Experiment 2

Measuring Percentage of AM Waveform (3-1)

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Course Title & Number:

RF Communications (EET-2325C)

Submitted to:

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Objective:

The objective of this experiment is to understand and demonstrate the principles of amplitude modulation (AM) by measuring the modulation index and the percentage of modulation in a practical setup. We intend to accomplish a thorough understanding of how the amplitude of the carrier wave can be varied according to the amplitude of the input signal, and to observe the effects of overmodulation and its impact on signal distortion. This will involve setting up an AM circuit using specific electronic components and analyzing the waveforms visually using an oscilloscope. The ultimate goal is to gain hands-on experience in manipulating and understanding AM techniques, which are fundamental in various applications of electronic communication.

Materials:

1. Oscilloscope with provision for external horizontal input
2. Frequency counter
3. 12-V dc power supply
4. Function generator with sine wave output
5. XR-2206 Exar function generator IC
6. Capacitors:
    - 0.002-μF
    - 0.47-μF
    - 1-μF
    - 10-μF
7. Resistors:
    - 150-Ω
    - 4.7-kΩ (two units)
    - 6.8-kΩ
    - 10-kΩ
    - 47-kΩ
8. Variable resistors (potentiometers)

- 1-kΩ
- 100-kΩ

9. Connecting wires and breadboard

Backgorund:

In amplitude modulation, the total amplitude of the AM signal varies according to the modulating signal. The key parameters in defining the modulation characteristics are VmaxVmax and VminVmin, which represent the maximum and minimum voltages of the modulated waveform, respectively.

Modulation Index (m)

The modulation index (m) is a fundamental concept in AM, which defines how much the carrier wave is affected by the modulating signal. It is calculated as:

$$m = \frac{(V_{max} - V_{min})}{(V_{max} + V_{min})}$$

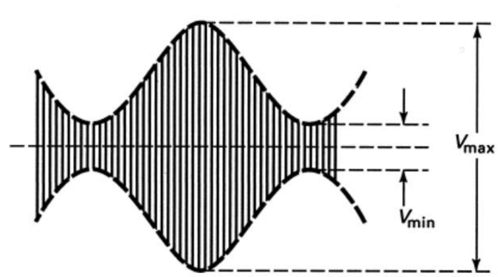

Fig. 3-2 Measuring voltages to calculate modulation index.

This equation highlights that the modulation index is derived from the peak-to-peak amplitude variations of the modulated signal, normalized by the sum of these maximum and minimum amplitudes.

Overmodulation

If the modulation index exceeds 1, overmodulation occurs, leading to signal distortion characterized by clipping in the AM waveform. Overmodulation must be avoided as it not only distorts the signal but also can lead to bandwidth spreading, which might cause interference with other communication channels.

<u>Procedure:</u>

Setup and Calibration

1. **Simulation Setup in Multisim**:
    - Before commencing the physical experiment, set up the amplitude modulation circuit in Multisim using the XR-2206 function generator IC and other components as per the schematic shown in Figure 3-5 of the manual.
    - Use Multisim's oscilloscope tool to visualize and measure the AM waveform, specifically noting V_{max} and V_{min} for different modulation depths.

