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ESE 2023 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-3 : Analog and Digital Communication Systems [All topics]

Signals and Systems-1 + Microprocessors and Microcontroller [Part Syllabus]

Network Theory-2 + Control Systems-2 [Part Syllabus]

Name : ....

Roll No :

Test Centres				Student's Signature
Delhi ☐	Bhopal ☐	Jaipur ☐		
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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	182

Signature of Evaluator ....

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Name : T. Manohar Reddy

Roll No : 23MTHY EC MTHY A002

Test Centres				Student's Signature
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DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

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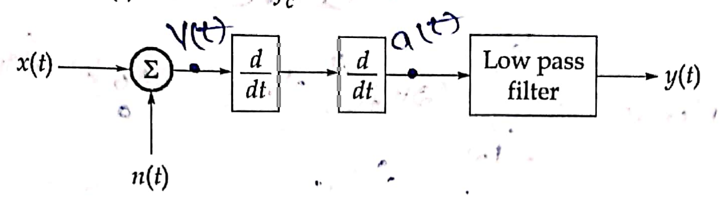
Section A : Analog and Digital Communication Systems

Q.1 (a) Consider the system shown in figure. The signal $x(t)$ is defined by:

$$x(t) = A\cos 2\pi f_c t$$



The low pass filter has unity gain in the passband and bandwidth W, where $f_c < W$. The noise $n(t)$ is white with two sided power spectral density $\frac{1}{2}N_0$. Determine the signal to noise ratio at the output $y(t)$.

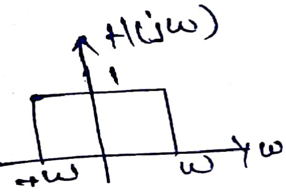
[12 marks]

$V(t) = x(t) + n(t)$

transfer function of sys Lowpass filter be $H(\omega)$

$\therefore \frac{d}{dt} \leftrightarrow j\omega$

$\therefore y(j\omega) \leftrightarrow (j\omega)^2 H(j\omega) \cdot V(j\omega)$



output Signal due to $x(t) = X(\omega)(j\omega)^2 \cdot H(\omega)$

at $a(t) = \frac{d^2}{dt}(x(t)) = \frac{d^2}{dt^2} A\cos 2\pi f_c t$

$\frac{d}{dt} A\cos 2\pi f_c t = -A 2\pi f_c \sin 2\pi f_c t$

$\frac{d}{dt}(-A 2\pi f_c \sin 2\pi f_c t) = -A(2\pi f_c)^2 \cos 2\pi f_c t$

Given $f_c < W$.

at $y(t) = -A(2\pi f_c)^2 \cos 2\pi f_c t$

Signal power $= \frac{(A(2\pi f_c)^2)^2}{2} = \frac{A^2(4\pi^2 f_c^2)^2}{2}$

$= \frac{A^2 (4\pi^2)^2 f_c^4}{2}$

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output PSD due to noise $= |(j\omega)^2 H(\omega)|^2 \times \frac{N_0}{2}$

$= (2\pi f_c)^4 \; ; \; -W < \omega < W.$

Output Noise $= \int_{-W}^{W} (2\pi f_c)^4 \frac{N_0}{2} = N_0 W (2\pi f_c)^4$

SNR at output $= \frac{A^2 (4\pi^2)^2 f_c^4}{2 N_0 W (2\pi f_c)^4} = \frac{A_c^2}{2N_0 W} \times \frac{4\pi^2}{4\pi^2}$

$(SNR)_{o/p} = \frac{A_c^2}{8 N_0 W \pi^2}$

$(SNR)_{o/p} = \frac{A_c^2}{2 N_0 W}$

Q.1 (b) Consider a continuous input signal whose amplitude V lies in the range $[-V_{max}, +V_{max}]$. This is applied to a uniform quantizer of mid-rise type where the step size is given by Δ and L denotes the number of representation levels. Let σ_Q^2 represent the variance of the quantization error and 'n' represent the number of bits per sample. Show that $\sigma_Q^2 = \frac{1}{3} V_{max}^2 \cdot 2^{-2n}$ and that the output signal to noise ratio of a uniform quantizer is

$$(SNR_0) = \frac{3P}{V_{max}^2} \cdot 2^{2n} \quad \text{where } P \text{ is signal power.}$$

[12 marks]

Step Size $\Delta = \frac{V_{max} - (-V_{max})}{L} = \frac{2V_{max}}{L}$

Part:- 1

for uniform quantizer, quantization noise power is $\frac{\Delta^2}{12}$

$E(Q_e^2) = \frac{\Delta^2}{12} = \frac{\left(\frac{2V_{max}}{L}\right)^2}{12} = \frac{4V_{max}^2}{12L^2}$

