

GEORGIA INSTITUTE OF TECHNOLOGY  
SCHOOL of ELECTRICAL and COMPUTER ENGINEERING

**ECE 3084**

**Lab #1: Amplitude Modulation**

Date: 16 Oct 2017

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## 1 Goals

This lab explores the principles of amplitude modulation, particularly double-sideband amplitude modulation, in both the time domain and in the frequency domain.

## 2 Procedures and Deliverables

Verification: The lab must be completed during your assigned lab time and the steps marked Instructor Verification must also be signed off during the lab time. One of the laboratory instructors must verify the appropriate steps by signing on the Instructor Verification line. Turn in the completed verification sheet to one of your lab instructors when you leave the lab. We need only one verification sheet per team.

## 3 Prelab

- (a) If you do not have a working set of drivers and programs for your Windows machine already, please download and install the latest NI ELVISmx (Version 16) software from <http://www.ni.com/download/ni-elvismx-16.0/6130/en>

Unfortunately, the myDAQ software for Macintoshes does not seem to work in the latest versions of Mac OS X. The drivers available from NI seem to be several of years old and are not guaranteed to work past OS 11.9. Mac users should ideally use a Windows Bootcamp partition on their system.<sup>1</sup> You may also have some luck with running the NI ELVISmx software in a virtualization tool such as Parallels, VMWare, or Virtual Box, although functionality may vary from inconsistent to nonexistent. **YOU MUST INSTALL THE SOFTWARE AND BE SURE YOUR myDAQ WORKS BEFORE COMING TO LAB!!!**

- (b) Make sure you can run the Java applet at this website: <http://www.falstad.com/fourier>
- (c) Read the lab carefully before coming to lab.
- (d) **BRING HEADPHONES TO LAB.**

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<sup>1</sup>If you are a Mac user and do not have Bootcamp set up, your best bet is to probably have a lab partner who is a Windows user.

## 4 Hardware

To help streamline the lab experience, we created a custom PCB with a connector that plugs directly into the side of the myDAQ, as shown in Figure 1. A top-down layout of the board is shown in Figure 5, and its schematic is shown in Figure 6. These figures are on two pages at the end of the document. You may want to detach these for ease of reference.

