CMPE 314 Lab Project
AM Radio Receiver

I. Objective

Design, implement, and demo a simple AM radio receiver circuit.

II. Introduction

An AM radio wave is an amplitude-modulated electromagnetic wave, as illustrated in Figure 1. It has a radio frequency carrier wave (red line) whose amplitude varies (modulated) with audio signals (dash line). The AM radio carrier frequencies are in the range of 540-1600 kHz, and the audio signal frequencies are in the range of 20 Hz to 20 kHz.

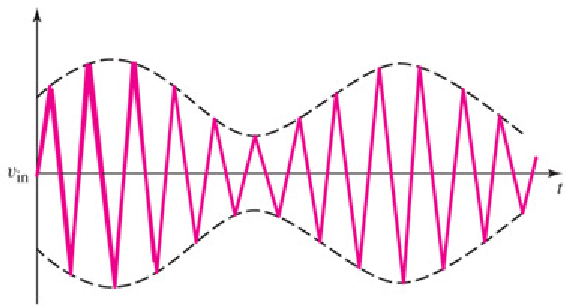


Figure 1. Amplitude-modulated wave form. The red is the carrier wave, and dash line shows the amplitude modulation.

An AM radio receiver consists of the following basic functional building blocks: a frequency-tuning antenna, a radio frequency (RF) amplifier, an audio signal detector, and an audio signal amplifier.

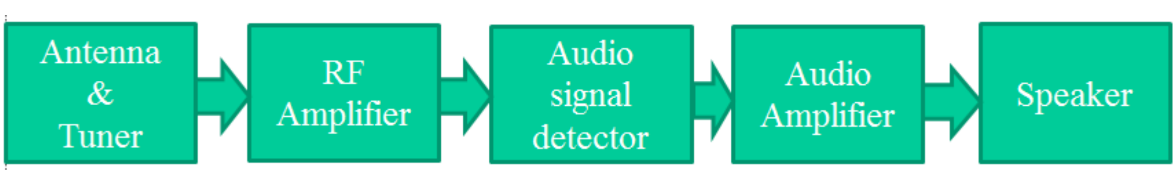


Figure 2. AM radio receiver basic building blocks.

- Antenna and tuner: The antenna picks up various radio wave signals. The frequency tuner has a band-pass frequency dependence and selects the correct carrier frequency (the correct radio station).

- RF amplifier: in remote areas, the received AM radio signal is usually weak. The RF amplifier serves to boost the AM radio signal strength (may consist of multiple stages).

- Audio signal detector: It serves to demodulate the AM radio signal, namely, removes the high-frequency carrier wave, and output only the low-frequency audio signals.

- Audio amplifier: Amplifies the audio signal to a sufficient level (may consist of multiple stages) to drive a speaker or earphone.

III. Design Guidelines

- AM antenna and tuner: Use the component provided in a lab kit.

- Audio signal detector: Use a diode and a low-pass filter to implement the audio signal detector. (Note the diode might not be needed in some AM radio receiver designs.)

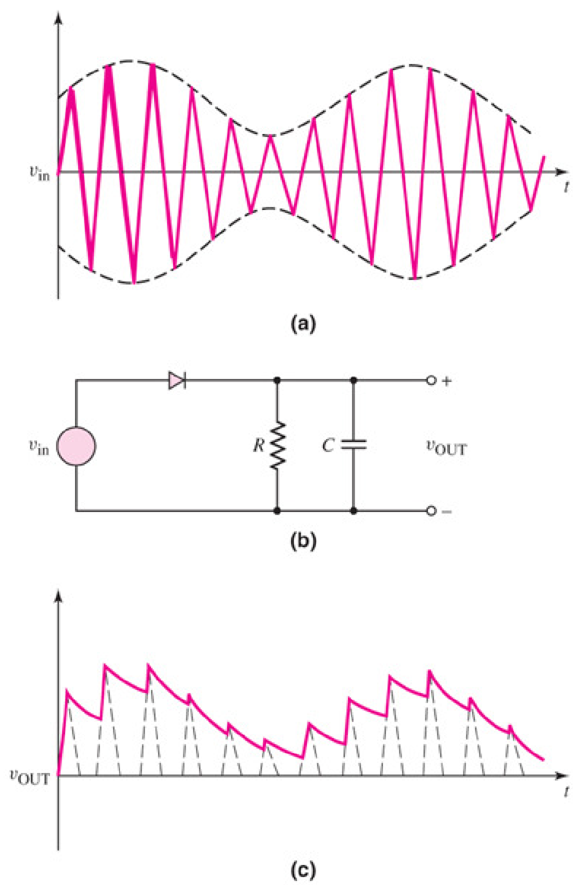


Figure 3. The signals and circuit for demodulation of an amplitude-modulated signal. (a) The amplitude-modulated signal. (b) The detector circuit. (c) The demodulated output signal.

- RF amplifier: Use transistor(s) to implement an RF amplifier with at least 10-dB (amplitude) gain. Note that the antenna signal is generally weak, less than 1 mV.

- Audio amplifier: Use transistor(s) to implement an audio amplifier that is sufficient to drive a speaker or earphone (> 100 mV is needed). Connect the audio amplifier output to a speaker or earphone (impedance 4 ~ 10 Ω) .

- A single 9-v dc battery will be the only power source.

- Bonus: with audio-volume control (10%).

You may search AM radio receiver examples online. However, you must digest those examples and come up with your own design. You are expected to explain and analyze the operation of each building block (so do not copy or follow more complex or advanced designs).

