Laboratory 3 : Amplitude Modulation and Demodulation

1 Objectives

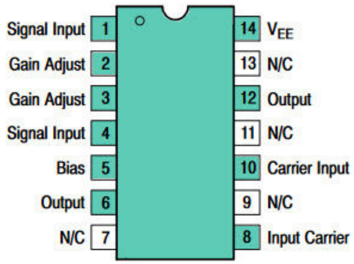
1. Operation of a mixer circuit
2. Implementation and understand of amplitude demodulation
3. Practical measurement of the modulation index
4. Implementation and understand of synchronous and asynchronous amplitude demodulation.

2 Fundamentals

2.1 MC1496 Balanced Modulator

The MC1496 is an integrated circuit designed as a balanced modulator-demodulator. It is widely used in communication systems to perform amplitude modulation (AM), double sideband suppressed carrier (DSBSC) modulation, and single sideband (SSB) signal processing.

(a) Photo of the MC1496 IC



(b) MC1496 Pins functions

Figure 1: MC1496 IC

The MC1496 operates by mixing two input signals to produce an output signal with the sum and difference frequencies, making it ideal for frequency conversion, signal mixing, and modulation applications. The MC1496 is commonly used in RF communication devices, transmitters, and receivers.

Overall gain of MC1496 can be controlled by externally connecting a resistor between pins 2 and 3. For AM modulation, the modulating signal should be applied to pins 1 and 4, and the carrier to pins 8 and 10. The output is on the pin 12.

2.2 MC1496 Amplitude Modulator

Figure 2 shows an AM modulator circuit whose carrier and audio signals are single-ended inputs, carrier to pin 10 and modulating signal to pin 1. The gain of entire circuit is determined by the R_8 value. Adjusting the amount of VR1 or the audio amplitude can change the index modulation.

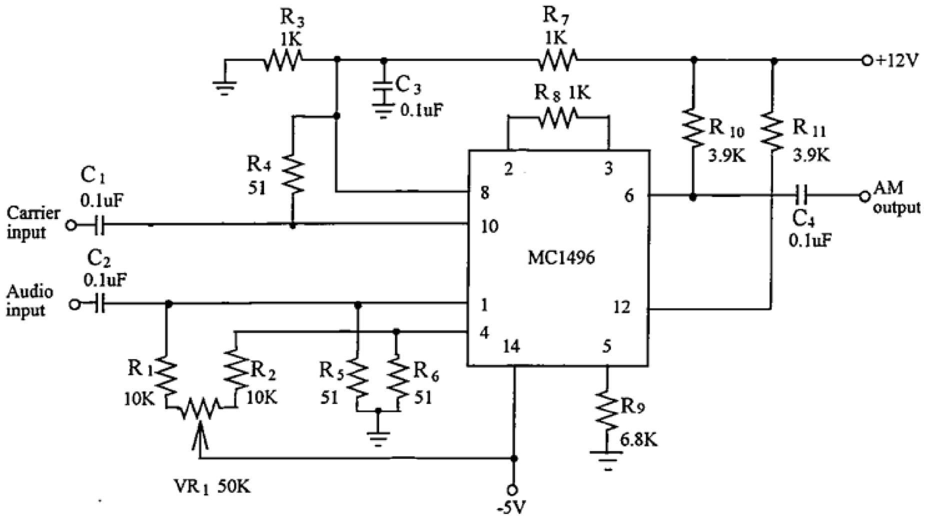


Figure 2: MC1496 Amplitude Modulator

The operating principle of this modulator is illustrated by the following figure. The MC1694 receives the carrier signal at pin 10, and the sum of the modulating signal with a DC signal A_{DC} at the second input, represented by the voltage difference between pins 1 and 4.

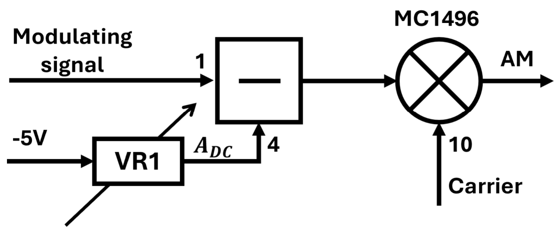


Figure 3: MC1496 amplitude modulator principle diagram.

The expression of the output signal is given by : $s_{AM}(t) = A_c(A_{DC} + s_m(t)) \cos(\omega_c t)$

The modulation index can be adjusted by varying A_{DC} using the potentiometer VR1. In this circuit, it is not possible to measure A_{DC} directly, so the modulation index is typically calculated from the oscilloscope by:

$$m = \frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min}} \tag{1}$$

Where : $V_{\max} = A_c + A_m \quad and \quad V_{\min} = A_c - A_m$

Questions :

1. Demonstrate the expression (1).
2. Determine the ratio of Vmax to Vmin if m=50%.

2.3 MC1496 Synchronous Amplitude Demodulator

An AM signal can be demodulated using a balanced modulator (mixer), commonly referred to as a synchronous demodulator. Figure 4 shows an MC1496 synchronous demodulator. The potentiometer VR1 controls the input level of the carrier signal, which will be multiplied by the AM signal. The output low-pass filter, consisting of $C7$, $C9$, and $R9$, is used to remove the $2f_c$ components. Finally, the DC level can be blocked by the capacitor $C10$.

