Ultrasonic range finding

In this lab you will build an ultrasonic transmitter and receiver. The transmitter will send out a short burst pulse (about 1-4 ms long) at the transducers frequency of 40 kHz. The receiver will find the very weak reflected acoustic signal, then filter, amplify, and rectify this signal. From the time difference in the transmitted and received signals, you can find the distance to the object. We use the same type of transducer to transmit and receive the signal. You will build two circuit systems, the transmitter and receiver. You need to build these circuits slowly and carefully. Keep everything as compact as possible. Build the transmitter and receiver circuits using one quad op-amp for each system. Test as you build.

Figure 1 is the complete transmitter circuit. Build each component, one at a time and check each stage. It is easiest to debug your circuit using the scope due to the high frequency signals involved. Build the low frequency oscillator first. Check that you get the ~5 Hz shark fin looking signal at the location indicated. Build the controlled voltage source next (bottom left). Make sure it works and you can adjust the level (over a narrow range) with the potentiometer. Build the comparator next. Make sure you can get a controlled 1-4 ms "blip" by adjusting the potentiometer. If this all works, build the 40 kHz oscillator last. It is important to check the oscillator's frequency as the frequency is influenced by the op-amp slew rate limit, thus the chip to chip variation might mean you need to adjust the frequency a little by changing the value of the 6K resistor. If all the component circuits work, you can build the driver for the transducer. Make sure you put the 2N7000 in the right orientation. The orientation displayed in the figure (backward D) is how the 2N7000 looks from the top on your breadboard. Measure Vout with the scope to make sure you have the pulse you want- we demoed this circuit in class on Wed. Adjust the potentiometer to get your blip to be about 1or 2 ms long.

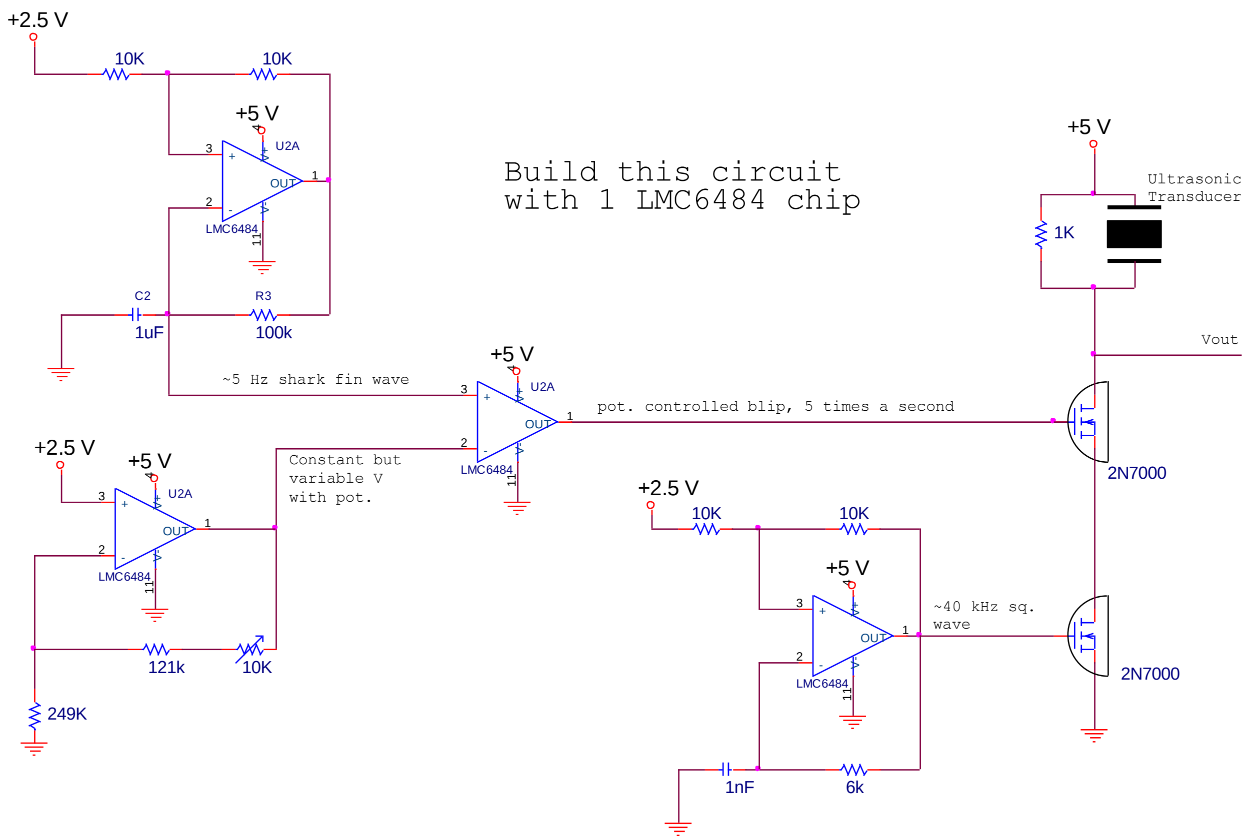

Figure 1: Complete transmitter circuit.

Now build the receiver circuit which is shown in Figure 2. You can test the receiver as you build it by first replacing the transducer with the signal generator set to a 40 kHz sine wave. Build one filter (up to the output of the first op-amp). Using the oscilloscope, test that this piece seems to behave as it is supposed to (we discussed what this circuit should do in Wednesday's class). Adjust the frequency of the driving on the signal generator and see if the circuit seems to cut out the frequencies that it is supposed to. Once working, add the next op-amp filter. As each stage adds more gain, you will need to turn the signal generator amplitude down very low. Pull the amplitude knob out and press the -20dB button. Test your circuit again up to this point. Finally, add the inverting amplifier. Test again. Add the final stage with the diode and replace the signal generator and connect the ultrasonic transducer.

