Laboratory 4
Exploring AC Waveforms

Introduction

In this lab you will use the BLIP to generate periodic waveforms (sine, triangle, and square) and explore various properties of these signals. You will build an audio amplifier with a speaker and listen to the period waveforms, as well as ambient noise and the signal from a microphone. You will use the microphone to generate oscillatory feedback. In the process, you will learn to use an oscilloscope to look at signals and measure their frequency and period.

Before you do anything else, make sure that the 9 V battery is not connected to the breadboard. Power for this lab will come only from the BLIP.

Parts List

BLIP board (operational)
LM386 audio amplifier
speaker, 8 Ω, 0.5 watt
Electret Condenser Microphone
  (WM-60PC)
100K potentiometer
26 gauge multi-stranded wire
velcro square with self-adhesive
various 5% resistors
various capacitors

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Using the Oscilloscope

The Tektronix Oscilloscope at each station is a basic tool that permits the viewing and measurement of time-varying signals, beyond what is possible with your multimeter. The oscilloscope, or simply "scope", has many features which are beyond this lab. In the first encounter, you will simply use it view and measure simple signals.

The User Manual for the Tektronix 200 series scope can be downloaded from the class schedule (next to this week's lab). You shouldn't need it, however. Just be sure the settings are correct for the 5 buttons to the right of the screen, as described on the following page. Most of the scopes in the lab are the 2-channel model (right, top), although one or two may be 4-channel (right, bottom). They both share the same basic adjustments of all scopes, (1) *voltage* on the vertical axis, (2) *time* on the horizontal axis, and (3) *triggering*.

(1) The *voltage* scale is controlled by the "VOLTS/DIV" (volts per division) knob above each input jack. The setting is displayed on the screen. Generally, 1 volt/div will work well in today's lab. Use the "POSITION" knob for each channel to move that trace vertically.

(2) The *time* scale is controlled by the SEC/DIV" (seconds per division) knob, with the setting displayed on the screen. The trace can be very slow (1 sec/div) to see entire events, or fast (1 msec/div to 1μsec/div) to see details of waveforms. The horizontal "POSITION" knob moves the trace left and right.
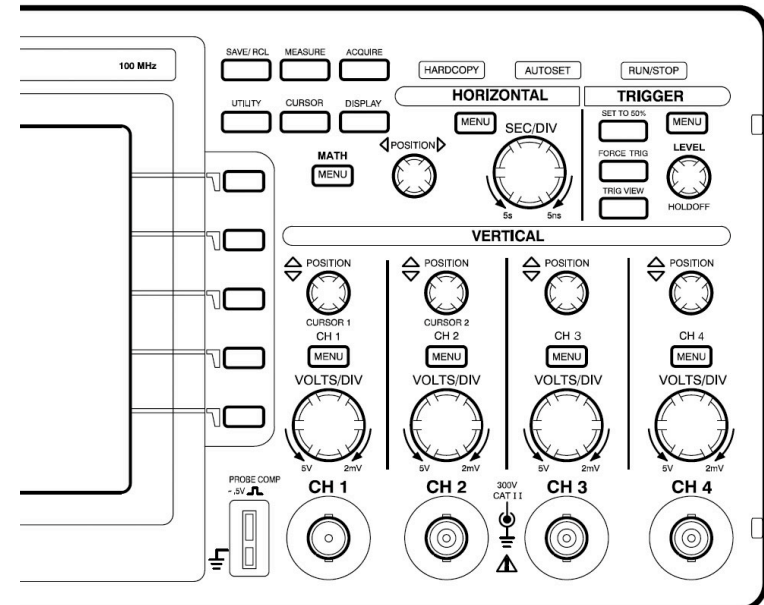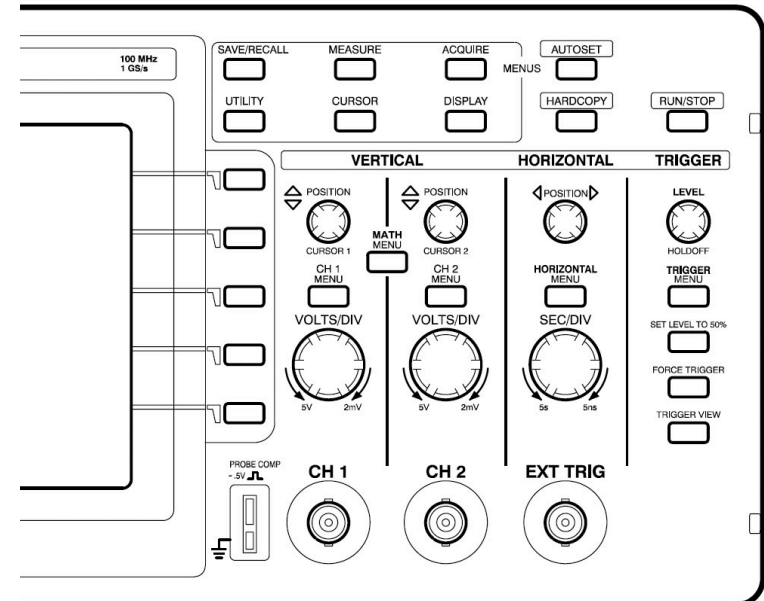
(3) *Triggering* is the act of synchronizing the start of each trace to make it appear stationary on the screen for proper viewing. This is a complex operation, but luckily your scope comes with an "AUTOSET" button that should accomplish satisfactory triggering to view the waveforms in this lab.