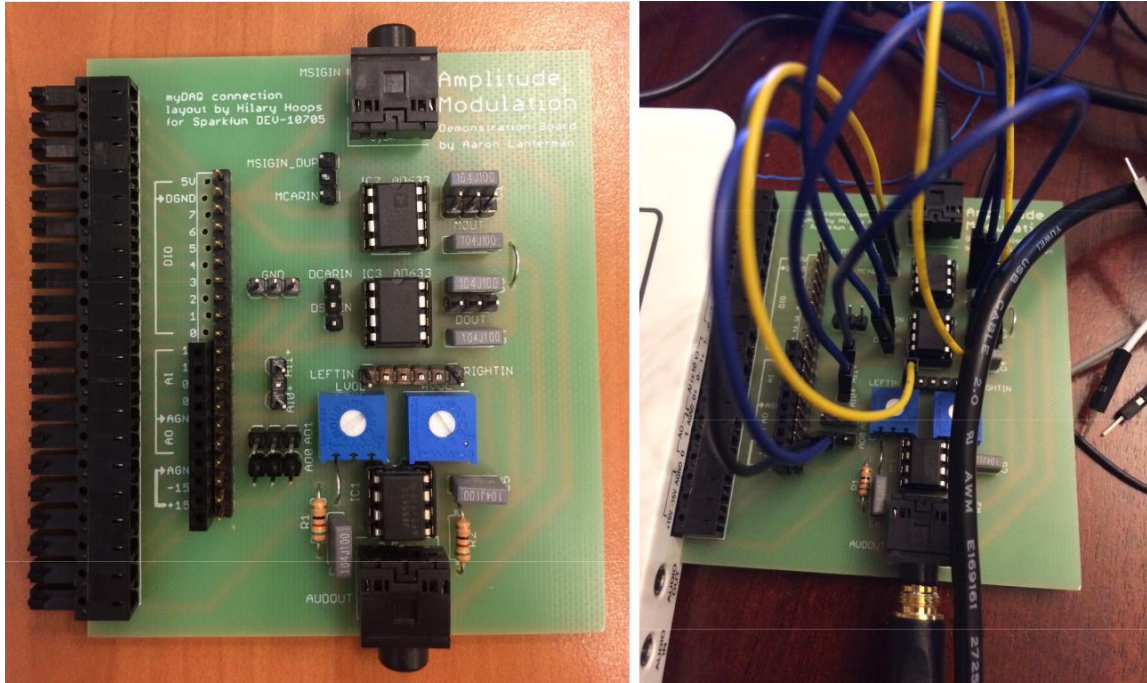


Figure 1: Custom PCB for this lab.

The PCB makes the 15 V power connections for the chips. It also connects the various ground pins of the myDAQ, and connects the negative analog inputs (A0- and A1-) to ground. The six 0.1 mF bypass capacitors help clean up the power lines.

Familiarize yourself with the various components on the board:

- (a) IC1 is a dual op amp that serves as a buffer for the headphone output jack, labeled AUD-OUT, at the bottom of the board. You can input an audio signal to the buffers through the LEFTIN and RIGHTIN pins to hear them on your headphones. The potentiometers LVOL and RVOL are volume controls. It can be instructive to listen to one signal on the left while hearing another signal on the right. Often these signals are at rather different overall amplitudes, so we provide separate volume controls for each channel so you can adjust as needed to hear equivalent sound levels. In general, you should start with the volume controls turned down and gradually turn them up to avoid overdriving your headphones. (The 51 ohm resistors are intended to limit the current the op amps have to provide, but you still wouldn't want to push it.)
- (b) The Analog Devices AD633 is a "multiplier" chip, whose pinout is shown in Figure 2. Its output at pin 7, labeled W, is given by

$$W = \frac{-(X1 - X2)(Y1 - Y2)}{10V} + Z; \quad (1)$$

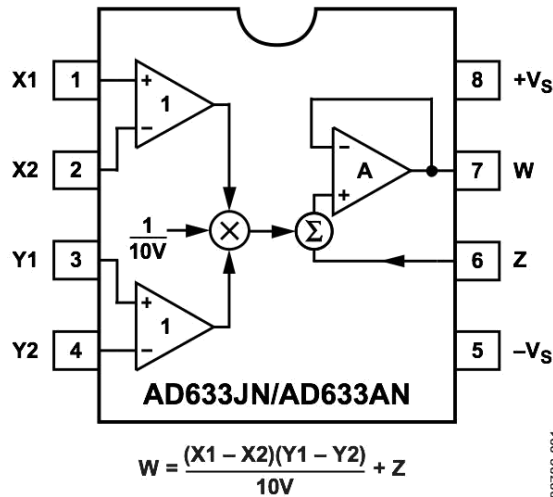


Figure 2: Pinout of the AD633.

where the inputs X1, X2, Y 1, Y 2, Z are at pins 1, 2, 3, 4, and 6, respectively. The PCB automatically hooks Z, X2, and Y2 to ground.

We will use two of these chips, labeled IC2 and IC3, as shown the Figure 5. IC2 (near the top of the board) will play the role of the "modulator" and IC2 (in the middle of the board) will play the role of the "demodulator." These chips are rather expensive; please be careful with them.

- (c) One input to the modulator, IC2, may be injected through a 1/8" jack at the top of the board, which is labeled MSIGIN (Modulator Signal Input). Only the left channel of the stereo audio signal is used; the right channel is ignored. This input is also connected to a pin labeled MSIGIN DUP (DUP stands for "duplicate"). This pin is provided for convenience so you can look at the input signal using the myDAQ virtual instruments. You could also, if desired, input a signal through the MSIGIN DUP pin, but you should be careful to not trying to input a signal through the MSIGIN DUP pin and MSIGIN at the same time.

The second input to the modulator is injected through pin labeled MCARIN, Modulator Carrier Input.