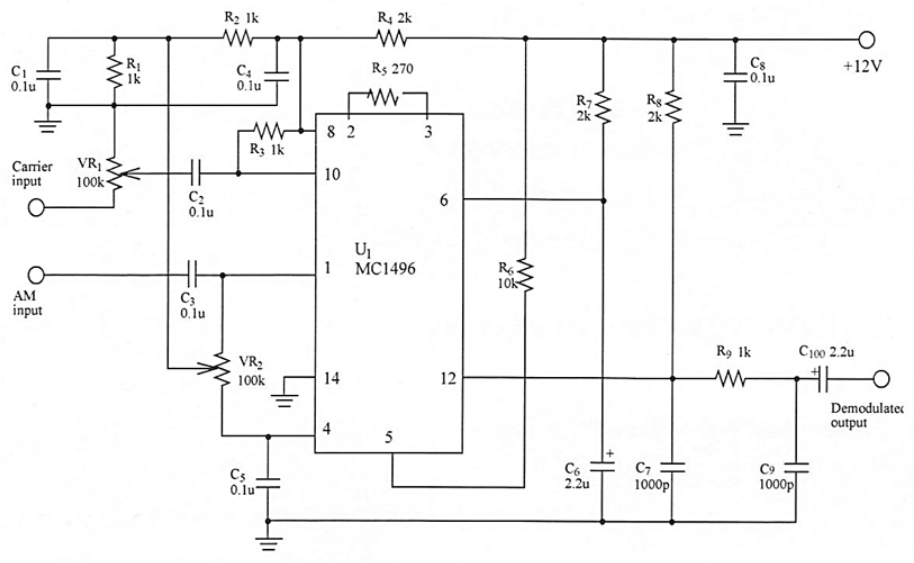


Figure 4: MC1496 Synchronous Amplitude Demodulator

2.4 Asynchronous Detector Circuit

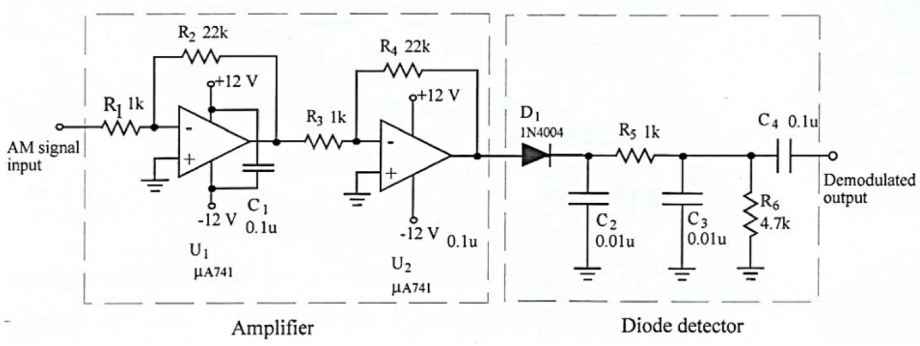


Figure 5: Asynchronous Detector Circuit

Figure 5 shows a practical diode detector circuit. The components R_1, R_2, R_3, R_4, U_1, and U_2 constitute two inverting amplifiers connected in cascade to provide the proper gain for the AM signal. The amplified AM signal is rectified by the diode D_1 and then fed into the input of the low-pass filter constructed by C_2, C_3, and R_5. The output signal of the low-pass filter is the positive-half envelope with a DC level. The capacitor C_4 is used to pass the AC components while blocking the DC component.

3 Experiments

Required equipment

1. KL-92001 Module
2. KL-93002 Module
3. Oscilloscope

Experiment 1 : Amplitude Modulator

1. Locate the AM modulator circuit on Module KL-93002. Insert jumpers in J1 and J3 to set $R8 = 1\,\text{k}\Omega$ and $R9 = 6.8\,\text{k}\Omega$.
2. Connect a 250 mVp-p, 1 kHz sine wave to the audio input (I/P2), and a 250 mVp-p, 10 kHz sine wave to the carrier input (I/P1).
3. Observe the output waveform and adjust the VR1 for a modulation index of 50%. Plot the signal with amplitudes values.

4. Using the spectrum analyzer, observe and record the output signal spectrum with amplitudes and frequncies values.
5. Using this spectrum, calculate the modulation index.
6. Connect a 50 mVp-p, 10 kHz sine wave to the carrier input (I/P1). Observe and record the output signal and its spectrum.

Experiment 2 : Diode Detector

1. Set the input signals of the AM modulator to a carrier of 250 mVp-p, 200 kHz sine wave, and a modulating signal of 150 mVp-p, 1 kHz sine wave.
2. Adjust the VR1 of the AM modulator to obtain the maximum amplitude of the AM signal output.
3. Connect the AM signal output to the input (I/P) of the diode detector.
4. Set the vertical input of the oscilloscope to DC coupling, then observe and record the output waveform.
5. Adjust the carrier frequency to a 10 kHz and adjust the VR1 of AM modulator to get maximum amplitude of AM signal output.
6. Observe and record the output waveform.
7. Set the audio frequency to 10 kHz, then record the output waveform.

Experiment 3 : Product Detector

1. Set the input signals of the AM modulator for the carrier of 250 mVp-p, 100 kHz sine wave, and the audio signal of 250 mVp-p, 1kHz sine wave.
2. Adjust the VR1 of the AM modulator to get the percent of modulation of 50%.
3. Connect the output of the AM modulator to the input of the AM signal (I/P2) of the product detector located on the bottom of Module KL-93002, and connect the same carrier to the carrier input (I/P1).
4. Switch the vertical input of the oscilloscope to DC coupling and observe the output waveform of the product detector then record the result.

Discussion

1. Why is it necessary to amplify the signal before the diode detector?
2. Comment and interpret the results.
3. What conclusions can be drawn ?