National University of Computer and Emerging Sciences, Lahore Campus

	Course:	Analog and Digital Communications	Course Code:	EE3003
	Program:	BS (Electrical Engineering)	Semester:	Fall 2024
	Exam:	Assignment 4	Page(s):	2
	Chapter(s):	5 (Angle Modulation)	Section:	ALL
	Submission Date:		CLO:	04
	Instructor(s):	Dr. S. M. Sajid, Mohsin Yousuf	Total Marks:	100

Question # 1 [CLO 04] **[10+10]**

FM Demodulation & Filtering

(a) **Discuss** in detail the Demodulation of FM using

  i. Slope Detection Method

  ii. Zero-Crossing Detector

  iii. Phase Locked Loop (PLL)

(b) **Explain** the use of pre-emphasis and de-emphasis filters in FM radio transmission.

Question # 2 [CLO 04] **[5+5+5+5]**

Exponential Modulation Parameters

An angle modulated signal with carrier frequency $\omega_c = 2\pi \times 10^6$ rad/s is described by the equation

$$\varphi_{EM}(t) = 5\cos(\omega_c t + 10\cos 2000\pi t)$$

a) **Find** the power of the modulated signal.

b) **Find** the approximate band of frequencies occupied by EM waveform.

c) **Find** the phase deviation $\Delta\phi$.

d) **Estimate** the bandwidth of $\varphi_{EM}(t)$.

Question # 3 [CLO 04] **[4+4+6+6]**

Frequency and Phase Modulation

A baseband signal $m(t)$ is the periodic sawtooth signal shown in Figure 1. Where $\omega_c = 2\pi \times 10^6$, $k_f = 2000\pi$, and $k_p = \pi/2$.

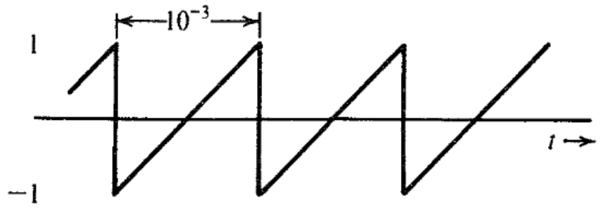

Figure 1. A periodic sawtooth waveform

(a) **Write** equations for $\varphi_{FM}(t)$ and $\varphi_{PM}(t)$.

(b) **Determine** the frequency deviation Δf.

(c) **Estimate** the bandwidth of the angle modulated signal. Assume the bandwidth of $m(t)$ to be the fifth harmonic frequency of $m(t)$.

(d) **Sketch** $\varphi_{FM}(t)$ and $\varphi_{PM}(t)$ for this signal $m(t)$

Question # 4 [CLO 04] **[10+10]**

Demodulation

Over an interval $|t| \leq 1$, an angle modulated signal is given by

$$\varphi_{EM}(t) = 10\cos(15{,}000\pi t)$$

It is known that the carrier frequency $\omega_c = 10{,}000\pi$.

a) If this were an PM signal with $k_p = 100$, **determine** $m(t)$ over the interval $|t| \leq 1$.

b) If this were an FM signal with $k_f = 100$, **determine** $m(t)$ over the interval $|t| \leq 1$.

Question # 5 [CLO 04] **[5+5+5+5]**

Demodulation of FM

A periodic square wave $m(t)$ (Fig.2 a) frequency-modulates a carrier of frequency $f_c = 20$ kHz with $\Delta f = 2$ kHz. The carrier amplitude is A. The resulting FM signal is demodulated, as shown in (Fig.2 b) by the *direct differentiation method (slope detection)*. **Sketch** the waveforms at points *b*, *c*, *d*, and *e*.

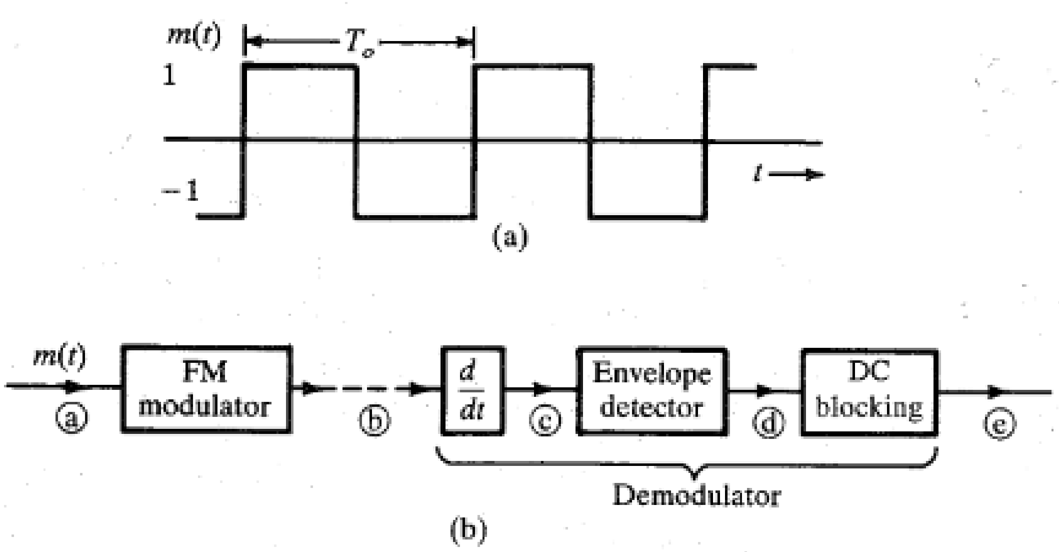

Figure 2. A message signal m(t) with FM Demodulator

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Analogue & Digital Communication

Assignment #04

Q. No. 1

(a)

Demodulation of FM.

i) Slope-Detection Method

The slope detection method is a simple technique for demodulating FM signals. It converts frequency variations in the FM signal into amplitude variations, which can then be extracted using an envelop detector.