- (d) The inputs to the demodulator are injected through the pins labeled DSIGIN (Demodulator Signal Input) and DCARIN (Deodulator Carrier Input). (Because of the way we installed the pins for DCARIN and DSIGIN, the label for DSIGIN may be somewhat obscured on your board.)
- (e) The outputs of the multipliers are found at the pins labeled MOUT (Modulator Output) and DOUT (Demodulator Output). Each output is available from three neighboring pins, allowing you to easily send the outputs to multiple places.
- (f) The myDAQ connections are available through a long header near the left side of the board, in the same order that they appear on the myDAQ connector. For convenience, we provide two rows of pins of the analog outputs (AO0 and AO1) and two pins for the positive analog inputs (AI0+ and AI1+), as well as a row of GND pins. These convenience pins may be found to the left of the LVOL potentiometer and IC3.

## 5 Setup

Before you begin, make sure the myDAQ is powered off, i.e., make sure it is not connected to a computer via the USB cable.

The screw terminals that come with the myDAQ are terrible. We will not use them. If your myDAQ has the screw terminal strip still attached, you can just pull it off (be sure not to lose it; put it in your box). Removing the screw terminals reveals a set of male connectors. Plug the custom Amplitude Modulation Demonstration board directly into the side of the myDAQ.

We will provide you with a set of jumper cables with female connectors to connect various pins on the PCB.

### 5.1 Preparing for the First Experiment

- (a) Unfortunately, the basic function generator software provided by National Instruments can only use one analog output at a time. So, to provide a signal to be modulated, we will use the audio output of your laptop. Use a 1/8" cable with male connectors (often called an "aux" cable, since people use them to connect their phones to the "aux" input jack on their older car stereo systems) to connect your laptop's audio output to MSIGIN, which is near the top of the board.
- (b) Connect Analog Output 0 (AO0) to MCARIN and DCARIN. This will use up two of the three pins in the AO0 row, which you can find to the left of the LVOL potentiometer. Hence, the same sinusoidal carrier will be provided to the modulator and the demodulator.
- (c) Connect Analog Input 0+ (AI0+) on the myDAQ to MSIGIN DUP. This will let us be able to look at the input signal coming from your laptop's audio output.
- (d) Connect Analog Input 1+ (AI1+) to MOUT, which is the modulator output. In a later part of the lab, we will switch this to the demodulator output.
- (e) Connect one of the MOUT pins to DSIGIN. We won't use this feature in Section 6.1, but we will in Section 6.2, and it will be convenient to have it already set up.
- (f) In addition to looking at signals on the screen, we'd like to be able to listen to them. Plug your headphones into the AUDOUT jack at the bottom of the board. Turn the volume controls down at first to avoid accidentally blowing out your headphones, and gradually turn them up as desired. Note that you may get loud pops and clicks when changing connections on the PCB, so you may want to turn down the volume controls before doing so. Connect MOUT to LEFTIN or RIGHTIN (or both { if you have earbuds that can be shared, connecting to both lets you and one of your labmates listen at the same time). The modulated signal can often sound annoying, even if the headphones are just sitting on the desk, so you may want to turn down the volume when you're not particularly needing to listen to anything. (Over the course of the lab, if things aren't working the way you expect, you may want to try listening to the input signals as a debugging tool.)

### 5.2 Connecting the myDAQ to the Laptop

Now we are ready to hook up the myDAQ to your laptop:

- (a) Connect the myDAQ to your computer using the USB connector.

- (b) Carefully touch the tops of the chips. If one of them feels like it is getting warm, immediately unplug the USB connection to the myDAQ check with a lab instructor before trying step (a) again.
- (c) Start up the NI ELVISmx Instrument Launcher software.

## 6 Experiments

### 6.1 Modulating Simple Signals

Before starting this section, be sure to make the various connections listed in the previous "Setup" section.

