Project XTAL Radio

We all love our electronic toys, radios, stereos, CD players, MP3 players, computers, DVD players, short wave radios, amateur radio, TV's, X-boxes, Play stations, VCR's, cassette tape players, 8 track tape players, reel-to-reel tape players, and record players. All these devices require electricity by either plugging the device into an electrical outlet or by inserting batteries.

The radio you are about to build does not require batteries or electricity from the wall socket. This radio will play forever for free! How? It obtains all of its power from the transmitted radio wave.

For as long as there are AM stations transmitting in the AM broadcast frequency range, this radio will work. That could be 10, or 100 or more years from now. Be as creative as you want building this radio, build it as neat or as unique as possible, keep it, and pass it children, grandchildren, or great grand children. This low-tech radio could outlive all of those electronic devices mentioned above … and it will still work for free!

Xtal is the radio abbreviation for crystal. These radios are called crystal (xtal) radios because the original radios used a crystalline mineral for the detector. The most popular mineral used is galena, followed by pyrite. Modern crystal radios often use manufactured devices called diodes. Careful examination of a diode will reveal a tiny hair-like structure coming in contact with a tiny crystal of germanium (see following pictures).

Physics Objectives:

1. Learn to identify electronic components by their schematic diagram symbol.
2. Learn to build an electronic device from a schematic diagram.
3. Learn to trace current flow through a schematic diagram.
4. Identify series component and parallel components in a schematic diagram.
5. Calculate the values of the capacitors and inductors.
6. Calculate the tuning range (frequency coverage) of the radio.

Parts:

1. insulated wire – 70' – enamel or plastic coated wire
2. coil form – toilet paper tube, or PVC; 1" to 4" in diameter - diameter will depend on wire size
3. two aluminum cans
4. aluminum foil
5. tape – clear mailing tape is best
6. diode - germanium diode model **1N34**, **1N34A**, **1N60** – the "crystal" for the crystal (xtal) radio
7. board – 8" X 8" is a good size – thick enough so screw/tacks do not penetrate to the opposite side
8. paper clips – ten
9. wood screws – 15
10. earphone or ear piece

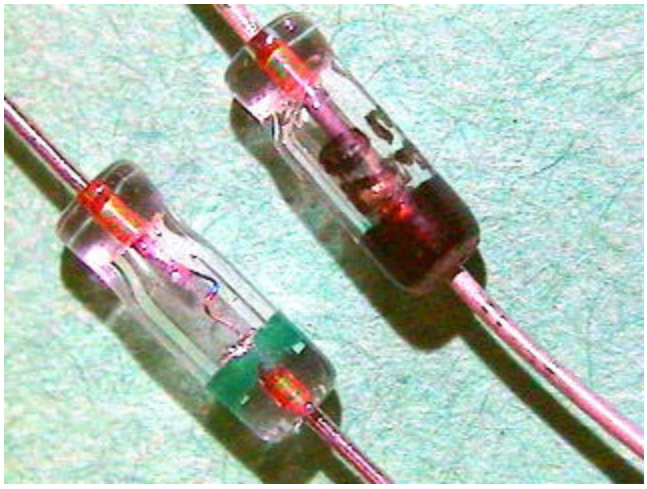
Optional Parts:

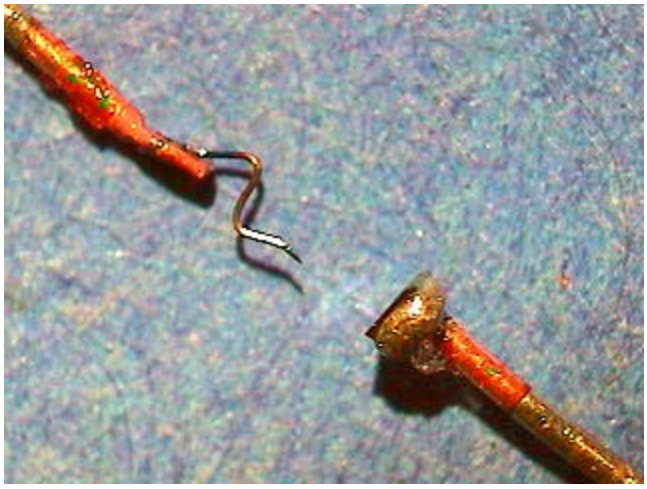
11. alligator clips
12. Fahnestock clips

