Germanium Diode AM Radio

LAB 3

3.1 Introduction

In this laboratory exercise you will build a germanium diode based AM (Medium Wave) radio. Earliest radios used simple diode detector circuits. The diodes were made out of Galena crystals (also called cat's whisker) and these radios were really simple. Despite all of the advances in modern electronics, there are thousands of crystal sets in daily use throughout the world. A crystal receiver is powered solely by the radio waves that it pulls from the air. Figure 3.1 shows the picture of an early Ge diode radio.

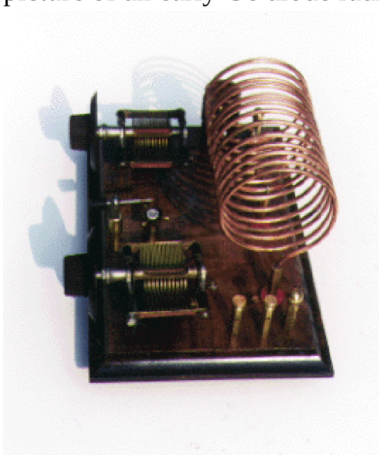

Figure 3.1—An antique diode radio. This radio is a MW and SW radio that works without any power supply.

Amplitude Modulation

The point to modulation is to take a message bearing signal and superimpose it upon a carrier signal for transmission. For ease of transmission carrier signals are generally high frequency for severable reasons:

1.For easy (low loss, low dispersion) propagation as electromagnetic waves

2.So that they may be simultaneously transmitted without interference from other signals

3.So as to enable the construction of small antennas (a fraction, usually a quarter of the wavelength)

4.So as to be able to multiplex; that is, to combine multiple signals for transmission at the same time.

For example AM radio is 550-1600 KHz, FM radio is 88 MHz-108 MHz, TV is 52-88 MHz (channels 1-6), 174-216 MHz (channels 7-12) and 470-900 MHz (UHF).

In Amplitude Modulation (AM), the amplitude of the high frequency signal is varied by a low frequency signal that needs to be transmitted. Figure 3.2 shows a

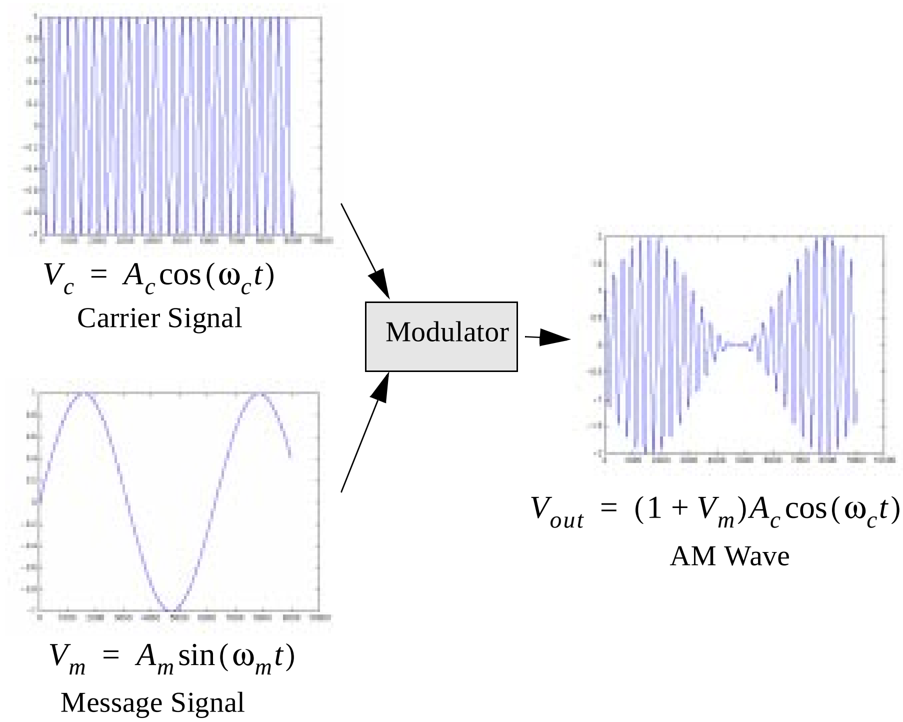

Figure 3.2—Amplitude modulated signal consist of a message signal V_m controlling the amplitude of the carrier signal V_c

message signal and a high frequency carrier signal multiplied to obtain the AM modulated signal. The carrier signal is the content transmitted by the radio station and the carrier is the frequency which the electromagnetic waves are transmitted.

AM Detection

Modern radios use complicated detection schemes to demodulate the transmitted electromagnetic waves to provide the kind of reception we have began to expect from our radios. However, the simplest way to demodulate the transmitted AM waveform is use an antenna, a tuned LC coil, a germanium diode and a earphone. In this lab we shall attempt to build the radio the earliest pioneers built using these simple components.

3.2 Diode detector

Figure 3.3 shows the circuit for the MW diode detector based radio receiver.