- (a) Start up the function generator FGEN and the Scope by clicking on their icons in the Instrument Launcher.
- (b) Let's set up the Function Generator (FGEN). Under Instrument Control (near the bottom of the panel), make sure that you see "NI myDAQ" under Device in the lower left panel, and make sure that Signal Route is set to AO0. Click on the sine wave button on the left side of the panel. Set Frequency to 2 kHz, Amplitude to 10 volt peak-to-peak, and DC O set to 0 volts. Click the green Run arrow.
- (c) Go to the website <http://www.falstad.com/fourier>, which has a Java applet that will help us generate various waveforms. Click the Sine button, and set the Playing Frequency slider so you have a tone somewhere between 100 and 300 Hz. Then make sure the Sound checkbox is checked. We should now be multiplying the sine wave from the myDAQ with the sine wave from the web applet. You can adjust the amplitude of the signal from the applet using the volume control on your laptop.
- (d) Now let's set up the Scope. Under Channel 0 Settings, set the Source to be AI0 and Scale Volts/Div to 200 mV. Under Channel 1 Settings, set the Source to be AI1 and Scale Volts/Div to 100 mV. Make sure both Enabled boxes are checked. Click the green Run arrow.
- (e) You should see two traces on your scope: one being the sinusoidal signal from your laptop, and the other being the modulated output (i.e. the signal from your laptop multiplied by the sinusoidal carrier from FGEN). Experiment with the Time/Div setting to get a feel for how it allows you to "zoom in" and "zoom out" along the time dimension. Make sure that the modulator output looks like a sinusoid multiplied by a sinusoid, along the lines of Figure 3. (If your readings don't "make sense," check your connections, and then ask a lab instructor for help if you still have trouble.)
- (f) Adjust the sinusoidal carrier frequency (produced by FGEN) and the frequency of the modulating sinusoid (produced by the web applet) and observe the changes in the waveform, changing Time/Div as desired along the way.
- (g) Briefly experiment with the Scale Volts/Div settings to see how they allow you to "zoom in" and "zoom out" along the amplitude dimension.