The coil form is dependent on the wire type and size. Enamel coated wire 28 to 18 gauge requires a form of 1 to 3 inches in diameter and plastic coated wire needs a form of 3 to 5 inches in diameter. The classic toilet paper roll tube, used mailing tubes, and scrap PVC all do nicely for coil forms.

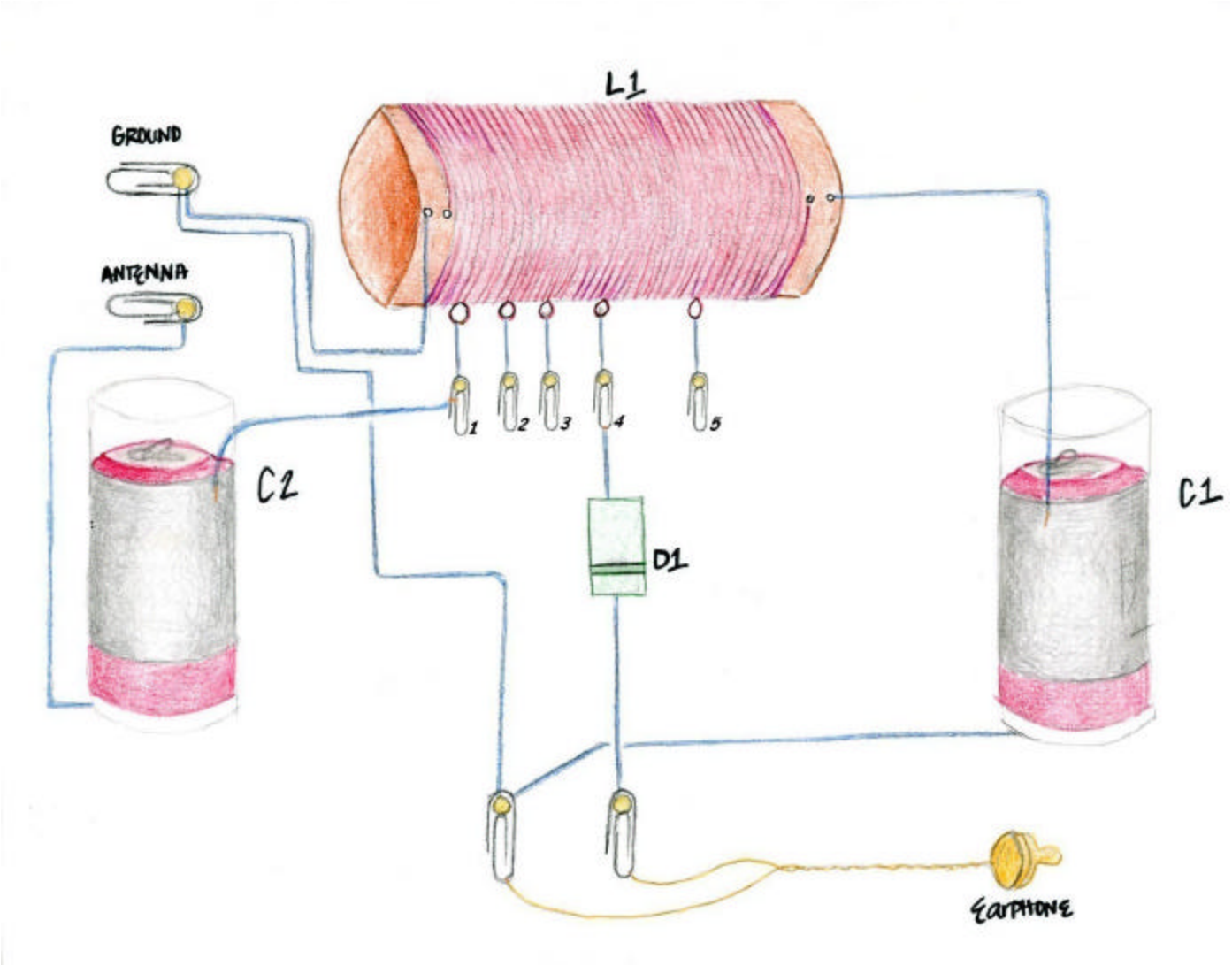
Aluminum cans, have your favorite beverage and use the can. The variable section of the capacitor can be aluminum foil or even a slightly larger diameter can.

