1b

Microphone Circuit

Overview

In this second part of the lab#1 you will construct a microphone circuit using a compact electret condenser microphone cartridge. The audio amplifier and microphone are important building blocks of many audio communications systems, and will be used in our ultrasonic transceiver system.

Table of Contents

Pre-lab Preparation

Before Coming to the Lab

☐ Read through the lab experiment to familiarize yourself with the components and assembly sequence. Before coming to the lab, each group should obtain a parts kit from the ECE Shop.

☐ With reference to the full schematic in Figure 1-1, calculate the lower cutoff frequency imposed by capacitors C1 and C2 and the resistances in the circuit:

$$f_{low} = \underline{\hspace{3cm}} Hz \qquad\qquad f_{high} = \underline{\hspace{3cm}} Hz$$

Parts List

The ECE2 lab is stocked with resistors so do not be alarmed if you kits does not include the resistors listed below. Some of these parts may also have been provided in an earlier kit.

Microphone Preamp	1	Electret Condenser Microphone Cartridge	MIC
	1	LF353N Dual Wide-band JFET Op-amp	U1
	1	8-pin low-profile IC socket	
	2	2.2kOhm 1/4W	R3,R5
	2	10kOhm 1/4W	R1,R2
	1	33kOhm 1/4W	R4
	1	10k trimpot	R6
	1	1uF 25V electrolytic (PC lead)	C1
	1	10uF 25V electrolytic (PC lead)	C3
	2	100uF 25V electrolytic (PC lead)	C6,C7
	1	0.001uF capacitor (CKO5 low-volt. Ceramic)	C2
	2	0.1uF capacitor (CKO5 low-volt. Ceramic)	C4,C5
	1	4.5" x 2.5" vectorboard	

Schedule for Lab #1

To stay on schedule, you must do the following:

- ■ Week #1:   Audio amplifier
- ■ Week #2:   Microphone circuit

The audio amplifier project is more difficult and time-consuming than the microphone pre-amp, so part of week #2 may be used to finish the audio amp. All breadboarding and testing can and should be done in lab. Soldering and hardwiring can and should be done outside lab.
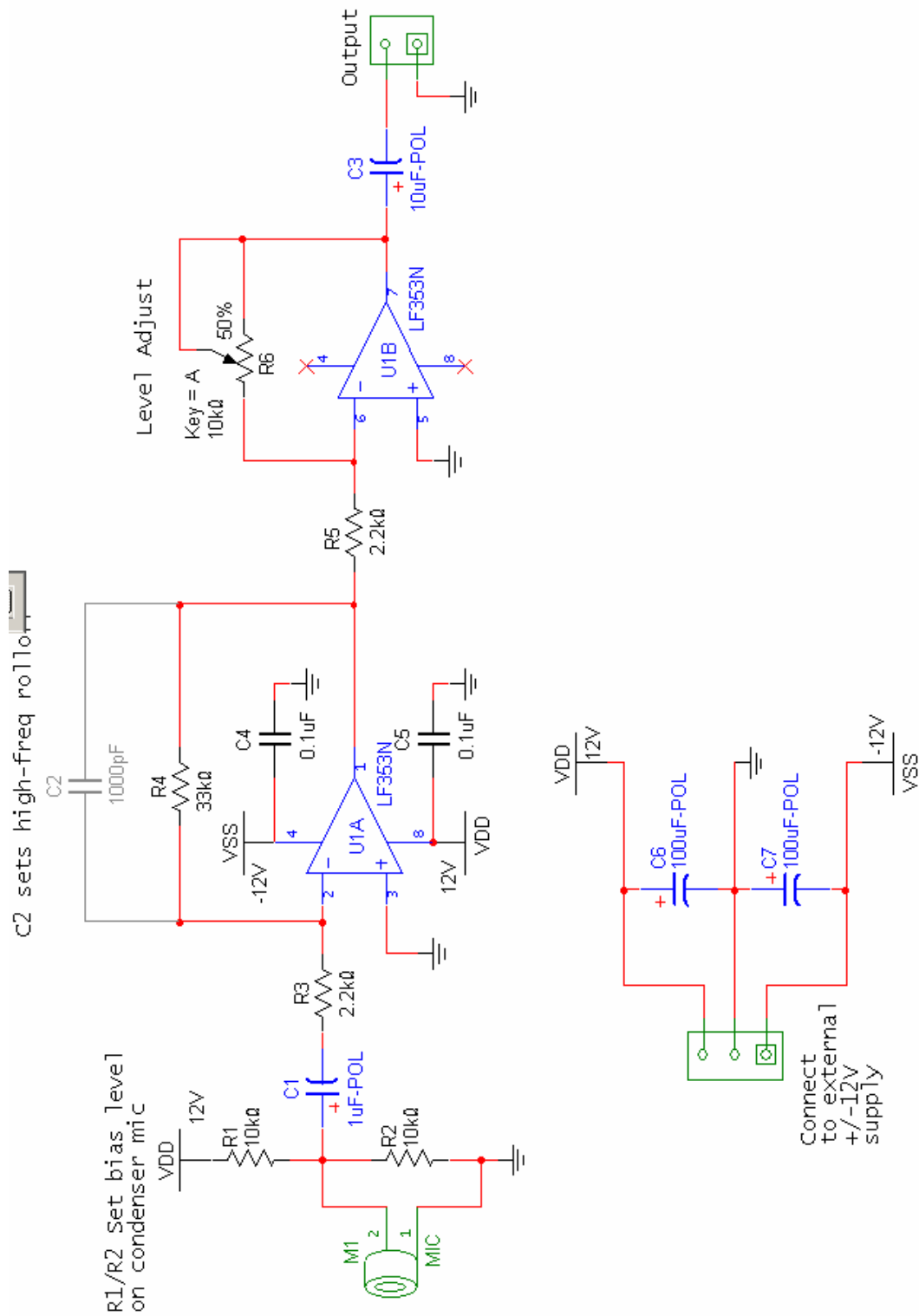
Full Schematics for Lab #1b

Figure 1-1 – Schematic for the microphone preamplifier.

Background information

Microphones

A speaker can be used in reverse to create a microphone. In the case the incoming sound wave leads to a mechanical deflection of the cone and voice-coil. According to Faraday's law, a time-varying current will be induced because the coil is moving in through a magnetic field (produced by the permanent magnet). Although any speaker could be used for a microphone, most speakers are unnecessarily large for this purpose, except in simple intercom applications where it is common to use the same component to perform both the speaker and microphone functions.
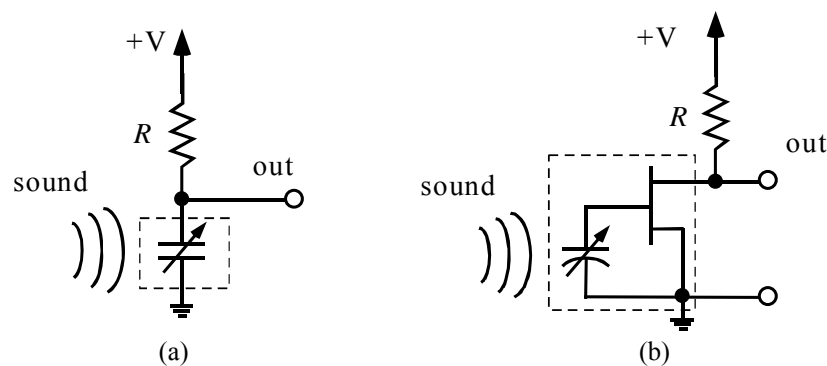

(a) (b)

Figure 1-2 – Two types of condenser (capacitance) microphones. (a) standard condenser mic. (b) electret condenser mic. The electret uses a special capacitance with a fixed charge (an electret) integrated with a FET buffer. The dashed line indicates the internal detail of the microphone cartridge; the resistor is supplied externally by the designer.

