Experiment 3

Pedro Cabrera

Course Title & Number:

RF Communications (EET-2325C)

Submitted to:

Dr. Radu Bunea

Department of Electrical & Computer Engineering Technology (ECET – B.S.)
School of Engineering, Technology, and Advanced Manufacturing (ETAM)

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Objective:

The objective of this experiment is to construct and analyze a diode detector circuit for demodulating an AM signal. By building a modulator circuit and varying the filter capacitance values, we aim to observe the effects on the output signal. This process will enhance our understanding of AM signal demodulation, the function of diode detectors, and the impact of different filter capacitance values on signal clarity and fidelity. Additionally, we intend to demonstrate how different capacitor values influence the degree of carrier signal removal and the quality of the recovered modulating signal. This experiment will provide practical insights into signal processing techniques and their applications in communication systems.

Materials:

In addition to the equipment and components used in Project 3-1, you will need the following:

- 1 x 741 IC op amp
- 1 x silicon signal diode (1N914, 1N4148, 1N4149, etc.)
- 1 x 470-pF capacitor
- 1 x 0.005-μF capacitor
- 2 x 0.1-μF capacitors
- 1 x 150-Ω resistor
- 1 x 1-kΩ resistor
- 1 x 10-kΩ resistor
- 2 x 100-kΩ resistors
- 1 x 10-kΩ potentiometer

Background:

In this experiment, we are focusing on the demodulation of Amplitude Modulated (AM) signals using a diode detector circuit. Demodulation is the process of recovering the original information signal from an AM waveform. A variety of circuits can be used to demodulate an AM signal, but the simplest and most widely used method is the diode detector circuit.

Theoretical Information

1. **AM Demodulation**: The process of demodulating an AM signal involves extracting the original modulating signal from the carrier wave. The diode detector circuit is commonly used for this purpose because of its simplicity and effectiveness.

2. **Diode Detector Circuit**:

   - **Rectifier Diode (D_1)**: The rectifier diode removes one half of the AM signal. This conversion results in a pulsating DC signal, which is a crucial step in the demodulation process.

   - **Filter Capacitor (C_2)**: Placed across the load resistor (R_2), the filter capacitor acts as a low-pass filter. It removes the high-frequency components of the carrier signal, leaving only the original modulating signal.

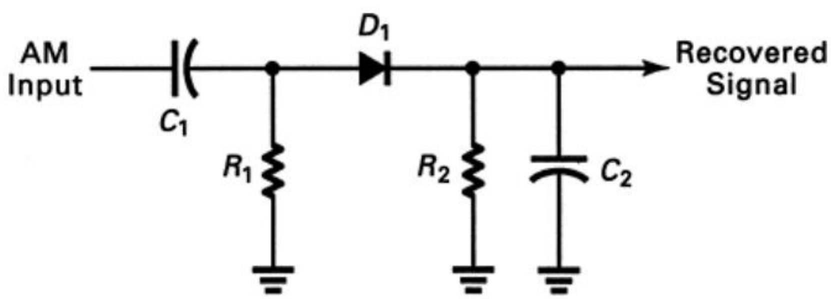

Figure 1 - Diode AM detector circuit.

3. **Role of the Filter Capacitor**: The value of the filter capacitor (C_2) is critical in determining the degree to which the carrier is filtered out. If the capacitor is too small, the carrier will not be adequately removed, resulting in a distorted recovered signal. If it is too large, it may cause excessive smoothing, leading to signal distortion and a loss of detail in the recovered signal. Thus, selecting a compromise value for C_2 is essential for optimal signal recovery.

Procedure:

1. **Setup Modulator Circuit**:

   - The modulator circuit you built in Project 3-1 will be used as the AM signal source in this experiment. Rewire the circuit to conform to Fig. 4-10. The modulating signal will come from an external function generator; the 741 op amp amplifies the AM signal to a level suitable for detection; and the 10-kΩ pot is used to adjust the carrier level.

