CRYSTAL RADIOS and LRC CIRCUITS - 2
PHYS 251 Laboratory

INTRODUCTION: How does one go about designing and building a crystal radio? The basic theory of a crystal radio was covered in the experiment last week. Also, experiments dealing with capacitors and inductors consumed most of the semester. One important bit of information is that the AM radio band is in the range of 530 kHz to **1600** kHz.
The basic design of the crystal radio is an LRC circuit that can be tuned thru the AM band. Basically this is determining the "best" values of resistance, R, capacitance, C and inductance, L for the LRC circuit. Because we are looking to tune to a range of frequencies, one of the components must be variable in its value.
Recall that at resonance the angular frequency, ω is given by:

$$\omega^2 = 1/LC$$

WHAT EXPERIMENT SHALL WE DO?

GOAL: To use a simple LRC circuit to design and build a crystal radio.

HOW SHALL WE DO THE EXPERIMENT?

There are several steps in this process of designing and building a radio. Because of potential problems with finding a "good" station and getting a good antenna, early testing of the radio will be done using an AM signal from a RF signal generator. The first step is to test the RF signal generator and the AM, amplitude modulated signal it produces. Then test the earphone / diode as a detector for the audio frequency, AF, signal, that modulates the radio frequency, RF, signal. For the actual design, one must choose the components for the LRC circuit from what is available. Finally there is construction and testing.

Test the RF Signal Generator
Set the RF signal generator as follows:

AF mode	(lower, left knob)	Int Mod /AF out
AF amplitude	(left, second knob from bottom)	ON and fully clockwise
Course Atten	(lower right knob)	Hi
Fine Atten.	(right, second knob from bottom)	Fully clockwise
Frequency Range	(lower, center)	B 310-1100 kHz
Frequency	(upper, center)	55 on range B

Connect the RF signal generator (from RF OUT connector) to the oscilloscope. With the oscilloscope, observe the RF signal and modulating audio signal. Measure both frequencies. Adjust the various controls on the RF signal generator to become familiar with the function.

Test the Earphone/Diode Acoustic Detector
Clean the earphone with Alcohol. Connect the signal from the RF signal generator across the earphone /diode, and listen.

figure 1

Choosing a resistor for the LRC circuit.

What is the effect of changing the resistance in an LRC circuit? In a previous lab, you mapped the resonance of two circuits with the same inductor and capacitor but with different resistors. Which had the narrowest resonance? Which had the largest current? An alternative way to think about it is, will a larger resistor dissipate (waste) more or less energy than a smaller resistor? In fact, for the crystal radio, one wants as little resistance in the circuit loop as possible, so generally one does not use a resistor in the circuit, but the resistance of the wire, the connections and the coil provide more than enough resistance. Explain why!

Choosing an inductor for the LRC circuit

If you look at Eq. 1 you can see that it does not provide enough information to select the inductor or the capacitor separately, but only the combination. In this experiment you are given the inductor. You need to both calculate and measure the inductance of this coil

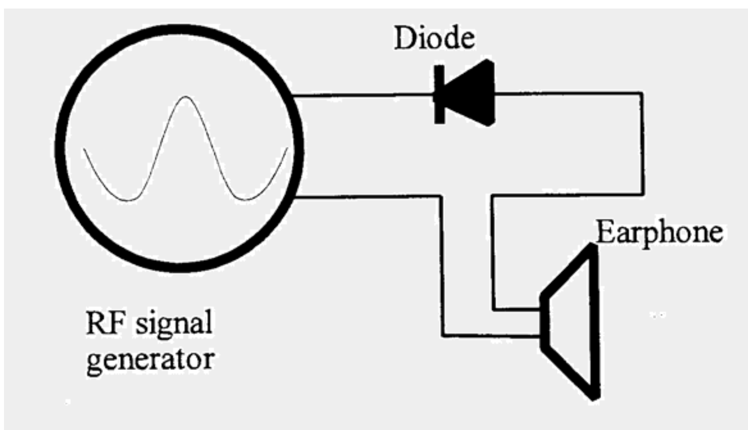
Although there are exact equations for the inductance of a single coil, an infinite solenoid, and a toroid, there is not an equation for a short solenoid. But there is an approximate rule of thumb for the inductance of a coil with an air core. The inductance, L, is given by