Another type of microphone is the "condenser" microphone, which exploits electrostatic forces instead of magnetic induction. The "cone" in this case is a thin metallic membrane that forms one side of a parallel-plate capacitor (**condenser** is an old-fashioned term for capacitor). An incoming sound wave causes the membrane to vibrate and hence the capacitance changes. If the capacitor is charged through an external pull-up resistor as shown in Figure 1-2a, the time-varying capacitance will induce a time-varying current through the resistor and hence an AC voltage.

Figure 1-3 – Construction of an electret microphone cartridge
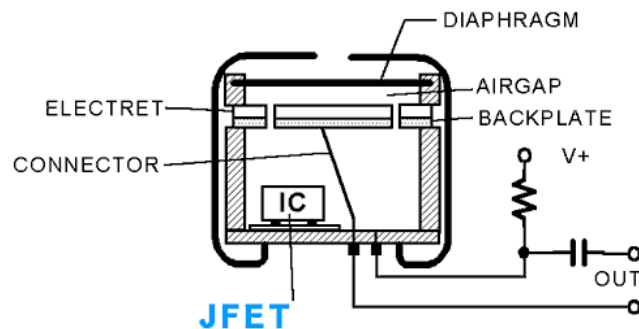
An especially popular type of condenser microphone today is the "electret condenser" variety in Figure 1-2b. In this case the time-varying capacitance is used to modulate the gate voltage on a built-in FET, which buffers and amplifies the signal. The capacitance is constructed from an electret material that has a permanent polarization or fixed charge, hence it is not necessary to bias the capacitor as in a conventional condenser mic, but of course the FET buffer *does* require biasing. An illustration of a typical electret

microphone cross-section and biasing network is shown in Figure 1-3. The output signal should be AC-coupled to the amplifier through a large-value DC blocking capacitor. The pull-up resistor R determines the output impedance of the device, and sets the bias voltage on the FET buffer. The FET typically draws about 0.1-0.2 mA, and can operate over a wide range of voltages, so the choice of R is not critical.

Most microphones generate very low-level signals, on the order of a millivolt or less. Hence we always need to amplify the audio signal substantially. This is the purpose of the circuit implemented in the second part of this lab. If you are interested, two good sources of information on microphones are:

http://en.wikipedia.org/wiki/Microphone
http://www.acoustics.salford.ac.uk/acoustics_world/id/Microphones/Microphones.htm

In-Lab Procedure

1.1 Some comments on our choice of ICs

Why the LM353?

Almost any generic op-amp can be used for a microphone pre-amplifier. The signal levels are very low, and all we need is a simple gain stage with a high input impedance. If we were to operate the microphone circuit from a battery, the LM358 would be fine, but this microphone circuit will be used in our AM modulator system later, and that is powered from a bipolar +/-12V supply, so we went with a dual-supply op-amp. Like the LM358, the main virtue here is cost and availability!
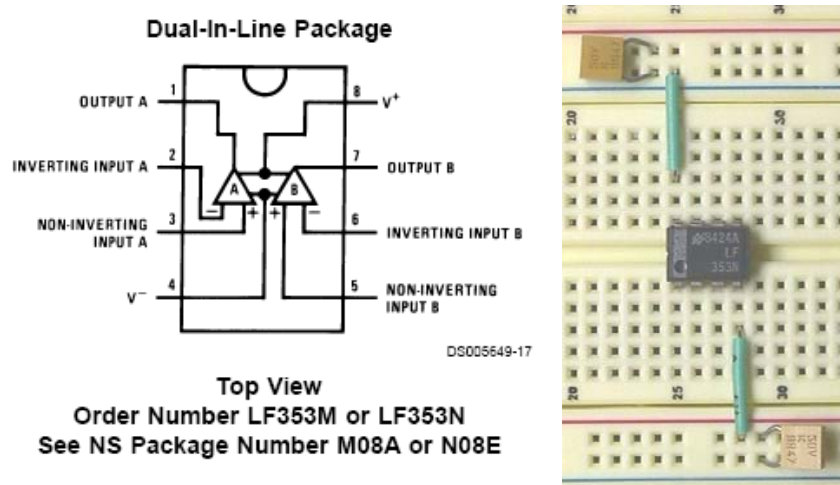

Figure 1-4 – LF353 pinout, and example power connections and bias decoupling capacitors.