Attach a scope probe (with red and black bongo clips) to Channel 1. Make sure the channel has the proper settings by pressing the "CH 1" menu button, and then using the column of 5 buttons to right of the screen to achieve the settings shown on the screen in the picture below.

The scope provides an internal 5 volt square wave test signal at the "PROBE COMP" connector. Attach your scope probe from CH 1 to this connector as shown in the picture and adjust the settings on the scope to view the square wave. You will need to set the "SEC/DIV" to something like 500 μsec/div. and "VOLTS/DIV" to something like 2 volts/div. You may need to press the "AUTOSET" button to establish triggering. What is the frequency and period of this square wave? **(A)**
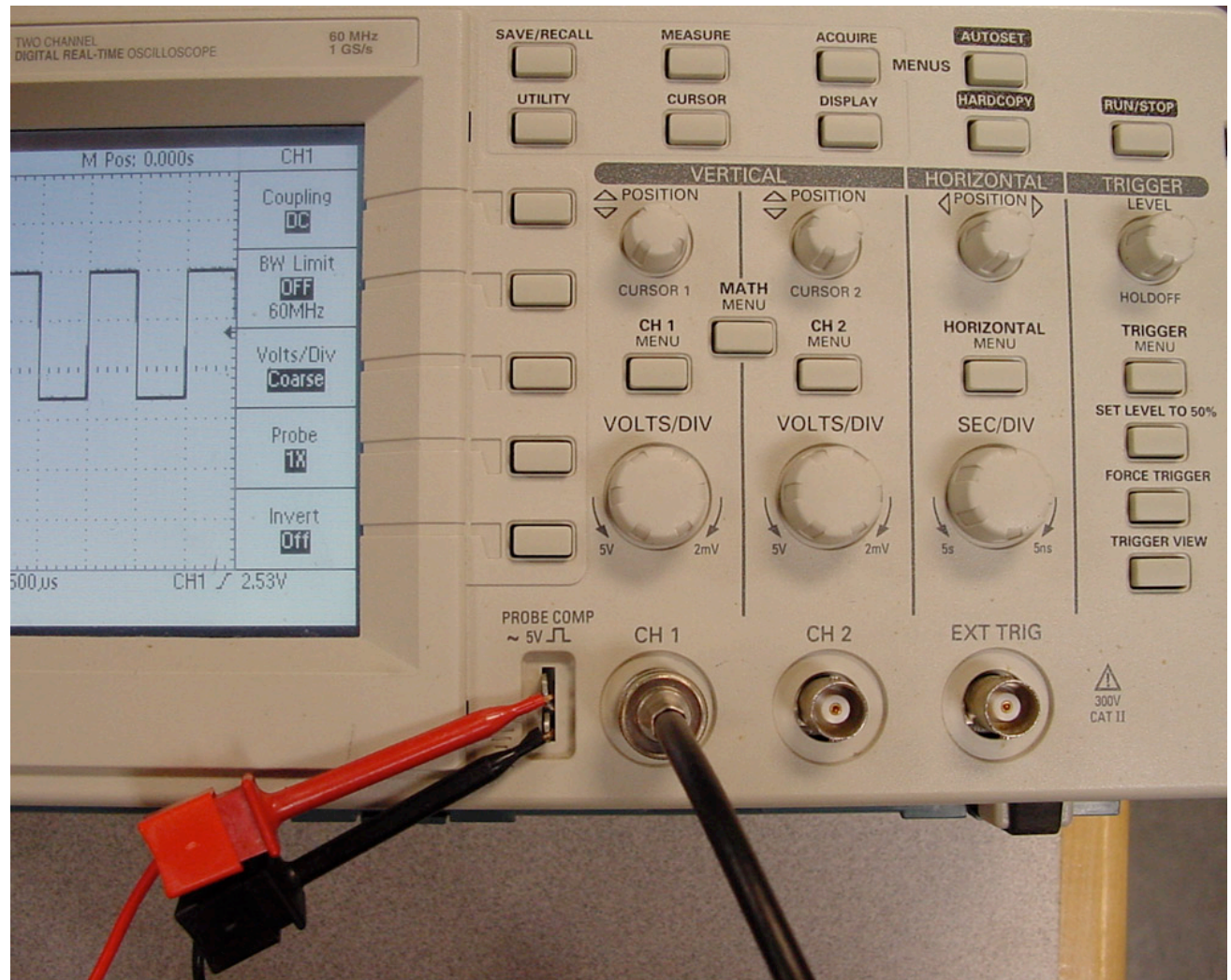
Listening to Signals with an Audio Amplifier

Now construct an audio amplifier, which takes small time-varying signals in the audio range (20 Hz - 20 KHz) and increases their voltage and current sufficiently to drive a speaker. Let's start with the speaker and work our way backwards.

Starting with two 1-foot pieces of 26 gauge multi-strand wire, strip ¼ inch from the end of each, twist, tin, and bend into a hook. Insert the hooks into the lugs on the speaker and carefully solder (don't melt the plastic!). Wrap the wires around the magnet to provide strain relief as shown. Solder short pieces of single strand 22 gauge wire to the other ends of the wires to plug into the breadboard, just as you did with the 9 V battery clips. Mount the speaker on the lower left corner of the breadboard with Velcro. The speaker surface is just paper, so treat it with care. **(B)**

The next piece of the puzzle is the amplifier to drive the speaker. This is based on an integrated circuit (IC), or "chip", in what is called a Dual Inline Package (DIP). The DIP chip is convenient because the pins have the same 1/10 inch spacing as your breadboard. The LM386 audio amplifier chip is shown to the right. Note the pin numbers, running from 1 to 8 counterclockwise from the end of the chip with the little notch. Normally, the chip is inserted into the board with pin 1 in the lower left, the notch to left, and the chip label right-side-up. Pin 6, V_S (source voltage) is connected to the +5 V bus, and pin 4 (GND) is connected to ground, to power the chip.