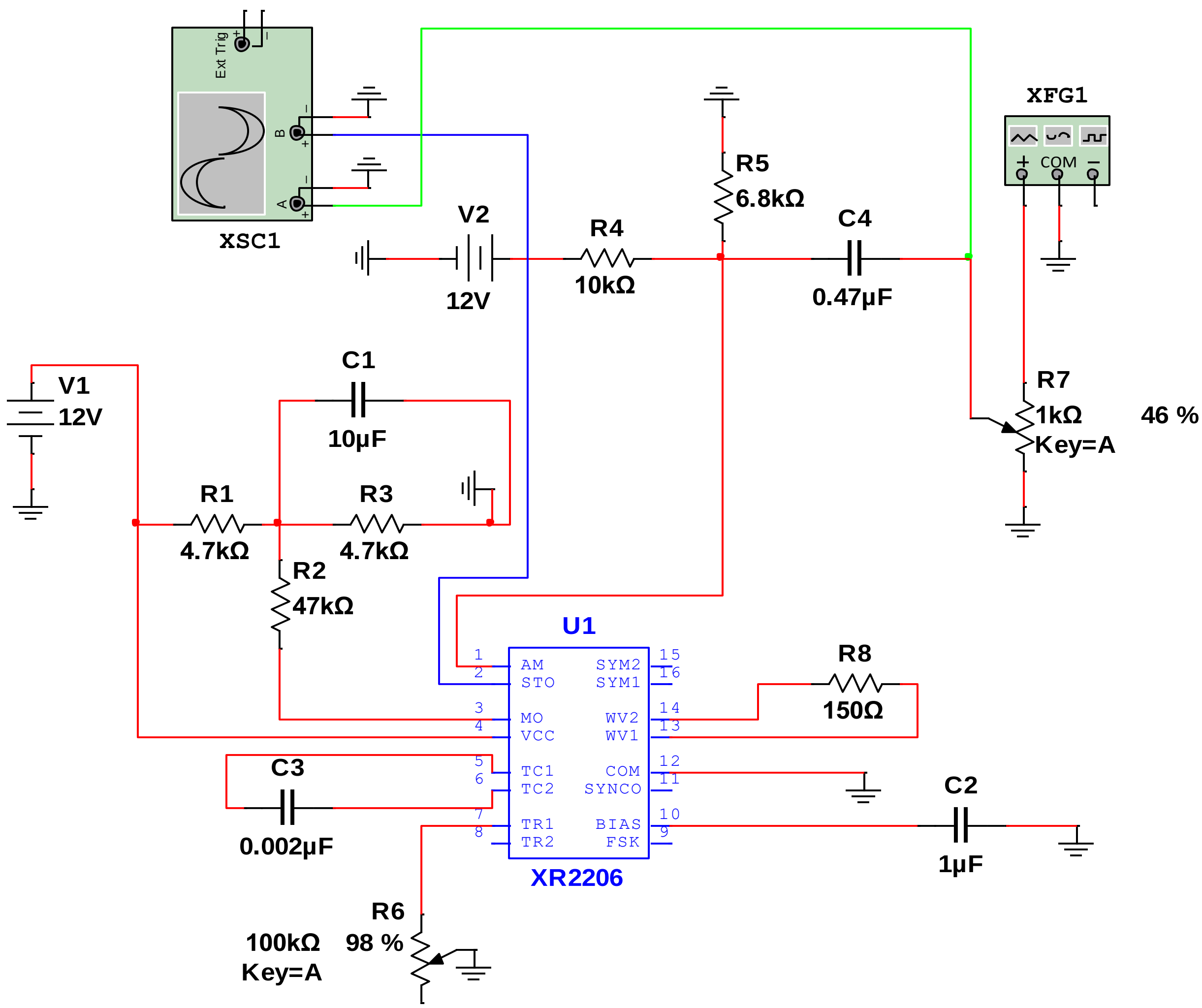

Figure 1 - Circuit schematic Multisim.

2. **Physical Circuit Assembly**:

    - Construct the AM circuit on a breadboard according to the schematic provided. Ensure that all connections are secure and that the component values match those used in the Multisim simulation.