This is a good place to offer a tip about using op-amps in analog or mixed-signal circuits: it is considered good practice to always include bias-decoupling capacitors for each IC in the circuit. Figure 1-4 shows the pinout and bias arrangement for the LF353 on a breadboard. To understand why the capacitors are useful, consider the fact that most circuits are processing time-varying or rapidly switching signals, and thus the DC current draw from the power-supply rails is not a constant. Instantaneous current surges in one part of the circuit can cause the supply voltage or current to vary in other parts of the circuit. Thus the bias-decoupling capacitors at each IC serve as a local charge reservoir to help maintain a steady supply current during operation. Obviously the bigger the capacitance the better, but 0.1µF is a very common choice. Unless your design is tightly constrained in terms of cost and parts count, it is advisable to add these decoupling capacitors in all your op-amp circuits.

1.2 Microphone Pre-amplifier

☐ Configure your solderless breadboard with +/- 12 Volt and ground connections using the bench power supply. Add the large 100µF supply capacitors (C6 and C7) onto your breadboard as shown in the schematic in Figure 1-1.

□ Begin construction by inserting the LF353 dual op-amp IC on the breadboard. Add power connections (pins 4 and 8) ***and bias decoupling capacitors*** as shown earlier.

□ Add the components for the first stage of amplification as in Figure 1-5. Note we are AC-coupling the microphone to the amplifier, and this sets a low-frequency cutoff (pre-lab calculation). Leave out C2 for now (the capacitor in the feedback path). We will talk about this later. You should have built the following circuit, minus the microphone cartridge:

□ Now test the amplifier circuit without the microphone. Using your bench function generator, apply a 0.1V sinusoid and sweep the frequency from 10Hz to 100kHz to locate the lower corner frequencies of response and record this in your lab record.
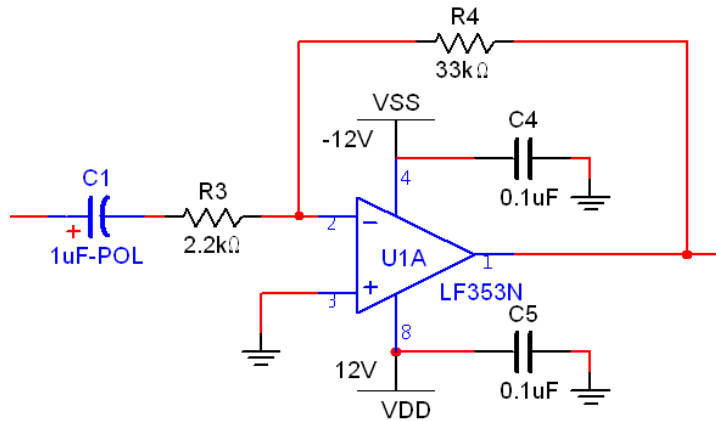
Figure 1-5 – Microphone gain stage

□ Now temporarily add in capacitor C2 (refer to the full schematic in Figure 1-1). This introduces another pole in the system to reduce the high-frequency gain (prelab calculation). Sweep the frequency to determine the resulting upper cutoff frequency, and record this in the lab record along with the voltage gain in the passband (around 1 kHz). Remove C2 when you are finished.

