UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Department of Electrical and Computer Engineering

EXPERIMENT 8 – AMPLITUDE MODULATION AND DEMODULATION

OBJECTIVES

The focus of this lab is to familiarize the student with the modulation and demodulation of an AM signal; prior knowledge of basic bipolar transistor theory is expected.

INTRODUCTION

An Amplitude Modulated signal is composed of both low frequency and high frequency components. The amplitude of the high frequency (carrier) of the signal is controlled by the low frequency (modulating) signal. The envelope of the signal is created by the low frequency signal. If the modulating signal is sinusoidal, then the envelope of the modulated Radio Frequency (RF) signal will also be sinusoidal. This would be the case in a common AM radio. The low frequency signal would be an audio signal and the high frequency would be the transmitting frequency of the AM radio station. Shown in Figure 8-1 is an example of an AM signal in the time domain.

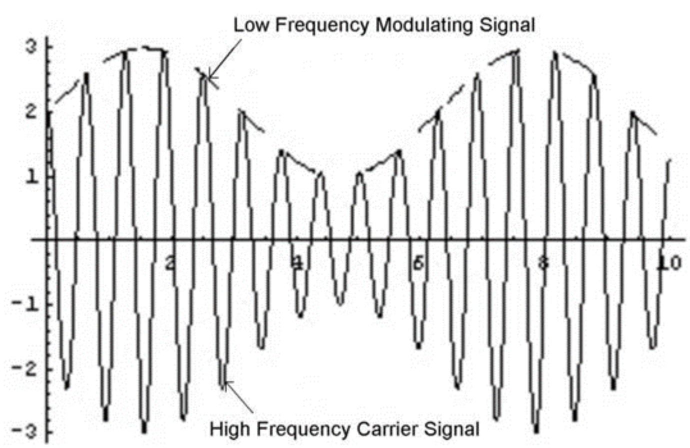

Figure 8-1 AM Modulated Signal

The mathematical representation for this waveform is as follows:

$$f_{AM}(t) = A\left[1 + \mu\cos(\omega_m t)\right]\cos(\omega_c t)$$

where,

A= DC value of the waveform
μ= modulation index
ω_m= modulation frequency (rad/s)
ω_c= carrier frequency (rad/s)

Figure 8-2 shows the physical interpretation of the mathematical equation given above. In this diagram, the quantities A and m_p are indicated.