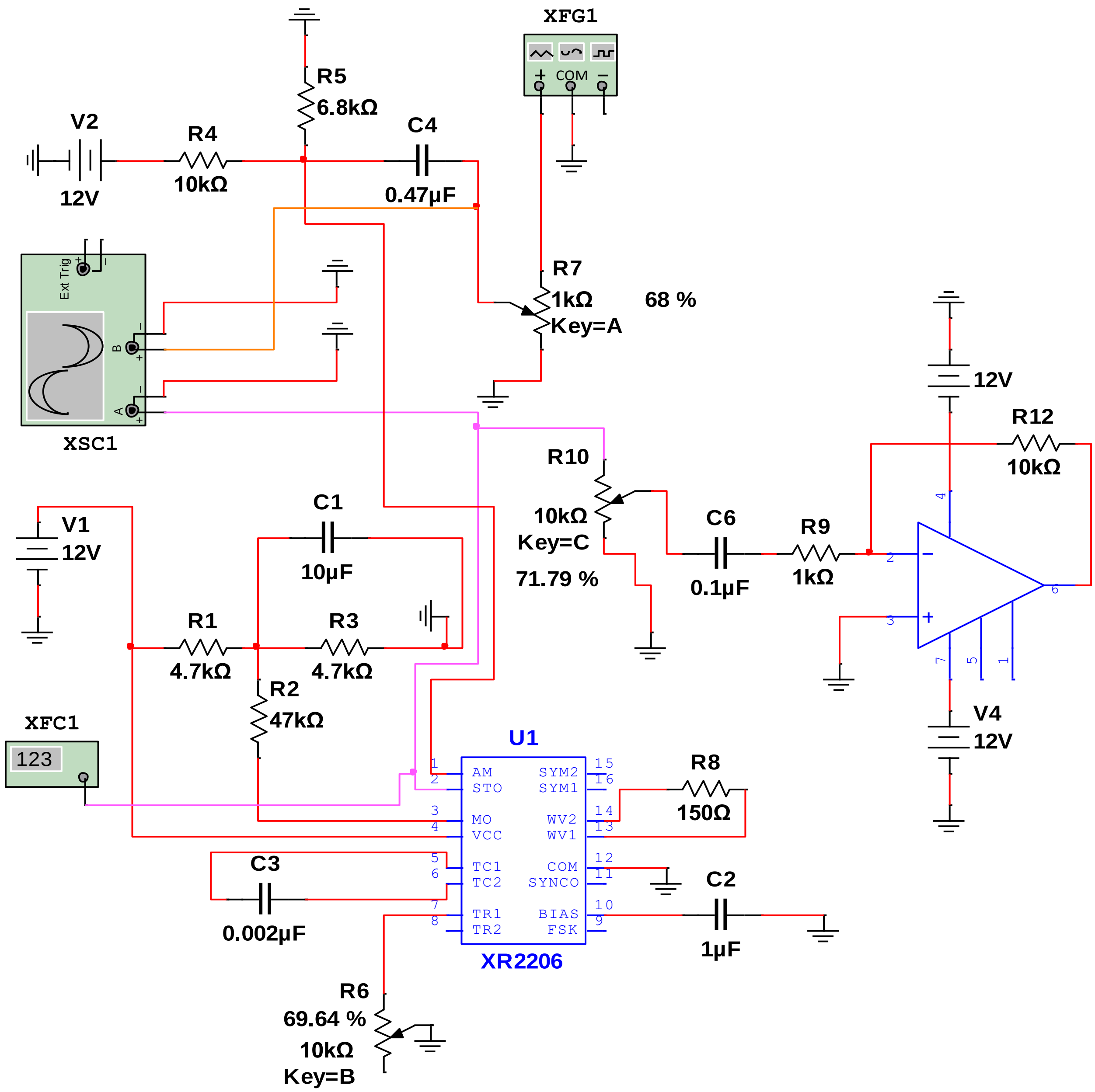

Figure 2 - Multisim Amplitude modulation of the 2206 function generator IC.

2. **Construct Diode Detector Circuit**:
    - Construct the diode detector circuit shown in Fig. 4-11. Note that a filter capacitor is not connected at this time.

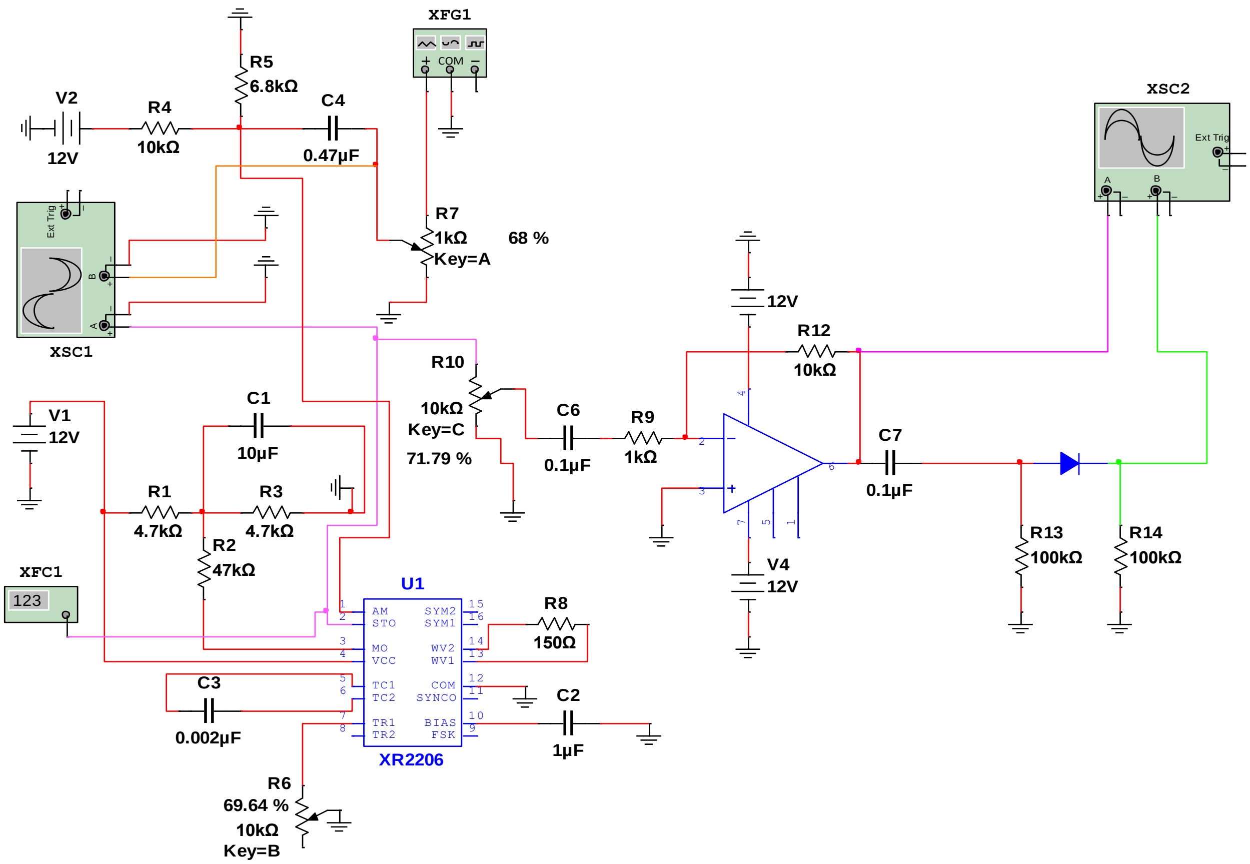

Figure 3 - Multisim Diode Detector Circuit.

