Lebanese American University

School of Engineering

Department of Electrical and Computer Engineering

Final Project
The Design of an AM Receiver

A. Introduction

Wireless technology is omnipresent. Wireless LANs, cells phones, and radios are part of our everyday lives. At the core of this wireless revolution, analog circuits will always be required. The critical component in all wireless systems is the front-end analog transceiver, which consists of a transmitter and a receiver. Signals are transmitted and received through electromagnetic (EM) emissions.

The signal information, also called the baseband signal, is usually a low-frequency signal which, in the case of audio systems, is comprised in the audio band ranging from 0 Hz to 20 kHz. As these signals cannot be transmitted efficiently (they would require very long antennas), they are usually transmitted on top of a high-frequency carrier signal, also known as the Radio Frequency (RF) carrier. The carrier frequency is a high-frequency signal which carries the baseband signal containing data. This process is known as signal modulation. There are many types of signal modulation, some of the simplest are amplitude modulation (AM) and frequency modulation (FM). This project will focus on the AM receiver shown in *figure 1*.

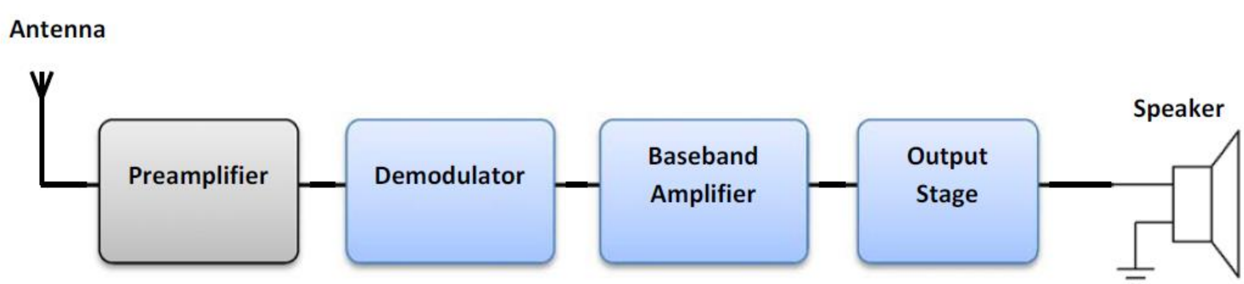

Figure 1 - System level diagram of the AM receiver

B. Demodulator

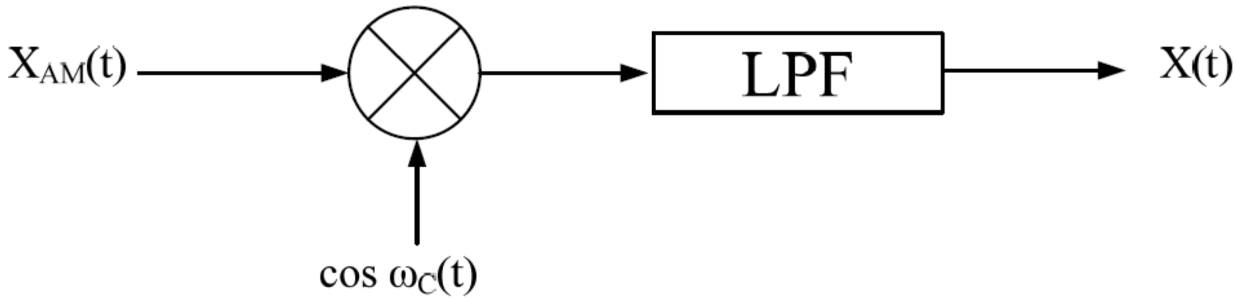

Figure 2 - High-level system diagram of an AM demodulator

In general, to down convert a signal to its baseband frequency, the signal must be multiplied by a carrier wave then sent through a low pass filter as shown in *figure 2*. This approach is further discussed in detail in your communication courses. However, for AM signals, a simpler method involving amplitude detection may be used. To do so, you will use the demodulator circuit shown in *figure 3*.

