BIRZEIT UNIVERSITY

**Faculty of Engineering and Technology**
**Electrical and Computer Engineering Department**


# COMMUNICATION SYSTEMS
# ENEE3309

## Course Project – Phase I Report

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## Introduction

In the intricate fabric of communication systems, there is a fundamental process, governed by the interplay of high-frequency carrier waves and vital information signals, which form the bedrock of communication, facilitating the transfer of data from one point to another through the orchestrated workings of a communication system. An electronic communication system serves as the conduit, transforming messages into electronic signals. These signals, modulated to embody the information they carry, ride upon carrier waves, traversing the space between sender and receiver. It is within this paradigm that the process of amplitude modulation (AM) emerges—a mechanism through which wave signals are transmitted by modulating their amplitudes. Which uses in particularly in the transmission of information through radio carrier waves. Its prevalence extends across various realms of electronic communication, including portable two-way radios, citizens band radios, VHF aircraft radios, and computer modems. [1]

### Normal Amplitude Modulation (Normal AM): **Double Sideband Large Carrier DSB-LC**

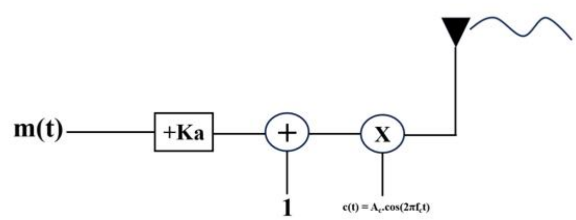
A normal amplitude-modulated signal is given by :

$$S(t)_{AM} = A_c\,[1+Ka.m(t)]\cos(2\pi f_c t)$$

where Ac is the carrier amplitude, $f_c$ is the carrier frequency, $K_a$ is the , and m(t ) is the modulating signal.

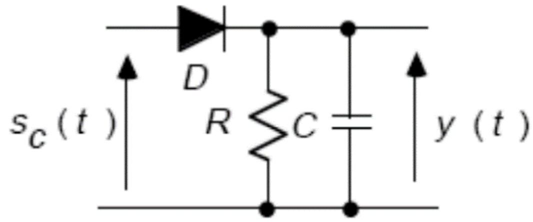
Modulating Signal or Message signal: $\mathbf{m(t) = A_m.\cos(2\pi f_m t)}$

Carrier Signal: $\mathbf{c(t) = A_c.\cos(2\pi f_c t)}$




### Demodulation of Normal AM Signals

The process of recovering the message signal from the modulated signal is called demodulation or detection are. By using Envelope Detection. In this method, an envelope detector is used to recover the message signal. An envelope detector consists of a diode and a resistor-capacitor combination.



## Problem Specification

The problem in the first part of the project at hand involves the generation of a Normal Amplitude Modulation (AM) signal using a switching modulator. The modulating signal, denoted as m(t), and the carrier signal, represented by c(t), are expressed in both the time and frequency domains. Additionally, the switching signal p(t), defined by the piecewise function f(x), introduces diode switching characteristics. The aim is to determine the complex exponential Fourier series of the switching signal p(t) using the fundamental period $Tc$ of the carrier signal c(t). After the modulation process, the output modulated signal s(t) is derived. The design of an appropriate bandpass filter is integral to generating the desired Normal AM modulation expressed by $\boldsymbol{s(t)}$. This involves the expression $\mathbf{2}\ [\mathbf{1} + \mathbf{0.8}\ \mathbf{cos}(\mathbf{2}\boldsymbol{\pi}\mathbf{103}\boldsymbol{t})]\ \mathbf{cos}(\mathbf{2}\boldsymbol{\pi}\mathbf{104}\boldsymbol{t})$.

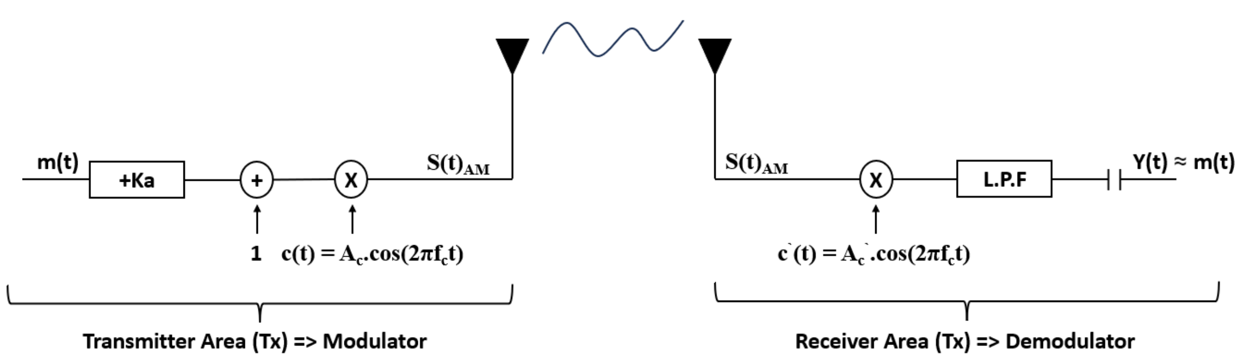
After that we will write a MATLAP codes to prove the solution of m(t) and c(t) in both time and frequency domain. And then design a circuit in PSpice to Simulink the generator of modulated signal.

The problem in the second part of the project involves the demodulation of the modulated signal using an envelope detector to recover the original message signal. Where we will design of the envelope detector which is crucial for this process. The demodulated output signal will be plotted and analyzed in both the time and frequency domains, providing insights into the effectiveness of the demodulation process.

This comprehensive investigation aims to simulating, constructing, and monitoring AM signals in both the time and frequency domains and bridging theoretical concepts with practical application.

