter to which a "sine wave noise" is fed. [Set the square-wave amplitude to 0 V for this task.]

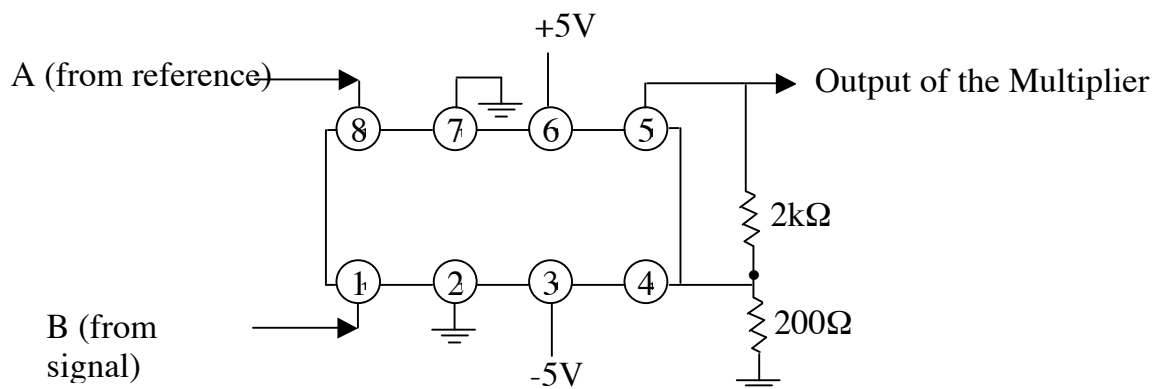
5. Compare the expected and real output of the band-pass filters when you feed in a “noisy signal” (i.e., the sum of the square wave signal and sine wave noise) to the upper filter and the square wave signal to the lower filter.
6. Connect the comparator (AD790) as shown in Figure 2. Refer to Figure 1, **units**

Figure 2. Comparator circuit



- 4 and 5. Note that the two possible outputs of this comparator are +0.4 and +4.6 V.
7. Compare the expected and real output of the comparator.
8. Provide a suitable bias to the output of the comparator using an op amp, converting the 0.4 V/4.6 V output from comparator to a -0.2 V/+0.2 V output.
9. Connect of the four quadrant multiplier (AD835) as shown in Figure 3, (**unit 6**, Figure 1).
10. Compare the expected and real output of the multiplier.
11. Assemble the low pass filter (**Op amp 7**, Figure 1). Determine the upper 3 dB frequency of this low pass filter. What does the ultimate output from this low-pass filter look like?
12. Investigate the dependence of the ultimate output of this lock-in-amplifier on the frequency and magnitude of the “noise”.
13. Investigate the dependence of the ultimate output of this lock-in-amplifier on the frequency and bias of the “signal”.

Figure 3. Multiplier circuit.



Report. Include the circuit diagram with the real resistor and capacitor values used in this circuit. Provide a sketch of the observed output of each unit of this circuit (i.e. **Op amps 1, 2, 3, 4, 7, AD790, and AD835**).

Plot the lock-in output versus the frequency and magnitude of the “noise”. Discuss your observations. Plot the lock-in output versus frequency and bias of the “signal”. Discuss your observations.

Discuss how the S/N changes when using lock-in amplifier. Discuss how you may use a lock-in amplifier in your Ph.D. research project.