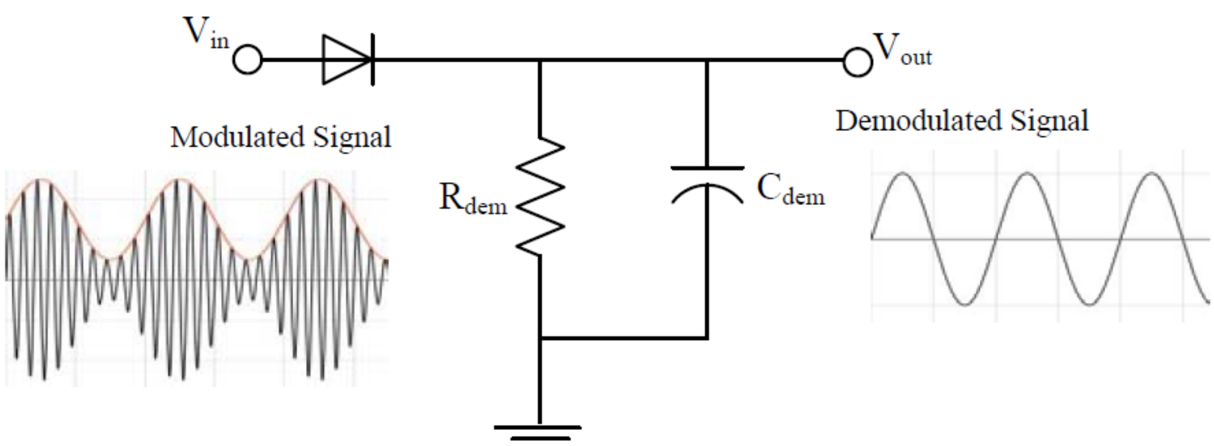

Figure 3 - Circuit diagram of a passive demodulator

I. Circuit Parameters

Germanium diode model: 1N34A

R_{dem} = ________

C_{dem} = ________

II. Background and Theory

1. In your own style, briefly explain the operation of the circuit shown in *figure 3* and indicate the factors to consider when selecting the capacitor and resistor values.

2. Select appropriate values for the capacitor C_{dem} and the resistor R_{dem}, knowing that the wanted baseband signal is in the 0-20 kHz range, and the unwanted carrier signal is in the 200 kHz – 1.2 MHz range.

Hint: The cutoff frequency of the passive RC low-pass filter should be larger than the bandwidth of the baseband signal and smaller than the frequency of the carrier.

3. What are the constraints on the DC point at the input of the demodulator for correct operation?

III. SPICE Simulation

Simulate your design to ensure correct operation using an appropriately modulation input signal. The signal can be generated using a multiplier which multiplies two sine waves. Refer to the SPICE tutorial on Blackboard for more information. Ensure that your modulating signal is correctly modulated so that your demodulator functions properly.

1. Plot the input and output signals confirming the demodulation of your signal.

2. Plot the gain response of the demodulator versus the baseband signal frequency, while using the carrier frequency assigned to you by your instructor.

IV. Hardware

Create the circuit shown in *figure 3*. Using the function generator, set the carrier signal to the frequency band assigned to you by your instructor. Modulate the signal using the AM modulation function of the generator. The audio signal will then be "carried onto" the carrier frequency through AM modulation.

Keep in mind that the human ear is capable of easily hearing signals between ~200 Hz and ~10 kHz.

1. Connect the input of the modulator to the function generator and plot the input and output signals confirming the demodulation of your signal.

C. Baseband Amplifier

Once the radio signal has been pre-amplified and demodulated, an amplifier circuit is used to provide gain to the resulting audio signal. To do this, a circuit like the one shown in *figure 4* can be used. The topology is based on a non-inverting amplifier and allows manual gain control through a potentiometer.