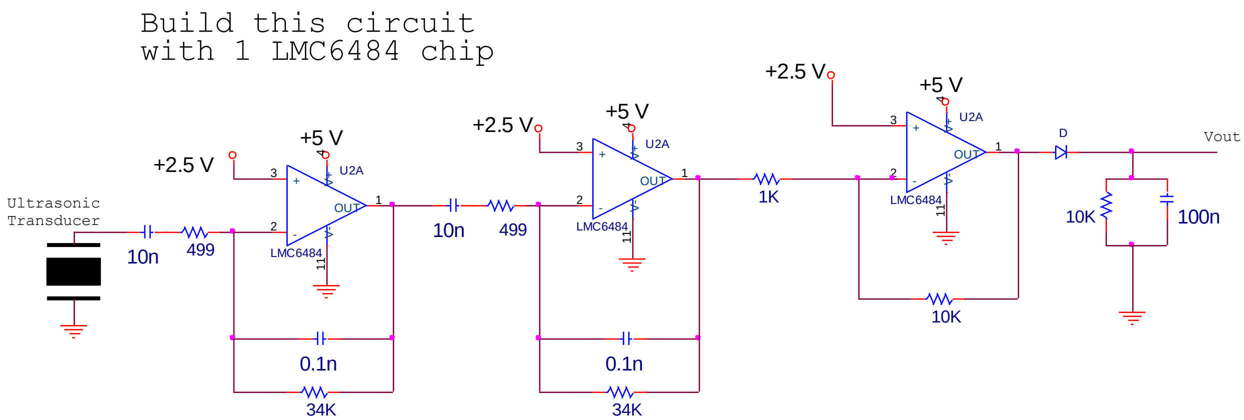

Figure 2: Receiver circuit.

Once your completed circuits work, remove the scope and measure things with the DAQ. Set your software to collect 2 channels at 24,000 samples per second for about 1 second. With the DAQ, measure the output of the comparator in the transmitter circuit and measure Vout of the receiver circuit. Each of these signals occurs on a millisecond time scale and thus resolvable with the maximum sample rate of the DAQ. Before proceeding to the experiments, make sure that the results seem reasonable. If you aim the transducer at the ceiling, you should get a reflection shortly after the transmission. Remember that sound travels at about 1 foot per millisecond (you should get the exact number for your data processing later). The 1ft/ms rule of thumb is convenient to make sure you are getting reasonable data. Aim your transducers at the wall, and walk towards it to see that you are getting a reasonable measure of the distance to the wall.

Experiment:

In the classroom, we will mark off with masking tape 1 foot increments from one of the whiteboards. Taking your system and your program (all on the DAQ, unplug your laptop from the wall). Walk in 1-2 ft increments starting from 2 ft, to about as far as you can go and still get a reasonable reflection (should have no problem getting 10-20 ft). It will probably work best to set your laptop and equipment on the floor, or a rolling desk. Run your program and collect the blips. Save the data – each distance as a different file. To analyze the data (after the fact), just plot both channels of the data in MATLAB and measure with the data cursor the time difference between the leading edge of the transmission and reception of the blip. If you collect data for 1 second, you should have 4 or 5 blips. Measure the time delay between 3 different blips on a single 1 second collection of data and record the time delay for each (they should be about the same!) and the known distance from the wall. Just type the numbers in a spreadsheet. Repeat this for 10 distances. It is not that important what the exact distances are, but that you know them from the markings on the floor or that measured them with a tape measure. Plot all your data as known distance versus distance inferred from your circuit measurement.

Deliverables

1) Take a picture of your final, breadboarded circuit. It should be compact and pretty.
2) Show representative data from a single blip. Show the transmitted and received signal as recorded from the DAQ on a single plot. Denote on the graph the time where the echo would be expected to be returned from the known distance to the wall.
3) Show a single plot of your processed data from the controlled experiment. Your plot should show measured distance from your ultrasonic range finder vs. the known distance. Plot all your data as points on a scatter plot (you should have 3 pts for each range, and 10 different ranges). Comment on how well your range finder works (is it linear, does it give the correct result). Comment on to what accuracy you would trust your range finder (this is an estimate, we have not discussed statistically how to make these judgments in a more formal way!).
4) Perform the analysis of the receiver circuit from the transducer up to the output of the 3rd op-amp. Using complex impedances, derive the expression for the voltage at the output of the 3rd op-amp divided by the input voltage as a function of frequency. Plot the amplitude of the output divided by the amplitude of the input as a function of frequency on a log-log plot. Include your analysis of this circuit in your lab report – hand written neatly is fine or typed up in an equation editor or LaTex.

Grading

1) 1 point for an awesome, neat, compact circuit. 0 points if your circuit is a disaster that makes a bowl of spaghetti look organized.
2) 2 points for clear data presented nicely. 1 point off if data looks fine, but plot is not labeled or clear. 0 points for unreasonable data.
3) 5 points for an excellent plot and good explanations; (i.e. data looks good, plot looks good, all the data is there, explanations are great). 1 point off for good data but poor looking plot. 2 points off for crappy and scattered looking data. 2 points off for poor explanations. 1 point off for OK, but slightly incorrect explanations.
4) 2 points for good analysis and good presentation of results. 1 point off if plot is poor or analysis is unclear (even if final result is right). 1 point off for minor mistakes in analysis. 2 points off for a just plain wrong result.

These are just guidelines for the Ninjas to follow, but they can use their best discretion.