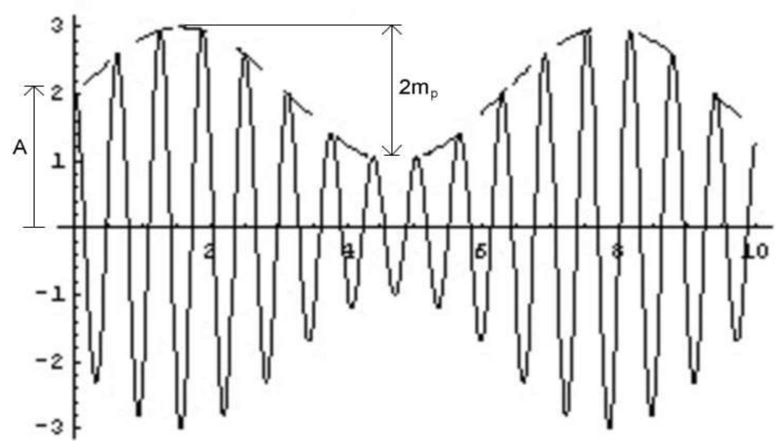

Figure 8-2 AM Modulated Signal Showing Values

The circuit for generating an AM modulated waveform must produce the product of the carrier and the modulating signal. This can be achieve in many ways, but often is done by biasing a transistor for nonlinear operation (creating the product term) and filtering the output with a tank circuit to remove the higher harmonics introduced. This type of modulator is shown in Figure 8-5. For class B operation, the transistor is biased such that when both the carrier and modulating signals are zero, the DC voltage at the transistor base will be 0.7 V (i.e., the knee voltage of the base emitter junction). If a carrier is added via the coupling capacitor C_1 while the modulating signal remains zero the transistor will be turned off for the negative half cycle of the carrier, producing only positive current pulses in the collector. The tank circuit will have large impedance at the carrier frequency, also the fundamental frequency of the current pulses, and low impedance at the higher harmonics of the current pulses. Thus, the voltage produced at the output will be a sinusoid of the carrier frequency. When the modulating signal is added via the coupling capacitor C_5 the emitter voltage of the transistor will follow the modulating signal, causing the cutoff voltage of the transistor and also the collector current pulse amplitude to vary with the modulating signal. The collector current waveform has the shape of the positive half of the waveform shown in Figure 8-2; the tank circuit attenuates the higher harmonics to produce an output voltage with the waveform of Figure 8-2.

The modulation index, μ, can be found with the following equation:

$$\mu = \frac{m_p}{A}$$

After receiving an AM signal, it can be demodulated to recover the low frequency signal. One of the simplest types of AM demodulating circuits is the envelope detector. In order to accurately recover the low frequency signal the envelope detector must satisfy an important condition; the time constant of the envelope detector network must be much longer than the period of the high frequency signal but much shorter than the period of the low frequency signal. Once the signal is demodulated, the high frequency signal is eliminated and what remains is the low frequency component. Figure 8-3 shows the general idea of the envelope detection method to regain the low frequency signal.

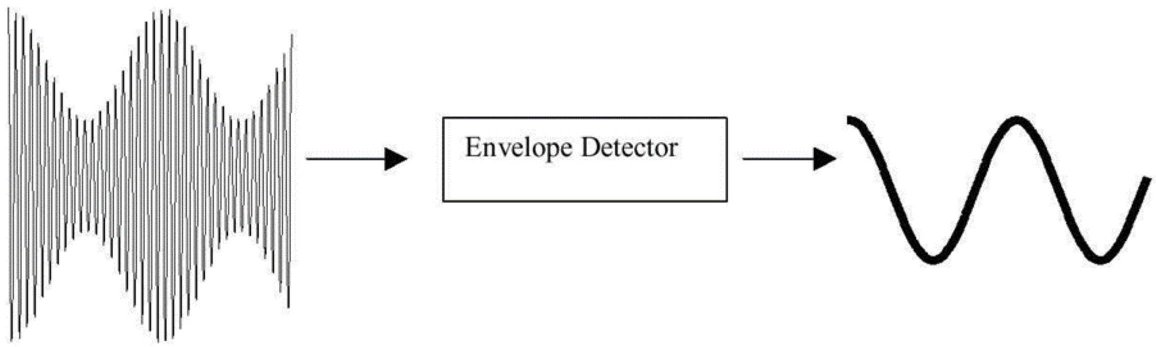

Figure 8-3 Demodulation of an AM Signal

A typical circuit used for an envelope detector is shown in Figure 8-4. It is composed of a resistor, capacitor, and diode. The time constant set by the values of the resistor and capacitor needs to be much less than the period of the audio signal but much greater than the period of the RF (high frequency) signal.

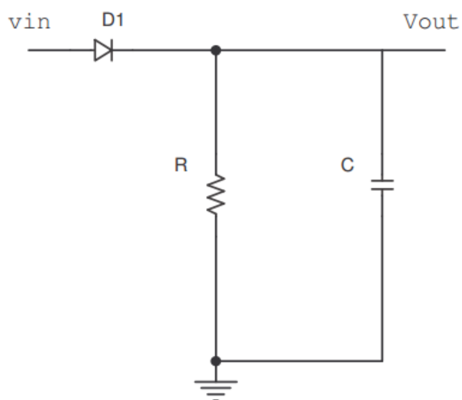

Figure 8-4 Envelop Detector

The relationship between the RC time constant, modulation frequency, and carrier frequency is shown in the equation below:

$$\frac{1}{2\pi\omega_c} \ll RC \ll \frac{1}{2\pi\omega_m}$$

PRELAB

1. For the circuit shown in Figure 8-5,
   a. Determine the resonant frequency of the collector tank circuit. How is the frequency related to the carrier frequency?
   b. Determine the standard value of R_2 that will cause the quiescent base voltage to be the closest to 0.7 V? Note that this will bias the transistor to operate as class B (i.e., 180 deg. of conduction).
   c. Assume the carrier and modulating frequencies to be 500 kHz and 500 Hz, respectively. Determine the capacitive reactance of capacitors C_3 and C_5 at both the carrier and modulating frequencies. Use these calculated values to explain the purpose of each capacitor.
   d. Resistor R_3 and capacitor C_4 form a low pass filter to isolate the carrier signal from the modulation input. What is the break frequency of this filter?