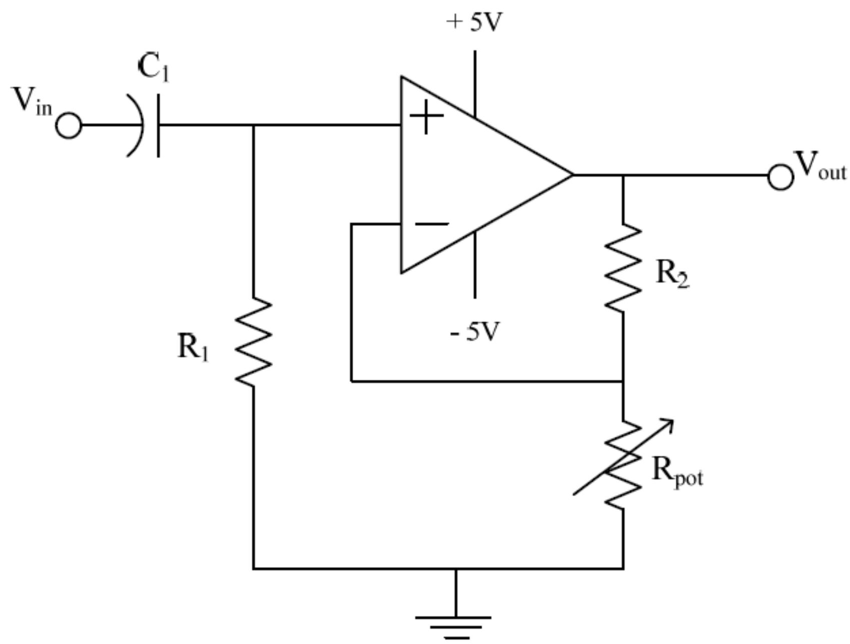

Figure 4 - Baseband amplifier schematic

I. Circuit Parameters

Operational amplifier model: TL084

$V_{cc} = +5V$

$V_{ee} = -5V$

$C_1 = 1\mu F$

$R_1 = 150k\Omega$

$R_2 =$ ________

$R_{pot} = 0 - 10k\Omega$

II. Background and Theory

1. Briefly explain the purpose of the capacitor C_1.

2. Briefly explain the purpose of the resistor R_1.

3. Derive the gain equation of the circuit shown in *figure 4*. Perform the analysis for C_1 neglected, then when considered. How does C_1 affect the gain of the circuit?

4. Choose values for R_2 and R_{pot} that will achieve a gain of 150V/V to the nearest 5% accuracy.

5. Considering the function of this circuit as a baseband voltage amplifier, what are the characteristics that this circuit should have regarding input impedance, output impedance, and bandwidth?

III. SPICE Simulation

1. Determine the 3-dB bandwidth of the circuit using the SPICE simulator. Use the TL084 operational amplifier model provided on Blackboard. Note that for frequency simulation of the op-amp, ensure that each pin is modeled as a 5pF parasitic capacitor from the pin's node to ground. Also, take into account the parasitic resistor and capacitor values of the oscilloscope (1MΩ resistor in parallel with a 20pF capacitor going from the measuring node to ground).

IV. Hardware

Assemble the amplifier circuit shown in *figure 4* and adjust the potentiometer so that the gain is 150V/V. Ensure that the amplitude is sufficiently small so that the amplifier operates within its linear region. You may have to use a voltage divider on the input signal to achieve that.

D. Class A Output Stage

Speakers are made up of a coil, with a magnetic core inside, attached to a diaphragm; therefore, they are low impedance devices, i.e. typically 8-32 **Ω**. When AC current flows into the coil, it causes a magnetic field that forces the coil to move back and forth. By pulling the diaphragm back and forth, sound waves are generated. To achieve a high enough output power to the speaker, large current amplitudes are required. Hence, a power amplifier is needed between the low-current drive output of the baseband amplifier and the speaker. The circuit used to achieve this can be a simple emitter follower biased at high current. It reduces the output impedance, and therefore the leading effect of the speaker.