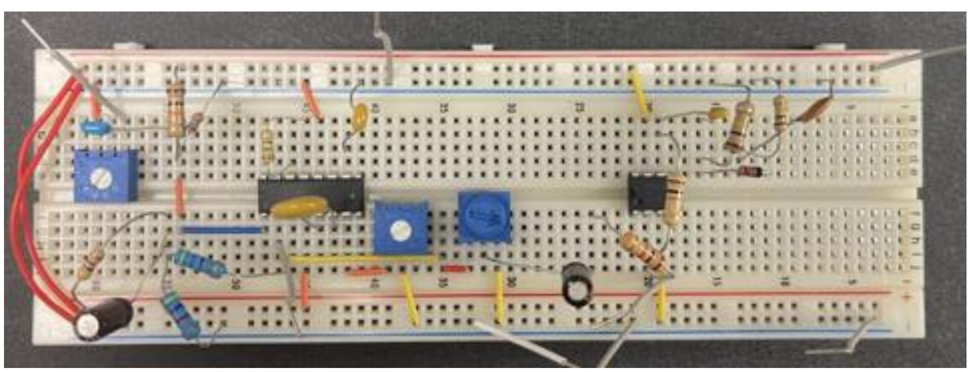

Figure 4 - Bench Diode Detector Circuit.

3. **Power Application and Signal Adjustment**:

   - Apply power to the circuit. Reduce the modulating signal amplitude to zero. While observing the carrier output of the 741 op amp, adjust the 100-kΩ pot on the 2206 for an output frequency of 30 kHz. Then adjust the 10-kΩ pot for an amplitude of 1.5 V_(p, p). Set the modulating signal frequency to 200 Hz, and then increase the modulating signal amplitude while observing the op amp output until 100 percent AM is obtained.

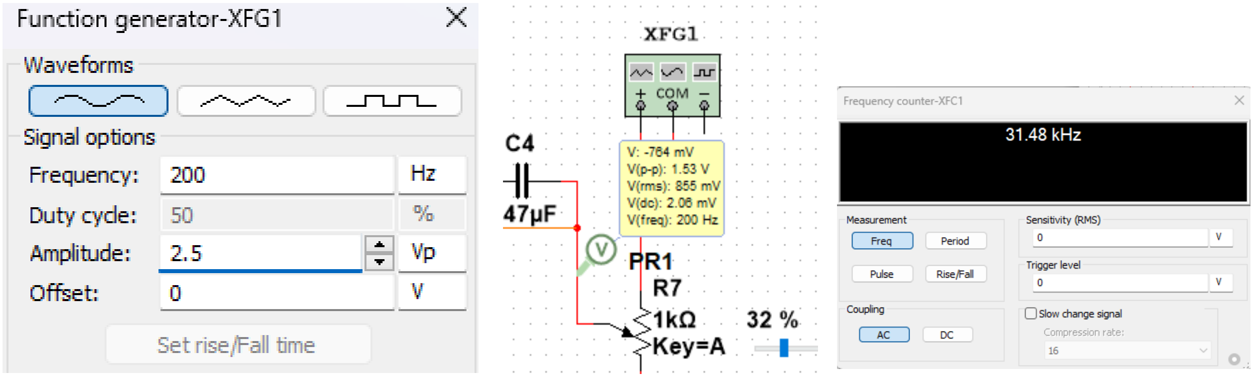

Figure 5 - Multisim Setup

Figure 6 - Bench Set Up.

4. **Observe Diode Detector Output**:

    - Observe the diode detector output across the 100-kΩ load resistor. Reverse the diode polarity and note the output waveform. Again reverse the diode connections.

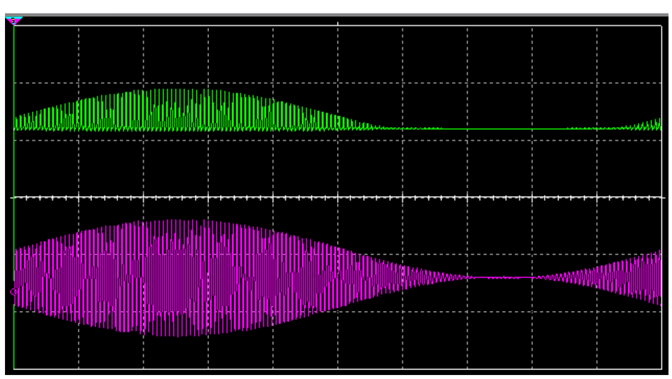

Figure 7 – Multisim Diode detector output at the 100k Ω Res. At 100% Modulation.

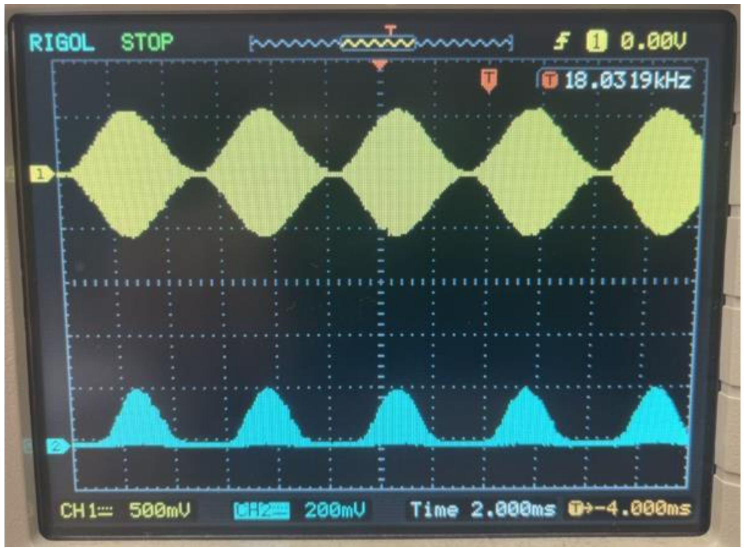

Figure 8 – Bench Diode detector output at the 100k Ω Res. At 100% Modulation.