The LM386 is a fixed gain differential amplifier with two possible fixed gains (20 and 200) by which it amplifies the voltage between the +input (pin 3) and the –input (pin 2). This specialized amplifier is meant to drive a speaker, and is quite different than the general comparators and operational amplifiers that we will use later in the course. For now, view it as a black box, a basic tool enabling us to listen to signals, just as your multimeter allows you to measure voltages or resistances as numerical values.
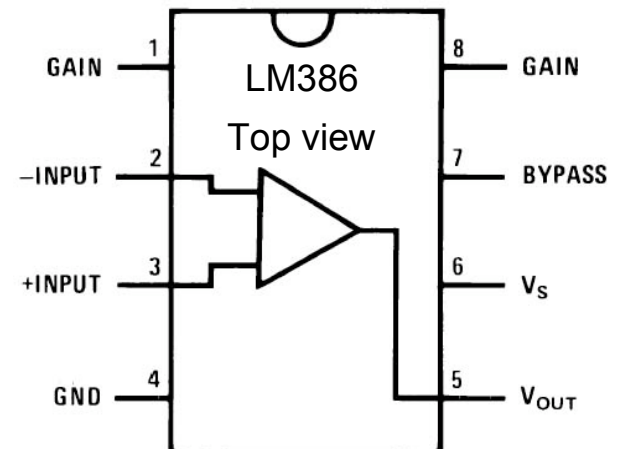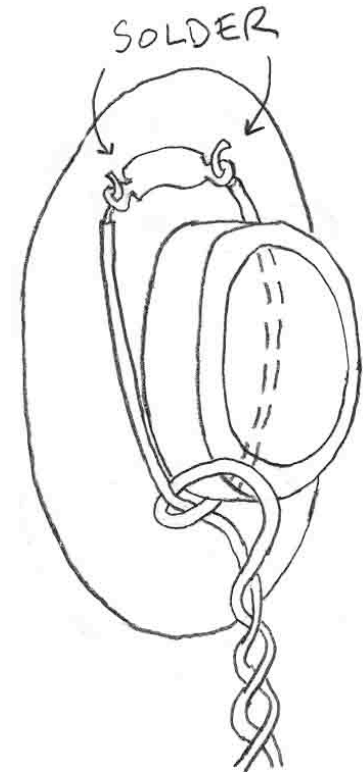
Build the audio amplifier circuit shown below around the LM386, on the bottom left side of the breadboard, taking care to get the polarity of the electrolytic capacitors correct. Note the use of a 1 µF capacitor to stabilize the power supply. Occasionally this circuit has been known to oscillate, due to internal feedback similar to that which you will introduce intentionally using a microphone later in this lab.