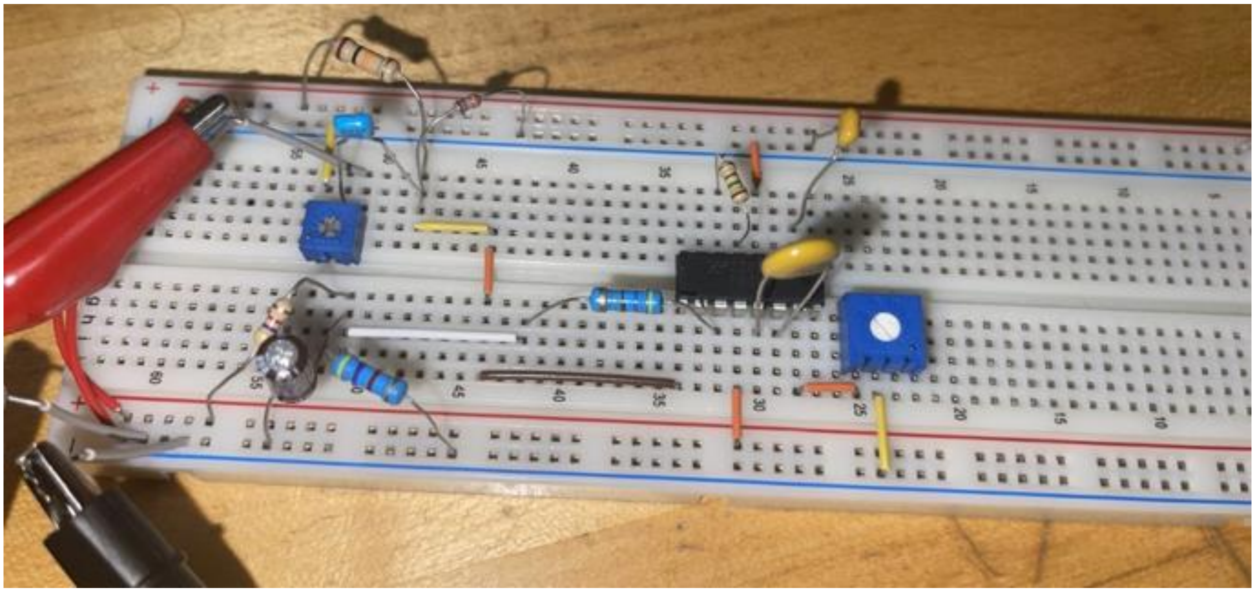

Figure 2 - Amplitude modulation of the 2206 function generator IC (Bench).

Execution

3. **Initial Testing and Adjustment**:

    - Apply a 12V DC power supply to the circuit.

Figure 3 - Bench Power supply

- Connect the external function generator to provide a 1 kHz modulating signal.

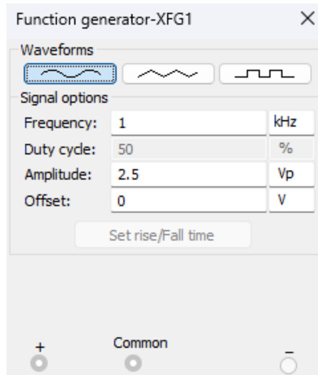

Figure 4 - Adjusting Multisim External Function Generator.

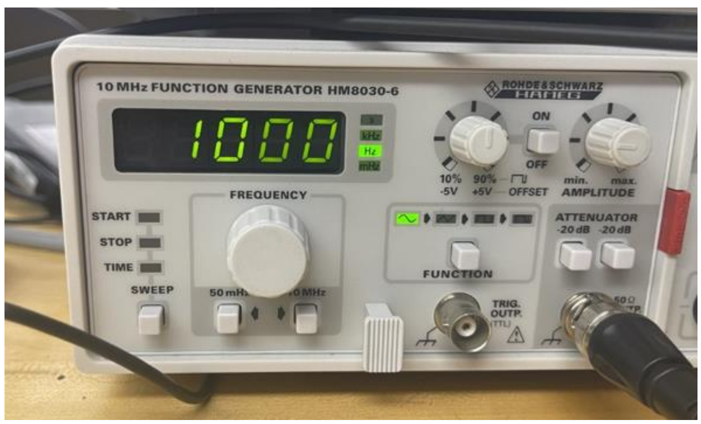

Figure 5 - Adjusting Bench External Function Generator

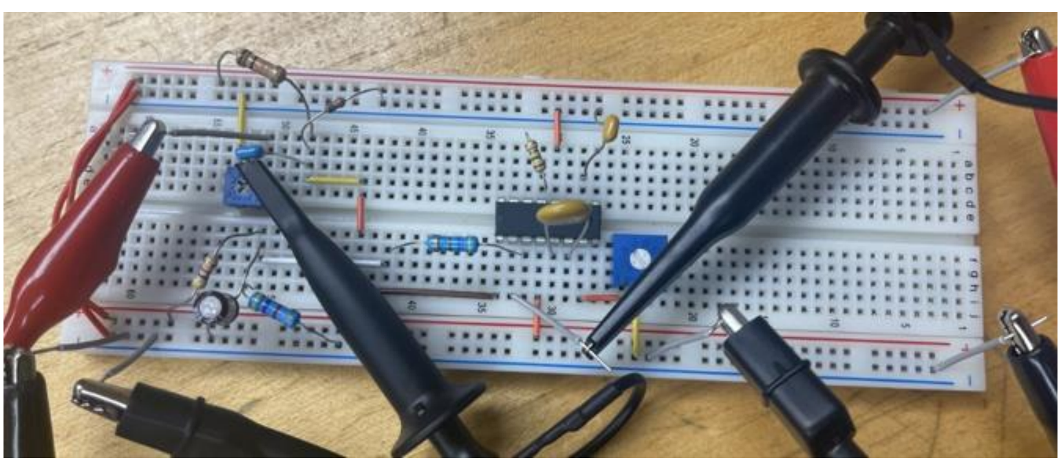

Figure 6 - Oscilloscope Probe placements (Bench).

- Start with no modulation and gradually increase the modulation depth using the 1-kΩ potentiometer while observing the output on the oscilloscope.

