BIRZEIT UNIVERSITY

Computer System Engineering Department

ENEE3309

COMMUNICATION SYSTEMS

-Project Phase One-

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Introduction

This project depends on knowledge of communication systems, focusing on normal amplitude modulation (AM). The objective is to design and implement a simple AM modulator and demodulator circuit, employing a switching modulator and an envelope detector. Executed in two distinct phases—simulation using Pspice, followed by hands-on construction on a breadboard with an oscilloscope—the project Emphasizing theoretical analysis, practical implementation, and the utilization of modern engineering tools, for skill development in circuit design and experimentation.

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Problem Specification

In this project we will use **Pspice** for creating and simulating the circuits. to find the optimal design and apply it in the second phase.

Part 1: Normal AM Modulator.

In this section we will design and analyze a simple AM modulator using a simple switching circuit, which consists of a rectifier, two voltages sources (message, carrier), resistor, and a band pass filter. to create the modulated signal. [1]
The general formula for the resulted modulated signal.
Certainly! The general formula for Amplitude Modulation (AM) in both time and frequency domains is as follows:

- **Time Domain**:

s(t) = Ac [1 +Ka * Am * m(t)] * cos(2*pi*fc*t)

where:

- **s(t)** is the AM signal in the time domain.
- **Ac** is the carrier amplitude.
- **Ka** * **Am** is the modulation index.
- **fc** is the frequency of the carrier signal.
- **t** represents time.

- **Frequency Domain**:

S(f) = Ac [0.5 * delta (f - fc) + 0.5 delta (f + fc) + Ka* Am ((0.25 * delta (f - fc - fm) + 0.25 * delta (f + fc + fm) + 0.25 * delta (f - fc + fm) + 0.25 * delta (f + fc - fm))]

where:

- **S(f)** is the AM signal in the frequency domain.
- **fc** the carrier frequency.
- **M(f)** the message spectrum.

Part 2: Normal AM Demodulator.

For demodulation we will design a simple envelope detector which consists of rectifier diode, capacitor, and s(t) **-modulated signal-**. [1]
The Envelope detector will get the modulated signal as input and only show the tips of it and use the capacitor and connect the tips together to form the original message.

The output from the envelope detector equal ~= Ac (1+km * Am * m(t))

Data

In this project we will try to design and simulate an Am modulator (switching circuit), and demodulator (envelope detector), to send a message from receiver to sender.
Where:

- **Message**: m(t) = $\mathbf{cos}\ (\mathbf{2\pi * 10^3} * \boldsymbol{t})$
- **Carrier**: c(t) = $\mathbf{cos}\ (\mathbf{2\pi} * \mathbf{10}^5 * \boldsymbol{t})$
- **Am** * **Ka**: 0.8
- **Ac**: 9

Evaluation Criteria

For the AM project, evaluating performance involves using the signal-to-noise ratio (SNR) at the receiver's output. SNR quantifies the quality of the received signal by comparing the average power of the signal to the average power of the noise. This objective measure helps showcase and quantify enhancements in the system, providing a valuable metric for assessing project success.

$$SNR_0 \equiv \frac{\text{average power of message signal at the receiver output}}{\text{average power of noise at the receiver output}}$$

- avg power of the message at the receiver = 170^2 = 28900
- avg power of the noise at the receiver = 1.5^2 * .5 * 1000 =1125

$\mathbf{SNR_0}$ = 28900 / 1125 = 25.68

Thus, we observe that the noise relative to the message is so small.

- We can calculate the efficiency of our system by using the following equation:
  - **eff = m^2 / (m^2 + 2)**

which equals 24%. this indicates that we have lost 76 % of the used power for the carrier signal.

this efficiency is very low even if we used m = 1.

So we need to consider another approach also we cannot forget that we have used a bandwidth of 2fm for a message signal of bandwidth fm this is another reason why we need to consider another approach.

Approach:

We will first analyze and find the theoretical values for the modulated and demodulated signal m(t), then we will build a simple switching modulator, and envelope detector and to modulate and demodulate the signal m(t) and compare the results.

Results and Analysis:

Part 1: Normal AM Modulator.