Attach the oscilloscope leads as follows. First (and always!) attach the ground (black) scope lead to the ground bus of your breadboard. Then attach the signal (red) lead to the ungrounded side of your speaker. Now whatever you hear, you will also see. Temporarily include the 10 µF cap (boosts gain to 200) and turn the volume control (pot in the amplifier circuit) to max. Touch the input with your finger, and examine the speaker output with the oscilloscope and with your ears. Adjust the VOLTS/DIV on the scope accordingly. Describe what you see and hear. **(C)** You may hear a local AM radio station, and you will probably hear 60 cycle "hum" from power sources around you. Using the oscilloscope, look for 60 cycle hum setting the SEC/DIV accordingly. What is its period in milliseconds? **(D)** This is a good number to remember, since 60 cycle hum is frequently an unwelcome guest.
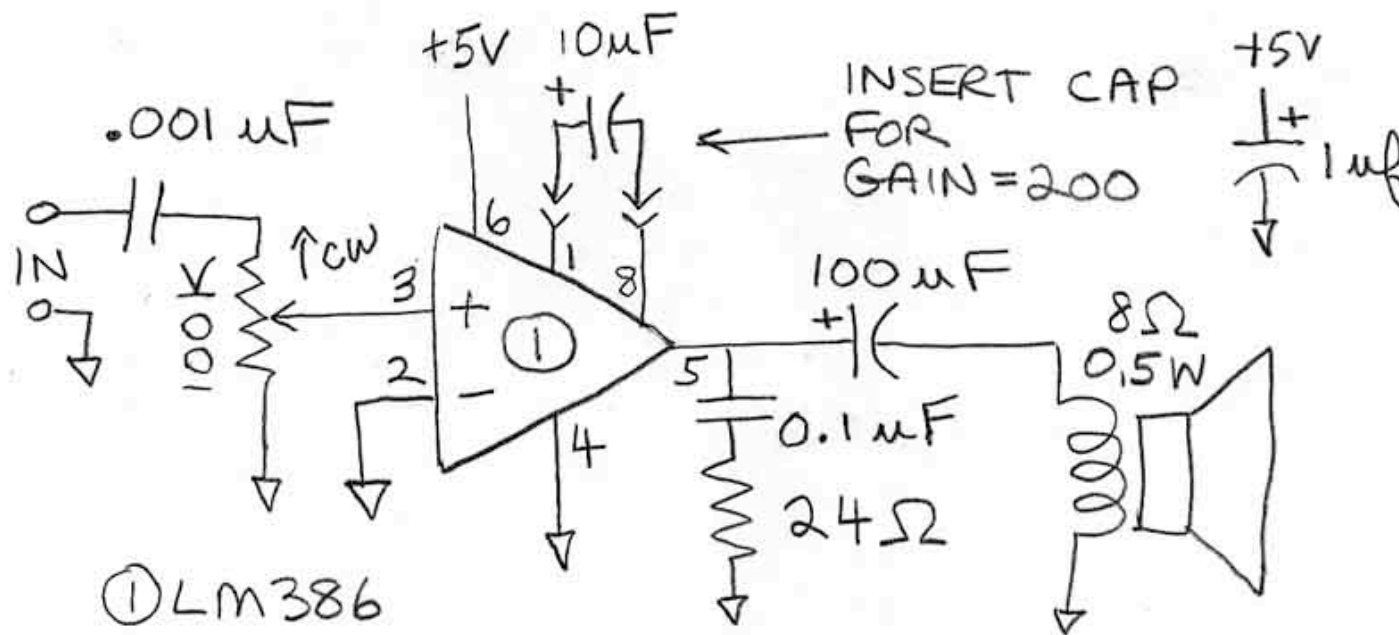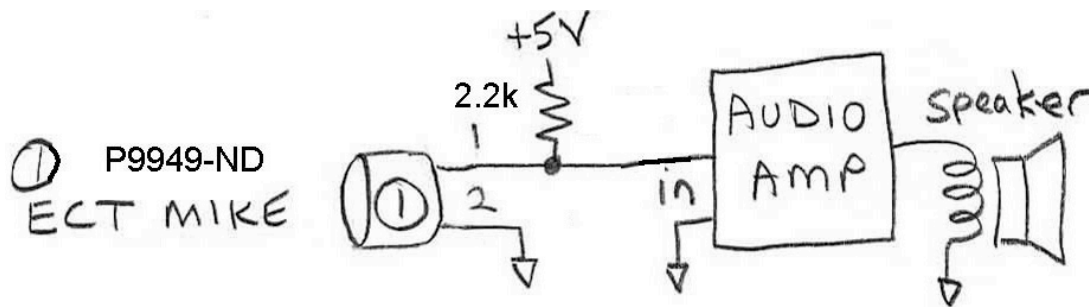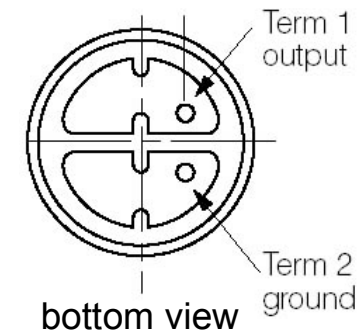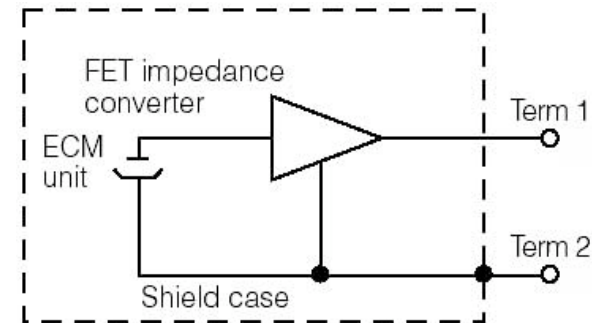
Connecting a Microphone to the Audio Amplifier