The FM signal is first passed through a band-pass filter that is slightly detuned from the carrier frequency. This detuning introduces a frequency-dependent gain, causing the amplitude of output signal to vary with frequency. The steepest slope of the filter's response corresponds to maximum sensitivity to frequency variation.

The amplitude-modulated signal at the output of tuned circuit is then passed through an envelop detector. This extracts the amplitude variations, which correspond to the orignal modulating signal. A low-pass filter is used to remove any high-frequency, leaving only the recovered baseband signal.

ii) Zero-Crossing Detector

Zero-Crossing Detector is a technique that extracts the original signal from an FM signal by analyzing the rate of zero-crossings in signal waveform. It is based on the principle that frequency of FM signal is proportional to rate of its zero-crossings.

The detector identifies the points where FM signal crosses the zero-voltage level (both +ive to -ive and -ive to +ive transitions). The time interval b/w successive zero-crossings are measured which are inversly proportional to the instantaneous frequency of the FM signal.

For every crossing detected, a pulse is generated, the width of which corresponds to the instantaenous frequency of FM signal.

The pulse train is passed through a low-pass filter to convert frequency information into a corresponding voltage. This output voltage is proportional to the instantaneous frequency of the FM signal and is thus, the orignal modulating signal.

iii) Phase Locked Loop (PLL)

Demodulating FM using PLL is widely used and effective method due to its accuracy, linearity and ability to handle noise.

PLL include a phase detector, a low-pass filter, a voltage-controlled oscillator and a feedback loop.

The FM signal is fed into the phase detector. It adjusts the VCO frequency to match the inst. frequency of the FM signal. The phase detector detects differences b/w input FM signal's phase and the VCO's output phase.

The phase difference, after low-pass filtering, corresponds to the frequency variations of FM signal, which are proportional to the original modulating signal. This filtered phase-detector output is the demodulating signal, consequently the original baseband signal.

(b)

Purpose of Pre-emphasis & De-emphasis

Pre-emphasis and de-emphasis are essential components ~~of~~ in FM-radio transmission. They improve the signal-to-noise ratio of the transmission by addressing the effects of high frequency noise.

In FM transmission, high-frequency components of audio signal are more susceptible to noise compared to low-frequency components. To counteract this, the system boosts high-frequency components before transmission (pre-emphasis) and attenuates them back to original level during reception (de-emphasis).

Pre-emphasis is the process of amplifying the high-frequency components of the modulating signal before FM modulation. It consists of a high-pass filter, typically designed with a time constant. It boosts higher frequencies relative to lower ensuring that high-frequency components are transmitted with greater strength.

De-emphasis is inverse process of pre-emphasis. It attenuates the high-frequency components of the recieved signal back to original levels using a low-pass filter, of same time constant.

Combined, the overall system improves the SNR for high-freq. components, enhancing quality of recieved audio.

Time-Constant : $\tau = RC$

Cut-off frequency : $f_c = \dfrac{1}{2\pi\tau}$

Q. No. 2

$$\varphi_{EM}(t) = 5\cos(\omega_c t + 10\cos 2000\pi t)$$

$\omega_c = 2\pi \times 10^6$ rad/s

(a)
Power

As $P = \frac{A^2}{2}$

$$= \frac{5^2}{2} = \frac{25}{2}$$

$$\boxed{P = 12.5\ W}$$

(b)
Approx. Band of Frequency

For f_c;

$$\omega_c = 2\pi f_c$$

$$f_c = \frac{\omega_c}{2\pi} = \frac{\cancel{2\pi} \times 10^6}{\cancel{2\pi}}$$

$$f_c = 10^6\ Hz$$

For f_m;

$$f_m = \frac{\omega_m}{2\pi} = \frac{2000\cancel{\pi}}{2\cancel{\pi}}$$

$$f_m = 1000\ Hz$$

For Δf;

$$\Delta f = \beta f_m = (10)(1000)$$

$$\Delta f = 10{,}000\ Hz$$

As $B \cdot W = 2(\Delta f + f_m)$

$= 2(10000 + 1000)$

$$\boxed{B \cdot W = 22\ kHz}$$

(c)

Phase Deviation

$$\boxed{\Delta\phi = 10\ rad}$$

(d)