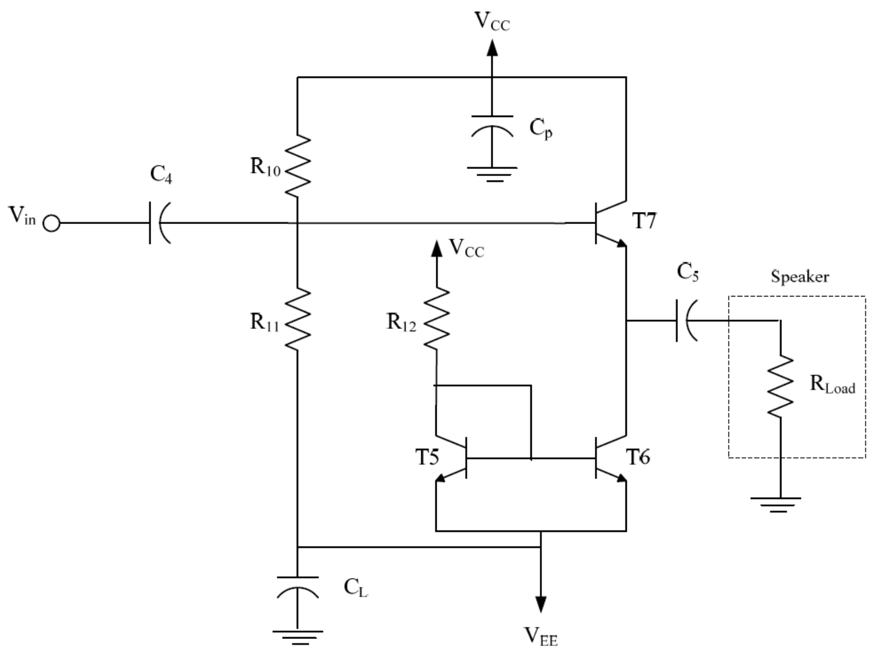

Figure 5 - Class A output stage

I. Circuit Parameters

NPN transistor model: MPS3704

$V_{cc} = +5V$

$V_{ee} = -5V$

$C_4 = C_5 = C_P = C_L = 22\mu F$

$R_{10} =$ ________

$R_{11} =$ ________

$R_{12} = 127\Omega$

$R_{load} = 8\Omega$

II. Background and Theory

1. Design the circuit to achieve a DC biasing voltage of around 3.2V at the base of the transistor T7. The value of the resistance R_{12} was chosen such that the biasing current is sufficient to supply a $1V_{pp}$ amplitude signal to the load resistance.

2. What is the main limitation of this circuit?

III. SPICE Simulation

1. Plot the input and output signal confirming the $1V_{pp}$ across the load resistance.

IV. Hardware

Note 1: Because of high current at which the transistors will be biased, this circuit may have stability issues (free oscillations that are not input related). To ensure the stability of this circuit, you may need to add an inductor in series with the speaker, or you may equally add a small capacitor to ground in parallel with the collector T6.

Note 2: To handle the high power without burning transistors, you will need to use several transistors in parallel. To determine the number of transistors you need, first estimate the maximum power the circuit will be providing to the speaker. Then, using the power ratings provided in the transistor's datasheet, figure out the number of transistors needed to handle this amount of power safely. Make sure to have a safety margin.

Note 3: Ensure that the transistors are not too close to each other in order for air to act as a heat sink and allow for heat dissipation, in order to prevent thermal runway.

1. Build the circuit shown in *figure 5*. Plot the input and output signals.

E. AM Receiver

The AM receiver is built by connecting the different stages together in a straightforward manner as shown in *figure 6*.