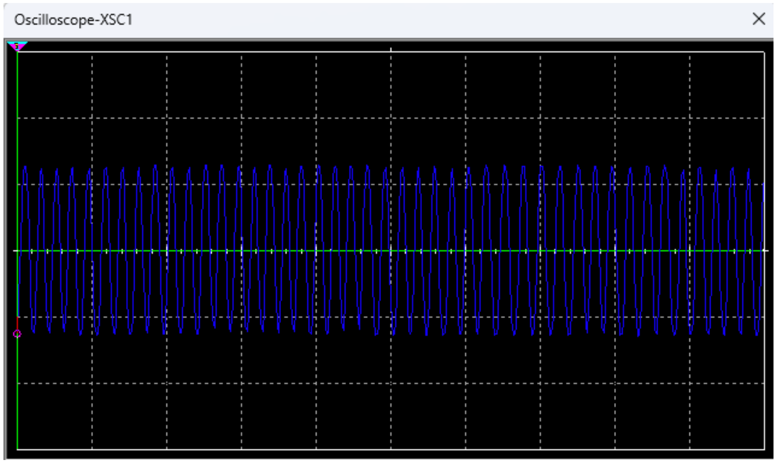

Figure 7 - Starting with an Unmodulated Carrier at 40kHz (Multisim).

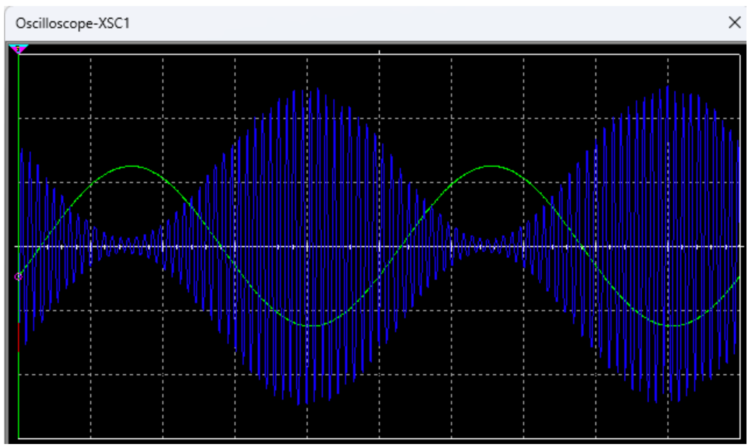

Figure 8 - Observed output in Multisim.

Figure 9 – Unmodulated Carrier Bench at 40kHz.

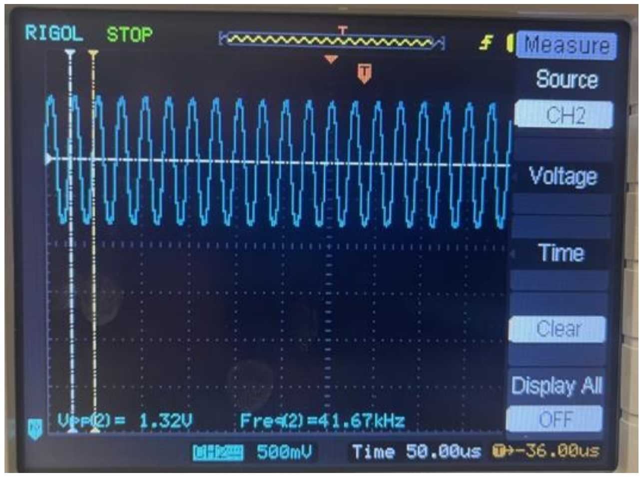

Figure 10 - Measuring Vpp

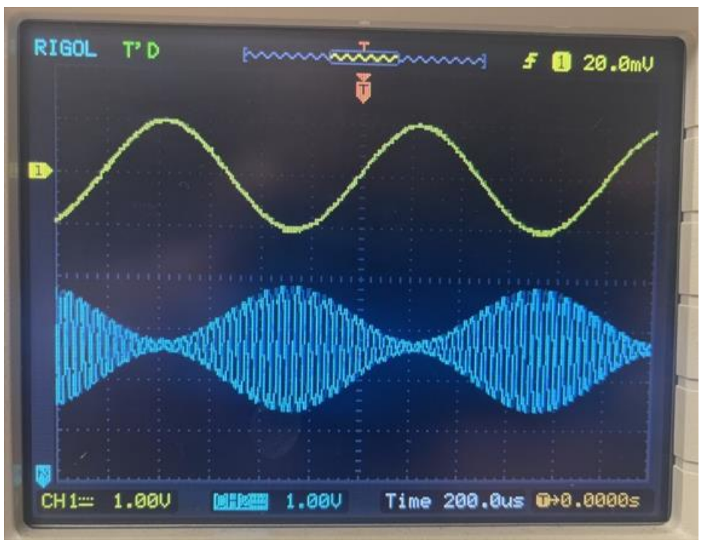

Figure 11 – Observed modulated output in the bench.