## Solution

**Normal AM Modulator and Demodulator:**



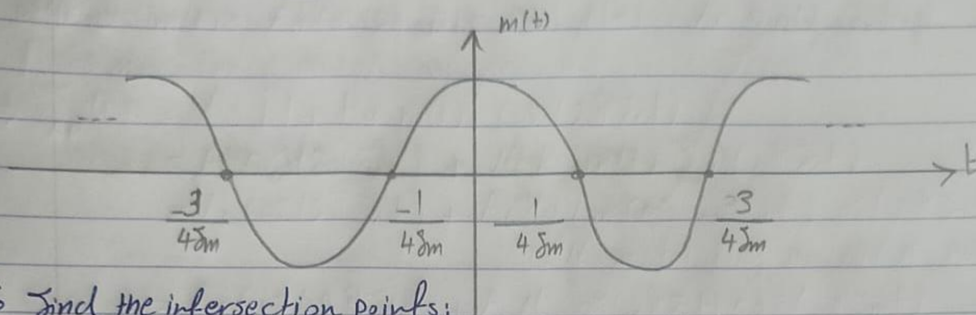
## Part 1: Normal AM modulation.

**1.1**

1.1 Express modulating signal m(t) and carrier signal c(t) in time domain and frequency domain.

* Modulating signal (or message signal) m(t):

- In time domain: $m(t) = A_m \cos(2\pi f_m t)$.



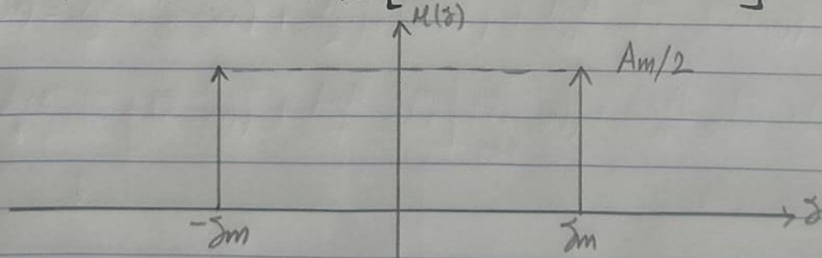

To find the intersection points:

$\cos(\theta) = 0$ when $\theta = \frac{\pm\pi}{2}, \frac{\pm 3\pi}{2}, \ldots$

$\Rightarrow 2\pi f_m t = \frac{\pm\pi}{2} \Rightarrow t = \frac{\pm 1}{4f_m}$. $\Rightarrow 2\pi f_m t = \frac{\pm 3\pi}{2} \Rightarrow t = \frac{\pm 3}{4f_m}$

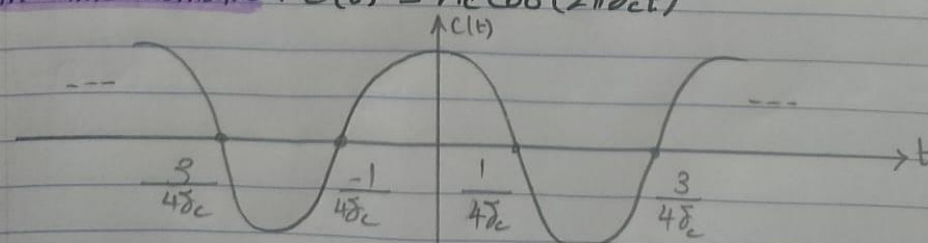
- In frequency domain: to find m(t) in frequency domain apply Fourier Transform.

$$M(f) = \frac{A_m}{2}\left[\delta(f-f_m) + \delta(f+f_m)\right]$$




* Carrier signal c(t):

- In time domain: $C(t) = A_c \cos(2\pi f_c t)$



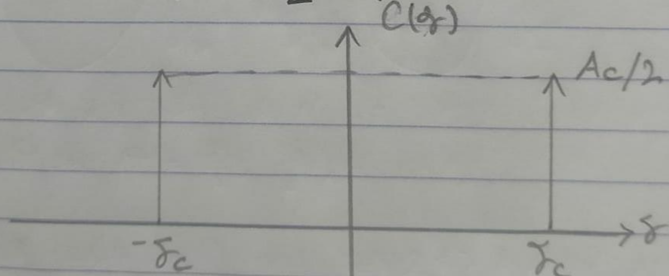
To find the intersection points:

$\cos(\theta) = 0$ when $\theta = \pm \frac{\pi}{2}, \pm \frac{3\pi}{2}, \ldots$

$\Rightarrow 2\pi f_c t = \pm\frac{\pi}{2} \Rightarrow t = \frac{\pm 1}{4 f_c}$. $\quad 2\pi f_c t = \pm\frac{3\pi}{2} \Rightarrow t = \pm\frac{3}{4 f_c}$.

In frequency domain: to find $c(t)$ in frequency domain apply Fourier Transform.

$$C(f) = \frac{A_c}{2}\delta(f - f_c) + \frac{A_c}{2}\delta(f + f_c).$$

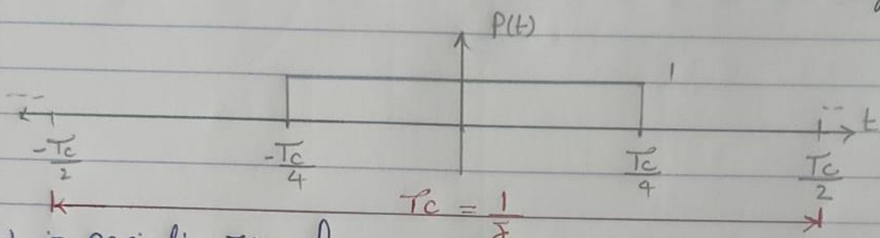



**1.2**

1.2 Assume the diode switching signal $p(t)$ is given by:

$$p(t) = f(x) = \begin{cases} 1, & -\frac{T_c}{4} \le x \le \frac{T_c}{4} \\ 0, & -\frac{T_c}{4} \le x \le -\frac{T_c}{4} \\ 0, & \frac{T_c}{4} < x \le \frac{T_c}{2} \end{cases}$$

Where $T_c$ denotes the fundamental period of carrier signal $c(t)$. Determine the complex exponential Fourier series of the signal $p(t)$.