□ Now let's add the microphone into the circuit. In our circuit we're biasing the mic through a resistor divider as shown in Figure 1-6. This is not the most common approach: usually R2 would be eliminated and R1 would be chosen to set the bias voltage in a safe region for the device based on its specified current. But in our case we wanted ensure that the bias voltage is always well below 10V no matter what kind of mic ends up in your parts kit! Since the FET buffer current draw is somewhat unpredictable between various manufacturers, it proved safer to use a divider as shown. The actual bias voltage will be somewhere in the range of 4-6V depending on how much current the mic will draw.

□ The electret condenser microphone cartridge is shown in Figure 1-7. Depending on which unit was selected this year, it may or not have mounting pins pre-installed. If it doesn't, you will need to add some wires as shown so that

Figure 1-6 – Mic bias network.

it can be easily inserted into your breadboard. Take care to note which is the ground pin: that is the pin that is electrically connected to the outer metal casing. The microphone will not work if hooked up incorrectly because of the internal JFET buffer
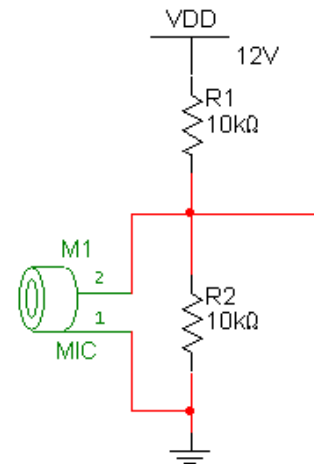
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□   Now test the microphone circuit by observing the output signal on the oscilloscope. Try whistling into the microphone—you should be able to produce a pretty nice sinewave. Record observations in the Lab RECORD. Note that when you stop talking into the microphone there is significant electrical noise in the system, appearing as a random voltage fluctuation at the output. Try to quantify the amplitude. Such noise is always present to a certain degree in any electronic circuit, and represents a lower limit on the sensitivity or fidelity of the signal transmission unless steps are taken to minimize it.
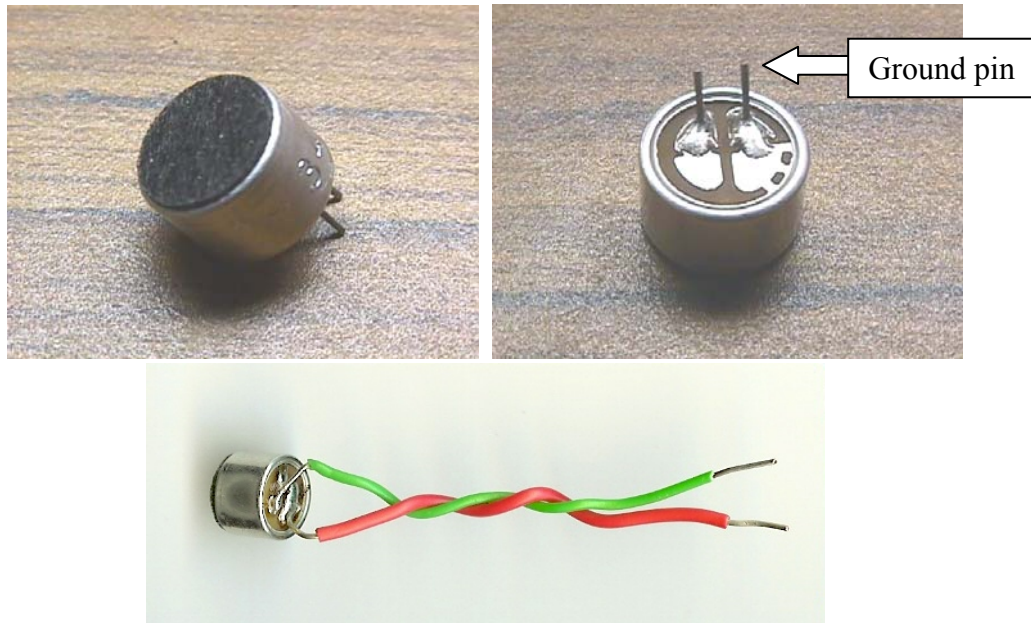

Figure 1-7 – Electret condenser microphone cartridge. If yours does not have mounting pins installed, solder some wire jumpers as shown in the lower figure. Take care not to solder the two connections together!