5. **Connect Filter Capacitor**:

   - Connect a 0.005-µF capacitor across the diode detector load as shown in Fig. 4-12. Observe the diode detector output and sketch the output waveform. If the signal is distorted, reduce the modulating signal amplitude until the distortion is minimized.

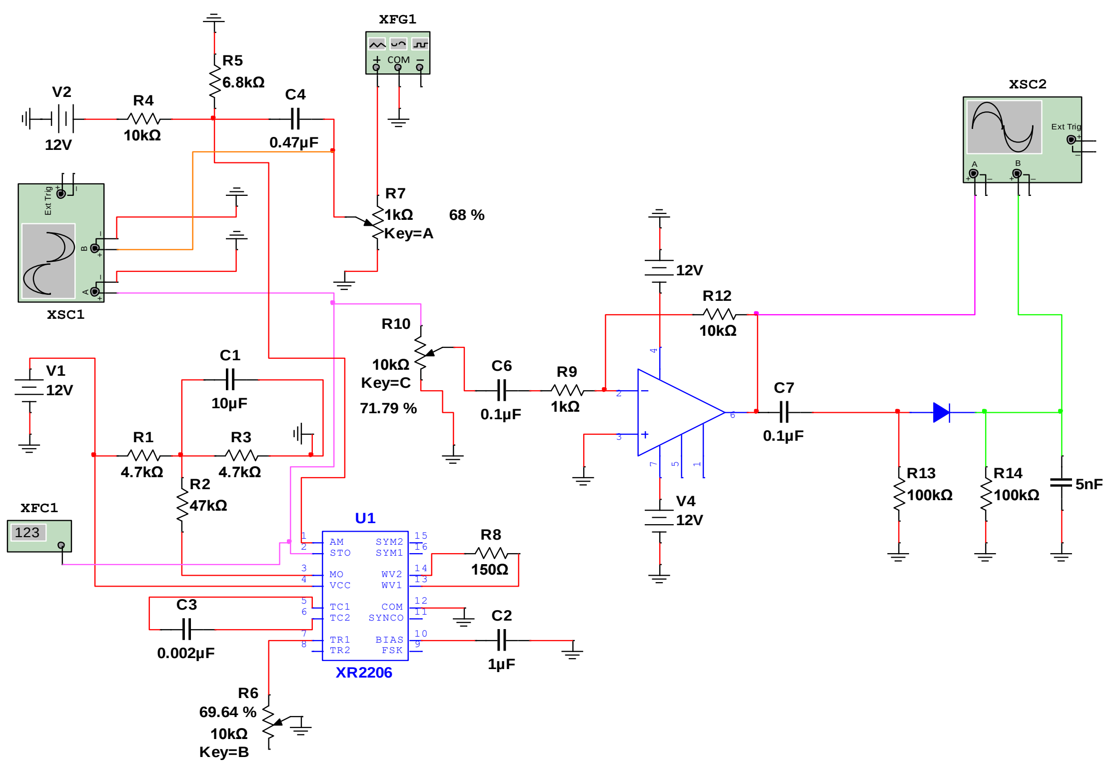

Figure 9 - Multisim Setup with the 5nF Cap.

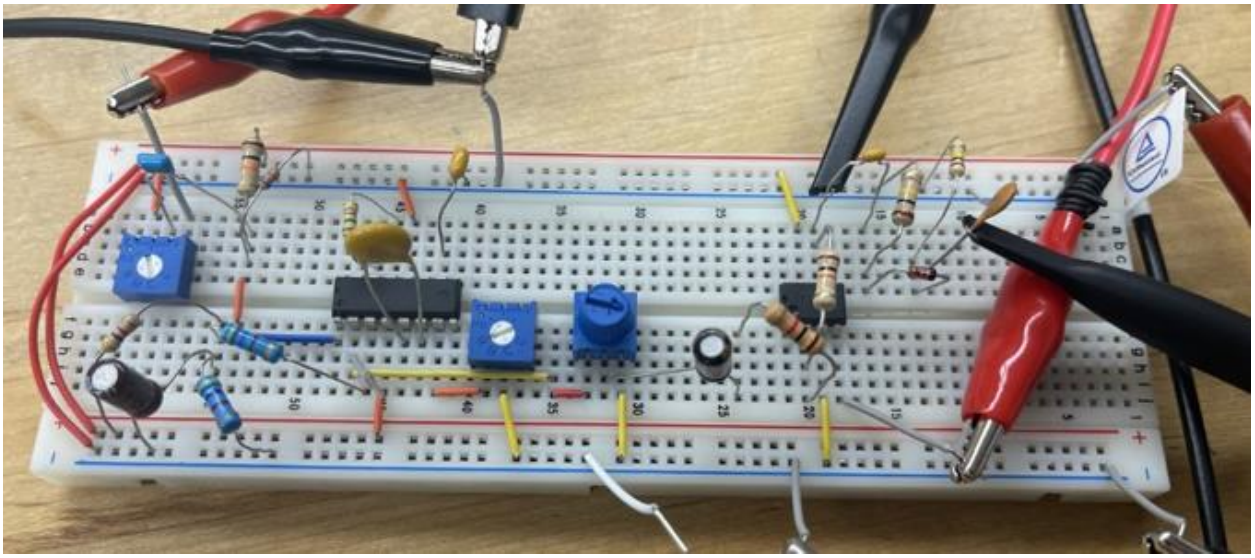

Figure 10 - Bench Diode Detector Ciruit.