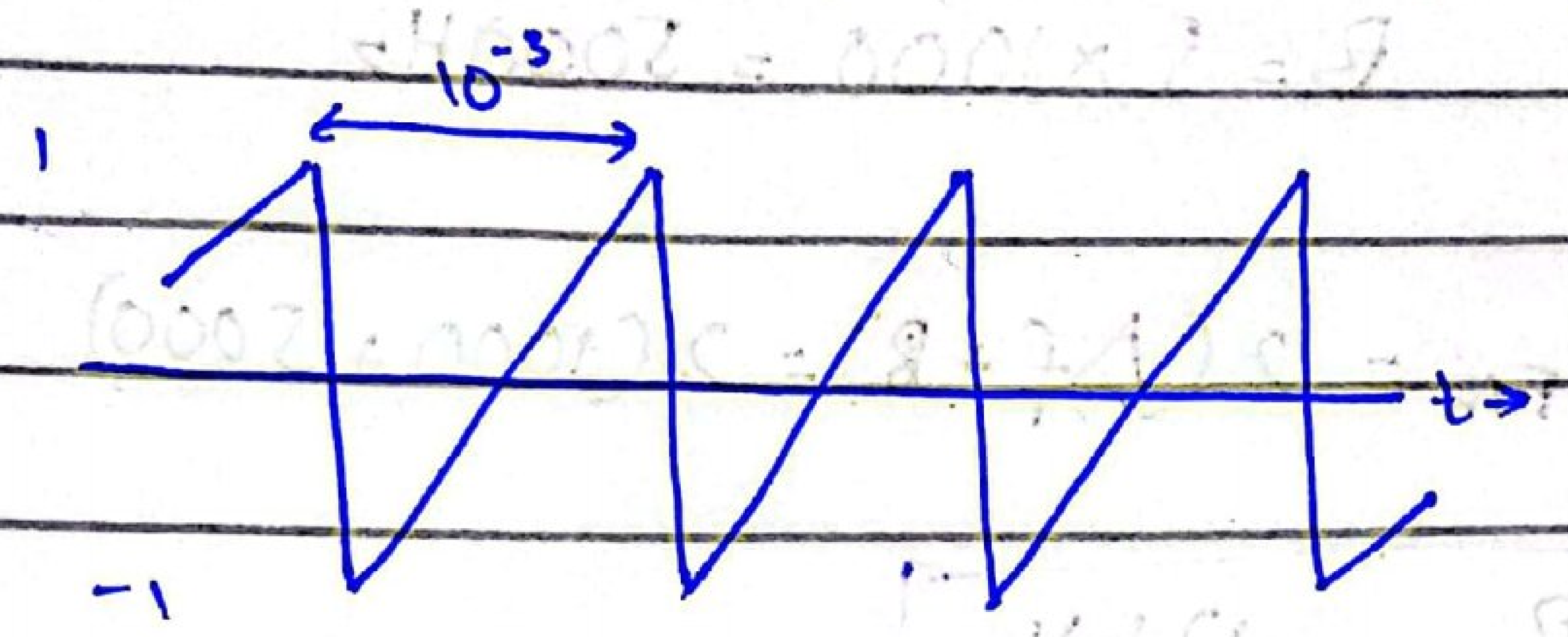
Bandwidth of $\phi_{EM}(t)$

As calculated earlier,

$$\boxed{B \cdot W = 22kHz}$$

Q. No. 3

$\omega_c = 2\pi \times 10^6$ rad/s ; $k_f = 2000\pi$; $k_p = \frac{\pi}{2}$



(a)

$\phi_{FM}(t)$ & $\phi_{PM}(t)$

As $\phi_{FM}(t) = A\cos\left[\omega_c t + k_f \int_0^t m(\alpha)\,d\alpha\right]$

$$\Rightarrow \boxed{\phi_{FM}(t) = \cancel{A} \cos\left[(2\pi \times 10^6)t + 2000\pi \int_0^t m(\alpha)\,d\alpha\right]}$$

As $\phi_{PM}(t) = A\cos\left[\omega_c t + k_p\, m(t)\right]$

$$\Rightarrow \boxed{\phi_{PM}(t) = \cos\left[(2\pi \times 10^6)t + \frac{\pi}{2} m(t)\right]}$$

(b)

Δf

As $\Delta f = \frac{k_f m_p}{2\pi}$

$= \frac{(2000\pi)(1)}{2\pi}$

$$\boxed{\Delta f = 1000\,\text{Hz}}$$

(c)
Bandwidth

For baseband signal bandwidth,

$$B = 5 \times 1000 = 5000\,Hz$$

$$\Rightarrow B_{FM} = 2(\Delta f + B) = 2(1000 + 5000)$$

$$\boxed{B_{FM} = 12\,kHz}$$

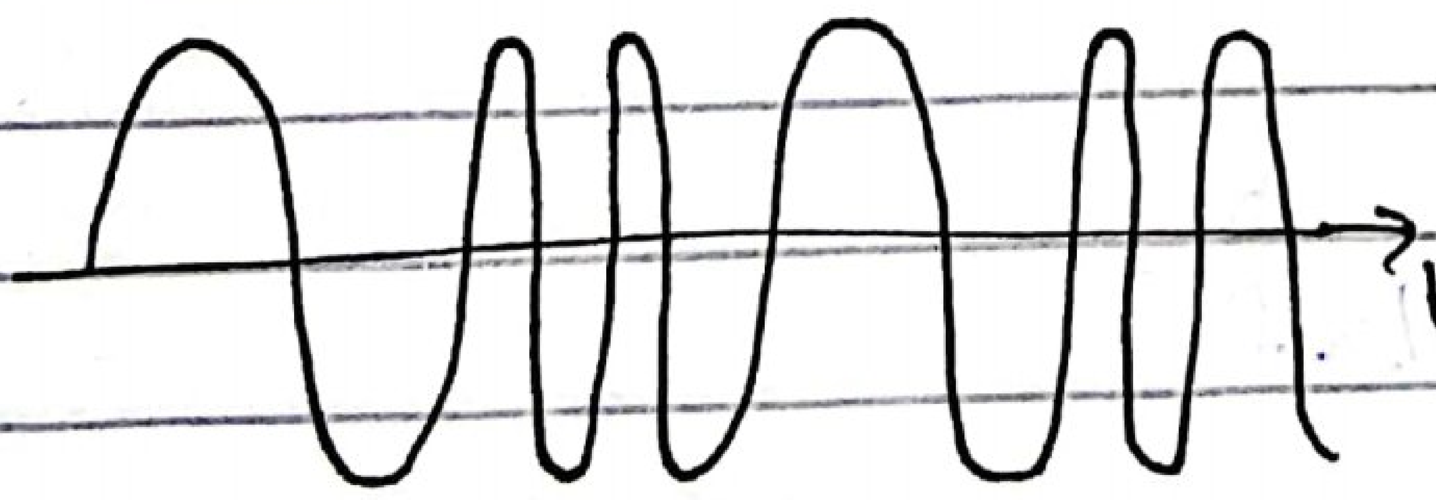
(d)

As $\Delta f = \frac{k_f m_p}{2\pi} = \frac{(2000\cancel{\pi})(1)}{2\cancel{\pi}} = 1000\,Hz$