IV. Equipment and Parts

Components from lab kit, breadboard, DC battery. Digital multimeter, oscilloscope.

V. Phase 1 --- Design

(1) Initial design (week 1)

Each team is expected to come up with a full design circuit schematic diagram with transistors, diode (optional), resistors, capacitors, and battery interconnected. Present the design circuit diagram and explain the functions of each building block to the instructor/TA.

(2) Quantitative design (weeks 2 and 3)

Consult with the instructor/TA appropriate components to be used. Specify the transistors, diode (optional), and resistors and capacitors (values) that will be used. Perform DC analysis (quiescent point values) and AC analysis (small signal voltage gain, input and output resistances) for the audio signal detector, RF amplifier, and audio amplifier. Calculate the corner-frequencies associated with each capacitors used.

(3) Write and submit the preliminary design report.

VI. Phase 2 --- Implementation (weeks 3 and 4)

Implement the designed AM radio receiver on a breadboard.

(1) Test the AM radio receiver building blocks.

You can use the function generator and scope to test some parts of the AM radio receiver circuit in the lab. Also, you can do Pspice simulations before physical testing.

(a) Testing the audio-signal receiver low-pass filter:

Measure the voltage transfer magnitude at at least the following frequencies: f_audio max, f_c1, f_AM min. Verify the frequency response requirement.

(b) Testing the audio amplifier together with its input coupling capacitor (do not connect any output coupling capacitor)

Measure the voltage gain at at least the following frequencies: f_audio min, f_c2. Verify the frequency response requirement.

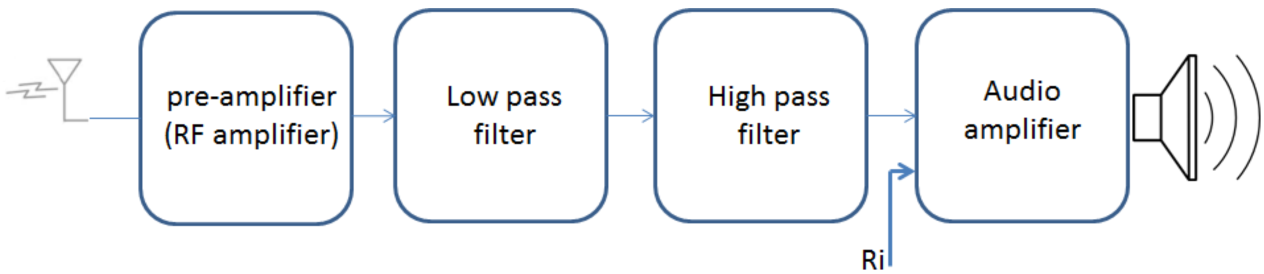
(c) Update your design if necessary.

(2) Demo the full AM radio receiver for some local AM radio stations (outside the building is easier).

(3) Final report: update the final circuit diagram and DC and AC analyses of the AM radio receiver.

Gain and Frequency-Response Considerations

A simple schematic of AM audio receiver system is shown here. As it can be seen from the figure it contains 4 main blocks which are going to be explained in detail.



Overall Gain:

The input signal coming from the antenna is approximately less than 1mV. Also, the speaker needs a few mW power to work. For example let say the speaker needs 1mW power to work. Hence, if we assume the resistance of the speaker is around 10 Ω, based on $p = V^2/R$, you will need 100 mV for the speaker, which is the output of the last stage amplifier (audio amplifier). Thus, if we assume the input signal is 1 mV, the overall gain of the circuit should be 100 in this case.

However, in the case that input signal is less than 1 mV or resistance of speaker is different from 10 Ω, you should be able to modify your circuit to have a gain more than 100, such as 300 or 400. This can be done by adding some amplification stages.

Important: in pre-amplification and audio-amplification stages you can use more than one transistor to satisfy the requirements. It means you can have multistage transistor circuit to make a RF amplifier or audio amplifier.

Corner frequencies:

In this circuit, there are two corner frequencies which you should pay attention to them and design your circuit based on them.

a. Low pass filter corner frequency (f_L):

After the pre amplification stage, a low pass filter is needed to remove the carrier wave (high frequency signal) and preserve the audio signal (low frequency signal). You can use a simple *RC* filter including one resistor and one capacitor. To design this filter you need to find R and C values. But, the values should be chosen to satisfy this criterion:

$$f_{audio} < f_L < f_{carrier}$$

You may want to look at chapter 7, page 476, in the book for more information.

b. High pass filter corner frequency (f_H)

After doing low pass filtering, a high pass filter is needed to block DC signal from output of the low pass filter to the input of the audio amplifier. Because the DC is very very low frequency and also the audio signal has frequency more than 20 Hz, so you should design this high pass filter to remove DC while preserve the audio frequency which starts from 20 Hz. Hence:

$$0 < f_H < f_{audio}$$

Important: to make the high pass filter network you need one capacitor and also a resistor. But, you don't need to use any extra resistor because the input resistance (R_i) of the last stage (audio amplifier) plays this role. Hence, first you need to calculate the input resistance of the last stage and then choose an appropriate capacitor to satisfy the above criterion for the high pass filter.
You may want to look at chapter 7, page 476, in the book for more information.

Rectifier:

Note, the rectifier block is not included to the figure since using a rectifier (diode) after the pre amplification state is completely optional. You can remove the rectifier and connect the output of the pre-amplifier to the low-pass filter directly.