4. **Measurement of Modulation Index**:

- Measure V_{max} and V_{min} from the oscilloscope connected to the output of the circuit.
- Calculate the modulation index using the equation:

$$m = \frac{(V_{max} - V_{min})}{(V_{max} + V_{min})}$$

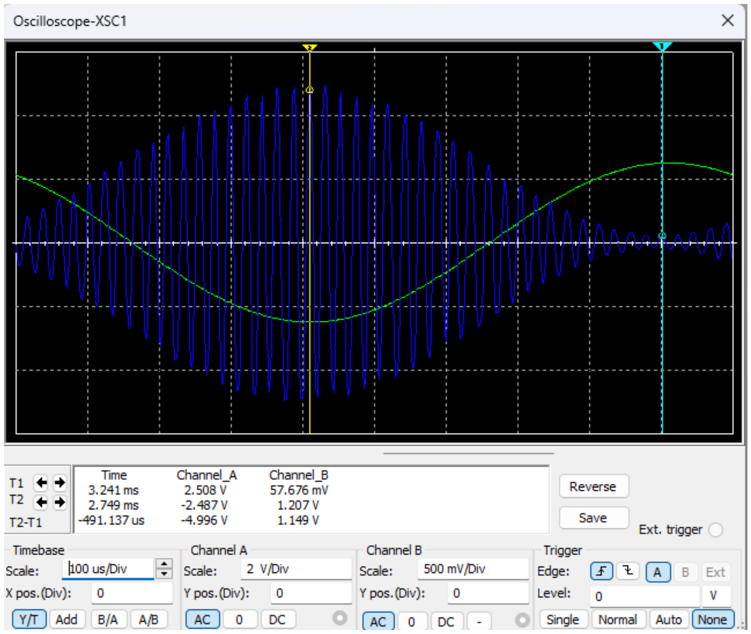

Figure 12 - Measuring V_{max} and V_{min} (Channel B)

5. **Observing Overmodulation**:
   - Increase the modulation depth beyond the point where m equals 1 to observe overmodulation.
   - Note the appearance of waveform distortion (clipping at the peaks) on the oscilloscope. Document these observations for comparison with the simulation.

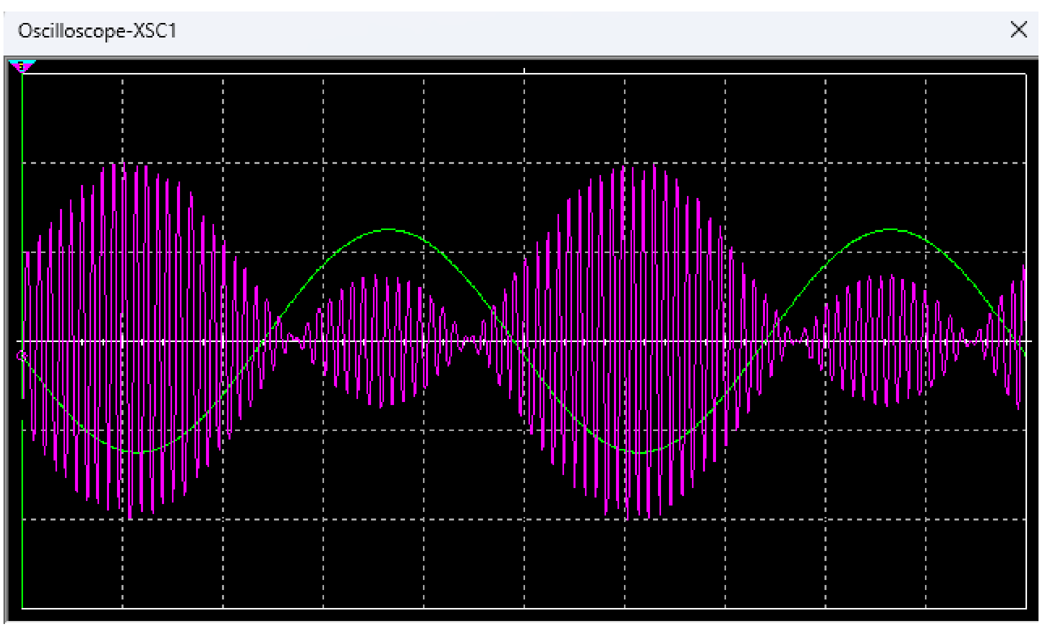

Figure 13 - Overmodulation (Multisim) Different color for more clarity.

