

## Lab 5

# Amplitude Modulation

### 5.1 Pre-Lab

1. Let an AM signal be expressed as

$$X_{AM}(t) = (A + m(t)) \cos \omega_c t \quad (5.1)$$

The *modulation index* is defined as

$$\mu = \frac{\max |m(t)|}{A} \quad (5.2)$$

With MATLAB, create two AM signals, one with modulation index 0.5 and the second with  $\mu = 1.0$ . Use sinusoids for both the message and carrier signals. What happens if the modulation index is greater than 100%? Is it still possible to use envelope detection to demodulate the signal?

2. What is one advantage of using DSB modulation? What is one disadvantage?
3. What is one advantage of using synchronous detection? What is one disadvantage?
4. The envelope detector of Figure 5.2 requires that the designer correctly choose the values for  $R$  and  $C$ . Use Equation (5.3) to calculate the range of the product  $RC$  for AM signals with the different modulation indices  $\mu = 0.99$ ,  $0.75$ , and  $0.5$ . Use  $B = 500$  Hz and  $\omega_c = 2\pi f_c = 2\pi \cdot 100$  kHz.

### 5.2 Overview

In amplitude modulation (AM), a message signal  $m(t)$  is multiplied by a signal with a desirable carrier frequency to generate the transmitted signal. In this

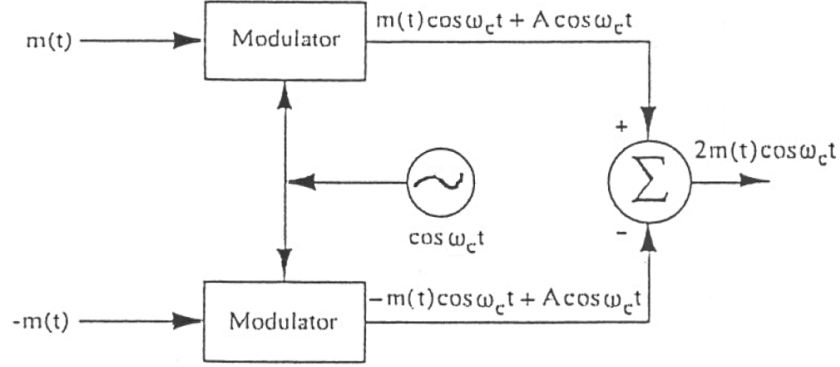


Figure 5.1: Balanced modulator for DSB transmitted signal

lab we will work with with a balanced modulator. It creates a double side-band suppressed carrier signal by generating a positive and negative version of the message signal,  $m(t)$ , multiplied by the carrier signal—as in Figure 5.1. The signal in the top half of the balanced modulator can be expressed as in Equation (5.1).

The envelope of signal  $X_{AM}(t)$  is  $A + m(t)$ . As you can see in Figure 5.1, if the modulator circuit is sufficiently balanced, the terms with  $A \cos \omega_c t$  will cancel and the resulting output signal is  $2m(t) \cos \omega_c t$ .

We will consider two forms of demodulation: *envelope detection* and *synchronous detection*.

### 5.2.1 Envelope Detection

Consider the signal  $X_{AM}(t)$  as in Eq. (5.1) and recall that  $A + m(t)$  is the envelope of this signal. A simple RC circuit with a diode operates as an envelope detector as in Figure 5.2.

To understand how this circuit operates, assume the capacitor voltage is zero initially. As the input voltage is greater than the diode's threshold voltage, the diode is forward biased and the capacitor charges to the peak value of the

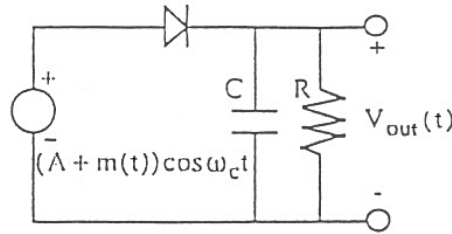


Figure 5.2: Envelope detector for AM signal

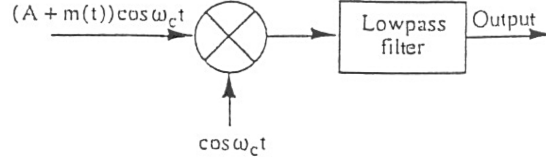


Figure 5.3: Synchronous detector for AM or DSB signal

input signal. As the input signal falls below this peak value, the diode is cut off because the the capacitor voltage is greater than the input voltage. With the diode open, the capacitor will begin to slowly discharge through the resistor.

During the next positive cycle, when the input signal reaches a higher voltage than the capacitor voltage, the diode conducts again and the capacitor again charges to the peak value of the input signal. The circuit designer must choose  $RC$  so that the capacitor discharges at the desired rate. As such,  $RC$  must lie within the bounds in Equation (5.3):

$$\frac{1}{\omega_c} < RC < \frac{1}{2\pi B} \frac{\sqrt{1 - \mu^2}}{\mu} \quad (5.3)$$

where  $B$  is the highest frequency in  $m(t)$  (in Hz),  $\mu$  is the modulation index, and  $\omega_c$  is the angular frequency of the carrier (in rad/sec).