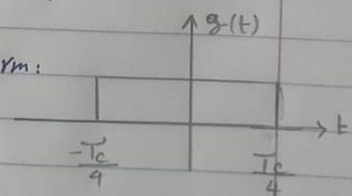

$p(t)$ is periodic signal.

* Exponential Fourier Series of p(t): $p(t) = \sum_{n=-\infty}^{\infty} P_n e^{jn\omega_c t}$, $\omega_c = 2\pi f_c$.

wher $P_n$ is the complex coeffecient exponential fourier series:

$P_n = f_c \, G(n f_c)$, where g is one period signal.

$g(t) = \Pi\left(\frac{2}{T_c} t\right)$, applying Fourier Transform:




$G(f) = \frac{T_c}{2} \operatorname{sinc}\left(\frac{T_c f}{2}\right)$, now substitute $f = n f_c \Rightarrow$

$$G(n f_c) = \frac{T_c}{2} \operatorname{sinc}\left(\frac{T_c n f_c}{2}\right) = \frac{T_c}{2} \operatorname{sinc}\left(\frac{n}{2}\right).$$

Then $P_n = f_c G(n f_c) = f_c \cdot \frac{T_c}{2} \operatorname{sinc}\left(\frac{n}{2}\right) = \frac{1}{2} \operatorname{sinc}\left(\frac{n}{2}\right)$.

So, $P(t) = \sum_{n=-\infty}^{\infty} \frac{1}{2} \operatorname{sinc}\left(\frac{n}{2}\right) e^{j2\pi f_c n t}$.

**1.3**

1.3 Evaluate the output modulated signal s(t).

* modulated signal in Normal AM can expressed by:

$$s_{AM}(t) = A_c [1 + k_a . m(t)] \cos(2\pi f_c t)$$

where $m(t) = A_m \cos(2\pi f_m t)$ and $c(t) = A_c \cos(2\pi f_c t)$.

$$\begin{aligned}
\Rightarrow s_{AM}(t) &= A_c [1 + k_a . m(t)] \cos(2\pi f_c t). \\
&= A_c \cos(2\pi f_c t) + A_c k_a m(t) \cos(2\pi f_c t) \\
&= A_c \cos(2\pi f_c t) + A_c k_a A_m \cos(2\pi f_m t) \cos(2\pi f_c t).
\end{aligned}$$

↳ $\mu$: modulating index ($\mu = k_a A_m$).

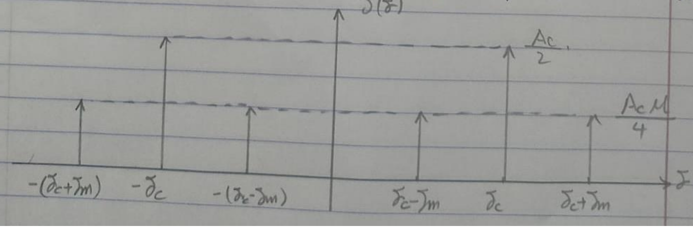
$$= A_c \cos(2\pi f_c t) + A_c \mu \cos(2\pi f_c t) \cos(2\pi f_m t)$$

Remember that: $\cos(\alpha)\cos(\beta) = \frac{1}{2}\cos(\alpha+\beta) + \frac{1}{2}\cos(\alpha-\beta)$.

$$s_{AM}(t) = \underbrace{A_c \cos(2\pi f_c t)}_{\text{Carrier}} + \underbrace{\frac{A_c \mu}{2} \cos(2\pi (f_c + f_m) t)}_{\text{Upper side band}} + \underbrace{\frac{A_c \mu}{2} \cos(2\pi (f_c - f_m) t)}_{\text{Lower side band}}.$$

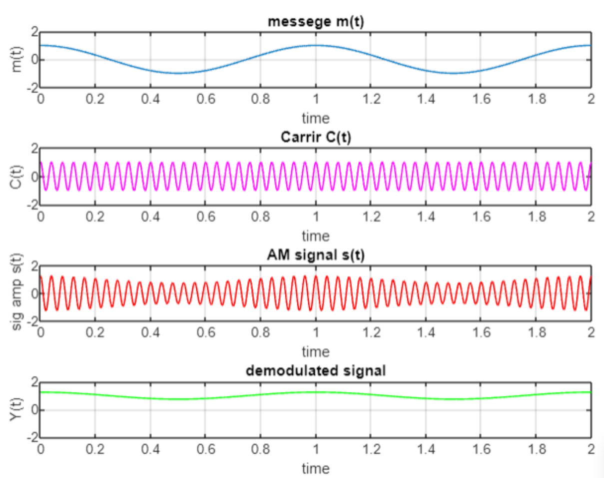
If we need to find it in frequency domain apply Fourier transform:

$$S(f) = \frac{A_c}{2}\delta(f-f_c) + \frac{A_c}{2}\delta(f+f_c) + \frac{A_c M}{4}\delta(f-(f_c+f_m)) +$$
$$\frac{A_c M}{4}\delta(f+(f_c+f_m)) + \frac{A_c M}{4}\delta(f-(f_c-f_m)) + \frac{A_c M}{4}\delta(f+(f_c-f_m)).$$