$= \frac{V_{max}^2}{3L^2}$

assuming the mean of quantizer is zero

Variance $\sigma_Q^2 = E(Q_e^2) - [E(Q_e)]^2$

$$\sigma_{Q_e}^2 = E(Q_e^2) \quad [\because E[Q_e] = 0]$$

$$= \frac{V_{max}^2}{3L^2};$$

We know that No. of Level $L = 2^n$

$$\sigma_{Q_e}^2 = \frac{V_{max}^2}{3\,2^{2n}} = \frac{V_{max}^2}{3} \cdot 2^{-2n}$$

Part 2:-

Signal power at output $= P$

$$(SNR)_o = \frac{\text{Signal power}}{\text{Noise power}}$$

at output of Quantizer the noise is due to Quantization error. So we can assume noise power as Quantization noise power

$$(SNR)_o = \frac{P}{\frac{V_{max}^2}{3} \cdot 2^{-2n}}$$

$$(SNR)_o = \frac{3P\,2^{2n}}{V_{max}^2}$$

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Q.1 (c) The random process X(t) is defined by

$X(t) = X\cos 2\pi f_0 t + Y\sin 2\pi f_0 t$

where X and Y are two zero mean independent Gaussian random variable each with variance σ^2.

(i) Find $m_X(t)$.

(ii) Find $R_X(t+\tau, t)$. Is X(t) stationary? Is it cyclostationary?

[12 marks]

Given $x(t) = X\cos 2\pi f_0 t + Y\sin 2\pi f_0 t$

(i) $m_x(t) = E[x(t)]$

$= E(X\cos 2\pi f_0 t) + E[Y\sin 2\pi f_0 t)$

$= E[X]\,E(\cos 2\pi f_0 t) + E[Y]\,E(\sin 2\pi f_0 t)$

$E(X) = 0$; $E(Y) = 0 \Rightarrow$ given

$m_x(t) = (0)E(\cos 2\pi f_0 t) + (0)\,E(\sin 2\pi f_0 t)$

$\boxed{m_x(t) = 0}$

(ii) $R_x(t+\tau, t) = E[x(t+\tau)\,x(t)]$

$= E\left[(X\cos 2\pi f_0(t+\tau) + Y\sin 2\pi f_0(t+\tau))(X\cos 2\pi f_0 t + Y\sin 2\pi f_0 t)\right]$

$= E[X^2\cos 2\pi f_0(t+\tau)\cos 2\pi f_0 t) + XY\cos 2\pi f_0(t+\tau)\sin 2\pi f_0 t$
$+ XY\sin 2\pi f_0(t+\tau)\cos 2\pi f_0 t + Y^2\sin 2\pi f_0(t+\tau)\sin 2\pi f_0 t]$

$= E[X^2\cos 2\pi f_0(t+\tau) + X^2\cos 2\pi f_0\tau + XY\cos 2\pi f_0(t+\tau)\sin 2\pi f_0 t)$
$XY\sin 2\pi f_0(t+\tau)\cos 2\pi f_0 t + Y^2(\cos 2\pi f_0(2t+\tau) - \cos 2\pi f_0 t)$

Given X and Y are independent $\therefore E(XY) = 0$

above equation can be written as

$R_x(t+\tau, t) = E(x^2)E(\cos 2\pi f_0(2t+\tau)) + E(x^2)E(\cos 2\pi f_0 t) + E(y^2)E(\cos 2\pi f_0(2t+\tau)) - E(y)^2 E(\cos 2\pi f_0 t)$

$= \sigma_x^2 \left(E[\cos 2\pi f_0(2t+\tau)] + \cos 2\pi f_0 t\right)] + \sigma_y^2 [E(\cos 2\pi f_0(2t+\tau)) - \cos 2\pi f_0 t)]$

$R_x(t+\tau)$ depends upon time

auto correlation

$\therefore$ $x(t)$ is not Stationary

Q.1 (d) A PCM system uses a uniform quantizer followed by a 8-bit binary encoder. The bit rate of the system is equal to 60 Mbps.

(i) What is the maximum message bandwidth for which the system operates satisfactory?

(ii) Determine signal to quantization noise ratio for uniform distributed sample of message signal having uniform quantization level.

