

**Franklin W. Olin College of Engineering**  
**Mathematics/Physics Project Spring 2007**  
**Prof. Moody and Prof. Zastavker**

**Building a Radio**

“ We start off confused and end up confused on a higher level.”  
- Alan Chalmers (“*What is this thing called Science?*”):

**Introduction:**

In this project, you will design and build a radio. To do so, you will need to think a bit about the mathematics and physics involved, since a few things need to be calculated in order for your radio to work. Start by thinking about the workings of a radio (you do NOT need to write this part up, just investigate these things to make sure that you understand what you are building!):

- (i) To design and build your AM radio receiver, first investigate the workings of Amplitude Modulation (AM) as the original method used for transmitting sound with radio waves, as compared to more recently used Frequency Modulation (or FM), single side band (SSB), pulse code modulation (PCM), etc. (To learn more about modulation see *Information Transmission, Modulation, and Noise* by Mischa Schwartz. This book is available in the Science Library at Wellesley.) Alternatively, you can find a lot of this information online; however, be careful in terms of choosing your sources, since not all of them are credible. Please, note that for commercial AM broadcast stations in the U.S., the frequency of the carrier is between 500 and 1500 kHz.
- (ii) Now, think about what happens to the radio signal and the reasons for it to pass through a non-linear element (like our friend, the diode).
- (iii) The signal is then passed through a filter. What do you think is the reason for doing so and what happens to the signal after this stage?

**Some Subtleties: Tuning the radio to your favorite (AM) station – the LC circuit.** (Please, write up relevant for your radio calculations that you that you are doing in the rest of this project. Make sure that it is clear what you are calculating but be brief and treat it as a problem set type of write-up.)

- (i) Build and investigate a parallel LC circuit, such as the one shown in Figure 1; particularly, investigate and find theoretically and validate experimentally a resonance frequency,  $f_0$  of this circuit.
- (ii) Your simple receivers will tune into the radio station by using a parallel LC circuit to select the frequency of the broadcast station. We can construct a circuit that **resonates** at a frequency that depends on the inductance and the capacitance. When the antenna receives a signal at this resonance frequency, a large voltage builds up in the circuit.

You will build a resonant circuit for an AM radio with either a variable capacitor or a variable inductor (preferably both). By changing either the capacitance or the inductance of the circuit, you will be able to select the signal from just one radio station and ignore the signals from all the other stations. You will know you have tuned in a station when the sound is loud and clear; this happens when the frequency of the station is equal to the resonant frequency of your LC circuit.

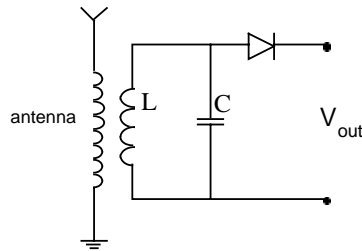


Figure 1

### The Front End – Detecting the Signal

(All the relevant equipment can be found in ECE stockroom, your labs, and the chips will be provided by yours truly ☺.)

The front end of your radio takes the signal from the antenna, selects the frequency with the LC circuit, and then passes the signal through a diode. (Remember that the diode provides a non-linearity that reconstructs the voice signal.) The circuit diagram for the front end of the radio is shown in Figure 1. Notice how the antenna is connected to a coil that is next to the coil for the LC circuit. So, a signal in the antenna induces a magnetic field, which in turn induces a current in the LC circuit.

#### STEP 1: BUILD A CAPACITOR

This is easy! You should already have it!

#### STEP 2: BUILD AN INDUCTOR

What inductance will be needed to make a resonant LC circuit with the required resonance frequency range? For a given cross-sectional area of the inductor, what length and how many turns do you need in order to get the required inductance?

#### STEP 3: ASSEMBLE AND TEST THE FRONT END

Put together the circuit shown in Figure 1. The components should be mounted on a piece of wood/blue foam/... that will prevent them from moving, which would alter the resonant frequency of the circuit. To test the front end, use an oscilloscope to verify that your LC circuit is working. Try connecting a function generator to the antenna and measuring the voltage across the capacitor as you adjust the frequency of the function generator through the expected resonance. Graph the voltage across the capacitor as a function of the frequency of the sine wave. What is the actual resonance frequency? Use this setup to calibrate your variable capacitor so that you can tune to your favorite (AM) radio station later.

### The Back End -- Amplifying the Signal

The signal from the diode ( $V_{out}$  in Figure 1) is not powerful enough to drive a speaker. To drive a speaker, you need an amplifier. Fortunately, amplifiers are easy to build. We will use an amplifier chip called an LM386. Figure 2 shows a potential circuit diagram of the amplifier. ( $V_{out}$  from Figure 3)

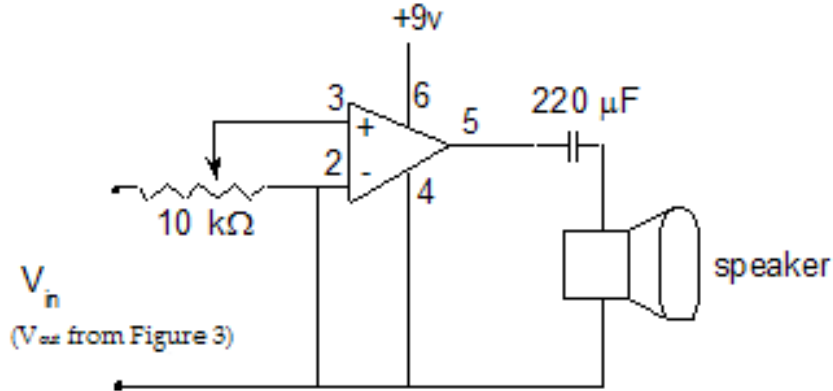


Figure 2

The connections on the LM386 chip are shown in Figure 3.