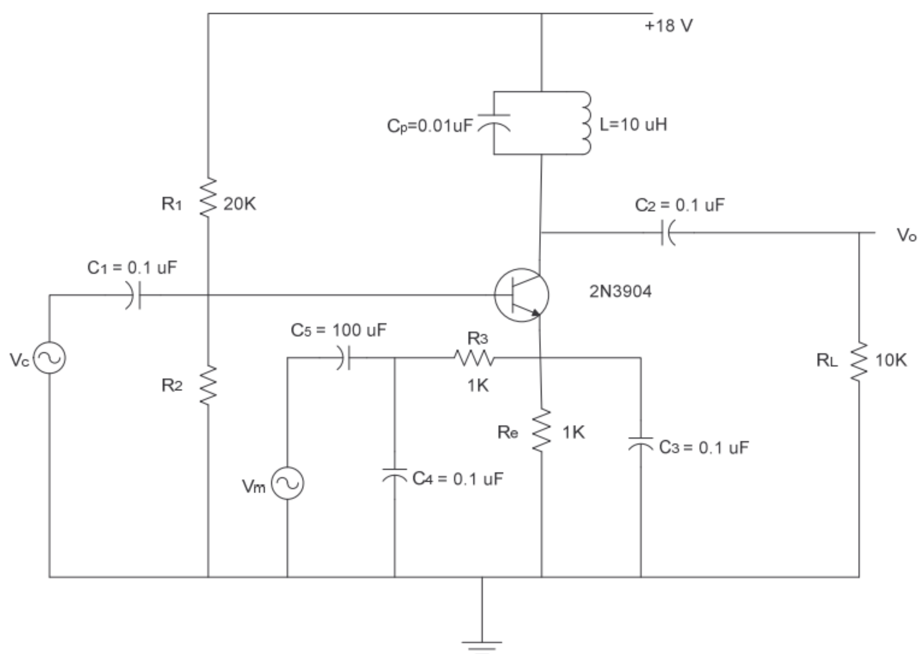

Figure 8-5 Common Emitter AM Modulator

PROCEDURE

1. Prepare the positive power supply to ensure a DC voltage of +18V.
2. Prepare one channel of the signal generator for a V_c of 500 kHz, and adjust the amplitude to something ≤1V.
3. Prepare the second channel of the signal generator for a V_m of 500 Hz, and adjust the amplitude to something ≤100mV.
4. Connect the circuit shown in Figure 8-5.
5. With the modulating voltage adjusted to zero amplitude, increase the carrier amplitude until V_o has a value of 2 $V_{p\text{-}p}$. This is the unmodulated signal.
6. Increase the modulated signal until an AM waveform appears. It may be necessary to adjust the level and frequency of both V_c and V_m to achieve a suitable waveform and index of modulation. To obtain a stable display will most likely require that the scope be triggered on the modulating signal, and the volts/div and sec/div be adjusted manually.
7. Observe V_o and record the values of A and B as indicated in Figure 8-6. Be sure to note that the quantity A as shown in Figure 8-6 is not the quantity A as shown in Figure 8-2. Save the waveform.