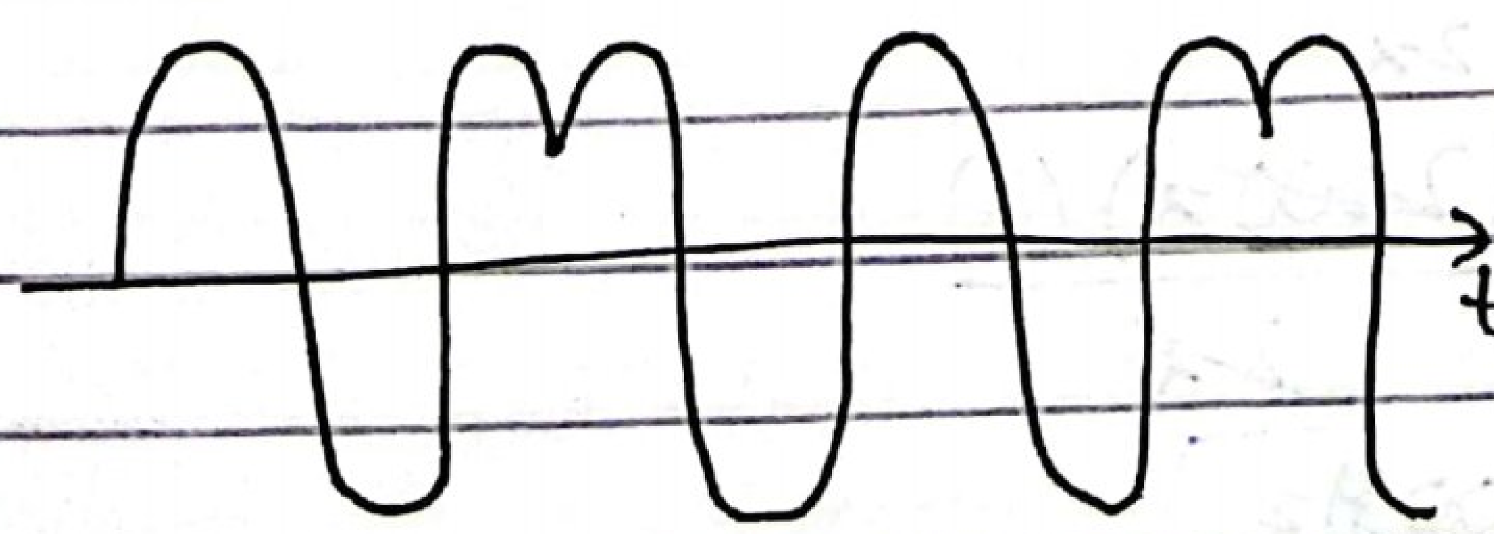
and $f_c = \frac{\omega_c}{2\pi} = \frac{2\cancel{\pi}\times 10^6}{2\cancel{\pi}} = 10^6\,Hz$

$$\Rightarrow f_{max} = f_c + \Delta f = 10^6 + 1000 = 1001\,kHz$$

$$\Rightarrow f_{min} = f_c - \Delta f = 10^6 - 1000 = 999\,kHz$$



$$\phi_{FM}(t) = \cos\left(2\pi\times 10^6 t + 2000\pi\int_0^t m(\alpha)\,d\alpha\right)$$



$$\phi_{PM}(t) = \cos\left[2\pi 10^6 t + \frac{\pi}{2} m(t)\right]$$

CamScanner

Q. No. 4

$\phi_{FM}(t) = 10\cos(15000\pi t)$

$\omega_c = 10000\pi$ rad/s

(a)

$k_p = 100$

For phase modulation,

$$\phi_{PM}(t) = A\cos(\omega_c t + k_p m(t))$$

$$\Rightarrow \omega_c t + k_p m(t) = 15000\pi t$$

$$10000\pi t + 100 m(t) = 15000\pi t$$

$$\cancel{100} m(t) = 50\cancel{00}\pi t$$

$$\boxed{m(t) = 50\pi t}$$

(b)

$k_f = 100$

For frequency modulation,

$$\phi_{FM}(t) = A\cos\left(\omega_c t + k_f \int_0^t m(\alpha)d\alpha\right)$$

$$\Rightarrow \omega_c t + k_f \int m(\tau)d\tau = 15000\pi t$$

$$10000\pi t + 100\int m(\tau)d\tau = 15000\pi t$$

$$\int m(\tau)d\tau = 50\pi t$$

By taking differential w.r.t t

$$\boxed{m(t) = 50\pi}$$

For Solving of m(t)

$$100 \int m(\alpha) d\alpha = 5000 \pi t$$

$$\int m(\alpha) d\alpha = 50 \pi t$$

By differential;

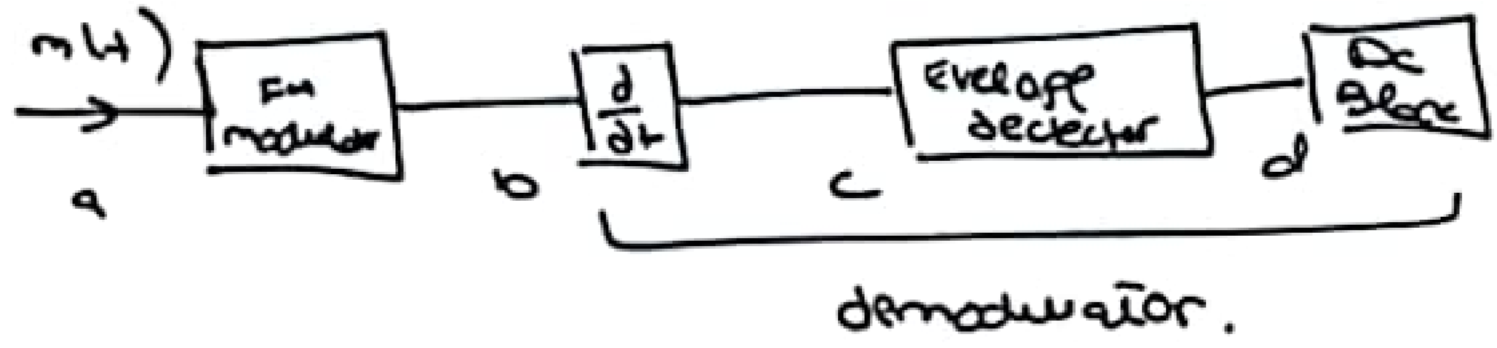
$$m(t) = \frac{d}{dt} 50 \pi t = 50\pi.$$

$$m(t) = 50 \pi t$$

For PM = $50 \pi t$

For FM = $50 \pi t$

Question no 5:



$f_c = 10KHz$ $\Delta f = 1KHz$ Period of $= T_0$

$$m(t) = A_m \cos(2\pi f_m) \cdots (1)$$

$$f_i(t) = f_c + k_f A_m \cos(2\pi f_m t)$$

$$= f_c + (\Delta f)\cos(2\pi f_m t) \; [\Delta f = k_f A]$$

$$f_i(t) = f_c + (\Delta f) \cos(2\pi f_m t)$$

(6)

$$S(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int_0^t m(\tau)\,d\tau\right)$$

$$\phi(t) = 2\pi k_f \int_0^t m(\tau)\,d\tau$$

$$S(t) = A_c \cos(2\pi f_c t + \phi(t)].$$

$$S(t) = A_c \cos(2\pi f_c t + \beta \sin(2\pi f_m t))].$$

$$\phi_{FM} = A\cos(\omega_c t) \pm (2000\pi t)$$

$$\omega_c = 2\pi f_c t$$

$$= 2\times10^3 \pi t.$$

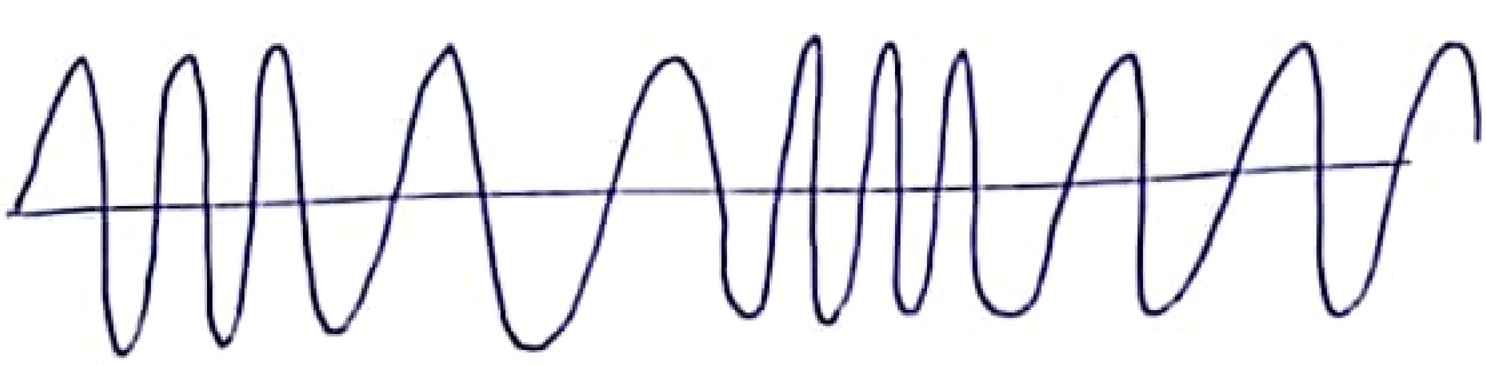
$$\omega_c = 2000\pi t.$$

$$\phi_{FM}(t) = -(2000\pi \pm 2000\pi) A \sin(2000\pi \pm 2000\pi t)$$

$$\phi_{FM}(t) = -(2000\pi \pm 2000\pi) A \sin(2000\pi \pm 2000\pi]$$

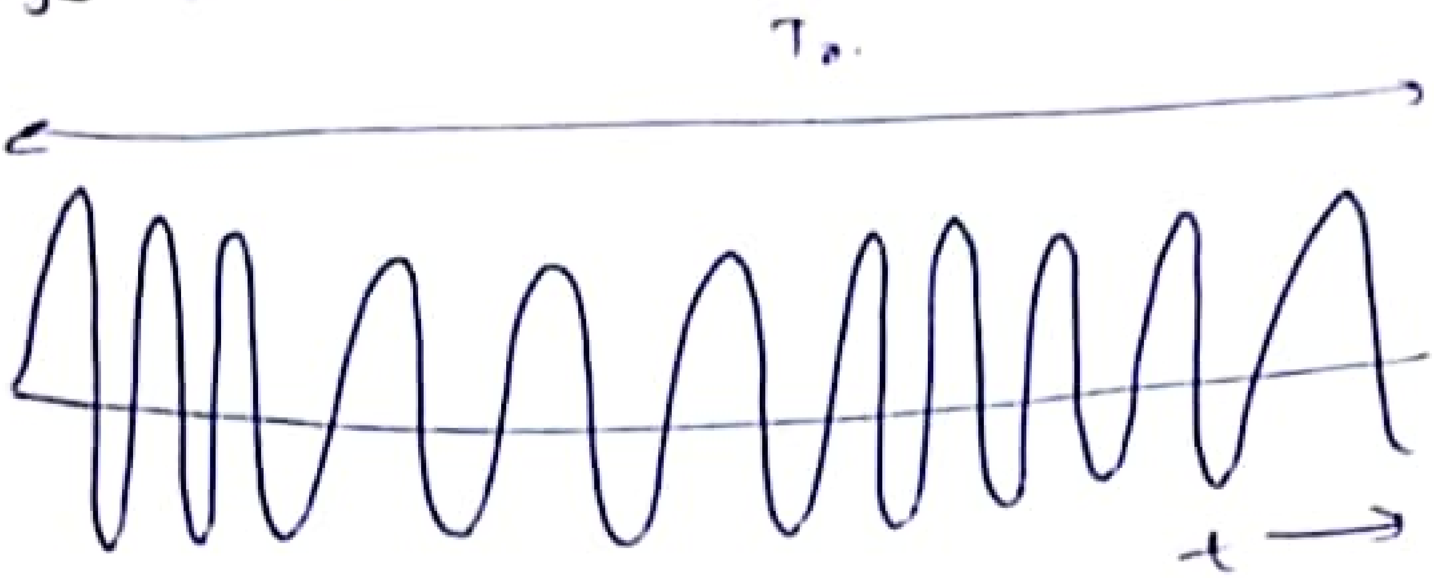
The output of Evelop is $(2000\pi \pm 2000\pi)$ After DC of $s(t)$.