Germanium diodes look like a ¼" tiny glass cylinder with a wire protruding from each end. This is the "crystal" for the radio. They will have a colored band on one end. If there are markings on them, look for **1N34, 1N34A, 1N60, or 1N270**. Do not use silicon or "switching" diodes. Below left are a couple of diodes photographed with the classroom stereoscope. The below right picture is the inside of a diode. The "cat whisker" is on the left and the mounted germanium crystal is on the right.



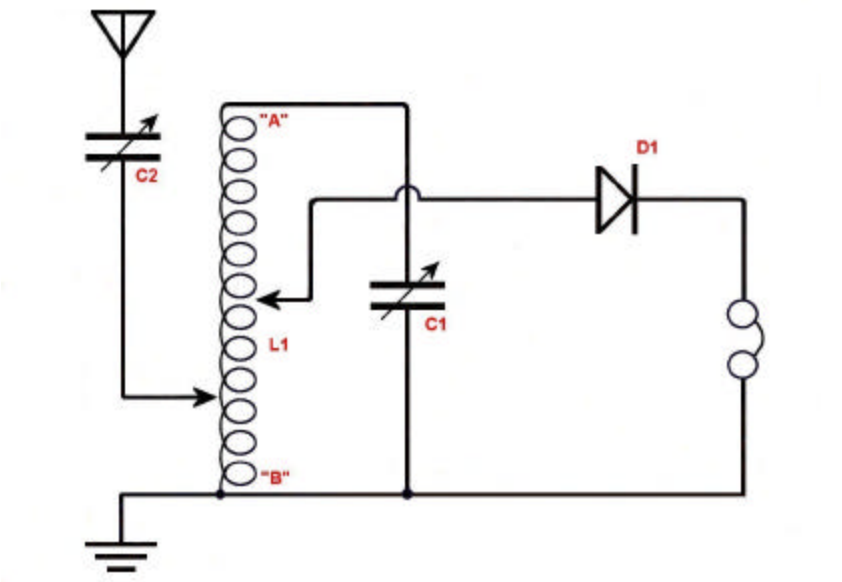


Project XTAL Radio – Pictorial Diagram



The above is a pictorial diagram of the crystal radio to show the approximate physical placement of the components.

Project XTAL Radio – Schematic Diagram



Key:

capacitor - variable		diode	
inductor		earphone	
wires connected		wires not connected	
antenna		ground	

The above schematic diagram shows the electrical wiring of the crystal radio. Schematic diagrams are used by persons involved in the assembly and/or trouble shooting of electronic devices. The arrow on the coil represents an adjustable connection to the coil.

Follow the flow of the signal through the radio with the schematic diagram. The radio wave is received by the antenna, flows through the antenna coupling capacitor (**C2**) and then into the tuning circuit. The tuning circuit is made of an inductor (**L1**) and a tuning capacitor (**C1**). Adjustment of the tuning capacitor (**C1**) selects the desired station. The selected signal flows into the diode (**D1**) which functions as a detector. A detector separates the audio signal from the selected radio signal. The audio signal flows into the earphone where electrical energy is converted into mechanical energy. This particular mechanical energy is the sound waves received by our ears.

