EENG18020 Ultrasonic Lab
Week 2 - Amplifier

1 Introduction

In this section you will build two amplifiers to amplify the signal from the transducers you built last section. As you have seen from the last section, for a 10 Vpp transmitter input, the receiver output voltage is only about 300 mVpp. The micro-controller you will be using in later sections, the input signal and output signal of the entire system has to be 3.3 Vpp. The difference in operating voltages between the micro-controller and ultrasonic requires we utilise amplifiers to increase the strength of the signal for both transmission and reception. You will be building two amplifiers, one for transmitter and the other for receiver.

2 Non-inverting Amplifier

Based on the model of the operational amplifier and the non-inverting op-amp configuration shown in Figure 1, we find that Equation 1 describes the relationship between the feedback resistors (R_f and R_g) and the gain ($\frac{V_{out}}{V_{in}}$) of the op-amp. This equation will be instrumental in designing appropriate amplification circuits for our system as it allows us to determine the feedback components required to convert from one amplitude to another. For example, to amplify a 3.3Vpp signal to 10Vpp, the gain will need to be approximately 3. In this lab, you will be using the TL071 operational amplifiers (op-amps), shown in Figure 2.

$$\frac{V_{out}}{V_{in}} = \left(1 + \frac{R_f}{R_g}\right) \tag{1}$$

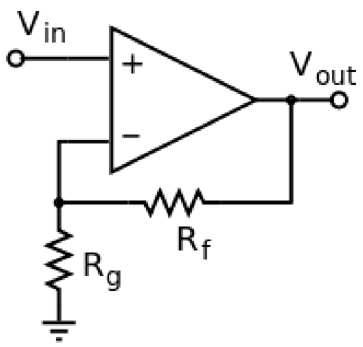

Figure 1: Non-Inverting amplifier

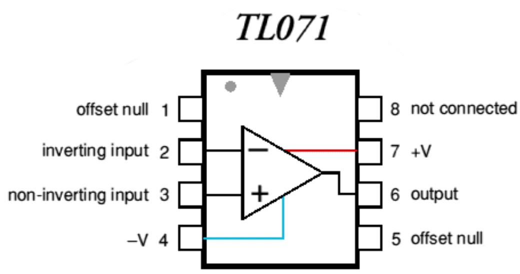

Figure 2: The TL071 Chip

3 Transmitter Amplifier

You need to build a non-inverting amplifier with gain being 3, so that it amplify a 3.3Vpp square wave to 10Vpp. We will connect the positive supply to +15V, and the negative supply to -15V. We will use a signal generator to simulate the input signal from micro-controller, with the frequency set to 40kHz, a waveform set to square , a duty cycle set to 52%, an amplitude set to 3.3Vpp and DC offset set to 1.65V.

We choose these values as they accurately model the open-loop characteristics of the micro-controller's 40kHz output.

Task 1: Based on equation 1, make your choice of R_f and R_g, build the circuit as shown in in Figure 3, measure your output signal to make sure the amplifier is working as expected

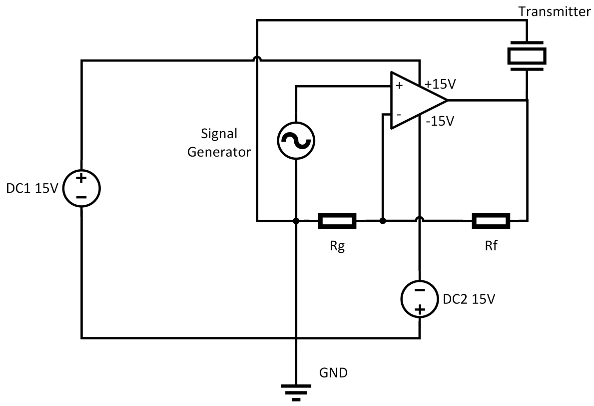

Figure 3: Transmitter Amplifier

4 Receiver Amplifier

The receiver amplifier is slightly different. The ultrasound signal received by the receiver will be a sine wave with 0V offset, its amplitude depends on the distance travelled. The required output from the receiving amplifier need to be within 0.1V-3.3V. Therefore you need to choose your amplification rate based on your experiments in last section. For example, if you obtained a 330mVpp signal with a 20cm distance between the transducer and the circuits, you could choose the amplification rate to be 10, then your output from the receving amplifier would have 3.3Vpp amplitude at 20cm which will be the minimal distance your system could handle. A larger gain let you detect object that are further away but also increase the minimal distance that you could detect.