Message Signal at t

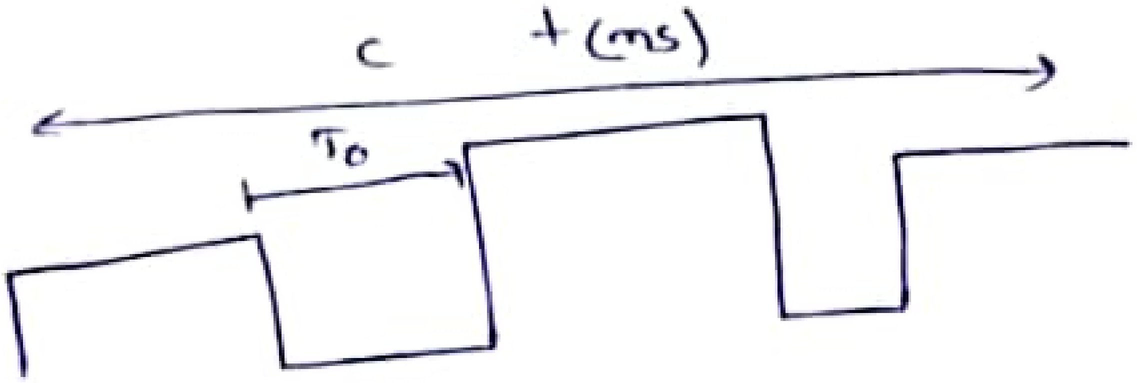


(2)

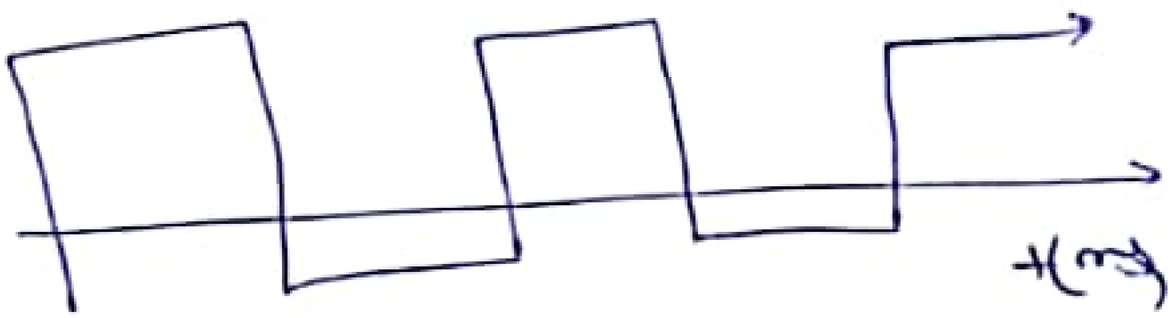
Massage at c



Massage at d



massage at e.



Question No1:

1- Slope dectecter:

Converts the Frequency variation of the FM Signal into Amplitude variation & then extract the original Signal.

