Experiment #5
Amplitude Modulation and Demodulation

Goal

Study of amplitude modulator and detector circuits and build a tuned RF radio to receive AM broadcast signals.

Amplitude Modulation and Detection:

Amplitude modulated signal can be represented by the following equation:

$$v(t) = V_c(1 + v_m(t))\cos\omega_c t\,.$$

Where $v_m(t)$ is the message signal that is modulating the carrier $V_c \cos\omega_c t$. For simplicity, let us assume that the message signal is a monotone given by the following equation:

$$v_m(t) = V_m \cos\omega_m t$$

The amplitude modulated signal can now be written as:

$$v(t) = V_c(1 + V_m \cos\omega_m t)\cos\omega_c t = V_c \cos\omega_c t + \frac{V_c V_m}{2}\left\{\cos(\omega_c - \omega_m)t + \cos(\omega_c + \omega_m)t\right\}$$

The following figure shows the modulated signal in both time and frequency domains.

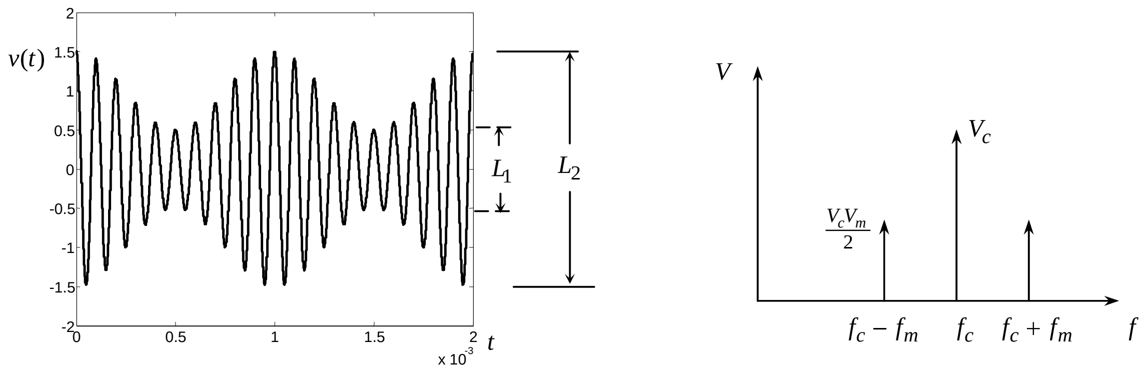

Figure 1: Amplitude modulated signal in time and frequency domains.

The modulation index (m) of an amplitude modulated signal is defined by the following equation

$$m = \frac{V_m}{V_c} = \frac{L_2 - L_1}{L_2 + L_1}\,,$$

which can also be used to calculate the modulation index from the oscilloscope display of the amplitude modulated signal. In this experiment, a Gilbert multiplier cell (MC1496) is used to generate amplitude modulated signal. Figure 2 shows the schematic of MC1496 along with the external components required to realize an amplitude modulator. The potentiometer is used to set the DC level of the modulating signal, which can be used to adjust the modulation index. An envelope detector is used to demodulate the signal.

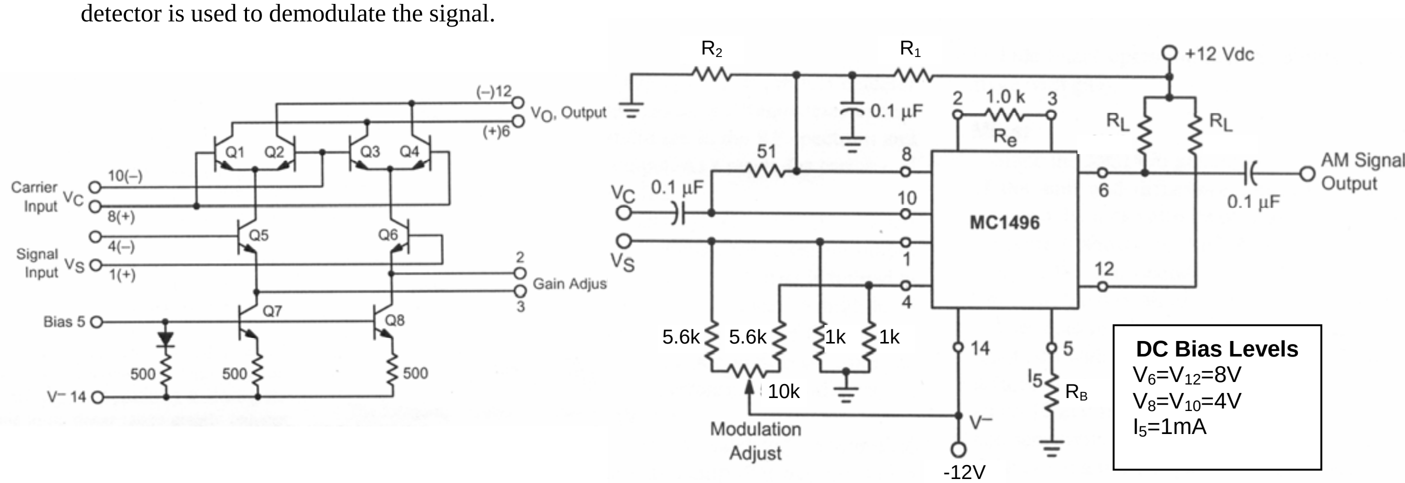

Figure 2: Schematic of MC1496 and circuit diagram of an amplitude modulator

Pre-lab tasks:

1. Study the operation of the Gilbert cell multiplier.

References:
Analysis and design of analog integrated circuits, Gray and Meyer
Data sheet of MC1496 (http://onsemi.com)
Application Note AN531/D MC1496 Balanced Modulator (http://onsemi.com)

2. Calculate the values of R_B, R_1, R_2, and R_L for the bias conditions shown in the figure 2.
3. Design an envelope detector using the diode OA79.

Radio Receiver:

Figure 3 shows the schematic of a simple radio receiver. The antenna is a long piece of wire. The length of the wire is small compared to the wavelength and hence is not critical in the design. The tuner circuit consists of a parallel combination of variable inductor and capacitor. It is possible to increase (decrease) the inductance by moving the ferrite core in to (out of) the coil. The envelope detector consists of a germanium diode (OA79) and a capacitor connected to ground. The input impedance of the gain stage itself forms the discharge path for the capacitor. The gain stages are realized using ua741 opamps operating in the inverting mode. The output of the second stage can be directly connected to the headphone.

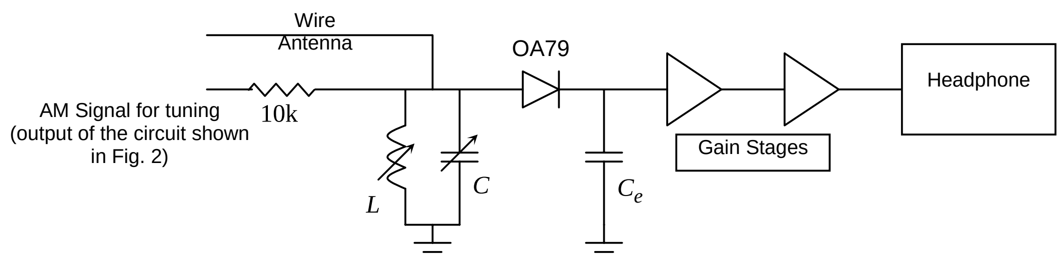

Figure 3: Schematic of a Radio Receiver

Pre-lab work:

1. Study the techniques to measure the resonant frequency and quality factor of tuned circuit. Since the capacitance of the tuner is in the range of 30pF – 300pF, use a coupling element to connect the oscilloscope to the parallel resonant circuit.
2. Design the gain stages to have an input impedance of 10kΩ and a reasonable gain. How do you choose the value of the capacitor used in the envelope detector? You may need to adjust the values of the capacitor and the gain by observing the output on an oscilloscope and listening to the received signal.

Laboratory Work

Please Note: It is very useful to keep the modulator and the receiver chain as far away as possible. Make sure that the coil and the antenna are as far away as possible from the lines carrying the modulated carrier signal. A suggestion, use the top portion of the board to make the modulator, and make the receiver in the bottom half of the board.

Part (a): Amplitude Modulator

1. Assemble the circuit as shown in Fig. 2 and **verify the bias conditions** without either signal sources connected.
2. Apply the carrier signal (fc=1.4MHz) and the modulating signal (fc=1kHz) from the signal generators and display the AM signal on the oscilloscope. *You may have to use a DC blocking capacitor for the modulating signal too*.
3. Adjust the potentiometer for different values of the modulation index and **plot the AM signal for m=0.2, 0.5, 1.0**.
4. Adjust the potentiometer for AM with m=0.5 and connect a diode detector to the modulator output. Display and **plot both modulating signal versus modulated and demodulated outputs**. You can use these plots to identify if the modulator and detector are linear or not.

Part (b): LC Network

1. Set the signal generator to 1.4MHz and connect it to the LC parallel network through a coupling element.
2. Connect the CRO to the LC network using a coupling element.
3. Set a value of inductance by inserting the ferrite rod into the coil and adjust the capacitance until resonance is observed. Measure the quality factor. **Measure the Q of the LC network with the inductance at maximum and minimum values. Calculate the 3dB bandwidth for these two cases**.
4. Repeat step 3 with the antenna connected to the LC network.

Part (c): Radio Receiver

1. Assemble the circuit as shown in Fig. 3. Inject the amplitude modulated signal obtained in part (a) at the LC network through a large resistance. Adjust the inductance and the capacitance until you hear the monotone in the headphone.
2. By now you should be receiving the signals from the AIR Kanpur station.
3. Detune the carrier, and adjust the capacitance so that you can listen in to the broadcast signals. You may need to adjust the values of the capacitor used in the envelope detector and the gain of the amplifier to get the best possible reception.
4. Change the inductance of LC network to the minimum and maximum values and tune in to the broadcast signal. **Do you observe any difference? Comment**.