Task 2: Choose your amplification rate for your system, make your choice of R_f and R_g, build the circuit as shown in Figure 4, measure your output signal to make sure the amplifier is behaving correctly

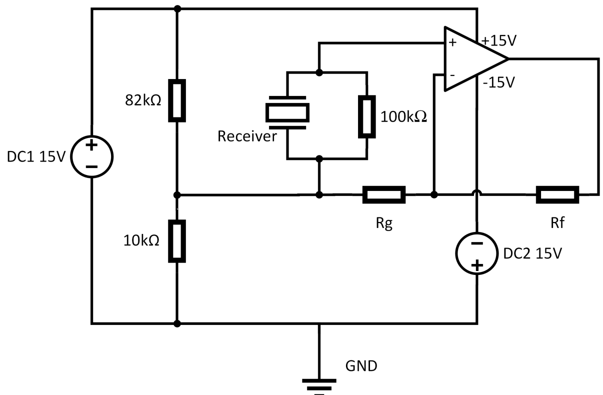

Figure 4: Receiver Amplifier

The complete system connection is shown in Figure 5. Note the circuit is exactly the same as the two you have built.

Task 3: Connect both transducers and amplifiers, connect signal generator to the transmitter amplifier and generate a 3.3Vpp square wave, measure the output from receiver

amplifier, find the minimal and maximum distance range that your system can handle (i.e. when the output fall within 0V-3.3V).

Note down your system's minimal detect distance, when you build the entire system with the micro-controller, never put any object closer to this distance, otherwise the micro-controller can be destroyed.

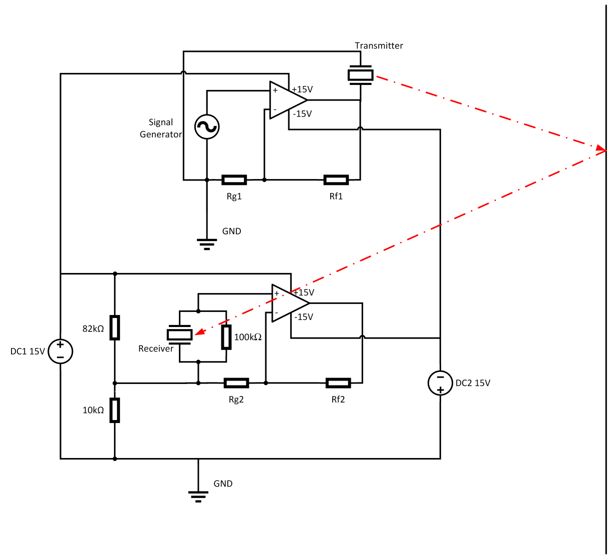

Figure 5: The complete system

5 Noise Reduction

If you observe a significant noise in your output, this might come from either the power supply, the amplifiers or radio waves. We could reduce the noise from power supply and amplifier by placing capacitors around them, as shown in Figure 6. This is only required if you think your signal is affected significantly. If you decide to put capacitors, be careful with the capacitor values and the polarity (longer leg should be connected to the positive voltage).

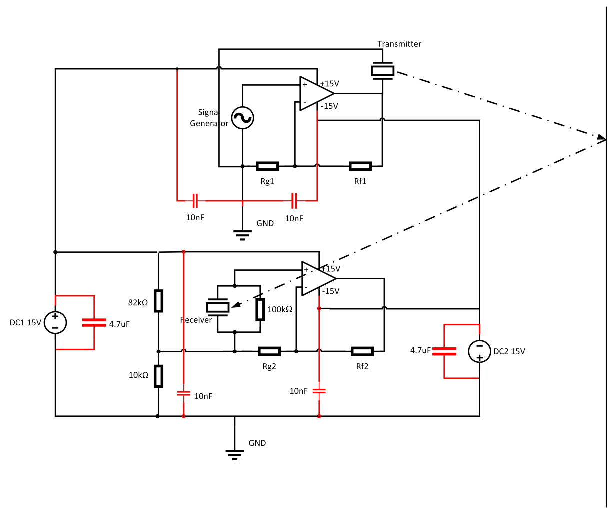

Figure 6: Reducing noise with capacitors