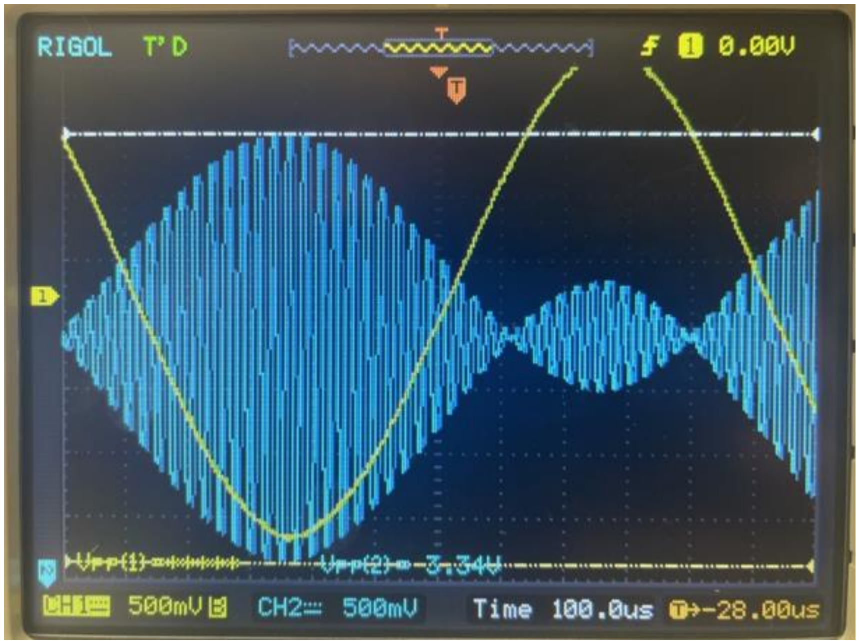

Figure 14 - Overmodulated wave Bench.

6. **Using Trapezoidal Pattern for Modulation Analysis**:

   - Connect the modulating signal to the horizontal input of the oscilloscope to generate a trapezoidal pattern, which helps in visualizing the linearity of the modulation process.
   - Adjust the oscilloscope settings to clearly display the trapezoid and measure V_{max} and V_{min} directly from the screen.