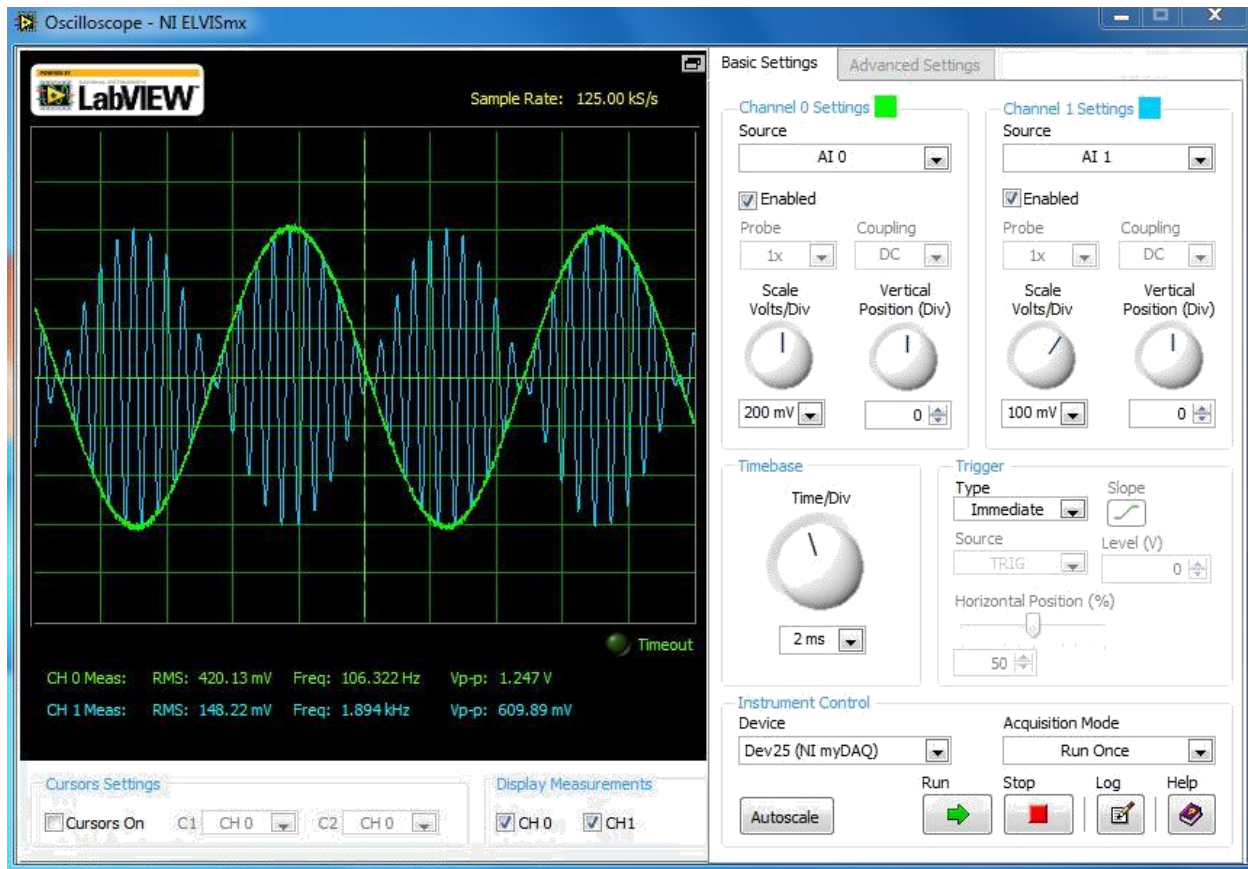


Figure 3: An example of a sinusoid modulated by another sinusoid.

- (h) The Scope gives us a time-domain representation of the signal. We'll now try looking at the signal in the frequency domain. Press Stop<sup>2</sup> on the Scope (but leave the window up, since we will want to go back to it). Start up the Dynamic Signal Analyzer (DSA) by clicking on its icon in the Instrument Manager. Make sure the Source Channel is set to AI 1. Set Frequency Span under FFT Settings to 10000 Hz. Under the Averaging category, set the Mode to 'None.' Under Frequency Display, set Units to linear. Click the green Run arrow.
- (i) You should now see two spectral lines, corresponding to the upper and lower sidebands. Experiment with changing the frequencies of the carrier and the modulating signal. Using headphones, try listening to the modulated signal as you make some of these adjustment. Make sure that the frequencies of the sinusoids you see on the horizontal axis of the DSA plot correspond to the sum and different frequencies that you'd expect to see.
- (j) Now let's try modulating with a more complex waveform. Click on the 'Square' button in the web applet; again manipulate the frequencies produced by the applet and FGEN, and watch the results on the DSA while listening to the output on headphones. (Some laptops seem to have a highpass filter on their headphone outputs; do not be alarmed if your raw square wave appears to be a bit misshapen. The frequencies present will still be in the right spot,

<sup>2</sup>As far as we can tell, the Scope and the DSA cannot be used to analyze the same signal at the same time; you will need to stop one before running the other.

they just might have different amplitudes.) Show the spectrum of your square-modulated sinusoid to a lab instructor. Also, explain why we used the Volts/Div settings of 200 mV for one channel but 100 mV for the other channel.

Instructor Verification (separate page)
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## 6.2 Modulating and Demodulating Complicated Signals

- (a) Close the web applet we used in the last section. Then find a recording of speech or music somewhere on the web (youtube is as good a place to look as any), and use that as the signal to be modulated. (You can alternatively play something from your iTunes library.)
- (b) In the DSA, set Frequency Span under FFT Settings to 40000 Hz.
- (c) Look at the output of the modulator, MOUT, while listening to it via headphones. Observe the change in appearance and sound while changing the carrier frequency. Try both extremely low carrier frequencies { with periods of seconds or less { as well as extremely high frequencies near 20 kHz. Low frequency carriers should result in a musical "tremolo" effect. (Some low frequencies will sound like the Daleks from the British science fiction show Doctor Who.) High frequency carriers should result in signals that are almost inaudible, since much of the frequency content will be on the edge of human hearing. For lower carrier frequencies, you may want to lower the Frequency Span in the DSA to more easily see what's going on.
- (d) Now for the fun part! let's demodulate the signal! For this, we will need to, finally, use the second multiplier. Set the carrier frequency in FGEN to 20 kHz, and move the AI1+ connection from MOUT to DOUT so you can watch the demodulated output on the spectrum analyzer.
- (e) We now have IC2 modulating the signal, and IC3 demodulating the signal, in a double-sideband modulation scheme. Alternate between listening to MOUT and DOUT; this can be readily achieved by connecting them to different headphone buffer inputs and alternating which headphone speaker you are listening to. The demodulated signal should sound surprisingly good, given the simplicity of our setup. (Note that we have cheated a bit by not including a lowpass filter to eliminate the spectral copies that appear at twice the carrier frequency after the second multiplication by the carrier; you will see these on the spectrum analyzer. We are relying on the inability of the headphones to reproduce these frequencies and the inability of your ear to detect those frequencies even if they could.)
- (f) Experiment with different carrier frequencies. Low frequencies will result in clangorous cacophony. Determine the lowest carrier frequency that you can use for your speech or music signal without introducing noticeable artifacts in the demodulated signal. (This is a subjective judgement; it will depend on both your particular example of speech or music, as well as your ears.) You will write this frequency, along with the name of your audio source, on your instructor verification sheet in the next part.
- (g) Entertain one of your lab instructors by letting them listen to your demodulated signal as you change the carrier frequency. Explain to your lab instructor why you think the quality of the demodulated signal degrades for lower carrier frequencies.

