

EE1000 Project 1

Crystal Radio

Overview

In this project, we build an AM crystal radio using a homemade capacitor and inductor. Crystal radios often use earphones, which is convenient since they don't require a power source.

Design

The crystal radio can be illustrated as shown in Figure 1. The resonant circuit attenuates (makes smaller) all the frequencies from the antenna except the one to which the radio is tuned. The rectifier turns the output of the resonant circuit into an audio signal to drive the earphones.

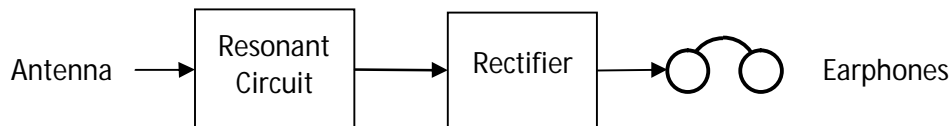


Figure 1 – Block Diagram

Resonant Circuit

The first step in this project is to design the resonant circuit. To do that, you must determine the maximum inductance (L) and capacitance (C) needed for AM reception. AM frequencies range from 540kHz to 1600kHz, so you will need to make the (adjustable) capacitor and inductor large enough to handle 540kHz, the lowest frequency.

The resonant frequency of a capacitor and inductor circuit is given by:

$$F_r = \frac{1}{2\pi\sqrt{LC}}$$

Start by deciding on a target capacitance and inductance. For example, you might choose to make a capacitor that can adjust up to 150pF (2×10^{-10} F), which would imply that the inductor should be adjustable up to about 600 μ H (6.0×10^{-4} H).

Next, build a capacitor. Aluminum foil makes good capacitors, but you can't solder to it. Instead you will have to use screw terminals or clamps. The layers of aluminum must be insulated, so you will need to choose some sort of paper or plastic wrap. Determine its thickness and find its relative dielectric constant, ϵ_r , (e.g. google dielectric table). The capacitance of a "parallel plate" capacitor with area A and dielectric thickness, d , is given by:

$$C = \frac{8.85 \times 10^{-12} \epsilon_r A}{d}$$

Use this to solve for A , but be aware that if one plate is sandwiched between two others, the effective area is doubled. Remember that the units of d and A must be meters and square meters respectively. You can make capacitance variable by sliding the conductors so that more or less of the area overlaps. (Note, the area of the capacitor may be quite small. If 0.0015" wax paper with $\epsilon_r=2.5$ is used between the plates, the area of a 150pF capacitor is less than 3 cm².)

Once the capacitor has been built, measure it using a multi-meter (if it is capable) or LC bridge. It is unlikely the actual capacitance will equal the target capacitance, but it should be in the

same ballpark. Based on the actual capacitance, recalculate the necessary inductance. The inductance of a coil of wire with length l and cross sectional area A is given (approximately) by:

$$L = \frac{4\pi \times 10^{-7} N^2 A}{l}$$

where N is the number of turns or loops the wire makes around the core. It is relatively easy to compute the cross sectional area, A , (in square meters) once you have chosen something to wrap the wire around, but computing l is trickier. This is because the length of the coil usually depends on the number of turns, but if the wire has a diameter of D meters and you lay the loops in the coil next to each other, then

$$l = ND$$

Careful application of Algebra results in the following equation for N :

$$N = \frac{LD}{4\pi \times 10^{-7} A}$$

Any type of wire may be used in the coil as long as one loop is isolated from the next. The best kind of wire is enamel coated magnet wire (available from Radio Shack).

Don't forget the inductor should also be adjustable. You are free to make that happen any way you like, however there are two approaches that have been successful in the past.

1. Place "taps" every 5-10 turns in the coil. A tap is a point on the coil that you can connect to. In this way, the inductance of the coil depends on which tap is connected.
2. Remove the insulation on one face of the coil (e.g. with sandpaper) and use a "wiper". A wiper is a conductive arm that can slide over and make contact with any loop in the coil.

A simple way to connect your capacitor and inductor to form a resonant circuit is shown in Figure 2. The output is connected as it is because the signal is actually stronger there than at the antenna.

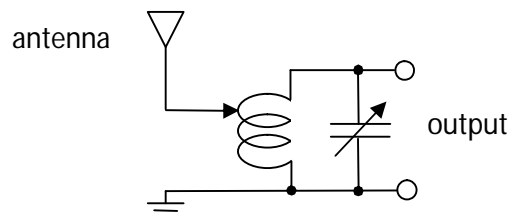


Figure 2 – Resonant Circuit – Arrows Denote Adjustable Components.

For more information on resonant circuits, feel free to consult any of the many web sites dedicated to crystal radios.

Rectifier

The rectifier of a crystal radio consists of a germanium diode and a resistor to ground as shown in Figure 3. A good germanium diode is the 1N34. The actual diode has a (usually black) color band on the cathode (the end that connects to the resistor). The resistor value is not critical but should be about 50-80k Ω .

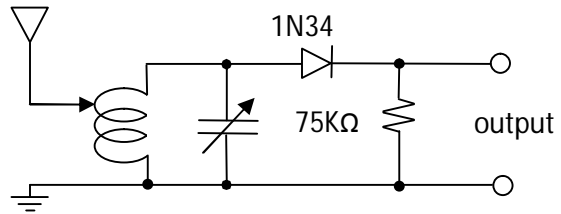


Figure 3 – Resonant Circuit with Rectifier.

Amplifier

All that remains is to connect a high impedance earphone to the output of the circuit in Figure 3 to complete the crystal radio.

Testing

Connect your radio to an antenna, turn it on and tune in stations. (Listen carefully; many stations will not be close enough to generate a loud signal.) To get full credit, your radio must be able to tune to at least 2 different stations.