Antenna

The antenna’s job is to capture electromagnetic waves from all sources and directions and funnel those charges into the antenna coil. The amplitude of received signals is directly proportional to the dimensions of the antenna. Antenna design

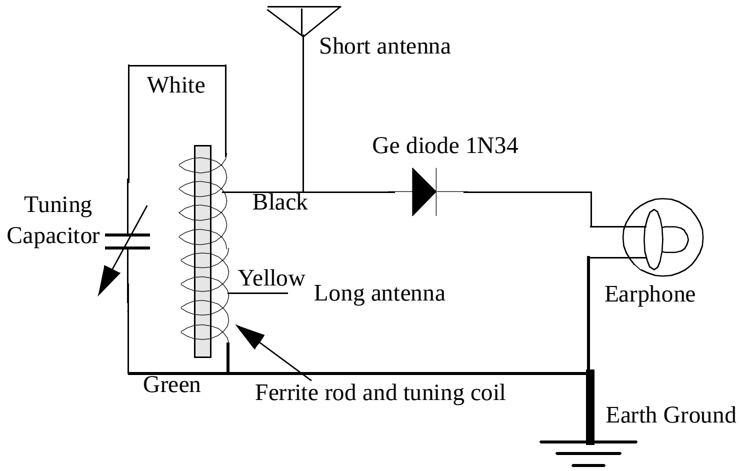

Figure 3.3—Schematic of the MW AM diode radio detector to be designed.

is not trivial and requires outdoor mounting. In this lab, since we are inside and without an amplifier, we expect to have poor sensitivity.

Earth ground

The earth ground connection effectively extends the antenna into the earth, which contains electrical signals. Keep the ground wire as short and straight as possible. There may be some sensitivity loss if the excess ground wire is coiled into a loop. Use the power supply ground (Earth) for this connection.

Tuning coil

The tuning coil is the inductor which, in series with the tuning capacitor, determines the resonant frequency of the receiver:

$$f_{res} = \frac{1}{2\pi\sqrt{LC}} \quad \text{(Eq. 3.1)}$$

Where L is the inductance of the coil, and C is the tuning capacitor. The amount of coupling (Q factor) is directly proportional to the distance between the windings. If you slide the windings far apart, there is little coupling and a narrow resonance peak (e.g., 100 KHz). If you move the windings closer, there is more coupling and a broader resonance peak (e.g., 200KHz). A broader resonance peak will mean less selective tuning; that is, several stations will be heard simultaneously at one tuner setting.

A tuning coil is provided to you. Connect it up as shown in Figure.

Tuning capacitor

The tuning capacitor is the variable component in the “tank” circuit which comprises the coil and the capacitor. By varying the capacitance, you can change the resonant frequency of the receiver within the limits of the coil inductance and the

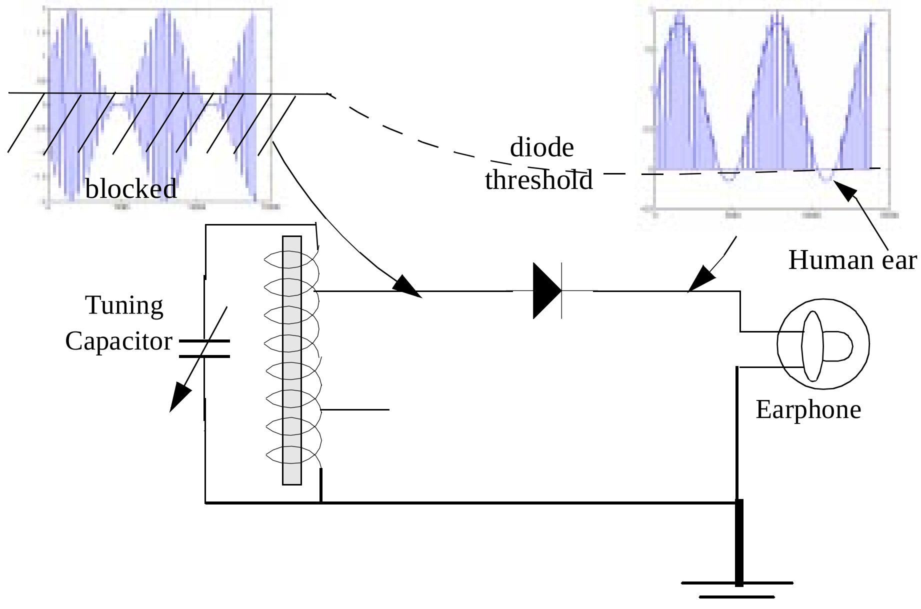

Figure 3.4—The waveforms at various points with an input AM as described in Figure 3.2

total capacitance available in the variable capacitor. A 50-500pF variable capacitor is provided. This enables us to tune from about 550 to 1600KHz.

Detector (diode)

In this radio, a diode serves as the detector, separating the fluctuating direct current (containing the voices and music of the broadcast) from the amplitude-modulated, radio-frequency, alternating-current carrier wave that was transmitted from the radio station antenna. The direct current generated by the detector will drive the output device.

Earphones

The output device changes the electrical energy in the detector circuit into mechanical energy that moves air against our ears to create sound.