Instructor Verification (separate page)
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## 7 Appendix: Debugging tricks

If you are getting strange results, rst try looking at the carrier instead of the signal from your laptop in order to make sure your carrier looks like a sine wave of the right frequency.

If you want to double-check to make sure an AD633 is working, one trick is to wire both inputs together and apply the same signal to both. The output should then be the square of the input, as seen in the examples in Figure 4.

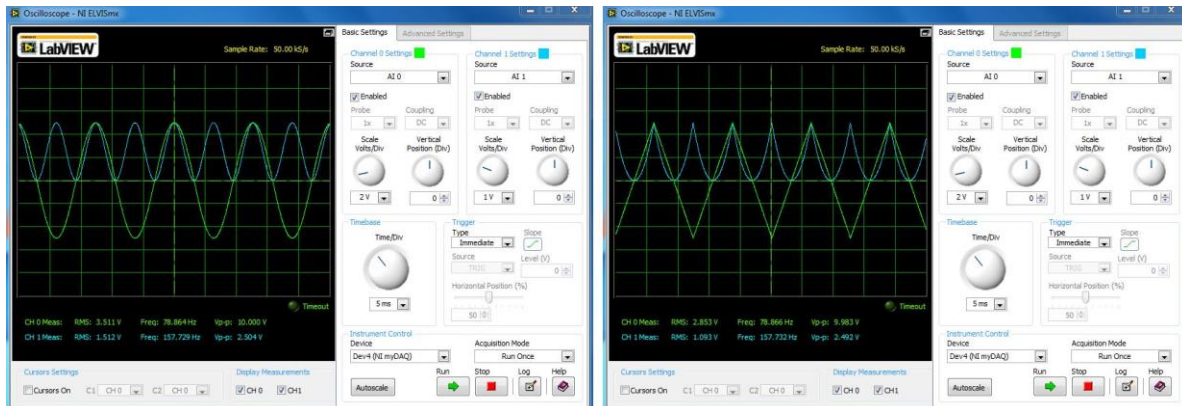


Figure 4: Squaring sine waves and triangle waves; these can be useful diagnostics for guring out whether an AD633 is having problems.



**Lab #1**

**ECE 3084**

**Fall 2017**

**INSTRUCTOR VERIFICATION PAGE**

Turn in this sheet to one of your lab instructors.

Name(s): \_\_\_\_\_

Date of Lab: \_\_\_\_\_

Part 6.1(j): Demonstrate the spectrum of a square-wave modulated sinusoid. Also, explain to your lab instructor why we used the Volts/Div settings of 200 mV for one channel but 100 mV for the other channel.

Verified: \_\_\_\_\_

Date/Time: \_\_\_\_\_

Part 6.2(h): Entertain and educate one of your lab instructors with your demodulated signal. Explain why the sound quality degrades for low carrier frequencies. Also, in the space below write the lowest carrier frequency that you can use for your speech or music signal without introducing noticeable artifacts in the demodulated signal, and also tell us what piece of music or speech you are using.