1.1 Let's assume **m(t)** = $\mathbf{cos}\ (2\boldsymbol{\pi} * 50 * \boldsymbol{t})$, **c(t)** = $9 * \mathbf{cos}\ (2\boldsymbol{\pi} * 600 * \boldsymbol{t})$

Hence, **M(f)** = 0.5 * δ(f-50) + 0.5 * δ (f + 50), **C(f)** = 9/2 * δ(f-600) + 9/2 * δ (f + 600)

1.2 For the given signal **p(t)** = π(2t/Tc) → to determine p(t) in complex exponential Fourier series:

First, we need Pn, **Pn** = P(n*Fc) * Fc → P(f) = Tc/2 sinc(f*Tc/2) → P(n*Fc) = Tc/2 * sinc(n*Fc*TC/2)

➔ P (n * Fc) = Tc/2 * sinc(n/2) → Pn = Tc/2 * Fc * sinc(n/2) → Pn = (sinc(n/2))/2. Hence:

$$p(t) = \sum_{n=-\infty}^{\infty} 0.5 \cdot sinc\left(\frac{n}{2}\right) \cdot e^{jW0nt}$$

1.3 **S(t)** = Ac (1 + Ka * m(t)) * cos (2 * π * fc *t) = Ac (1 + Ka * m(t)) * cos (2 * π * fc * t) →

S(t) = Ac [{cos (2 * π * 10^5 * t} + {0.5 * μ * cos (2 * π * 99*10^3 * t)} +

{0.5 * μ * cos (2 * π * 101*10^3 * t)}].

S(f) = F{S(t)} = Ac * [0.5 * {δ (f – 100 * 10^3) + δ (f + 100 * 10^3)} + μ (0.25 * {δ (f – 99 * 10^3)} +

{δ (f + 99 * 10^3)} + 0.25 * {δ (f – 101 * 10^3)} + {δ (f + 101 * 10^3)})].

1.4 To design the BPF firstly we need to determine what f3db(H/L) we need the filter to have.

Assuming R1 = R2 = 1 KΩ.

The signal S(t) gives us that the bandwidth of the message signal is fm = 1 KHz

But the bandwidth of the normal AM modulated signal is equal to (2 * fm) = 2 KHz

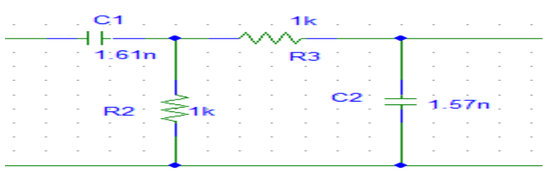
The filter has to pass signals between 99 KHz and 101 KHz. And for the center frequency:

fr = (f1 * f2) ^ (1/2) = 100 KHz Hence, f3dbl = 99 KHz, f3dbh = 101 KHz, fr = 100 KHz.

Now to find c1 and c2 we can apply: c1 = (1/ (2 * π * R1* f1)), c2 = (1/ (2 * π * R2 * f2)).

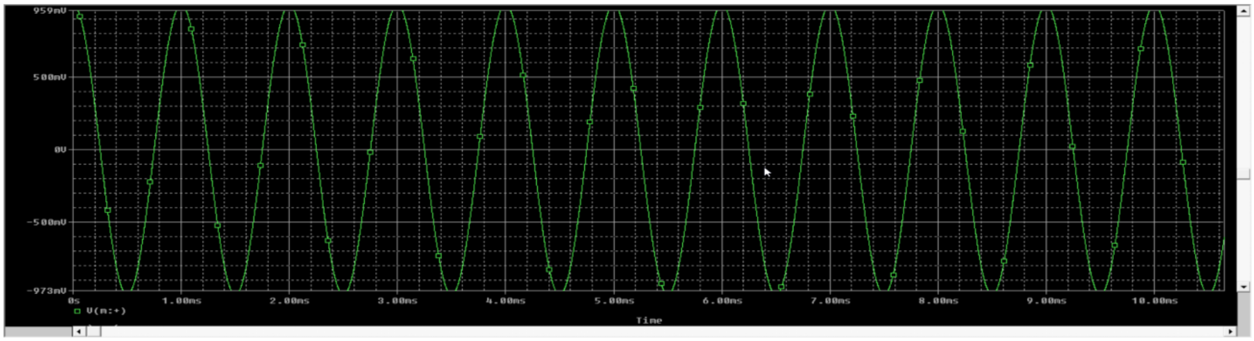
- ➔ c1 = 1/ (2 * π * 1000 * 99000) = 1.61 nf
- ➔ c2 = 1/ (2 * π * 1000 * 101000) = 1.57 nf

here we have the priorities of the BPF we can now design it:

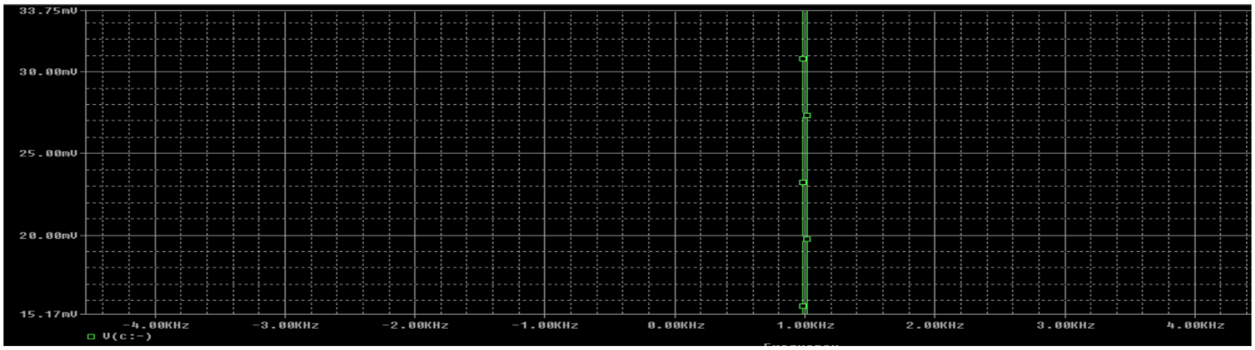


1.5 After designing the full modulator circuit: we can use PSPICE to simulate the results:

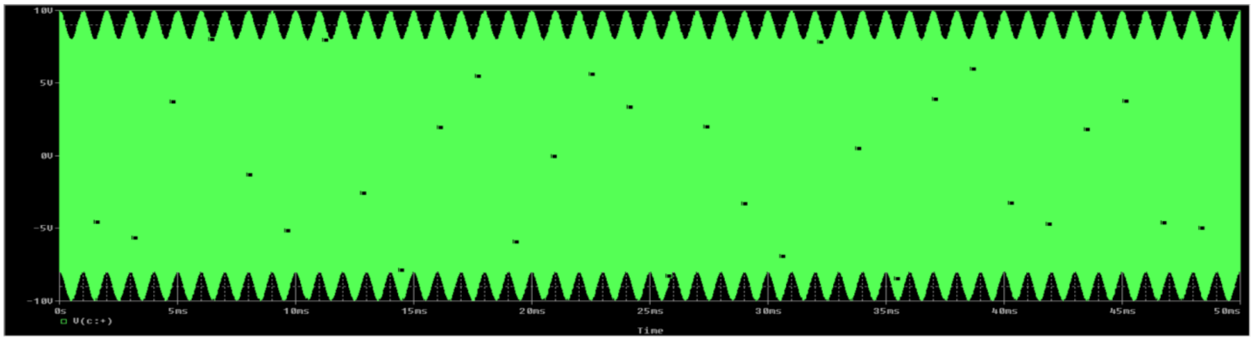
- **Modulating signal**
  1. Time domain:



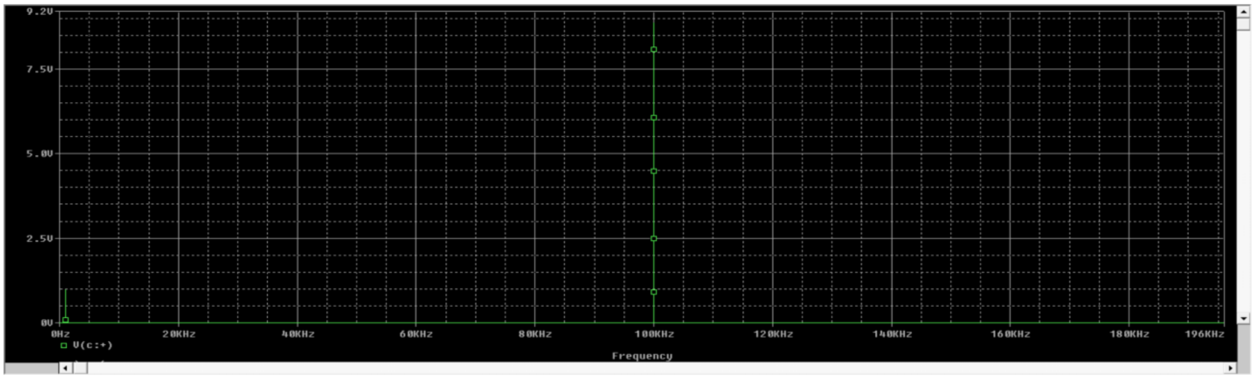
  2. Frequency domain:



- **Carrier signal**
  1. Time domain:

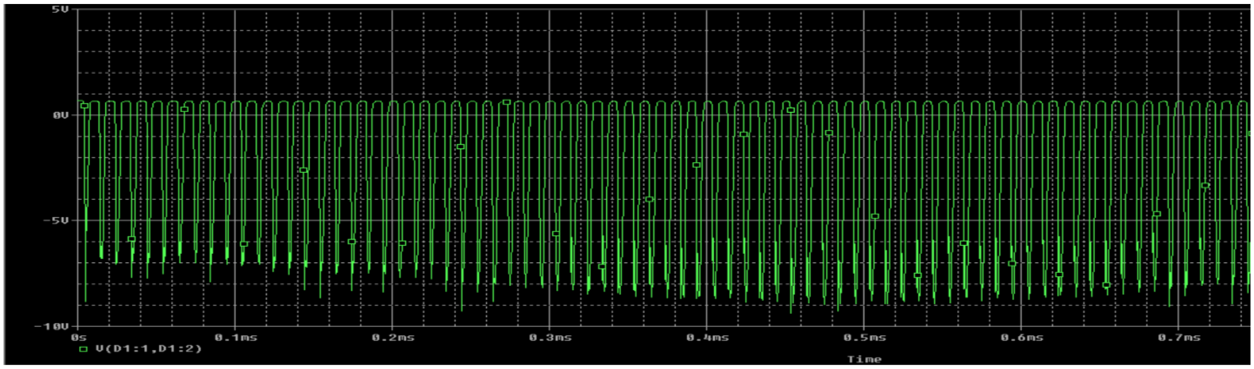


  2. Frequency domain:

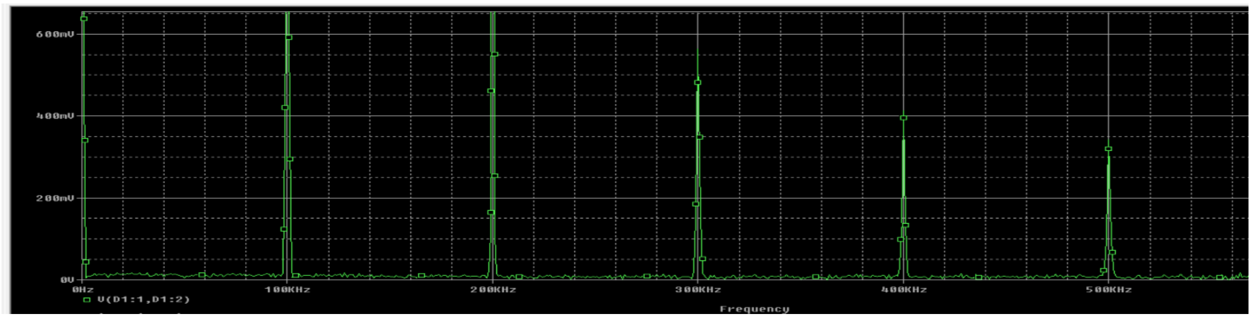


❖ **Switching signal**

1. Time domain:

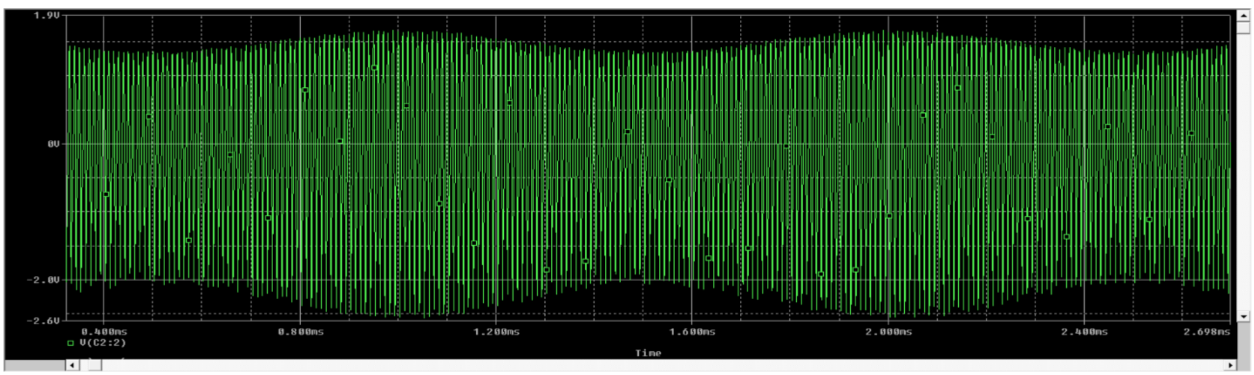


2. Frequency domain:

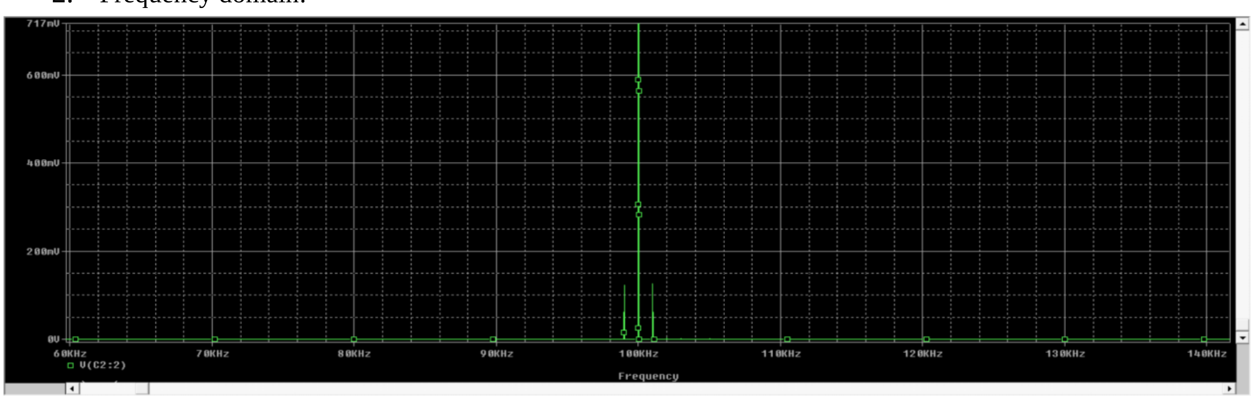


❖ **Modulated signal**

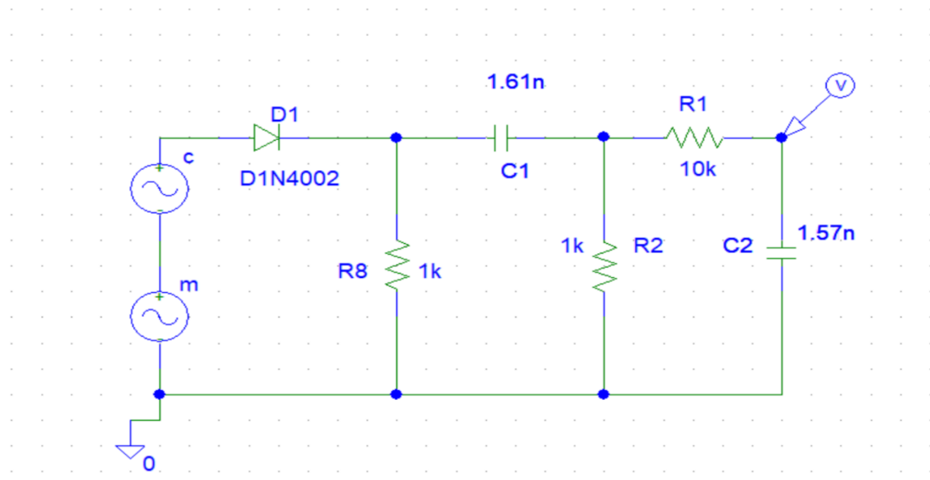
1. Time domain:



2. Frequency domain:



- ➢ This is the full design modulated Normal AM Modulator:



Part 2: Normal AM Demodulator.