### 5.2.2 Synchronous Detection

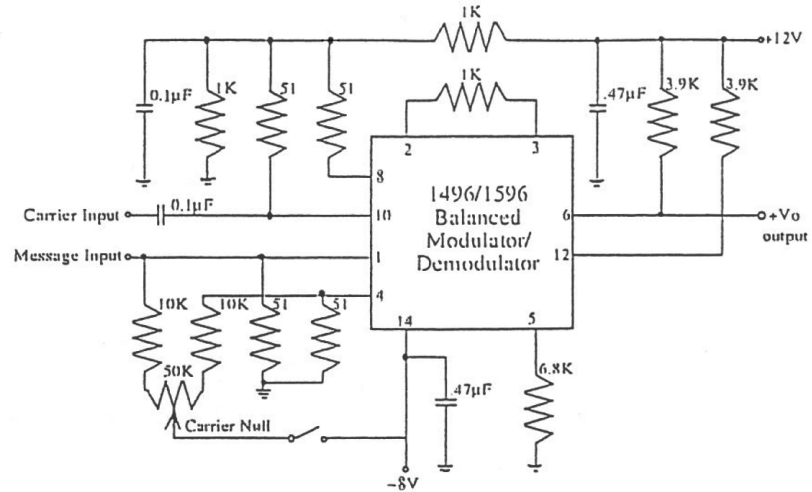
This type of detection multiplies the received waveform by another waveform of identical carrier frequency. The high frequency terms resulting from this operation are filtered off by a lowpass filter. See Figure 5.3.

## 5.3 Procedure

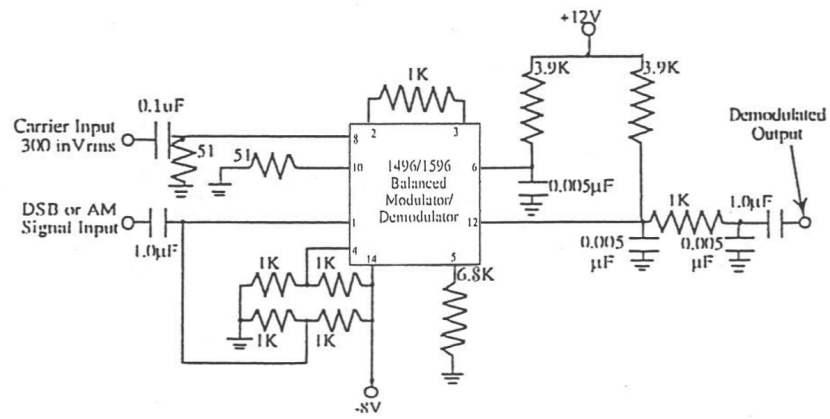
For the implementation of this experiment, we will use the LM 1496 Integrated Circuit as a balanced modulator. This integrated circuit is used for balanced modulation in the circuit shown in Figure 5.4a. For the synchronous detector, again we will use the LM 1496 in the circuit in Figure 5.4b.

### 5.3.1 Modulator

1. Build the modulator shown in Figure 5.4a.
2. Use two function generators to provide a message input signal and a carrier input signal to the balanced modulator. Use sine waves for both signals. Connect the oscilloscope to the message signal  $V_{in}(t)$  and to the modulator output,  $V_{out}(t)$ . Set  $f_c = 100$  kHz and  $f_m = 500$  Hz.



(a) Balanced modulator circuit



(b) Synchronous detector circuit

Figure 5.4: Implementation and circuit diagrams of LM 1496 Integrated Circuit

3. Adjust the amplitude of the message signal, the carrier signal, and the varistor in Figure 5.4a to yield a DSB modulated waveform. Sketch  $V_{in}(t)$  and  $V_{out}(t)$  in your lab books. Change  $V_{in}(t)$  to a triangular waveform and again sketch the input and output voltages.
4. Adjust the offset of the message oscillator to produce an AM signal. Again sketch  $V_{in}(t)$  and  $V_{out}(t)$ , first for sinusoidal and then for triangular  $V_{in}(t)$ .

### 5.3.2 Synchronous Detection

1. Build the synchronous detector shown in Figure 5.4b.
2. Connect the modulator with the demodulator and observe the demodulator output. Sketch the waveforms recovered for all the cases under the Modulator section (5.3.1) i.e., AM and DSB with both sine and triangular waves as messages. Has the signal been recovered?

### 5.3.3 Envelope Detection

1. Build the envelope detector shown in Figure 5.2. Use a varistor in this circuit.
2. Use a function generator to produce an AM signal with modulation index of 0.75. Set  $f_c = 100$  kHz and  $f_m = 500$  Hz. Connect the output of the envelope detector to the oscilloscope.
3. Use a small value of  $C$  initially. Gradually increase the value of  $C$  and note the difference on the output waveform as  $C$  increases. For  $C = 470$  pF, 5 nF, and 22 nF, find  $R$  such that the demodulated waveform is optimal. Sketch the optimum demodulated waveform. Compare the demodulator output with  $V_{in}(t)$ .
4. Repeat step 3 for a triangular modulating signal.