□   Add in the remaining circuit elements according to the schematic in Figure 1-1. This last step just adds a simple inverting stage that can amplify or attenuate the signal. This will be helpful later to adjust the microphone signal level for a desired amplitude to drive the AM modulator.

1.3 Simple One-Way Audio Link System

The last step is to hook up both circuit modules (microphone and audio amplifier/speaker) to make a complete audio system that detects/receives an acoustic signal, electronically amplifies it and transmits it over a cable, and converts it back to an acoustic signal. This is obviously the basis of most telephone, intercom, and public address systems.

□   Connect the microphone circuit output to the unused "aux" input on your amplifier circuit. Demonstrate the working circuit to the TA and answer the remaining questions in the LAB RECORD. For this step, C2 should be removed from the circuit, and the level-adjust potentiometer should be set to the middle of its range. It also helps to keep the

microphone and audio amp circuits as far apart as possible, try using a long cable as suggested in Figure 1-8.
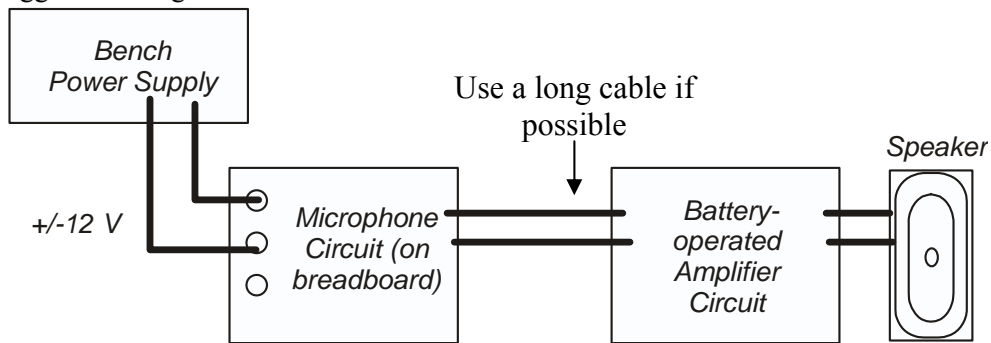

Figure 1-8 – Test circuit for microphone and amplifier modules

☐ Since the electret condenser microphone is omni-directional, it may prove difficult to operate the system under full volume conditions. One issue that can exacerbate these unwanted feedback effects is that some cheap microphone cartridges have a little more sensitivity at the high frequencies, such as shown in Figure 1-9. This is where an extra pole in the response may help. Try adding C2 into your circuit and see if that improves the system's ability to operate under high-volume conditions with a voice signal. If you built the tone-control circuit, that can also help in a similar fashion.
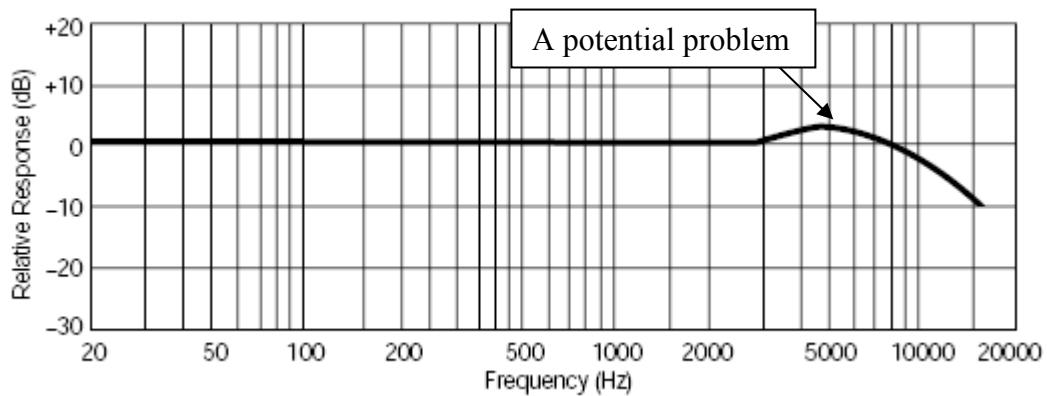