Project XTAL Radio – Assembly

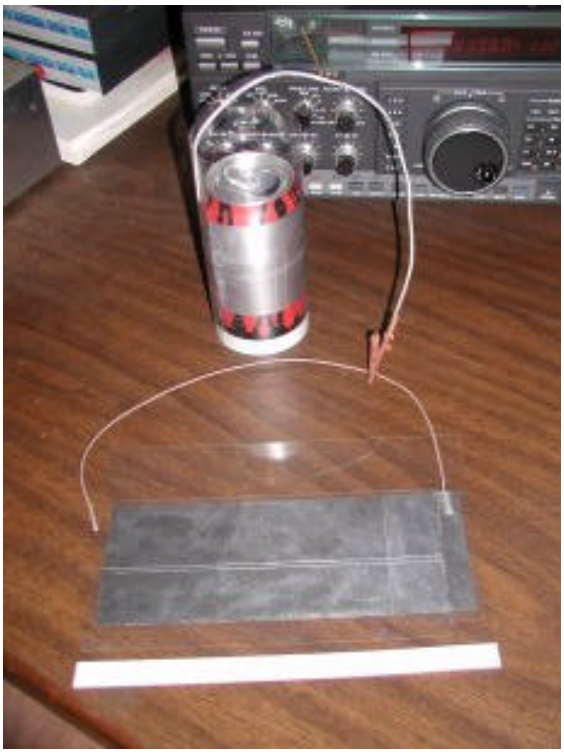
Tools: Needle nose pliers, knife, sandpaper, wire cutters, screw driver

Construction Procedures:

A **variable capacitor** is used in most AM/FM radios to tune in different radio stations. Changing the capacitance will change the frequency of the tuning circuit. On most radios this will be the "tuning" knob or "tuning" controls. A simple capacitor consists of two parallel metal plates insulated from each other. The capacitor and coil work together as a tuning circuit to select the desired station for reception. A second variable capacitor may be needed to adjust the coupling of radio signals from the antenna to the tuning circuit. Construction for both capacitors is the same. The tuning capacitor is designated as "**C1**" and the coupling capacitor is designated as "**C2**" in the schematic diagram.

Building the capacitor:

1. Cut the paper or transparency film to a size of 8 ¾ inches long by 5 inches wide.
2. Cut a piece of aluminum foil to a size of 8 inches long by 2 inches wide
3. Carefully attach the foil to the transparency 1 ½ inches from the bottom of the transparency using the clear mailing tape **BUT** leave ½ inch of one end uncovered.
4. Cut a 10" piece of hook-up wire, remove 1" of insulation from each end and tape one end of the hook-up wire to the uncovered end of the foil. Make sure there is a good connection between the section of bare wire and the foil.
5. Wrap the foil-transparency assembly, foil side out, snuggly around the can and secure with the tape. The assembly will slide up and down over the can functioning as a tuning capacitor.



The **coil**, in conjunction with the capacitor, forms the tuning circuit for the radio. The coil is designated as "**L1**" in the schematic diagram. Both the coil and capacitor, working together can separate the various stations. The "perfect" coil that yields the best all-around performance is a "square" coil, one in which the diameter of the coil is approximately each to the length of the windings. Good performance can be obtained with coils of many differing dimensions. The ideal value of inductance of the coil for the AM broadcast band is 240 µh. Inductance values from 160 µh to 350 µh will also work but part of the tuning range of the radio may be limited or outside the AM broadcast band.