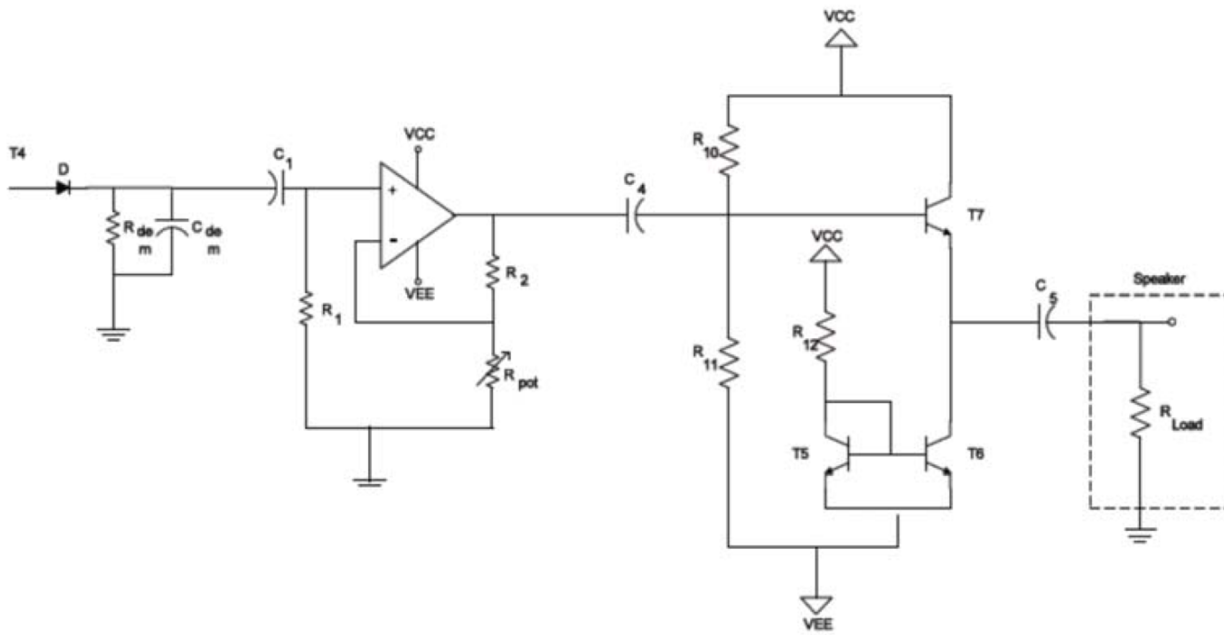

Figure 6 - AM receiver schematic

I. Background and Theory

1. Simulate the whole system. Provide a plot of the input and output signals, so that the modulation and demodulation are apparent.

II. Hardware

1. Connect the speaker as shown in *figure 6*. Input an AM modulated signal corresponding to your carrier frequency from the generator. Listen to the output and confirm that you can hear different musical tones depending on the baseband signal's frequency. Table 1 gives a reference for the different tones you should subject your system to. *Note that you can use the potentiometer for volume control and then you may have to use a resistor in series with the signal generator to reduce the input amplitude to levels which are comparable to antenna received radio signals (few mV).*

Table 1 - Musical tones frequencies

Note	**C**	**D**	**E**	**F**
Frequency (Hz)	1046.502	1174.659	1318.510	1396.913
Note	**G**	**A**	**B**	**C**
Frequency (Hz)	1567.982	1760.000	1975.533	2093.005

2. Disconnect your generator and the series resistor that might have been required with it, and connect a long stripped wire in to act as an antenna. Now fix a stripped wire to the signal generator to act as a transmitter antenna and tune to the same frequencies you did before. You may need to increase the amplitude of the generator to a few volts to achieve adequate transmission/reception. Ensure that the volume is maximized. Listen to the output and confirm that you can hear different musical notes depending on the baseband signal's frequency.

3. Solder your system on a perforated breadboard **(BONUS QUESTION)**.