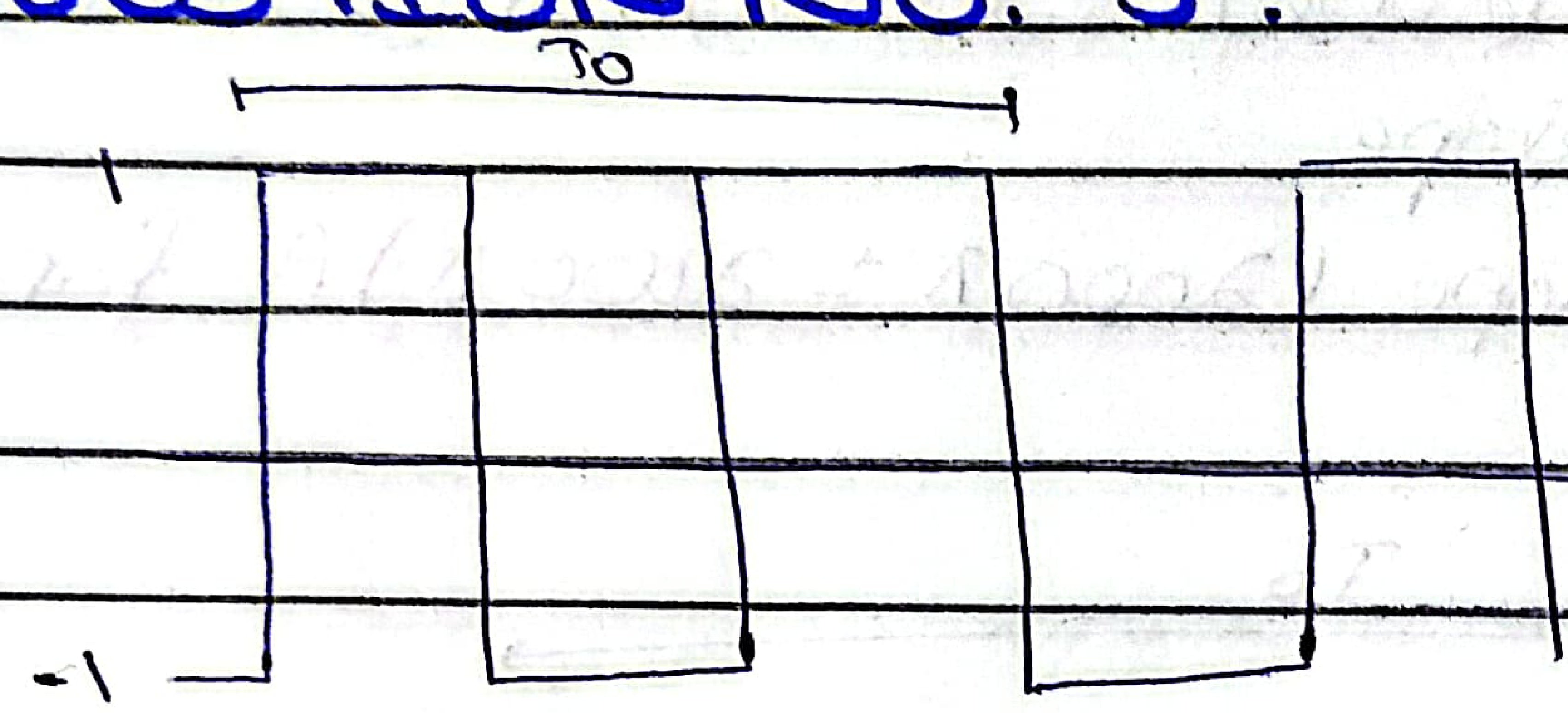
taking derivative w.r.t t

$$m(t) = \frac{d}{dt} 50\pi t = 50\pi$$

hence for FM,

$$m(t) = 50\pi$$

QUESTION NO. 5 :-



$f_c = 20\,KHz$; $\Delta f = 2\,KHz$

first for frequency deviation

$$m(t) = A_m \cos(2\pi f_m)$$

$$f_t(t) = f_c + k_f A_m \cos(2\pi f_m t)$$
$$= f_c + \Delta f \cos(2\pi f_m t)$$
$$f_t(t) = f_c + \Delta f \cos(2\pi f_m t)$$

For incomming FM signal

$$S_i(t) = A_t \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(\tau)\,d\tau\right]$$