3.3 Working of the diode detector.

The electromagnetic waves from the transmitted from the radio station are picked up by the antenna. The impedance of the LC circuit is very high at the resonant frequency and very low at all other frequencies. This means that only the frequency at which the LC circuit is tuned to develops a voltage across it.

The Germanium diode that has a low cut-in voltage allows current only in one direction and only the one half the cycle is transferred to the earphone. The earphone acts as a low pass filter as it is designed for the human ear (20Hz-20KHz). The waveforms at various points of the circuit for a modulated signal in Figure 3.2 is shown in Figure 3.4. Note that it is difficult to actually see audio waveforms on an oscilloscope so a test signal with a single message frequency must be used.

3.4 The Experiment

The inductor and the variable capacitor to need to be soldered on to a separate printed circuit (PC) board so that it is easy to connect them to the bread board. The wires from the inductor are multi-strand and are difficult to plug into the protoboard. Soldering also reduces the parasitic capacitance that could cause tuning frequency drift (Why?).

Hook up the circuit as shown in Figure 3.3 with the LC circuit mounted on the printed circuit board. Making sure that the coils are connected with the proper color coded wires and the diode polarities are correct. Note the diode polarities are not really important for the operation of this circuit (Why?).

Establish the ground connection by connecting to the earth of the voltage supply.

Make an antenna anyway you like from the wire provided (what criteria?). A good choice is to make the wire length about one-fourth of the *wavelength* of electromagnetic wave you are trying to receive. *Perform some prelab research and calculate the wavelengths that you need. Show you work in your lab book and in your report.*

Listen carefully to the earphone and play with the tuning capacitor to find a radio station. Warning: It might be difficult to tune into any signal radio station. You may need to listen really hard.

Suggestions to improve performance

Hookup up an Operational amplifier base voltage amplifier to this circuit so that the output is large enough to be heard using the headphone. Hint: Make a gain of at least 10 in the first stage. The preamplifier should have a large input impedance. You can add a few more stages of gain so that the stations can be heard comfortably. Too much gain is a bad thing (why?)

Testing

Which AM stations are you receiving? Do you observe anything weird?

A test AM signal will provided in class, with a carrier frequency of 1MHz and a message frequency of 1KHz.

The carrier frequency can be varied by the TA under special conditions if you need to verify the range of operation of the circuit. We do not have the resources to provide each bench with a special signal generator.

Record the waveforms at every point with the test signal. sketch and see if you get waveforms described in this report.

We will also broadcast RADIO EE which had the music of the TA’s choice. Try to tune in.

Make suggestions to improve the sensitivity of your radio?

Why are present radios so complicated? What limitations of the your design do they overcome?

3.5 Lab notebook

Record all your observations and the techniques you used to improve your sensitivity. Make a note of what radio stations you were able to receive.

3.6 Lab Report

Your lab report should contain all of the lab results (data, graphs, drawings, etc.) It should be a self-contained self-explanatory report. It should be more than a list of answers to the questions in the lab notes. Your comments on the results should reflect your understanding of the lab exercises. Your well thought out reasoning and analyses of the experimental results will be appreciated and reflected in your grade. The report need not be typed or prepared with a word processor, however, points will be deducted for a sloppy, un-professional report.

Appendix

A.1 Diode Polarity,

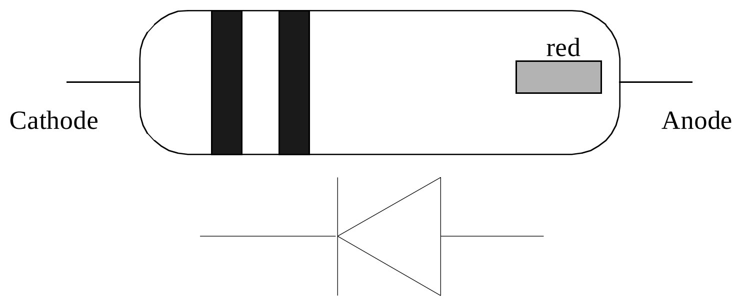

Figure 3.5—.Diode (1N34) Connections

A.2 Tuning Coil

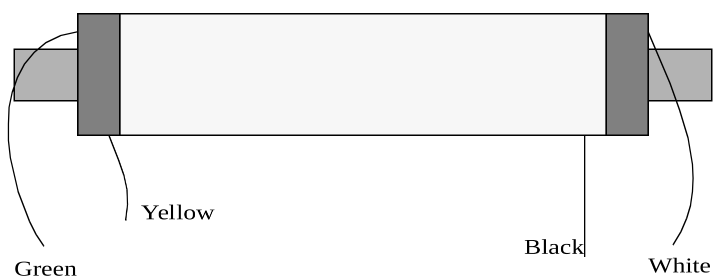

Figure 3.6—Schematic of the Medium Wave Coil

Parts List

Medium Wave Tuning Coil

Variable Capacitor (50-500pF)

1N34, Germanium diode

(3) LM741 Operational Amplifiers

1 small PC board

Miscellaneous components like Antenna wire, soldering iron etc.

Resistors

Capacitors