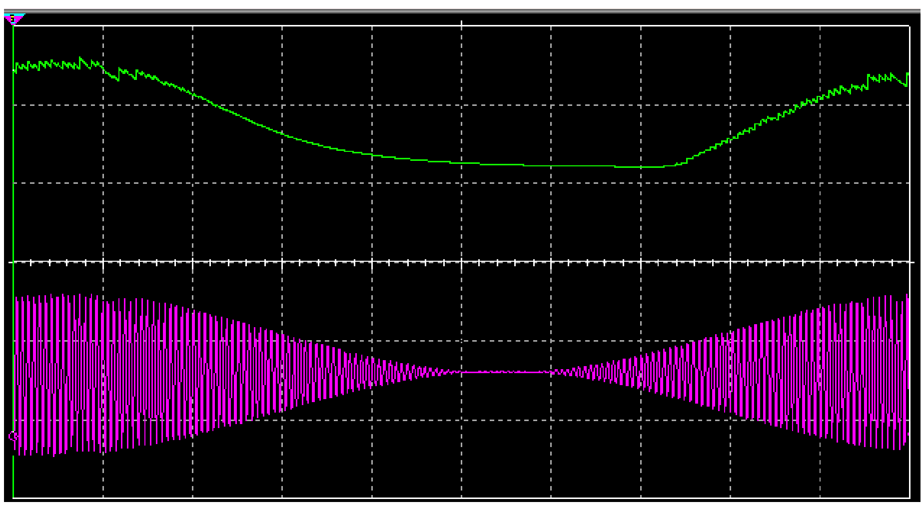

Figure 11 - Oscilloscope output waveform Multisim.

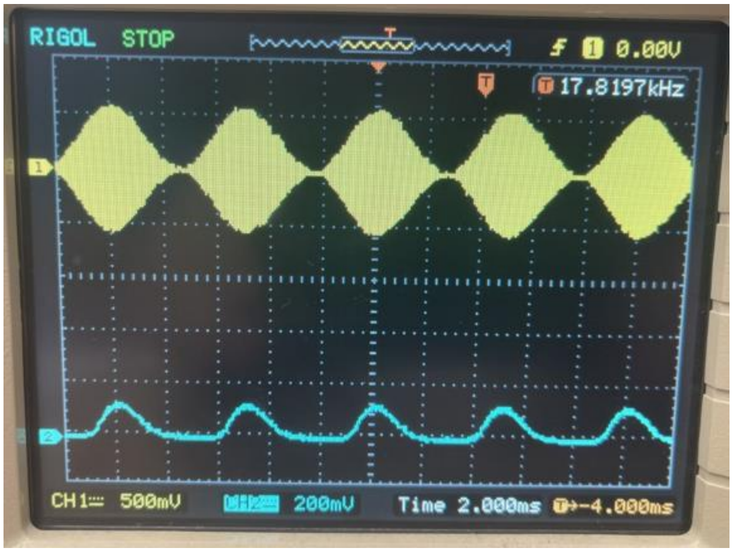

Figure 12 - Oscilloscope output waveform Bench.

6. **Test Additional Capacitors**:

    - Connect the 470-pF and the 0.1-µF capacitors, one at a time, in place of the 0.005-µF capacitor as filters in the diode detector circuit. Note the resulting output waveforms.

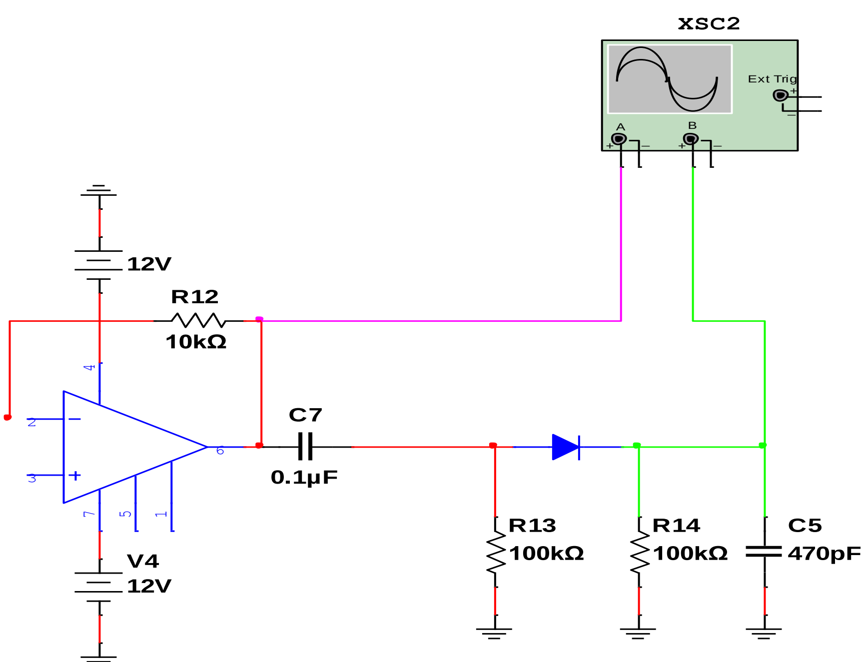

Figure 13 - Multisim with the 470pF Cap.