Next, you will connect the microphone ("mike") that came with your kit, an Electret Condenser Microphone, which is essentially two plates of a capacitor (the old word for which is "condenser") with a fixed charge Q on them. When the plates move because of incoming sound, the capacitance changes, and thus the voltage $V = Q/C$ also changes. Because the charge is very tiny, the mike is packaged with a Field Effect Transistor (FET) amplifier whose input impedance is extremely high (we will learn about the FET later). The mike is powered through a resistor to its output, a method known as "phantom" power, since it avoids a separate power connection. The specifications for the mike are shown. The 54 dB SPL (sound pressure level) describes the quietest sound that can be picked up.

Build the circuit below. Remove the 10 µF cap from the audio amp to return gain from 200 to 20. The "mike" is powered through the 2.2 K output resistor. Have someone talk into the mike while you report sound quality at speaker. **(E)** The low frequency response of the small speaker is limited. Move the mike near the speaker until you hear "feedback", a runaway condition caused by sound from the speaker returning to the mike with ever-increasing volume. What controls the frequency of the feedback? Explain in terms of the speed of sound in air vs. the speed of electrons in a circuit. **(F)**

WM-60PC microphone	
Signal-to-noise ratio	>40 dB
Current	0.5 mA
Type	Omnidirectional
Freq. response	20 Hz–12 KHz
Sensitivity	54 dB SPL

Looking at, and Listening to, the Sine, Triangle, and Square Waves

Remove the microphone and 2.2 KΩ resistor from the input of the audio amplifier. Run red and black power wires from the BLIP to the breadboard as in Lab 3. Run a white signal lead from the BLIP's I/O header pin 1 (Signal Generator Output) to a blank column on the breadboard and then connect a 1 MΩ resistor from that to the input of the audio amplifier as shown in the circuit below.

Signal Generator waveform jumpers		
Signal Type	Pin 38	Pin 37
Square Wave	yes	yes
Sine Wave	no	yes
Triangle Wave	no	no

In the previous lab, you used the BLIP in Data Acquisition Mode. In the present lab, you will set the BLIP to Signal Generator Mode by having a jumper at pin 40 and no jumper at pin 39. You will then select sine, triangle, and square waves using jumpers at pins 38 and 37, as defined in the table to the left. Begin with jumpers in the sine wave setting.

The periodic waveforms generated by the BLIP (sine, triangle, and square) can be varied in frequency between approximately 460 Hz and 6.8 kHz by adjusting the potentiometer on the BLIP. Open a new document in Microsoft Word on your computer and click the mouse in the document. Pressing the top button on the BLIP (not the Reset button) will now type the present frequency (Hz) of the waveform on the computer through the USB. Adjust the frequency of the sine wave, reporting 4 different frequencies from the computer and their corresponding periods as shown on the scope. Show that frequency is the inverse of period. **(G)**

Adjust the BLIP to 600 Hz and listen. Now adjust to 900 Hz, 3/2 the original frequency. These two frequencies should sound like the first and second notes in "Twinkle, twinkle, little star…", an interval called the *perfect fifth*. The ear likes small whole number ratios. Adjust to 1200 Hz, or twice the original frequency. This is called an *octave*, and in a way sounds like the same note as the original 600 Hz, only higher. **(H)**

Returning to 600 Hz, listen to the sine wave carefully. Then, using the waveform table given earlier, change the jumpers on pins 38 and 37 to give first the triangle wave and then the square wave. Describe the differences in tone. **(I)**

Keep the audio amplifier assembled on your breadboard. It is a handy tool and you will use it in later labs.