[12 marks]

(i) $n = 8$; Bit rate $R_b = 60$ Mbps

& We know that $R_b = n f_s$

$60 \times 10^6 = 8 \times f_s$

$f_s = 7.5$ MHz

assuming f_s satisfies Nyquist Sampling rate

$f_s \geq 2 f_m$

$f_m \leq \frac{f_s}{2} = \frac{7.5}{2}$

$f_m \leq 3.75$ MHz

$\therefore$ Maximum message bandwidth $= 3.75$ MHz

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(ii) for uniformly - quantized encoder and assuming input as Sinusoidal

$$S_QNR = (1.8 + 6n)\ dB$$

$$= 1.8 + 6 \times 8$$

$$\boxed{S_QNR = 49.8\ dB}$$

Q.1 (e) What are the capture effect and threshold effect in an FM system? List two different methods used for FM threshold improvement.

[12 marks]

Capture effect :-

When at the input of FM receiver, we receives two different signals of same frequency then receiver doesn't understand which signal to received between two signal. There is a tendency for the receiver to accept the signal which have higher magnitude and it doesn't accept low magnitude signal compared to both.

This phenomeonon of accepting higher amplitude signal from different signals having Same frequency is known as Capture effect

Threshold effect :-

When the Signal to noise ratio of input decreases then output Signal to noise ratio also decreases proportionally, but when SNR at input decreases below certain value called threshold then output SNR decreases rapidly and this is known as threshold effect

Methods to ~~improve~~ decrease threshold effect

① Use pre emphasis circuit at transmitter and deemphasis circuit at receiver side

② by using feedback circuits in demodulator circuit like phase locked loop and frequency locked loop.

Q.2 (a) A communication channel has a bandwidth of 100 kHz. This channel is to be used for transmission of an analog source $m(t)$, where $|m(t)| < 1$, whose bandwidth is 4 kHz. The power content of the message signal is 0.1 W.

(i) Find the ratio of the output SNR of an FM system that utilizes the whole bandwidth, to the output SNR of a conventional AM system with a modulation index of $\mu = 0.85$. What is this ratio in dB?

(ii) Show that if an FM system and a PM system are employed and these systems have same output signal to noise ratio, we have

$$\frac{BW_{PM}}{BW_{FM}} = \frac{\sqrt{3}\beta_f + 1}{\beta_f + 1} \quad (\beta_f = \text{Modulation index of FM})$$

[10 + 10 marks]

Q.2 (b) An analog signal having 5 kHz bandwidth is sampled at twice the Nyquist rate and each sample is quantized into one of 256 equally likely levels. Assume the samples to be statistically independent.

(i) Calculate the information rate of the source.

(ii) Can the output of the source be transmitted without error over an AWGN channel with a bandwidth of 10 kHz and $\left(\frac{S}{N}\right)$ ratio of 40 dB?

(iii) Find the $\left(\frac{S}{N}\right)$ ratio so that the output of this source is transmitted without error over an AWGN channel with a bandwidth of 10 kHz.

(iv) Find the bandwidth requirement for an AWGN channel for an error free transmission of the output of this source if $\left(\frac{S}{N}\right)$ ratio is 40 dB.

[20 marks]

Q.2 (c) **(i)** The two sided power spectral density of the channel noise is 1×10^{-11} W/Hz and the carrier used in the transmitter is $15 \cos(2\pi f_c t)$ mV. Binary data (equiprobable bits) with a rate of 0.5 Mbps is transmitted through an AWGN channel using different modulation schemes. In each case of different modulation schemes, the signal are received by their respective correlator receiver with exact phase synchronisation and with optimum threshold detection. Find the average symbol error probability for modulation schemes BASK, BFSK and BPSK.

(ii) For a minimum hamming distance of "5",

1. How many errors can be detected?

2. How many errors can be detected and corrected?

[14 + 6 marks]

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Q.3 (a) A Gaussian signal pulse given by,

$$x(t) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(t^2/2\sigma^2)}$$

is applied to the input of matched filter and the noise on the channel is a white noise with power density spectrum of $\frac{N_0}{2} = 10^{-20}$ Watt/Hz, then calculate the maximum signal to noise ratio $\left(\frac{S}{N}\right)_{max}$ in dB achieved by this filter with $\sigma = 1$.