Verified: \_\_\_\_\_

Date/Time: \_\_\_\_\_



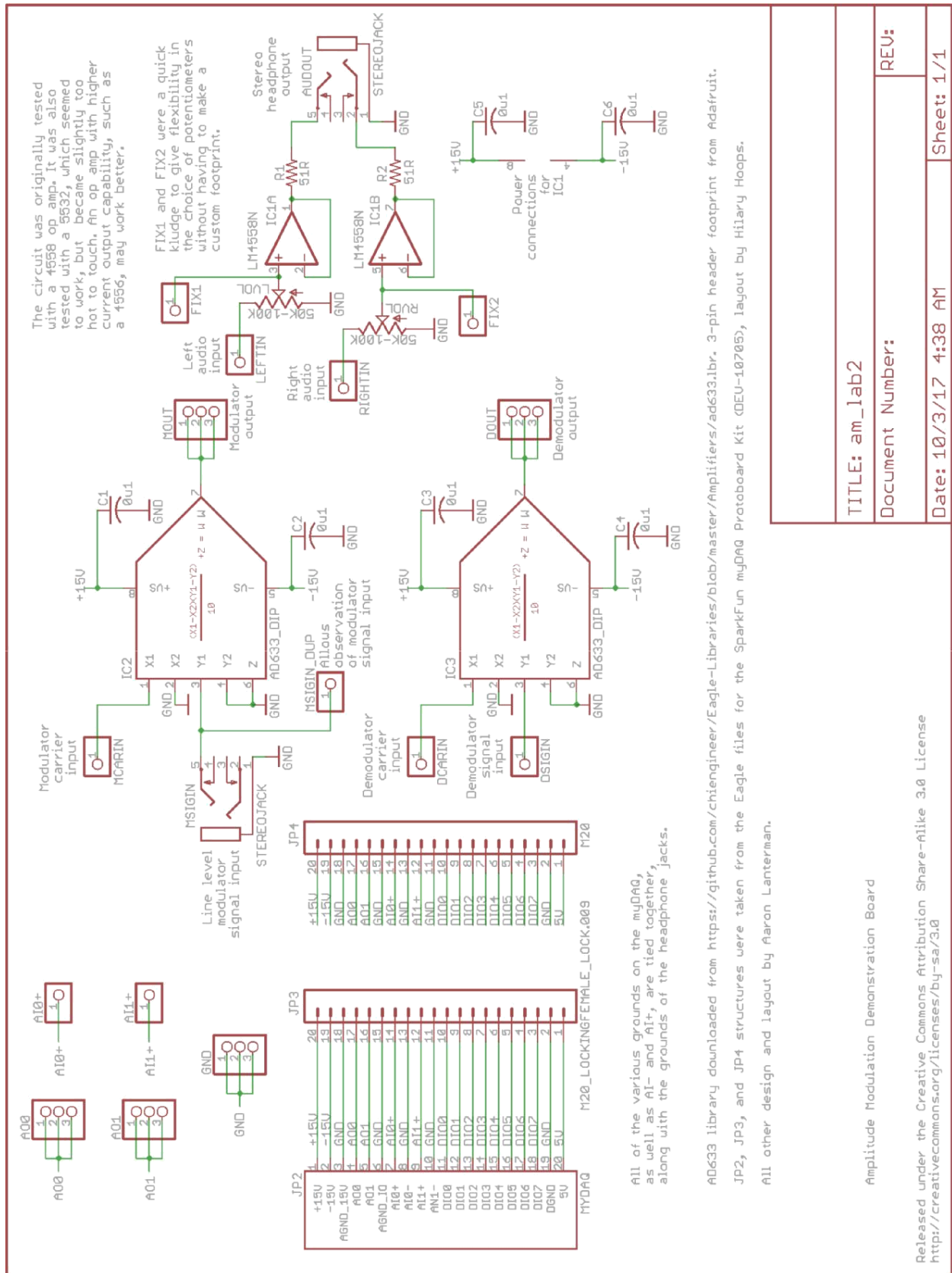


Figure 6: Schematic of the PCB for this lab.