Matlab code to check our solution in 1.1, 1.2, and 1.3:

```
t= 0:0.001:2;
fc=25;
fm=1;
m=0.25;
Ac=1;
mt= cos(2 * pi * fm * t);
ct= cos( 2 * pi * fc * t);
st= Ac* ct .* (1 + m.*mt);
subplot(4,1,1);
plot(t,mt);
axis([0 2 -2 2]);
title('messege m(t)');
xlabel('time');
ylabel('m(t)');
grid on;
%***********
subplot(4,1,2);
plot(t,ct,'m');
axis([0 2 -2 2]);
title('Carrir C(t)');
xlabel('time');
ylabel('C(t)');
grid on;
%***********
subplot(4,1,3);
plot(t,st,'r');
axis([0 2 -2 2]);
title('AM signal s(t)');
xlabel('time');
ylabel(' sig amp s(t)');
grid on;
%***********
absm=(1 + m.*mt);
env= abs(absm);
subplot(4,1,4);
plot(t,env,'g');
axis([0 2 -2 2]);
title('demodulated signal');
xlabel('time');
ylabel('Y(t)');
grid on;
```



## 1.4

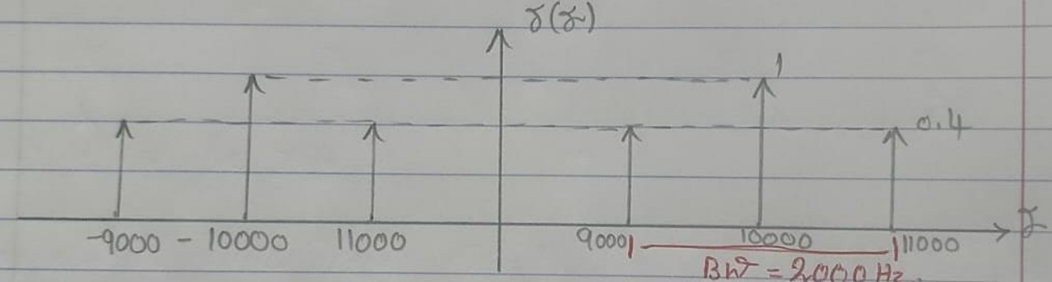
1.4 Design a suitable band pass filter to generate normal AM modulation expressed below.

$$s(t) = 2\left[1 + 0.8\cos(2\pi 10^3 t)\right]\cos(2\pi 10^4 t).$$

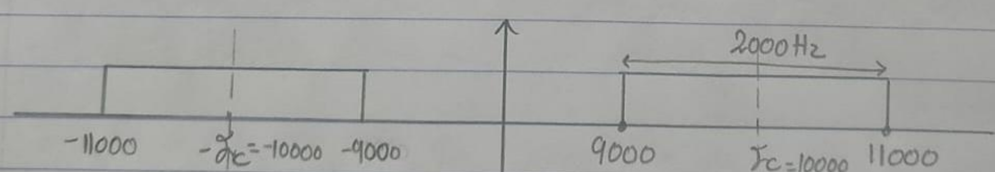
$$s(t) = 2\left[1 + 0.8\cos(2\pi 10^3 t)\right]\cos(2\pi 10^4 t)$$
$$= 2\cos(2\pi 10^4 t) + 1.6\cos(2\pi 10^4 t)\cos(2\pi 10^3 t).$$
$$= 2\cos(2\pi 10^4 t) + 0.8\cos(2\pi 11000 t) + 0.8\cos(2\pi 9000 t).$$

now apply Fourier Transform to find $s(t)$ in frequency domain:

$$S(f) = \delta(f - 10^4) + \delta(f + 10^4) + 0.4\,\delta(f - 11000) + 0.4\,\delta(f + 11000)$$
$$+ 0.4\,\delta(f - 9000) + 0.4\,\delta(f + 9000).$$




Band width of $s(t)$ is 2000 Hz.




Band pass filter with/of center $f_c = 10000$ and width = 2000 Hz.

to find the value of the capacitor in B.P.F:

$$f_{3dB} = \frac{1}{2\pi RC}$$

using RC to get BW = 2KHz.

BW = $f_{3dB}$ = 2KHz.

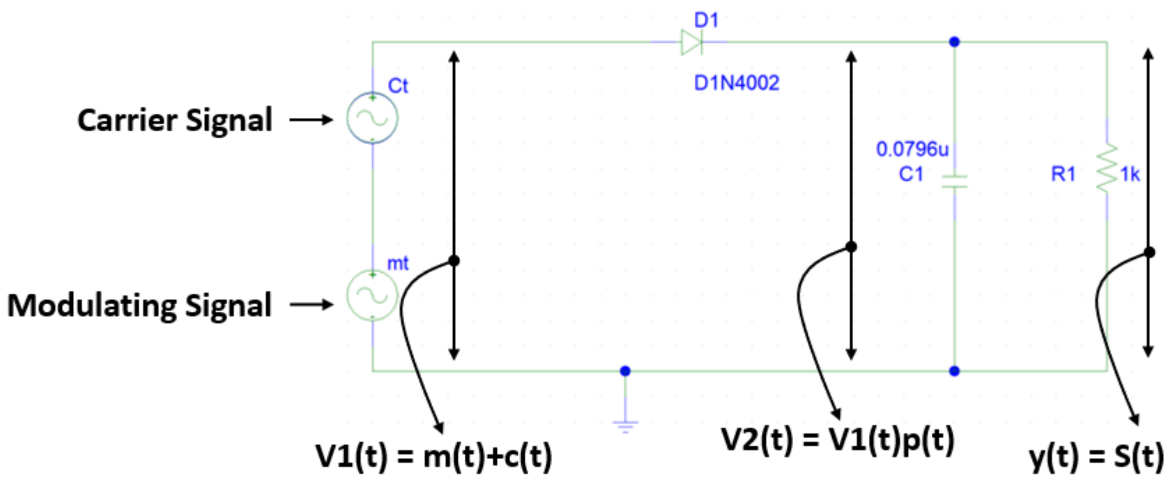
Then:

$$2\,KHz = \frac{1}{2\pi RC}, \quad \text{let } R = 1K\Omega.$$
$$2\,KHz = \frac{1}{2\pi C}$$
$$4K\pi C = 1$$
$$C = \frac{1}{4K.\pi} = 0.0796\,\mu$$