Figure 1-9 – Typical sensitivity response for inexpensive electret microphones

☐ Remove C2 and use the potentiometer on your microphone circuit to adjust the output level to around 100mV max. amplitude under normal speaking conditions. This is a convenient level for use in our system project later.

☐ Lastly, transfer your working design to the vectorboard. Use flea clips for external power supply connections and output signal/ground connections.

Congratulations!
You have now completed Lab 1b

1.4 Possible Improvements

In contrast to the audio amplifier, potential improvements to the microphone circuit are more subtle and largely involve the microphone itself, not the electrical circuit. The little omnidirectional electret component that we choose is very convenient because it is small, and cheap, but do we really want an omni-directional mic in our system? Probably not, since people are usually speaking directly into the mic, hence the omni-directionality just creates problems by picking up unwanted noise from the surroundings, or undesired feedback from the distant speaker. There are some electrets on the market that have a more unidirectional "cardoid" reception pattern, but these are quite expensive. One fairly simple way to make our mic directional is to put a little cone around it, which can be fashioned out of some heavy paper as shown in Figure 1-10.

Condenser microphones are very sensitive devices, and will generate a signal in response to any nearby air movement. In a "windy" environment, such signals can easily swamp out the desired audio signal. So another useful improvement is to put some kind of a "windscreen" in front of the microphone. The windscreen is, in effect, a

Figure 1-10 – Common microphone directional receiving patterns. The photo shows a simple method to improve the directionality of the microphone

mechanical high-pass filter, and helps improve the dynamic range of the microphone. Even with the windscreen, microphones can still be sensitive to bursts of air associated with the actual voice signal, such as "p" sounds. These effects can be reduced with a so-called "pop-filter", which is a large windscreen some distance away from the microphone. You will often see such things on microphones used in professional recording studios, as in Figure 1-11.
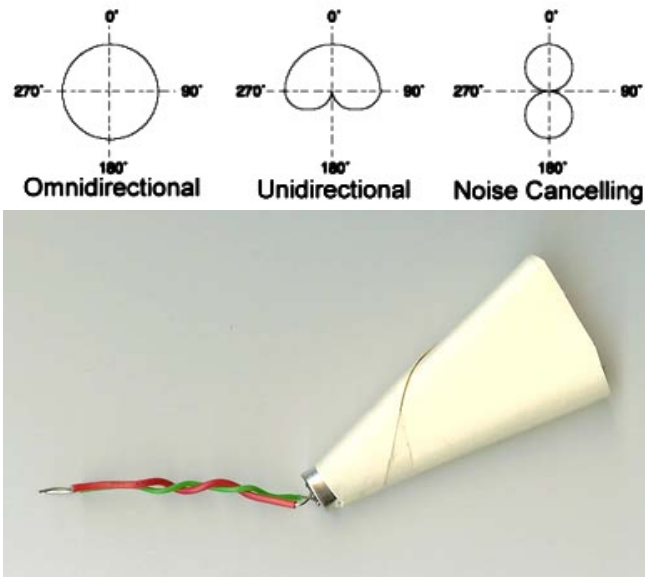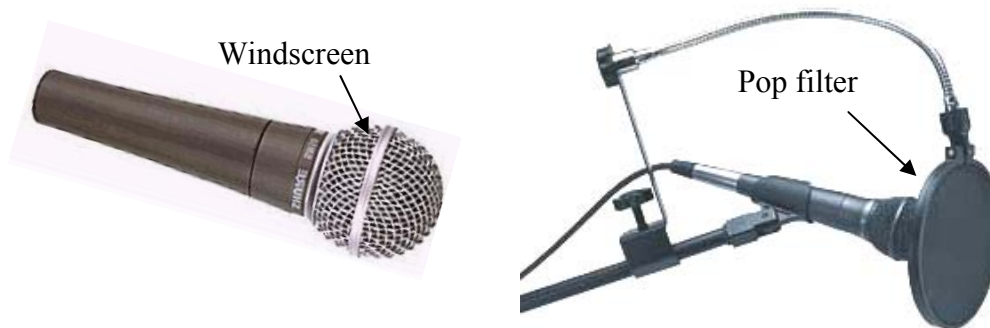