$$L \text{ (in henrys)} = a^2\, n^2 10^{-6}/(9a + 10b)$$

where a is the radius of the coil in inches, b is the length of the coil in inches and n is the number of turns. This is an old Ham Radio formula, and is a close approximation if $b > 0.8$ a. You will have at your disposal an inductor with a radius of about 1 inch, a length of 2 inches and about 40 turns. Make appropriate measurements of the inductor with which you are provided to be able to calculate the inductance. **Note:** do not include the antenna coil in this calculation.

Experimentally, inductance can be determined using the idea of reactance (thus measuring current as a function of frequency) or, alternatively, the idea of a resonance. Find an experimental value of the inductance of your coil by a method of your choice. Document your determination, and compare to the calculated value. [Recall that, by putting a resistor in series with L you can determine the current by measuring the IR drop across the resistor; then the current as a function of frequency provides a measure of the inductance.]

figure 1



Choosing a capacitor for the LRC circuit

From the measured inductance found above and Eq.1 calculate the required capacitance. (Remember the difference between angular frequency, (A) and normal frequency, f.) If possible select this value using the capacitor substitution box.

Building the radio

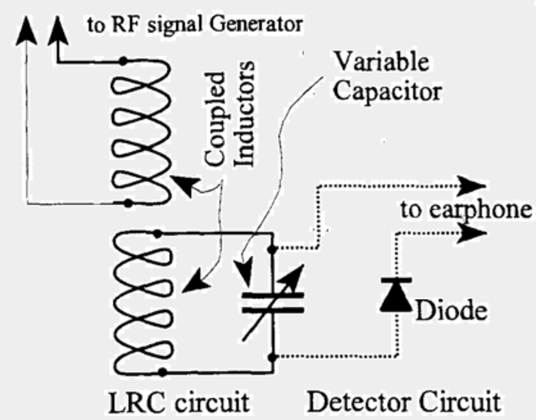


Figure 3 The circuit for a basic crystal radio when testing with the RF signal generator.

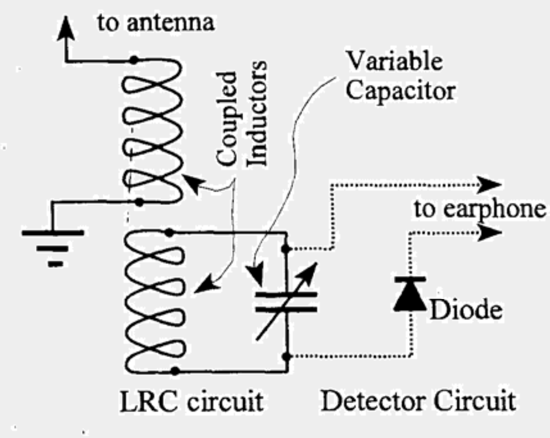


Figure 4 The circuit for a basic crystal radio when listen to a real radio signal

Assemble the circuit as shown in Fig. 3. Set the RF signal generator as suggested in the section on testing the signal generator. Set the capacitor box as calculated above. While listening, tune to get the loudest signal by varying the capacitance. Make a table to capacitances to tune various parts of the AM band (530- 1600 kHZ). Also note the range of capacitance that can tune an RF frequency.

Try your radio using an antenna and ground. This lab is complete when your radio, hooked up to the antenna, permits you to hear an AM radio station!

Equipment

RF Signal Generator (Heath IGW-19) RF to banana cables

Capacitor Boxes (-O.OOOl-O.O1µF)
screw terminal to banana adapters
Inductor with antenna coupling
Earphone I Diode Unit Ruler

Oscilloscope
Audio Function Generator
DMM
Resistor board
Capacitor / Inductor board
General: Wires
Alligator Clips
Cleaning supplies
Alcohol
Chemwipes