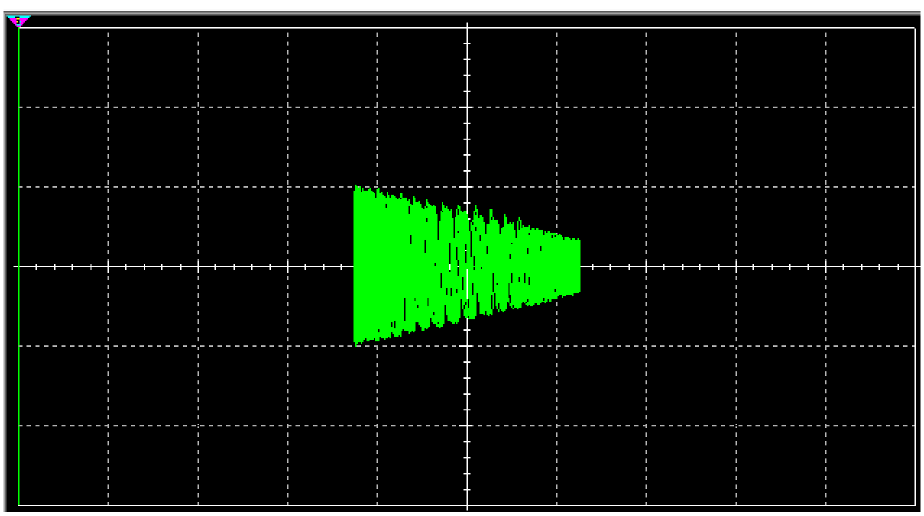

Figure 15 - Trapezoid Analysis with m=50%

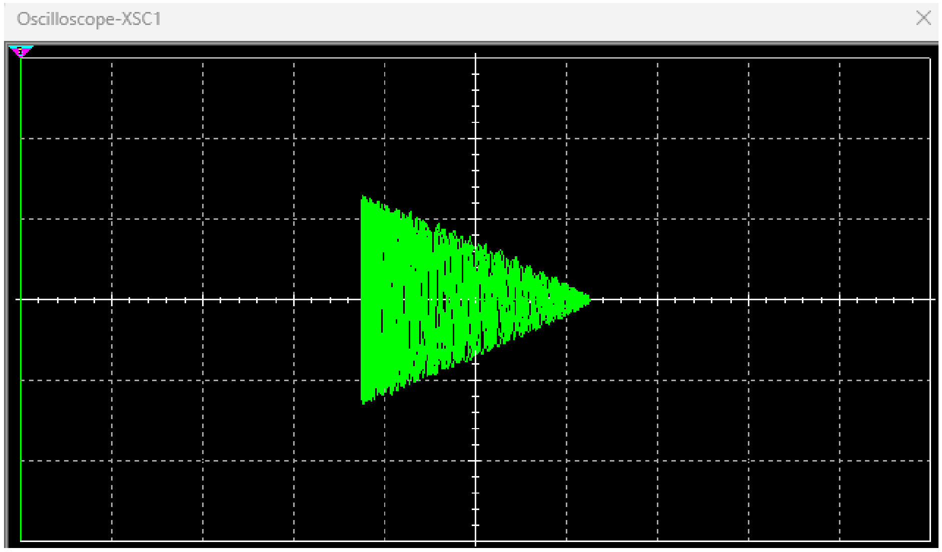

Figure 16 - Trapezoid Analysis with $m \approx 1$

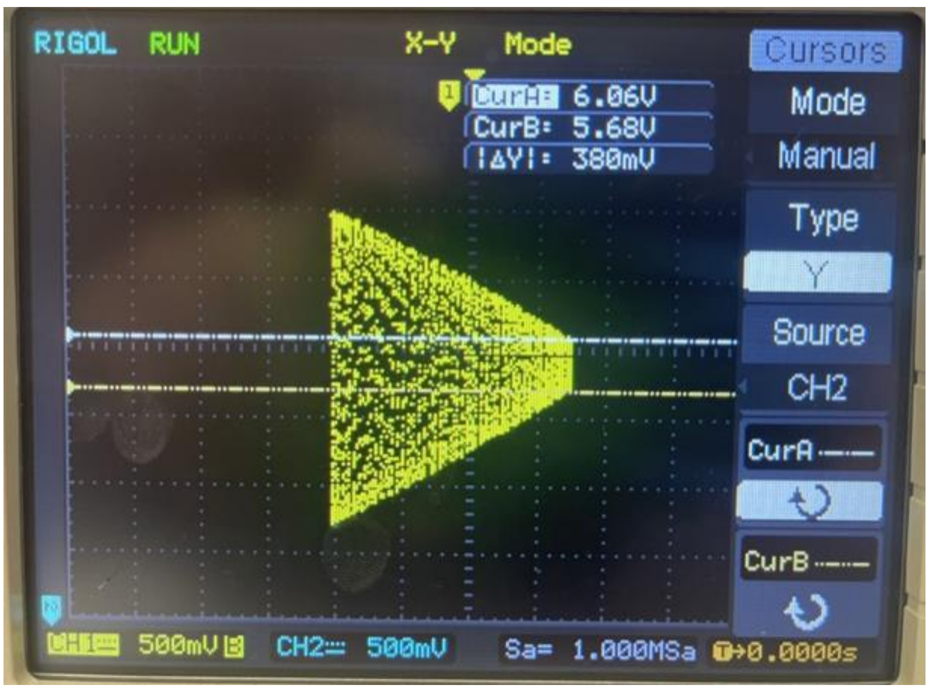

Figure 17 - Trapezoid Analysis with $m \approx 50\%$

Figure 18 - Trapezoid Analysis with m ≈ 1

Documentation

7. **Recording Results**:

    - Document the settings, measurements, and observations at each step of the modulation depth adjustment, including zero modulation, 50% modulation, 100% modulation, and overmodulation.
    - Include comparative analysis with simulation results to validate the experimental findings.

<u>Data & Observations:</u>

Measured Data and Resulting Calculations

During the experiment, measurements of V_{max} and V_{min} were recorded at various modulation depths, which allowed for the calculation of the modulation index (mm) using the formula:

$$m = \frac{(V_{max} - V_{min})}{(V_{max} + V_{min})}$$

These calculations were pivotal in determining the extent to which the amplitude of the carrier wave was being modified by the modulating signal, providing insight into both undermodulation and overmodulation conditions.