2.1 In the envelope detector the same principle is used by adding a diode and write it's Fourier transform we see that it has the m(t) and other components multiplied by the c(t) shifted. and by applying it to low pass filter we can recover the message. We need the filter out 2fc and keep fc so f3dbh = fm = 1000 Hz

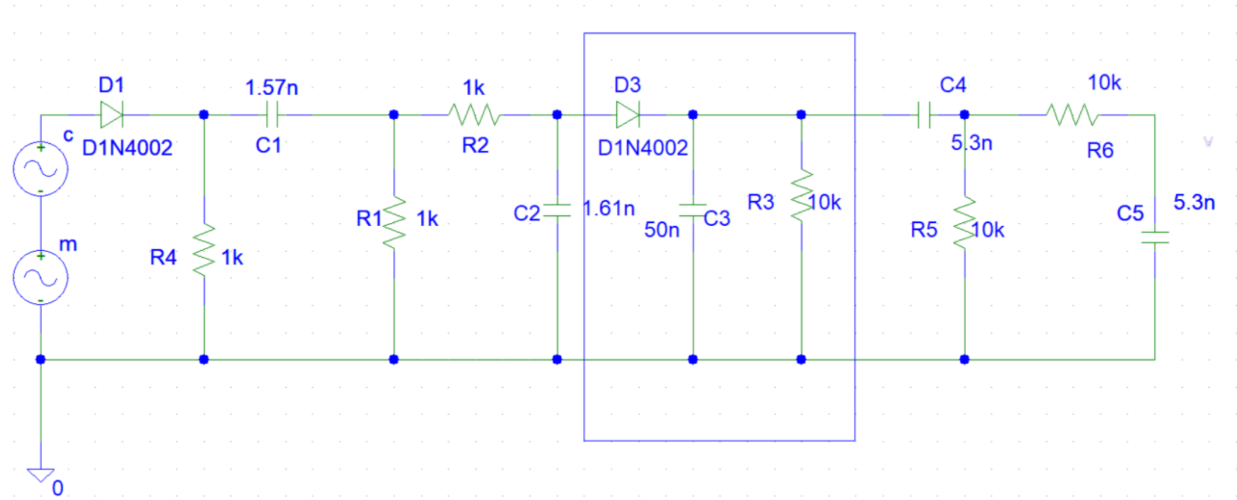
We need to use a 1/fc << RL << 1/fm

C = 1/ (2 π R f3db) = 1/ (20 π * 10^6) = 16 nf.

But we know that for better results: 1/fc << Rl * C << 1/ (band width) m

So, we need to take a value that fits with these priorities let take (1/fc + 1/bwm)/2 = 1/10^5 + 1/10^3 which will give us after multiplying it with Rl = 10 KΩ the best value of c which is equal to 50 nf