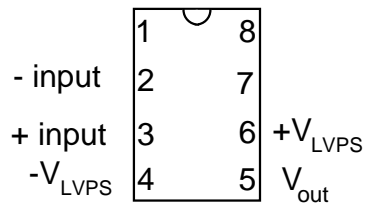


Figure 3

#### STEP 4: ASSEMBLE AND TEST THE AMPLIFIER

The circuit is shown in Figure 2. The 9 volts from the LVPS that you can optionally build (please, see the description of how to build it below) or a 9-V battery must be turned on before you attach the input ( $V_{in}$  in Figure 2) to pins 2 and 3 or else the amplifier may be damaged. Set the function generator to produce a 1 kHz signal for use as an input to the amplifier. Connect the oscilloscope to show what the voltage between pin 3 and ground. Rotate the volume control resistor until you get a signal with the largest amplitude. Now look at the voltage across pin 5 and ground. This is the amplified version of the previous signal. If the signal is not amplified, check your connections.

#### STEP 5: TEST YOUR RADIO!

Test the radio with a speaker (see below). You should connect the radio to the antenna as well as to the ground wire.

#### STEP 6: BUILD A SPEAKER (possibly, similar to a paper cup one we showed in class)

You can either build one (see, for example, <http://www.exo.net/~pauld/activities/magnetism/speaker.html> or [http://www.sfu.ca/physics/ugrad/courses/teaching\\_resources/demoinde/eandm/em5h/cupldspkr.html](http://www.sfu.ca/physics/ugrad/courses/teaching_resources/demoinde/eandm/em5h/cupldspkr.html)) or use a speaker from your dorm room, or your earphones.

#### STEP 7 (Optional): BUILD A LOW VOLTAGE POWER SUPPLY (LVPS)

*Note: you will need to use ZAP! manual for this exercise, which will be waiting for you in the library on reserve. Please, do not take the manual out of the library as this is the only copy I own. You will need the following equipment:*

- wall transformer 120/12Vac, 1A;
- bridge rectifier
- electrolytic capacitor, 1000  $\mu$ F, 25 V, polarized
- electrolytic capacitor, 1  $\mu$ F, 50 V, polarized
- potentiometer, 5K
- voltage regulator, LM317T
- resistor, 240  $\Omega$
- wire
- solderless circuit board, size UBS-100
- heat sink
- some insulated hookup wire, 22-gauge (not crucial)
- for experiments: 2 - #47 bulbs and 2.4 Ohm resistor

*Please, speak to Eric Gallimore when you are ready to pick up these items. This work needs to be performed in the same pairs as you worked while building your capacitors. Please note, that although this is a group work, your write-ups need to be individual. Please, place an electronic copy of the write-up of this problem on the share drive. This is in addition to handing a hard copy of it in with the rest of your problem set.*

#### a) **Building:**

Building the LVPS is a relatively easy task. ZAP! has a nice picture and circuit diagram (Figure 3-6 on page 58) of the power supply. Parts of this circuit diagram should look familiar to you now (note the transformer, the "full-wave" rectifier and the 1000 mF capacitor). The LM317T component in the diagram is a regulator that helps to keep the voltage constant and independent of the total resistance (or *load*) in the circuit. Understanding the regulator is not crucial, but we hope that you will satisfy your curiosity about it by reading pages 62, and 69 - 70 in ZAP! Pages 60-62 have a nice summary of the conversion process you've been learning about. Skim pages 53 - 59 and then begin wiring the power supply circuit. If the LVPS does not appear to be working properly, perform Experiment 3.1 - An Overall Check of the LVPS on page 63 in ZAP!, to find the problem.

#### b) **Seeing the regulated voltage**

Connect the circuit shown in figure 3-14 of ZAP! (page 64) with the ammeter and light bulbs disconnected for the moment. To see the regulator at work, increase the voltage by turning the pot. You will see it plateau at around 15 volts; i.e., you will not be able to increase the voltage beyond about 15 volts. Notice that you can still rotate the pot and the voltage remains at 15 volts. With the pot rotated fully clockwise, connect the ammeter and light bulbs and watch the voltage on the voltmeter. What happens when you connect the light bulbs and ammeter? When the LVPS output voltage is set this high, the output voltage is **unregulated**. There is, however, a range of voltages where the output voltage doesn't decrease as you add a load; in this range, the LVPS output voltage is **regulated**. Take some time to determine this range. When using the LVPS in later experiments, you will want to use this range of regulated voltages.

Keep in mind that the whole point of an ideal power supply is to supply constant voltage, independent of the load.