Sample Calculation:

$$m = \frac{1.279\ V - 40.8\ mV}{1.279\ V + 40.8\ mV} = .938$$

$$m(\%) = .938 * 100 = 93.8\%$$

Data:

Table 1

Modulation Depth (%)	$\boldsymbol{V_{max}(V)}$ (Multisim)	$\boldsymbol{V_{min}(V)}$ (Multisim)	**Calculated Modulation Index ($\boldsymbol{m}$)** (Multisim)	$\boldsymbol{V_{max}(V)}$ (Bench)	$\boldsymbol{V_{min}(V)}$ (Bench)	**Calculated Modulation Index ($\boldsymbol{m}$)** (Bench)
0	$592.9\ mV$	$593.6\ mV$	$.023$	$660\ mV$	$660\ mV$	0
50	$1.024\ V$	$301.9\ mV$	$.54$	$1.15\ V$	$389\ mV$	$.494$
100	$1.279\ V$	$40.8\ mV$	$.938$	$1.31\ V$	$30\ mV$	$.955$
$m > 100\%$	$2.026\ V$	$-742.5\ mV$	2.15	$1.67\ V$	$-427\ mV$	1.68

Discussion of Experimental Results

The results confirmed the theoretical expectation that the modulation index should not exceed 1 to avoid distortion. At higher modulation depths, where the modulation index exceeded 1, the waveform exhibited clipping, indicative of overmodulation. This was visually confirmed both on the physical oscilloscope and in the Multisim simulation.

Sources of Error

Several sources of error could have influenced the results:

- **Component Tolerances:** Variations in the actual values of resistors and capacitors from their nominal values could lead to changes in the observed modulation index.
- **Oscilloscope Accuracy:** The precision of the oscilloscope in measuring peak voltages could also introduce error, especially at higher frequencies.

- **Alignment of Measurement Tools:** Misalignment or incorrect calibration of the measurement setup, including the oscilloscope and function generators, might have led to slight discrepancies in the voltage readings.

Accuracy of Measurements

To mitigate measurement inaccuracies, calibration of the oscilloscope was performed prior to the experiments, and components were tested to ensure they were within acceptable tolerance limits. Despite these precautions, the inherent uncertainties in the equipment and environmental factors could still impact the results.

Answers to Lab Questions:

Questions

1. On an AM wave, V_{max} 2 V and V_{min} 0.5 V. The modulation index is ________ .

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} = \frac{2 - 0.5}{2 + 0.5} = \frac{1.5}{2.5} = 0.6$$

A. 0.25
B. 0.4
C. 0.6
D. 0.85

2. For 100 percent modulation, what is the relationship between the carrier voltage Vc and the modulating signal voltage V_m?

A. $V_m = V_c$ = 0
B. $V_m = V_c$
C. $V_m > V_c$
D. $V_m < V_c$

For 100% modulation, the peak amplitude of the modulating signal V_m equals the amplitude of the carrier V_c.

3. When overmodulation occurs, ________ .

A. $V_m = 2\,V_c$
B. $V_m = V_c$
C. $V_m < V_c$
D. $V_m > V_c$

Overmodulation occurs when the amplitude of the modulating signal exceeds that of the carrier, leading to distortion.

4. When you are using a trapezoidal pattern to measure modulation percentage, 100 percent modulation is indicated by what shape of pattern?

a. Triangular

b. Rhomboid

c. Square

d. Rectangle

This is due to the V_{min} being near 0, therefore that end of the shape is a sharp tip.

5. (True or False) The frequency of the modulating signal affects the percent of the modulating signal.
False, the frequency of the modulating signal does not affect the percentage of modulation; it's the amplitude that does.

Conclusion:

The amplitude modulation experiment aimed to apply practical modulation techniques and observe the effects of modulation depth on an AM signal, using both simulation and a physical circuit. The results demonstrated the relationships between V_{max}, V_{min}, and the modulation index (m), confirming that the modulation index properly increased with modulation depth up to a maximum of 1.0, corresponding to 100% modulation. Overmodulation was effectively observed as expected, showing waveform distortion when the modulation index exceeded 1.0.

This experiment reinforced the theoretical aspects of amplitude modulation with practical findings. The observed data from the oscilloscope provided clear insights into how modulation affects signal integrity and highlighted the critical nature of controlling modulation levels to prevent signal distortion.

The findings suggest the importance of precise setup and calibration in experiments involving electronic components. Future experiments could benefit from exploring different modulating frequencies and signal shapes to further understand their effects on amplitude modulation. Enhancing measurement techniques could also improve the accuracy and depth of experimental results.