The angle

$$\phi(t) = 2\pi k_f \int_0^t m(\tau)\,d\tau$$

$$s(t) = A_t \cos(2\pi f_c t + \phi(t))$$

frequency
At switching from 11kHz to 9kHz

$\phi_{FM}(t) = A\cos(\omega_c t) \pm (2000\pi t)$

$\omega_c = 2\pi f_c t$

$\omega_c = 2000\pi t$

$\phi_{FM}(t) = A\{\cos(2000\pi t) \pm (2000\pi t)\}$

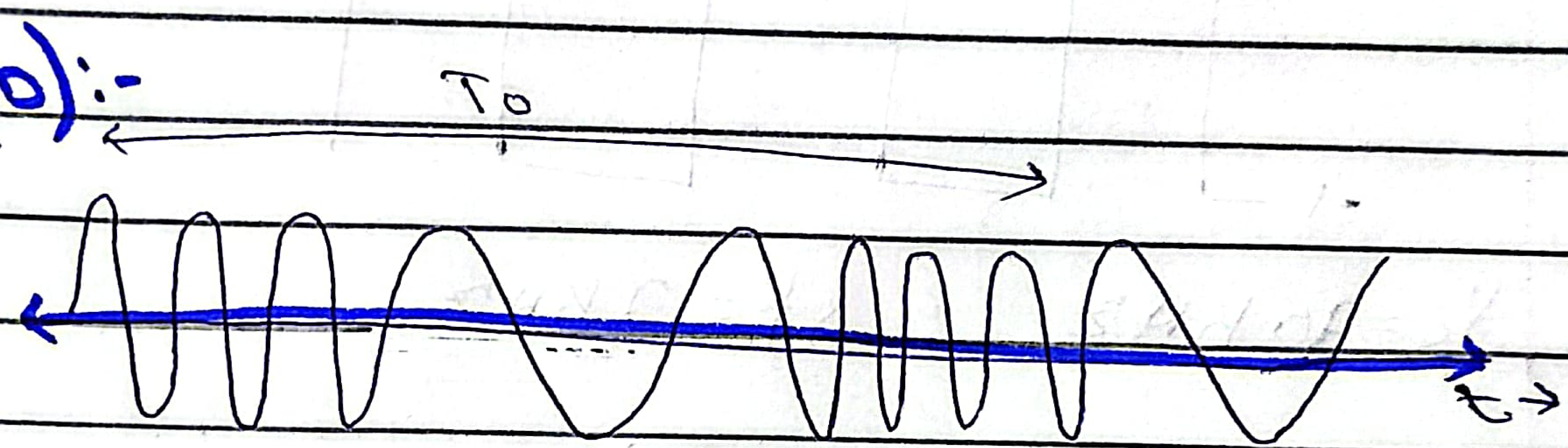
The ideal modulator

$\dot{\phi}_{FM} = -(2000\pi \pm 2000\pi)A\sin\{2000\pi t \pm 2000\pi t\}$

developing envelope,

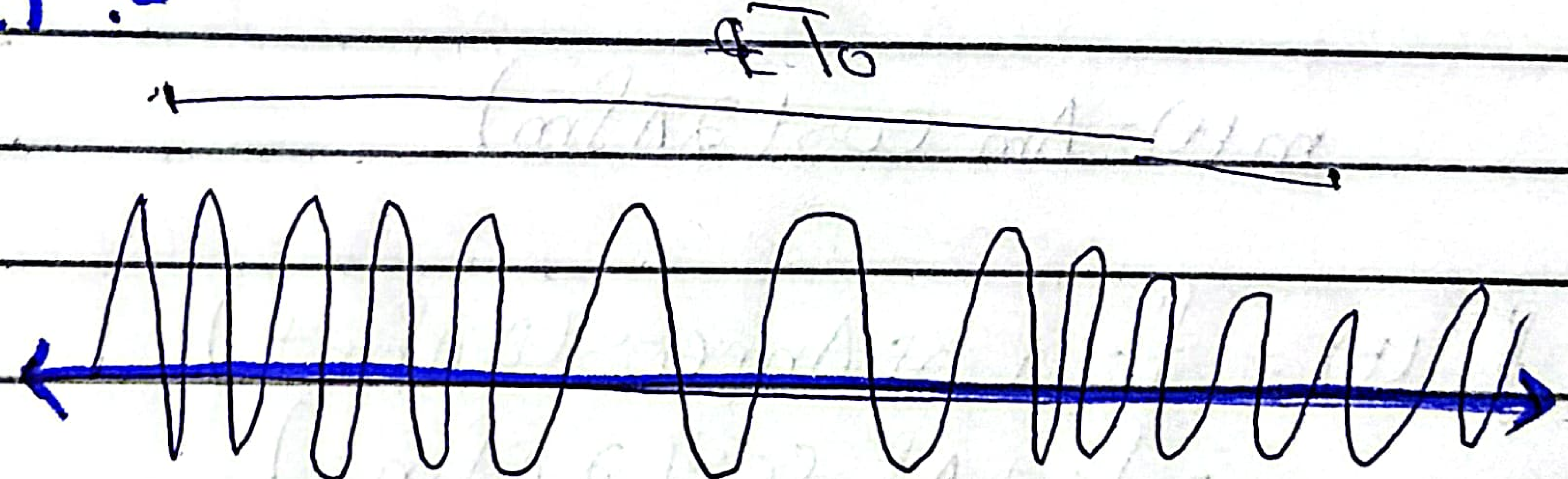
o/p of envelope $(2000\pi \pm 2000\pi)A$ for DC of sol

For (b):-



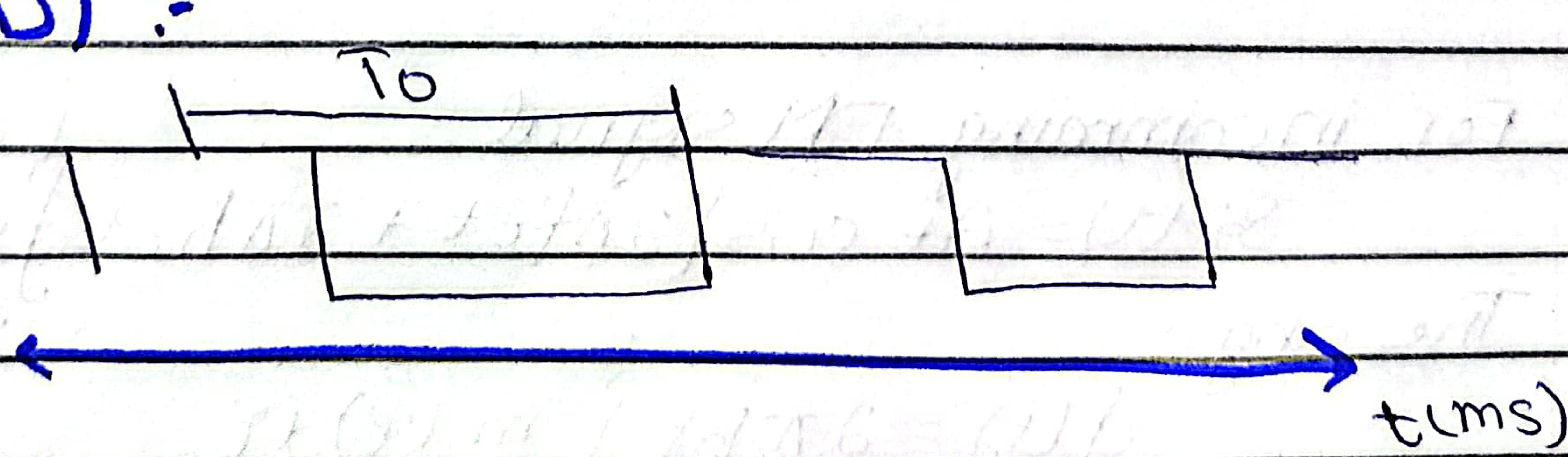
(b)

For (c):-



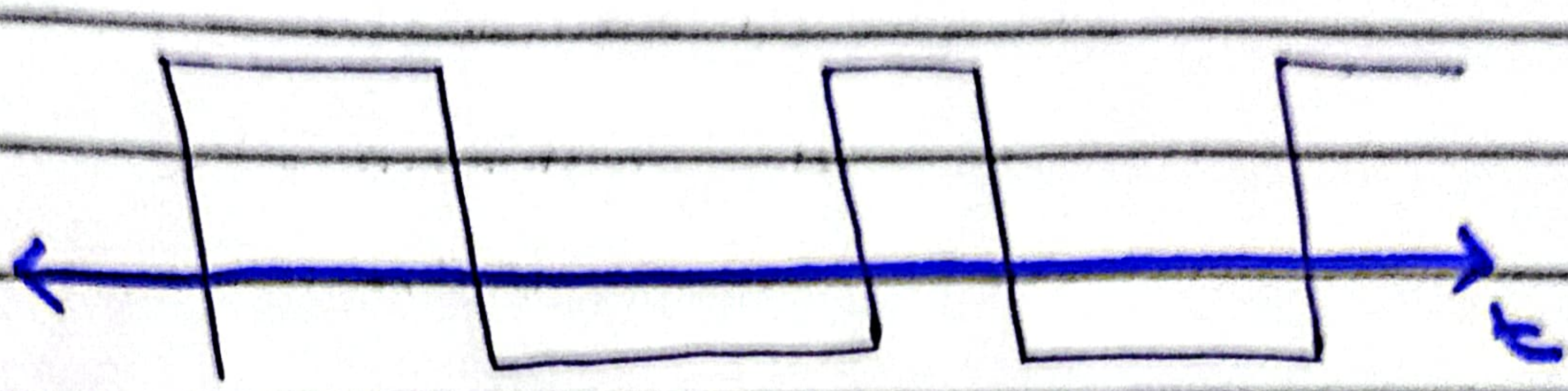
(c)

For (D):-



(D)

At (e) :-



(e)