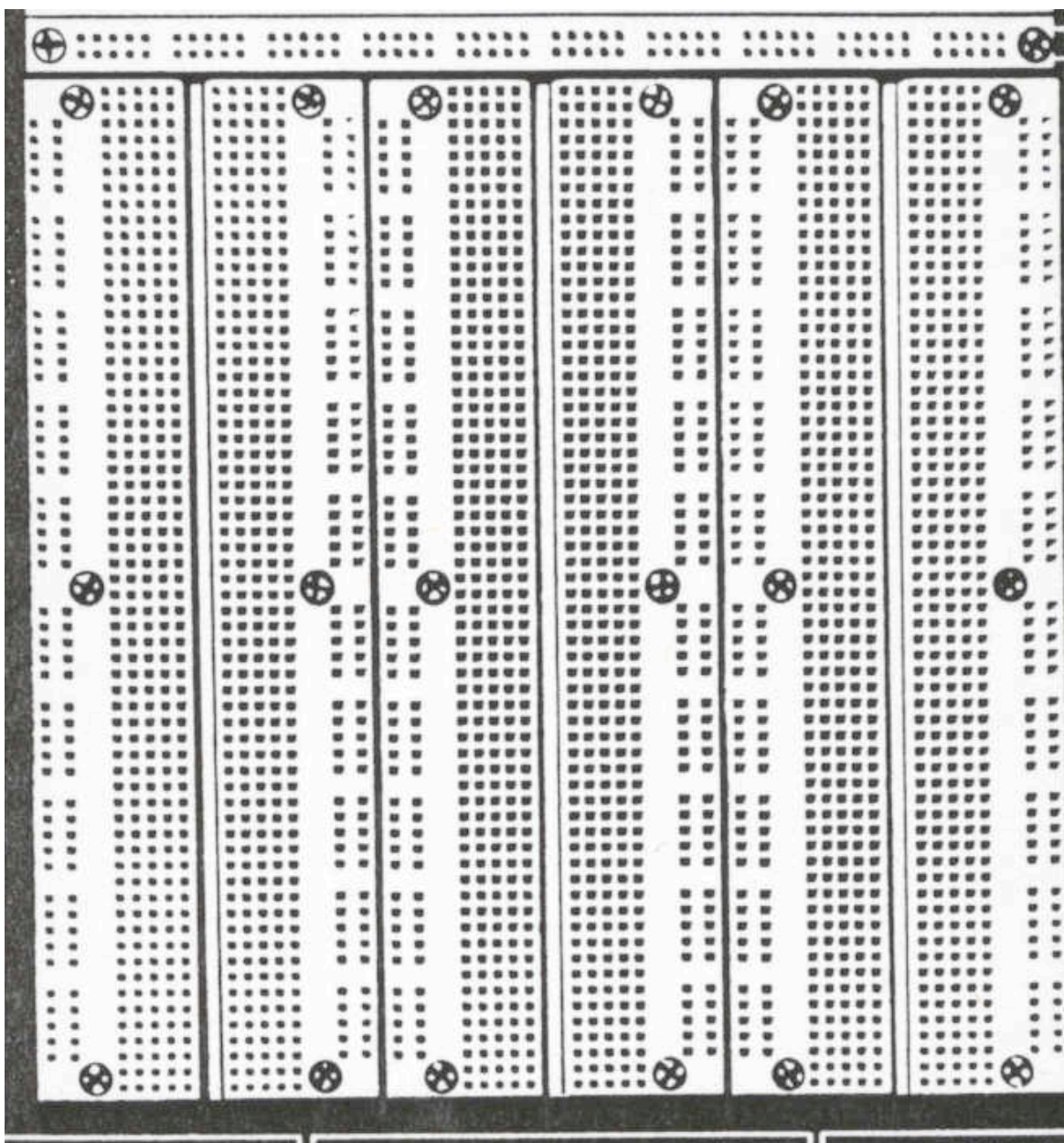


Figure 4.

Advise from previous students that did this lab...

“ I think the class in general got too excited building the circuit and completely forgot about the resonance frequency. So when we went back to start trouble shooting, we first encountered problems with the resistors, and focused on fixing that. [By the second week], everyone forgot that the resonance frequency even needed fine tuning (we pretty much forgot about the lab manual and signal generator altogether).

Basically, we all did the same thing that drives us nuts when we're teaching. We got over zealous and stopped reading the instructions carefully.”

Advise from previous instructor... “Make sure each power supply voltage is correct when the whole circuit is running. You are not using ideal power supplies. Therefore, the output voltages may change as you add on more sub-units.”