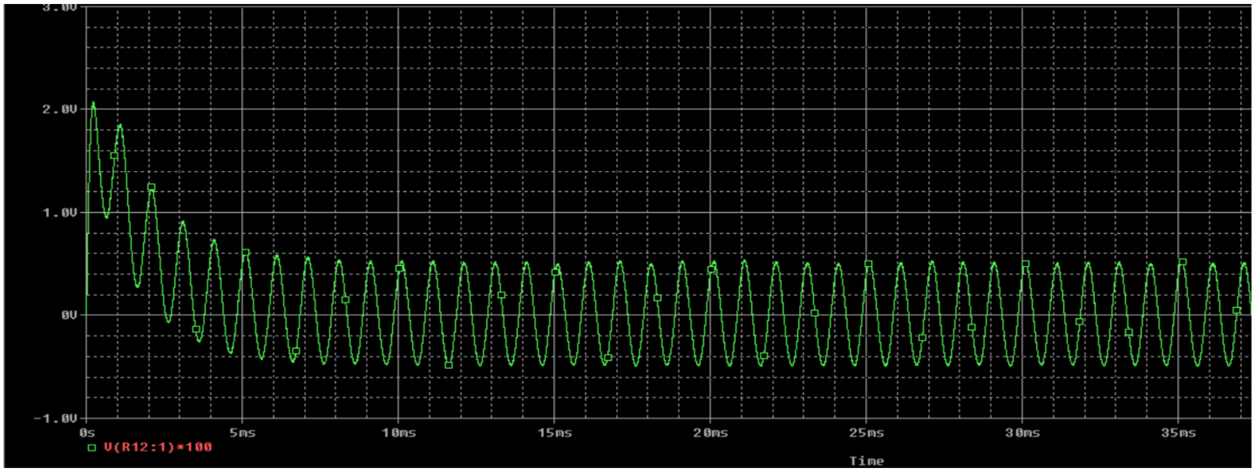
So, we are considering C = 50 nf



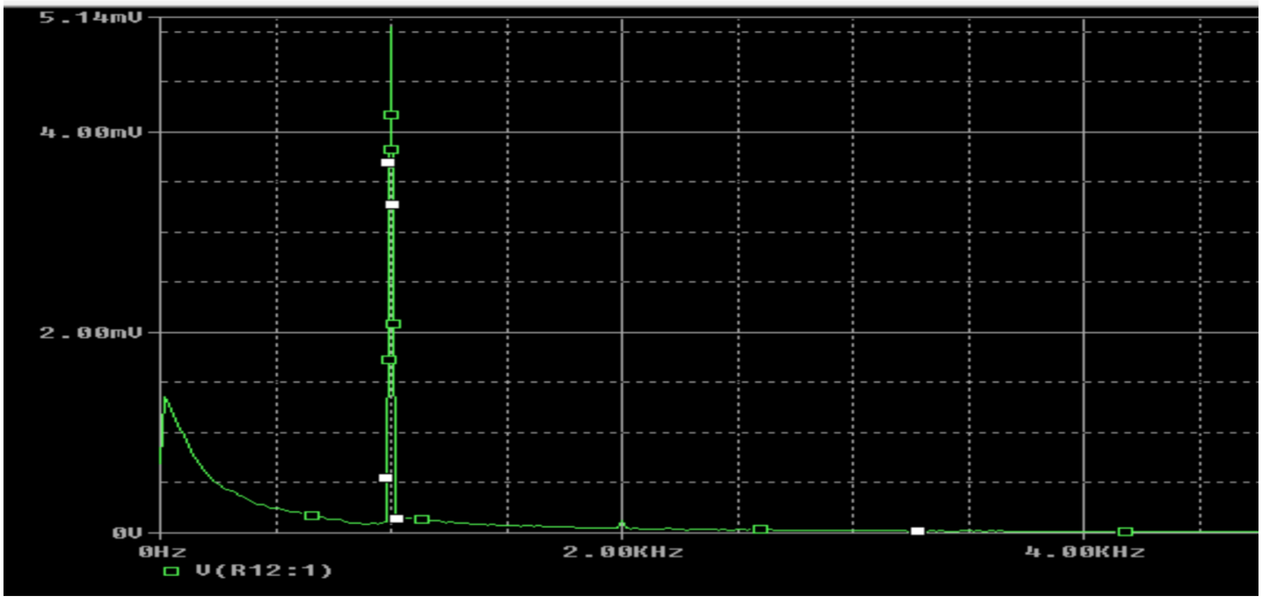
2.2 Now to make more accurate results, we need to use another band pass filter which resistor are equal to 10 KΩ and we can calculate capacitance values by using c = 1/ (2 π R f) and approximations

C1 = 5.3nf, c2 = 5.3nf. Finally, we can get back our message signal in a good shape.

1. Time domain:



2. Frequency domain:



Based on your observation, it seems that the Amplitude Modulation (AM) system was successful in transmitting the desired message. The demodulated message spectrum only contains a single harmonic with a frequency of 1000 Hz. The noise around 0 represents the transition interval of the capacitor before it reaches the steady state.

the result message signal's phase is shifted by 90 due to the capacitor effect.

Conclusion:

In conclusion, we have applied the principles and techniques of modulation to create an Amplitude Modulation (AM) circuit. We designed a switching circuit with a bandpass filter to create a modulator and an envelope detector to create a demodulated circuit. We tested these designs using PSPICE by creating schematics for the circuit and making simulation figures for the results. After testing, we observed the effects of real-world applications and designs like the filter. Since we cannot create an ideal filter, we created another filter to smooth the demodulated signal and remove the DC component.

References:

1. Slides of Communication.
2. https://www.youtube.com/watch?v=ENy_zg9dX5c