[20 marks]

When $x(t)$ is given as input then SNR at output of matched filter ~~the~~ is $\frac{2E}{N_0}$

E = energy of input $x(t)$

$$E_{(x(t))} = \int_{-\infty}^{\infty} |x(t)|^2 dt$$

$$\int_{-\infty}^{\infty} \frac{1}{\sigma^2 2\pi} \left(e^{-\frac{t^2}{2\sigma^2}}\right)^2 dt$$

$$= \frac{1}{2\pi\sigma^2} \int_{-\infty}^{\infty} e^{-\frac{t^4}{\sigma^4}} dt$$

~~Put $\frac{t^2}{\sigma^2} = x \Rightarrow \frac{2t}{\sigma^2} dt = dx$~~

given $\sigma^2 = 1 \Rightarrow \sigma^2 = 1$

$$E_{x(t)} = \frac{1}{2\pi} \int_{-\infty}^{\infty} e^{-t^4} dt$$

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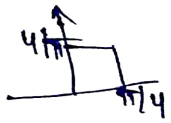
Q.3 (b) For each of the following processes, find the power spectral density.

(i) $X(t) = A\cos(2\pi f_0 t + \theta)$, where A is a constant and θ is a random variable uniformly distributed on $\left[0, \frac{\pi}{4}\right]$.

(ii) $X(t) = x + y$, where x and y are independent, x is uniformly distributed on $[-1, 1]$ and y is uniformly distributed on $[0, 1]$.

[10 + 10 marks]

(i) $X(t) = A\cos(2\pi f_0 t + \theta)$



$R_X(\tau) = E[X(t)X(t+\tau)]$

$= E[A^2\cos(2\pi f_0 t + \theta)\cos(2\pi f_0 t + \tau) + \theta]$

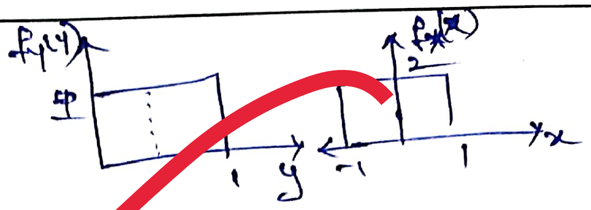
$= E[A^2\cos(2\pi f_0 t + \theta)\cos(2\pi f_0 (t+\tau)) + \theta]$

$= E(A^2) E[\cos(2\pi f_0 t + 2\pi f_0 (t+\tau) + 2\theta)] + E[\cos(2\pi f_0 t - 2\pi f_0 (t+\tau))]$

$= E(A^2)\, E((\cos 2\pi f_0 \tau) + 2\theta)$

$= A^2 \int_0^{\pi/4} \cos 2\pi f_0 \tau \times \frac{4}{\pi}\, d\tau =$

(ii) $X = x + y$



$E(y) = \int_0^1 x \, dx = 0.5$

$E(y) = \int_{-1}^{1} y \, dy = 0$

$E(y^2) = \int_0^1 x^2 dx = \frac{1}{3}$

$E(y^2) = \int_{-1}^{1} y^2 dy = \frac{y^3}{3}\Big|_{-1}^{1} = \frac{1+1}{3} = 2/3$

$R_x(\tau) = E(x(t)\,x(t+\tau))$

$= E\left((x+y)(x+y)\right)$

$= E\left[x^2 + 2xy + y^2\right]$

$= E(x^2) + E(2xy) + E(y^2)$

$= E(x^2) + 2E(xy) + E(y^2)$

given x and y are independent $\therefore E(xy) = 0$

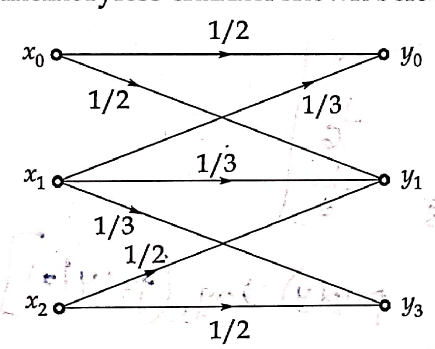
$R_x(\tau) = \frac{1}{3} + \frac{2}{3} = 1$

$R_x(\tau) = 1$

$S_x(\omega) = F.T\ R_x(\tau)$ $\quad 1 \leftrightarrow 2\pi\delta(\omega)$

$S_x(\omega) = 2\pi\delta(\omega)$

Q.3 (c) Consider the discrete memoryless channel shown below:



If the input probabilities are $P(x_0) = P(x_2) = \frac{1}{4}$ and $P(x_1) = \frac{1}{2}$, then determine the mutual information $I(X;Y)$.