Figure 1-11 – Techniques for improving microphone dynamic range.

Another potential improvement to minimize noise pickup is to use a balanced amplifier configuration instead of the single-ended system we used. One example is described in http://www.eclectic-web.co.uk/index.php?jump=mike/electret_a.htm .

A typical vocal signal is comprised mostly of frequencies in the 300-3000 Hz range. Therefore, any frequencies outside of this range are unnecessary in our system and hence represent unwanted noise. Thus one improvement might be to include a bandpass "speech filter" in the system to pass only frequencies in the vocal range. One possible 2nd-order active bandpass speech filter schematic is shown in Figure 1-12, comprised of cascaded low-pass and high-pass filters. This is not the only way to make a bandpass filter, but it is an easy one to understand. We will use similar filters in the design of the IR receiver in a later lab.
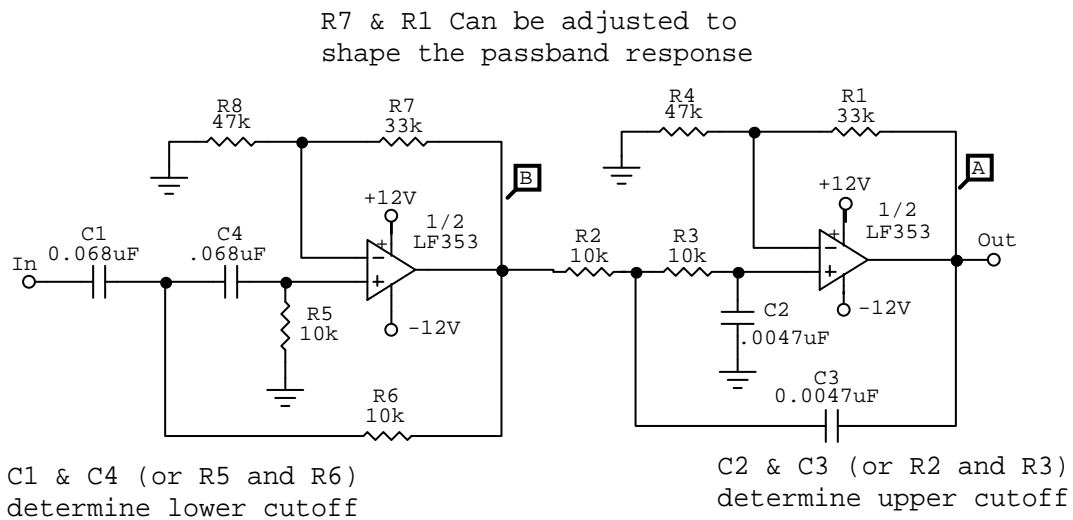

Figure 1-12 – Speech Filter schematic (bias decoupling capacitors not shown)

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Lab 1 Record

Section_____   Names: _____

                                           _____

Microphone preamp circuit

Low frequency 3dB cutoff: Predicted: _____ Hz   Measured: _____ Hz

High-frequency cutoff (w/C2): Predicted: _____ kHz   Measured: _____ kHz

Measured Mid-band Gain: _____

Typical output signal amplitude for a
whistling tone in mind-band at 6" away from mic: _____ V

Approximate output noise amplitude: _____ V

Mini Intercom System

Do you experience difficulty in operating the system under full-volume conditions? If so,
Why?