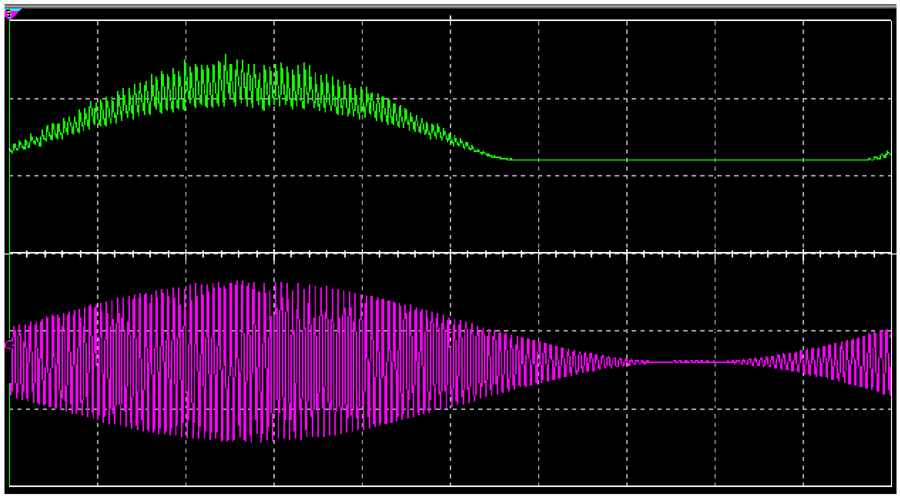

Figure 14 - Multisim Output waveform for the $470pF$ Cap.

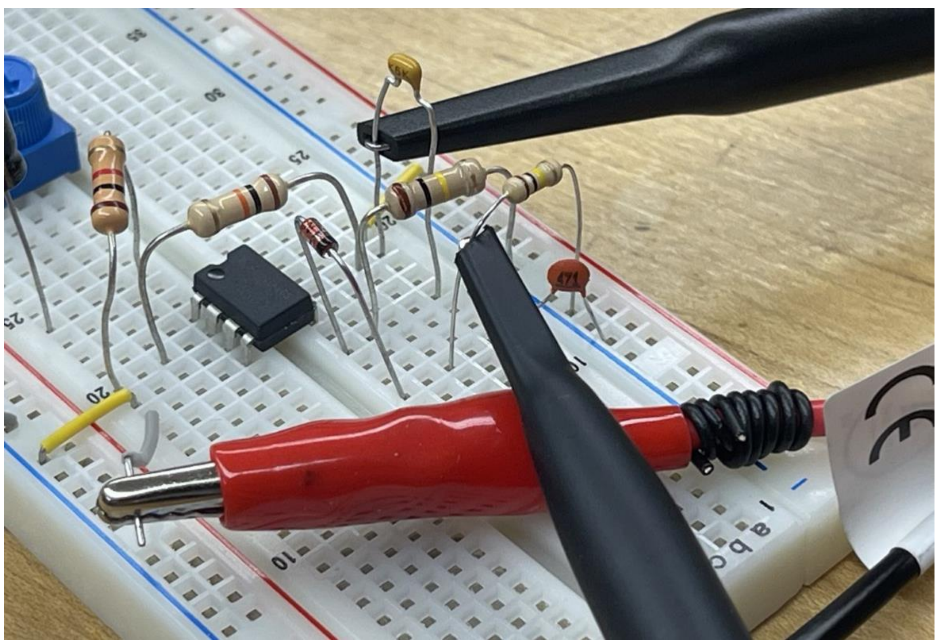

Figure 15 - Diode Detector with $470pF$.

Figure 16 – Bench Output waveform for the $470pF$ Cap.

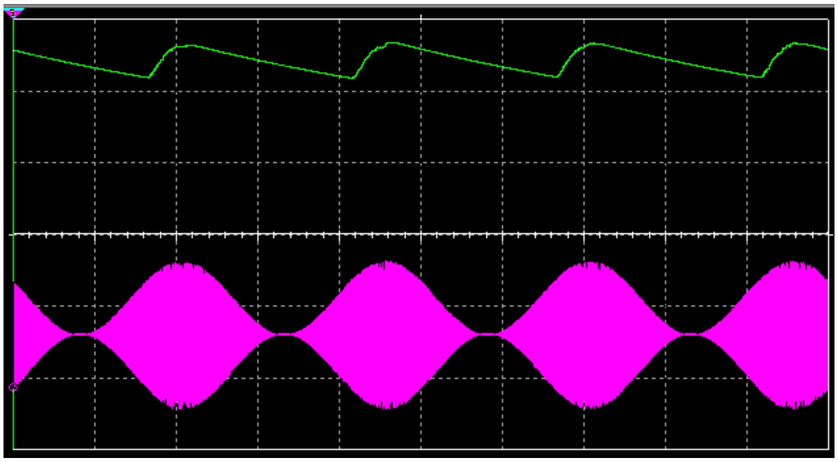

Figure 17 - Multisim Output waveform for the $0.1\mu F$ Cap.

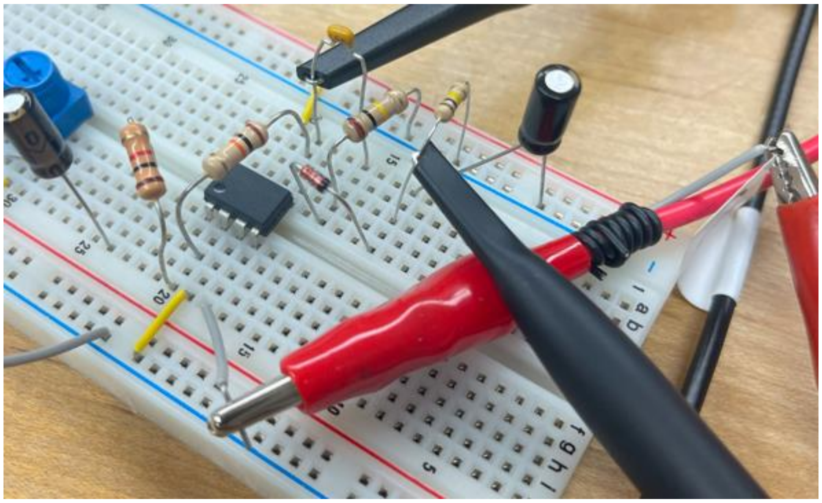

Figure 18 - Diode Detector with $0.1\mu F$.