**1.5**

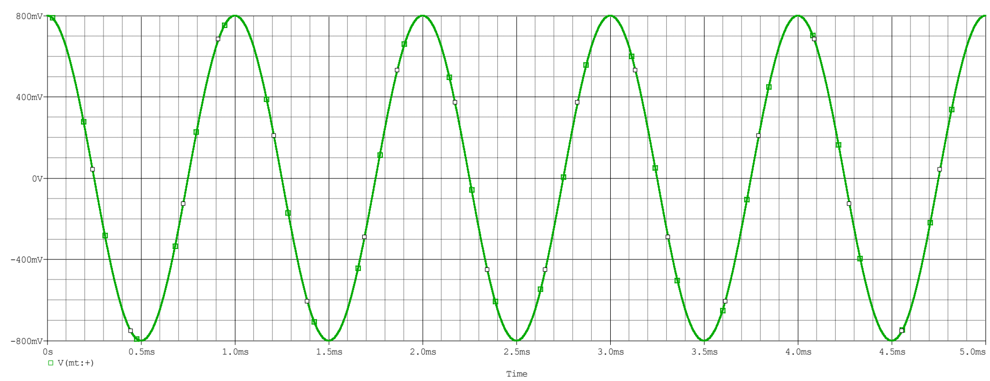
Use Pspice software to plot the modulating signal, carrier signal, switching signal, and modulated signal in the time domain and frequency domain. Explain your results.

Modulation Generator Circuit in Pspice:

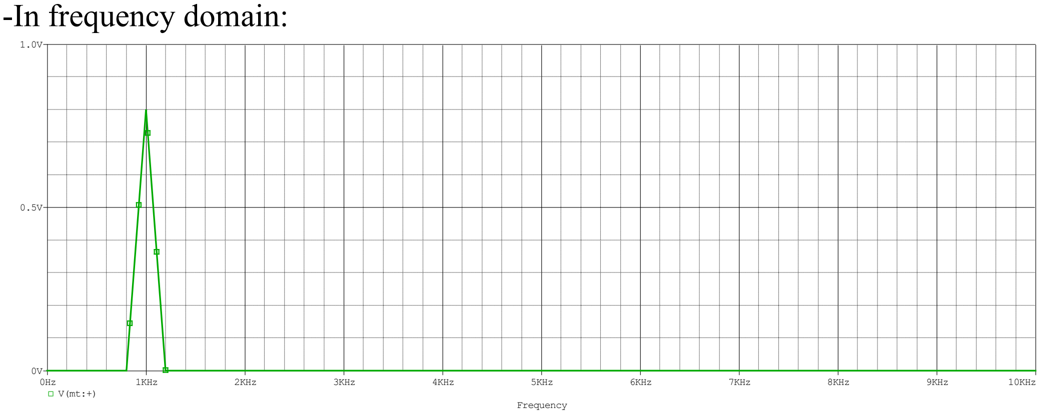



⇨ **Modulating signal:**

-In time domain:

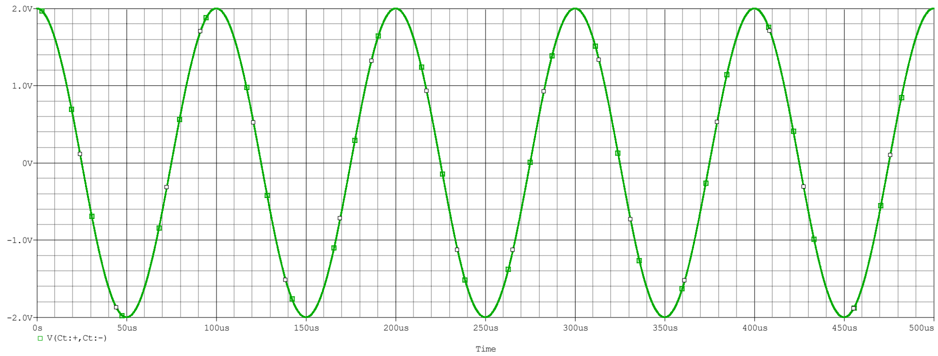



-In frequency domain:

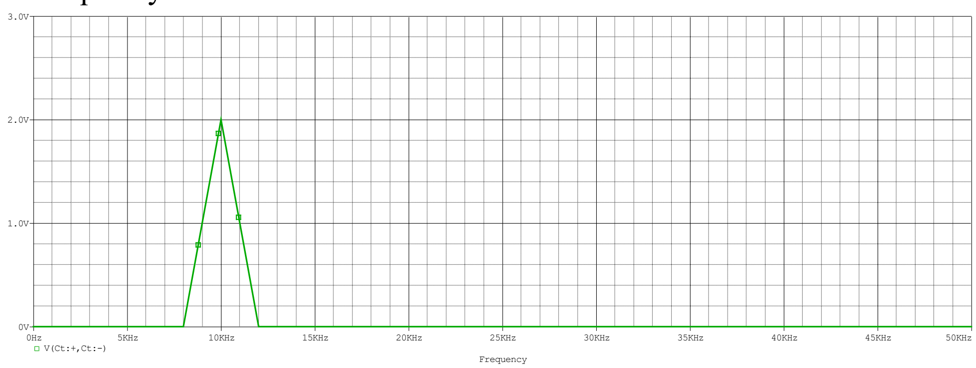


⇨ **Carrier signal:**

-In time domain:

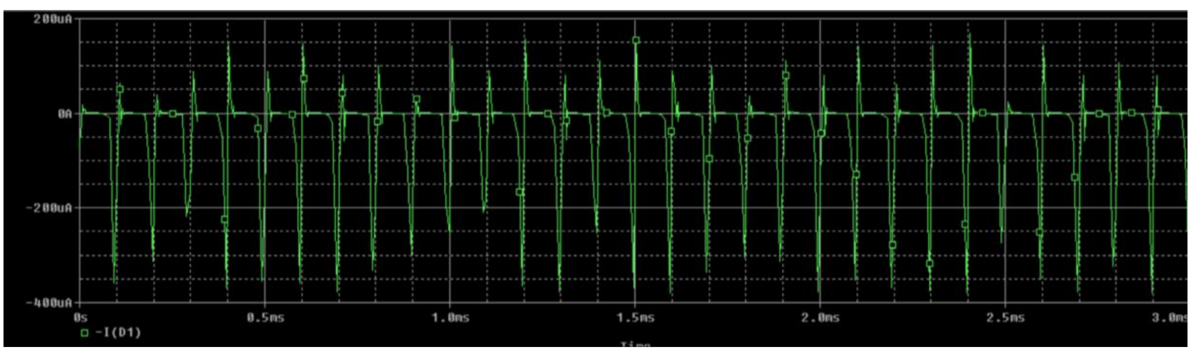



-In frequency domain:

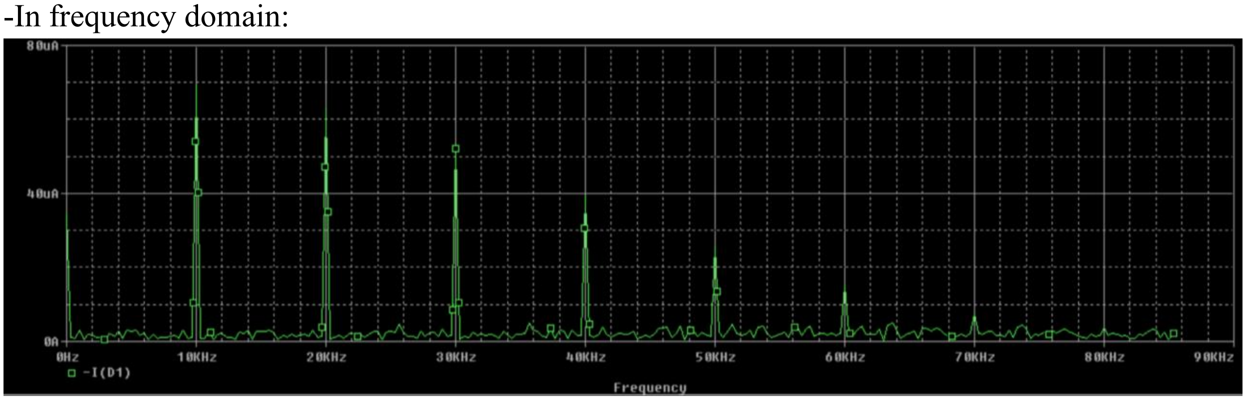



⇨ Switching signal:

-In time domain:

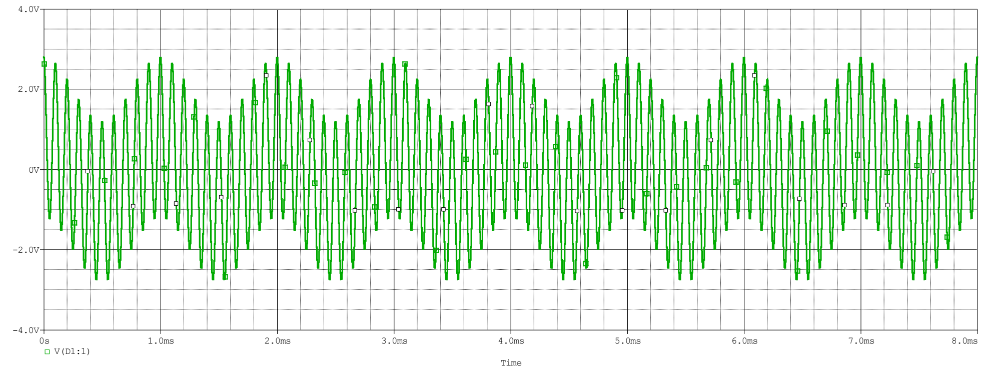



-In frequency domain:

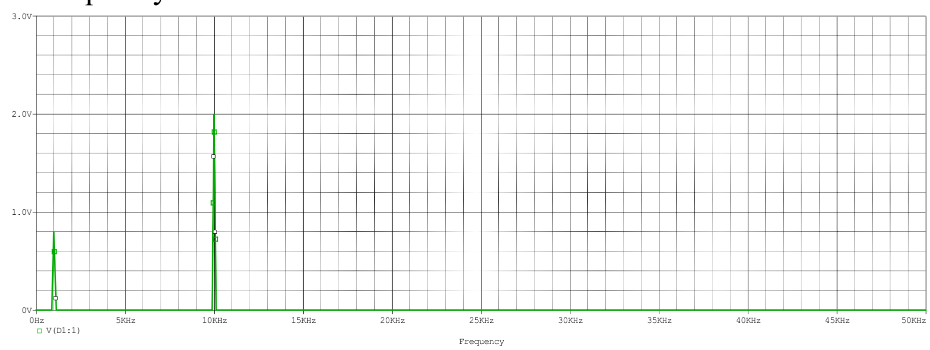


➩ Modulated signal:

-In time domain:

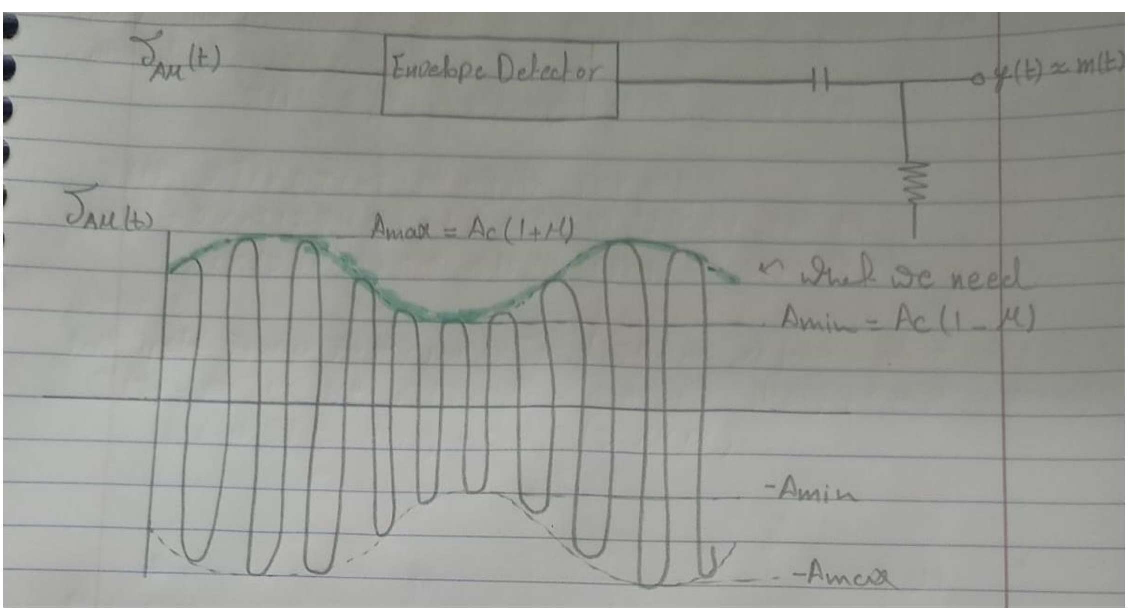


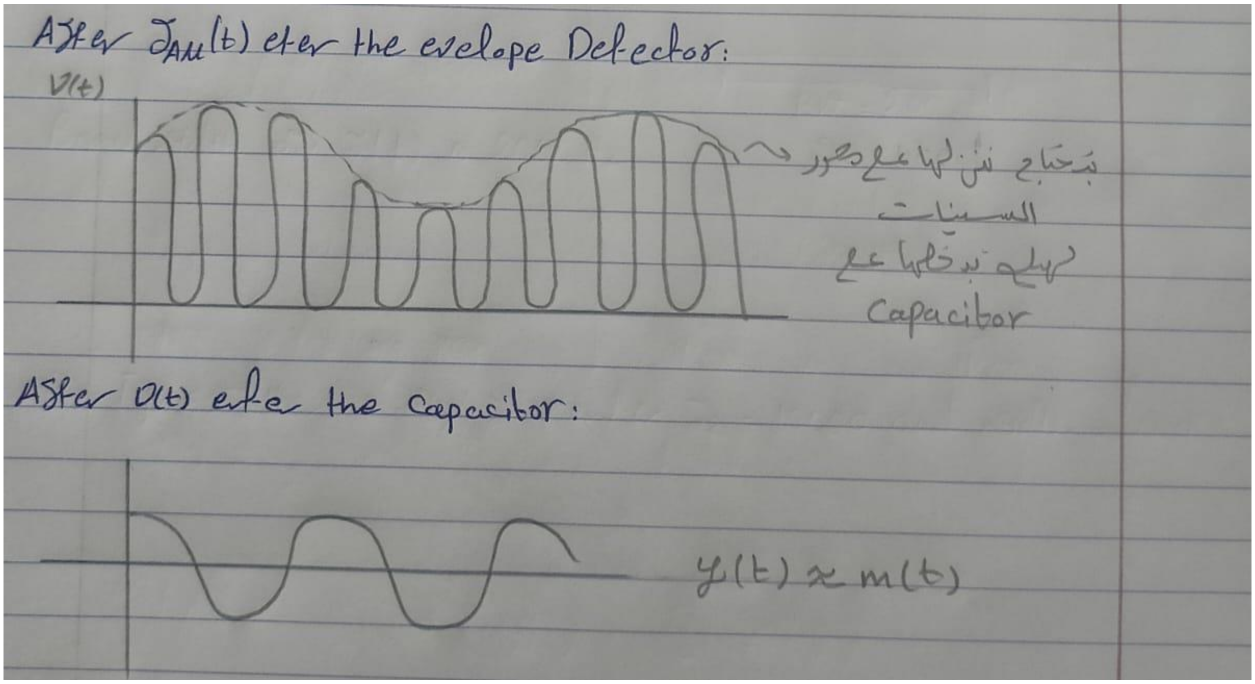

-In frequency domain:



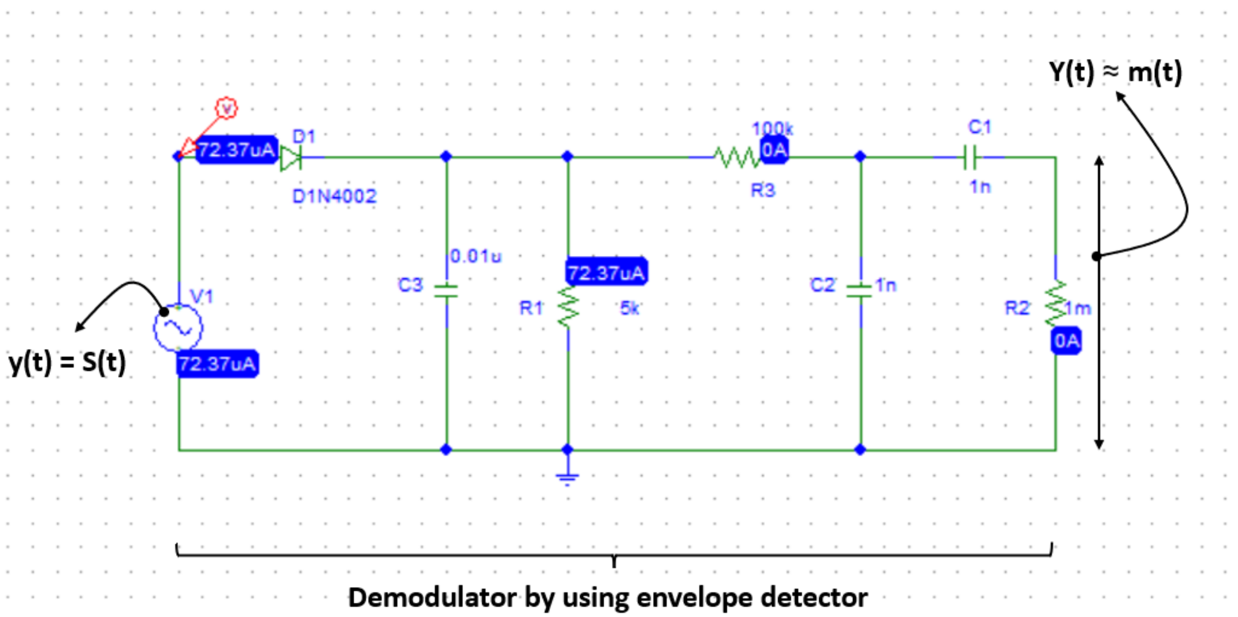

## Part 2: Normal AM demodulation.

To recover the message signal from the modulated signal, use an envelope detector.



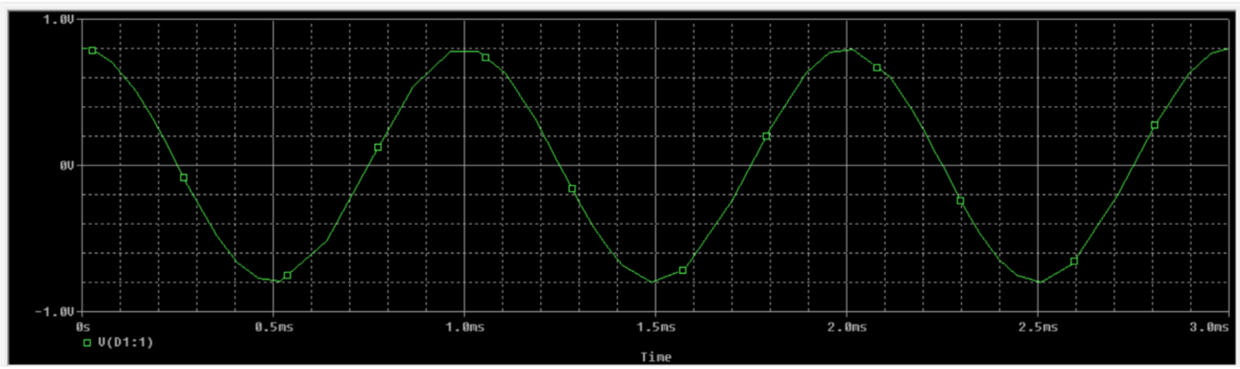

After $\delta_{AM}(t)$ eter the evelope Detector:
$V(t)$
بتحتاج نشيلها عن محور السينات
لهيك بندخلها ع
Capacitor
After $D(t)$ eter the capacitor:
$y(t) \approx m(t)$

**2.1**

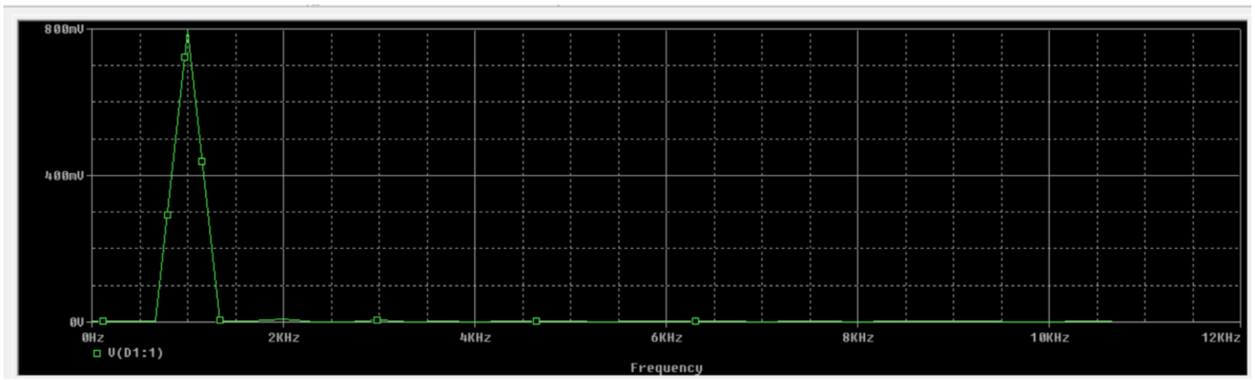

Y(t) ≈ m(t)
D1
72.37uA
D1N4002
100k
0A
R3
C1
1n
0.01u
C3
72.37uA
R1
5k
C2
1n
R2
1m
0A
V1
y(t) = S(t)
72.37uA
Demodulator by using envelope detector

**2.3**

⇨ Modulated signal:
-In time domain:




-In frequency domain:



## Conclusion

In conclusion, modulation and demodulation are essential processes in communication systems. Modulation the efficient transmission of information by encoding it onto carrier signals, enabling various forms of communication such as radio, television, and wireless networks. On the other hand, demodulation is the counterpart that extracts the original information from modulated signals at the receiver end. Together, these processes form the backbone of modern communication, ensuring the reliable exchange of data in diverse applications. Understanding modulation and demodulation is fundamental for designing and optimizing communication systems that underpin our interconnected world.

## References

[1]: Amplitude Modulation - Definition, Types, Solved Examples, AM Uses (byjus.com)

[2]: Principle of Communications (uotechnology.edu.iq)