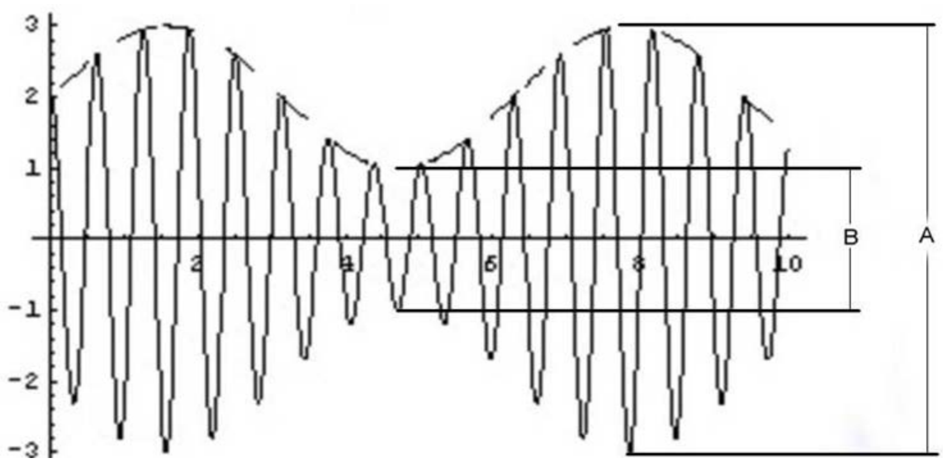

Figure 8-6 Measurement of Modulation Index using the Oscilloscope

8. Calculate the modulation index μ as follows $\mu = \dfrac{A-B}{A+B}$
9. Increase and decrease the signal level of the modulated signal (V_m) to observe changes in the modulation index. As before, this may require a manual adjustment of the volts/div and sec/div to obtain a suitable waveform.
10. Adjust the carrier and modulated signals for a modulation index of 0.3. Save the waveform.
11. Now we will observe the demodulation of an AM signal with the circuit shown in Figure 8-7.
    a. Provide the demodulator input with the AM modulator constructed in this lab.
    b. With the oscilloscope observe the modulated waveform (input to the demodulator) and the demodulated waveform (output of the demodulator). You should observe the 500 kHz modulated waveform at the input and the 500 Hz modulating signal at the output.

c. Save the demodulator output. The demodulator output should be a replica of the modulation signal; however, it is likely that the trace will be blured and wider than desired. Explain. Does this represent a weakness of the demodulator above?
d. While observing the demodulated waveform, vary the frequency of the modulating signal in both directions until significant distortion is observed. Record the upper and lower frequencies. The difference is an estimate of the bandwidth. What is the percentage bandwidth (i.e., $(100*\Delta f_m)/f_c$)?

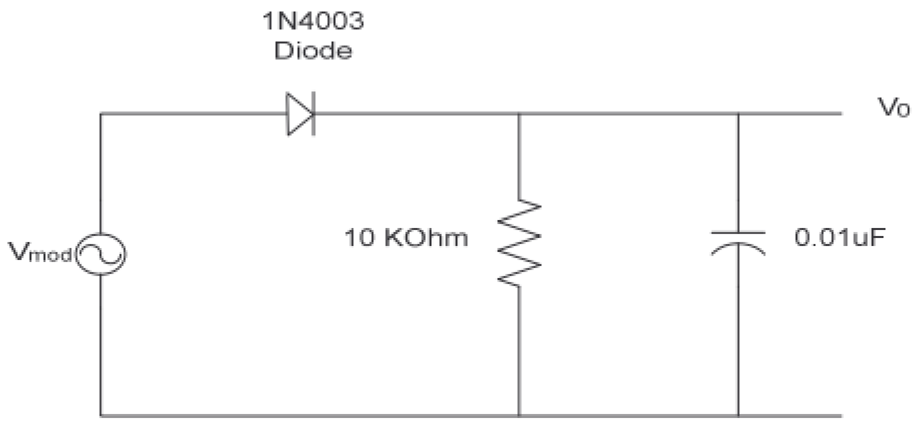

Figure 8-7 Demodulation Circuit Using Envelope Detection Method

Figure 8-8 Demodulation of AM Signal

POST-LAB

Post-Lab questions must be answered in each experiment's laboratory report.

1. What effect did the variation of the modulating signal amplitude have on the modulation index in the circuit of Figure 8-5?
2. For the circuit in Figure 8-7, how did the time constant of the RC network compare with the period of the audio and carrier waveforms, 500 Hz and 500 kHz, respectively? Does the relationship meet the criteria set forth in the Prelab section?

Be sure to include all items from the post-lab exercise above in your written lab report.