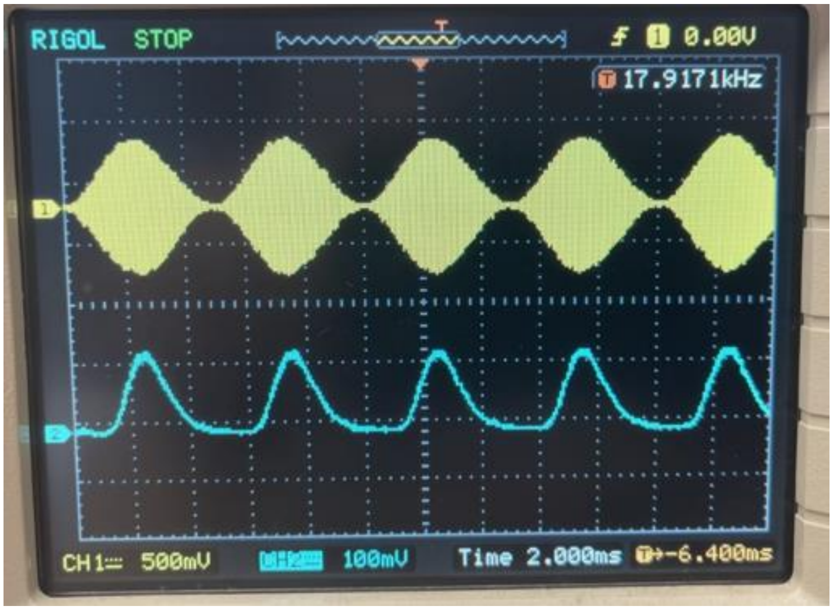

Figure 19 – Bench output waveform for the $0.1\mu F$ Cap

7. **Analyze Waveforms**:
    - Considering the waveforms observed in steps 5 and 6, explain how small and large values of capacitance affect the output signal.
8. **Reconnect Original Capacitor**:
    - Reconnect the 0.005-µF capacitor across the 100-kΩ load, and then reverse the connections to the diode. Monitor the output waveform.

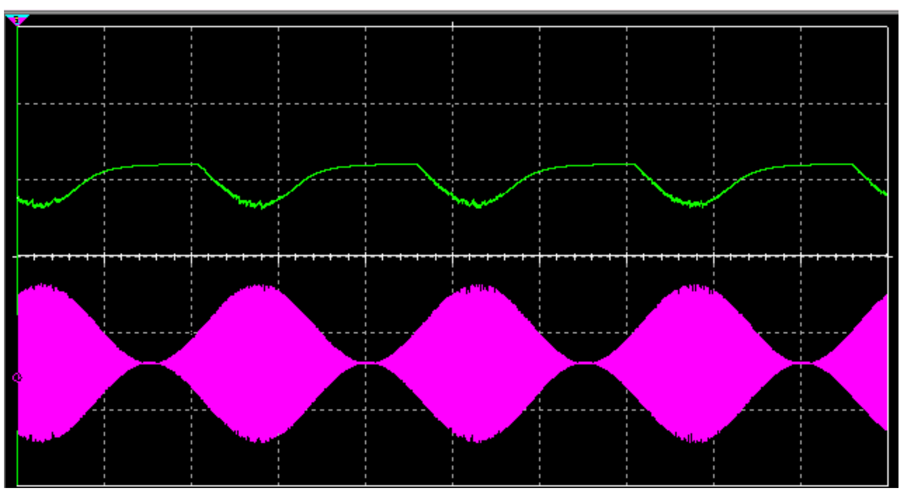

Figure 20 - Multisim waveform with $5nF$ Cap, and reversed diode.

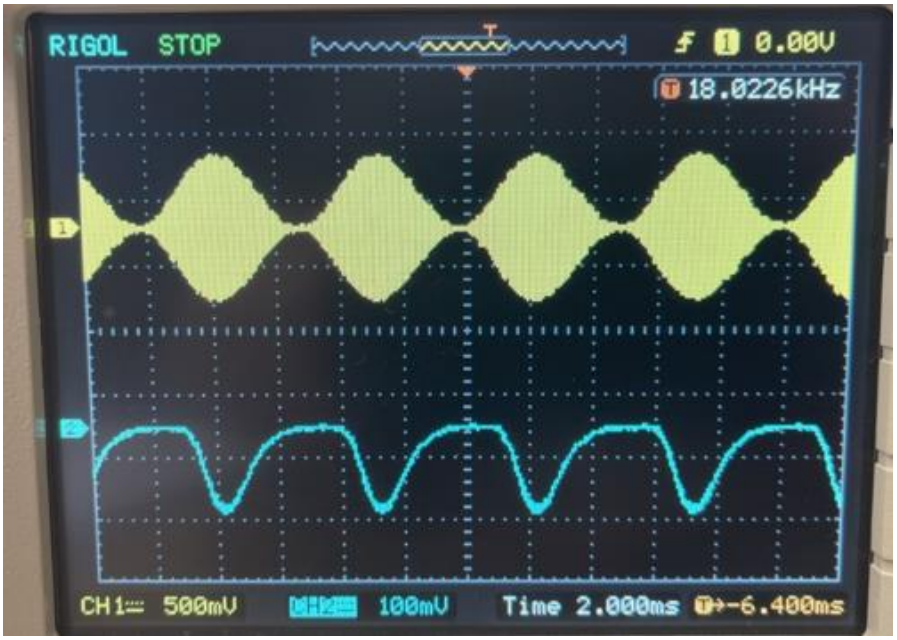

Figure 21 – Bench waveform with $5nF$ Cap, and reversed diode.