Winding the coil – generalized instructions for a toilet paper form and 28 to 22 gauge enamel coated wire:

1. Punch two holes at the end of the paper toilet form as shown and thread 10" wire through the holes.
2. Wind 90 turns of wire around the form and tap as follows: 5 turns, 10 turns, 15 turns, 30 turns, 45 turns, and 60 turns. Make the taps by twisting ½ inch of the wire to leave a loop at the end.
3. Punch two holes at the other end of the paper toilet form and thread the wire through to anchor the turns. Leave 10" and cut the wire.
4. Use the sandpaper or knife to remove insulation from the wiretaps. Remove an inch of insulation from the wire ends. The coil is complete. The coil to the right follows the above instructions.
5. Adjust these steps to suit different size coil forms.

The coil below uses 60 turns of #18 plastic coated stranded wire wound on a mailing tube with a 4.2" outside diameter. The taps are at turns number 5, 10, 15, 30, and 45. The plastic-coated wire is not as stiff as the enamel wire so a wood dowel is used as an aid for tap formation. Use this number for inductance in addition to the capacitance to solve for the tuning range of your radio.

Final Radio assembly:

1. Place **L1** (inductor) to the rear of the board as shown in the pictorial diagram and fasten with thumbtacks or wood screws. Connect a wire from each tap on **L1** to a paper clip on the board as shown in the pictorial.
2. Layout the paperclips for the antenna connection, ground connection and earphone as shown in the pictorial diagram. Use wood screws to attach them to the board but do not completely tighten.
3. Connect the wire from the ground ("**B**") end of **L1** to the paperclip for the ground connection. Connect a length of hookup from the ground clip to the left earphone paperclip as shown. Tighten the screw for the ground clip.
4. Fasten the can end of **C1** (tuning capacitor) to the front right corner of the board with a screw through the bottom of the can. Before the screw is tightened, connect a 6" length of hook-up wire to the can end of **C1**. Connect the other end of this wire to left earphone paperclip as shown. Tighten the screw for left earphone clip.
5. Connect the wire from the foil of the **C1** to end "**A**" of **L1**.
6. Connect the glass end of **D1** (diode) to second tap from the "**A**" of the coil and connect the end with the colored band to the right earphone paperclip. Tighten the screw for the right earphone clip.
7. Fasten the can end of **C2** (antenna coupling capacitor) to the front left corner of the board with a screw through the bottom of the can. Before the screw is tightened, connect a 6" length of hook-up wire to the can end of **C2**. Connect the other end of this wire to antenna paperclip and tighten the screw for the antenna clip.
8. Attach the foil end of **C2** to the antenna clip to first paperclip from the ground end of **L1**.

Operation:

1. Connect a 100' wire (or as long as you can get) to the antenna clip and connect a wire from a ground rod to the ground clip on the radio. If a ground rod is not available lay 50'to 100' of wire on the ground as a substitute for the ground rod.
2. Connect the earpiece the earphone clips and listen.
3. You should immediately hear a station, or perhaps two stations at the same time.
4. Slide the foil side of C1 up and down to tune in one station at a time.
5. Experiment with different adjustments of the diode tap, antenna tap and tuning capacitor tap to receive different stations.

The function of the antenna tap on the coil is to provide for the maximum transfer of energy from the antenna to the tuning circuit. The function of the detector tap is to provide a maximum transfer of energy from the tuning circuit to the detector. The function of the antenna coupling capacitor is to regulate the amount of energy from the antenna to the tuning circuit. If the crystal radio is operated near a powerful station, adjustments of the taps can reduce the amount of energy from the nearby station so distant stations (DX) can be received.

Trouble shooting - if the radio does not work:

1. Check for wiring errors.
2. Check for complete removal of insulation on the wire at connection points, this is especially important with enamel-coated wire. An ohm meter or continuity meter is very helpful for this task.
3. Check the connections; make sure they are secure.

Good Luck and 73! ~WA5POK~

73 - a radio communication abbreviation for "Best Regards!"
WA5POK - my amateur radio call sign issued to me by the FCC - this is how other amateur radio operators around the world know me