9. **Compare Results**:
   - Compare your results to the result obtained in step 5. Explain the reason for the waveform observed in step 8.
10. **Monitor AM Waveform**:
    - With the oscilloscope, monitor the AM waveform input to the diode detector. Increase the amplitude of the modulating signal to produce overmodulation and clipping.
11. **Observe Recovered Waveform**:
    - Observe the recovered waveform. Explain the results obtained.
12. **Vary Modulating Signal Amplitude**:
    - While observing the recovered signal at the output of the diode detector, vary the modulating signal amplitude from zero until distortion occurs. Explain what effect the percent of modulation has on the output signal.

Data & Observations:

Observations without Filter Capacitor:

Initially, the diode detector circuit was observed without a filter capacitor connected. The output waveform appeared as a half-wave rectified version of the AM signal. This waveform retained the high-frequency carrier components and showed a significant ripple, indicating that the carrier was not adequately removed.

Observations with $\mathbf{0.005-\mu F}$ Capacitor:

When the 0.005-μF capacitor was connected across the diode detector load, the output waveform started to smooth out, but still exhibited some ripple. The high-frequency carrier components were partially filtered, and the recovered signal began to resemble the original modulating wave more closely than without the capacitor, but the presence of residual ripple suggested incomplete filtering.

Observations with $\mathbf{470-pF}$ Capacitor:

Connecting the 470-pF capacitor in place of the 0.005-μF capacitor resulted in a similar but less effective smoothing of the output waveform. The signal still displayed noticeable high-frequency components and ripple, indicating that the 470-pF capacitor was too small to effectively filter out the carrier, leading to a less clear representation of the modulating wave.

Observations with $\mathbf{0.1-\mu F}$ Capacitor:

The 0.1-μF capacitor, when used as the filter, provided a significantly smoother output waveform. The high-frequency carrier components were substantially reduced, and the signal closely resembled the original modulating wave. The oscilloscope displayed a clean, demodulated waveform with minimal ripple, indicating that the 0.1-μF capacitor was the most effective in filtering out the carrier signal.

Observations with Reversed Diode:

Reversing the polarity of the diode in the circuit altered the output waveform. The rectified signal became inverted, and the amplitude of the recovered signal was reduced. This inversion affected the quality of the demodulated signal, demonstrating the importance of correct diode orientation in the circuit for proper signal recovery.

Effect of Varying Modulating Signal Amplitude:

Varying the amplitude of the modulating signal had a direct impact on the output waveform. As the modulating signal amplitude increased, the recovered signal amplitude also increased, closely tracking the original modulating signal. However, when the amplitude was increased excessively, overmodulation and clipping occurred, leading to signal distortion and a clipped waveform on the oscilloscope.

<u>Answers to Lab Questions:</u>

1. **If the filter capacitor in a diode detector is too small, the ________.**

- **a. Carrier is not removed**
- b. Recovered signal is distorted
- c. Carrier is distorted
- d. Signal amplitude is reduced

A small filter capacitor does not adequately remove the high-frequency carrier components, leading to distortion in the recovered signal.

2. **If the filter capacitor in a diode detector is too large, the ________.**
    - a. Carrier is not filtered out
    - **b. Recovered signal is distorted**
    - c. Carrier is distorted
    - d. Signal amplitude is reduced

An excessively large filter capacitor over-smooths the signal, causing distortion due to excessive filtering and loss of signal detail.

3. **Decreasing the percent of modulation causes the demodulated signal amplitude to ________.**
    - a. Increase
    - **b. Decrease**
    - c. Remain the same
    - d. Drop to zero

Lowering the percent of modulation reduces the amplitude of the demodulated signal since the modulation depth directly affects the signal amplitude.

4. **(True or False) Distortion produced by overmodulation is filtered out in the diode detector.**
    - **True**

Overmodulation causes signal clipping, but the distortion produced can be filtered out by the diode detector circuit's filter capacitor.

5. **Reversing the polarity of the detector diode causes the recovered signal to ________.**
    - **a. Be inverted**
    - b. Be lowered in amplitude

- c. Be increased in amplitude
- d. Remain the same

Reversing the diode polarity inverts the rectified signal, changing the phase of the recovered signal by 180 degrees.

Conclusion:

In this experiment, we successfully constructed and analyzed a diode detector circuit to demodulate an AM signal. The results demonstrated the effectiveness of the diode detector in recovering the original modulating signal and highlighted the importance of the filter capacitor for optimal signal clarity.

Without a filter capacitor, the output waveform was a half-wave rectified version of the AM signal, retaining significant high-frequency components and ripple. Using a 0.005-µF capacitor improved the signal but still left some ripple. The 470-pF capacitor was too small for effective filtering, resulting in a distorted signal. The 0.1-µF capacitor provided a smooth output waveform closely resembling the original modulating signal, indicating effective carrier removal. Reversing the diode polarity inverted the signal and reduced its amplitude, emphasizing the need for correct diode orientation. Varying the modulating signal amplitude showed that overmodulation and clipping occurred at high amplitudes, demonstrating the importance of maintaining optimal signal levels.

The experiment achieved the desired results by demonstrating the diode detector circuit's functionality and the impact of different filter capacitance values on signal quality. It confirmed that the filter capacitor value is crucial for achieving a clear, demodulated signal. Incorrect capacitor values or reversed diode orientation can lead to signal distortion and inadequate demodulation.

The experiment provided insights into the role of filter capacitors in AM signal demodulation and the importance of correct component orientation. Future experiments could explore different types of diodes, advanced filtering techniques, and varying modulation frequencies to further improve signal clarity and understanding of AM signal processing.

Overall, this experiment successfully demonstrated the principles of AM signal demodulation using a diode detector circuit, providing a solid foundation for further exploration in communication systems.