[20 marks]

$I(x;y) = H(y) - H(y/x)$

$$P(y|x) = \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/3 & 1/3 & 1/3 \\ 0 & 1/2 & 1/2 \end{bmatrix} \quad p(x) = \left[\frac{1}{4} \;\; \frac{1}{2} \;\; \frac{1}{4}\right]$$

$$P(y) = P(x)P(y|x) = \left[\frac{1}{4} \;\; \frac{1}{2} \;\; \frac{1}{4}\right] \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/3 & 1/3 & 1/3 \\ 0 & 1/2 & 1/2 \end{bmatrix}$$

$$= \left[\frac{7}{24} \;\; \frac{5}{12} \;\; \frac{7}{24}\right]$$

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$P(y_0) = \frac{7}{24}$; $P(y_1) = \frac{5}{12}$ $P(y_2) = 7/24$

$H(y) = -\left[P(y_0)\log_2 P(y_0) + P(y_1)\log_2 P(y_1) + P(y_2)\log P(y_2)\right]$

$= -\left[2\left(\frac{7}{24}\log_2\left(\frac{7}{24}\right)\right) + \frac{5}{12}\log_2\frac{5}{12}\right]$

$= 1.563$ bits/symbols

$P(xy) = [P(x)]_d [P(y|x)]$

$= \begin{bmatrix} \frac{1}{4} & 0 & 0 \\ 0 & 1/2 & 0 \\ 0 & 0 & 1/4 \end{bmatrix} \begin{bmatrix} 1/2 & 1/2 & 0 \\ 1/3 & 1/3 & 1/3 \\ 0 & 1/2 & 1/2 \end{bmatrix}$

$= \begin{bmatrix} \frac{1}{8} & \frac{1}{8} & 0 \\ \frac{1}{6} & \frac{1}{6} & \frac{1}{6} \\ 0 & \frac{1}{8} & \frac{1}{8} \end{bmatrix}$

$H(y|x) = -\left[\sum_{x=1}^{i-1} \sum_{y=0}^{j-1} P(xy) \log_2 (P(y|x))\right]$

$= -\left[\frac{1}{8}\log_2(1/2) + \frac{1}{8}\log_2(1/2) + \frac{3}{6}\log_2(1/3) + \frac{2}{8}\log_2(1/2)\right]$

$= -\left[\frac{1}{2}\log_2(1/2) + \frac{1}{2}\log(1/3)\right] = 1.29$ bits/sym

$I(x;y) = H(y) - H(y|x)$

$= 1.563 - 1.29$

$I(x;y) = 0.273$ bits/symbol

Q.4 (a) An AM signal has the form

$u(t) = [20 + 2\cos 3000\pi t + 10\cos 6000\pi t]\cos 2\pi f_c t$

where $f_c = 10^5$ Hz.

(i) Sketch the (voltage) spectrum of $u(t)$.

(ii) Determine the power in each of the frequency components.

(iii) Determine the modulation index.

(iv) Determine the power in the sidebands, the total power, and the ratio of the sidebands power to the total power.

[5 × 4 marks]

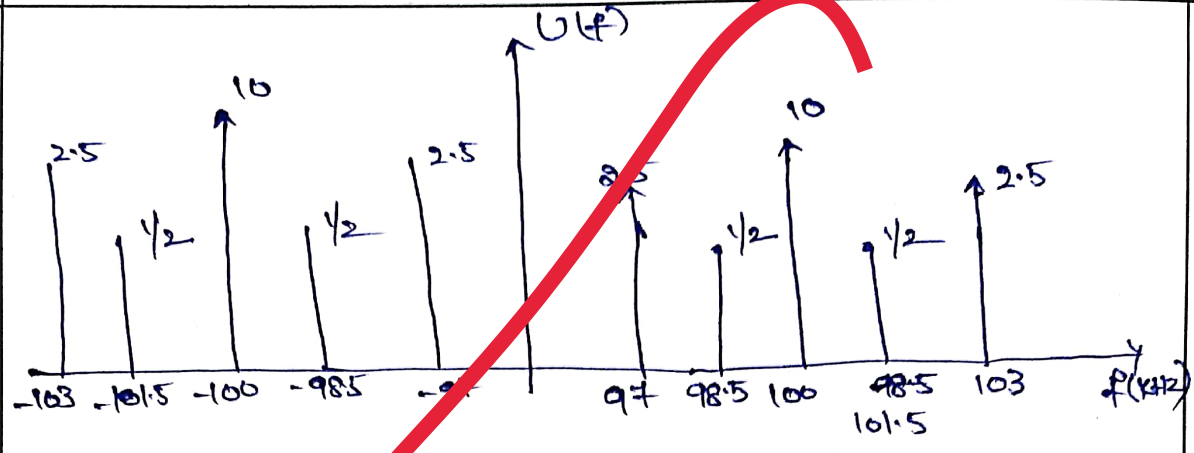
Given $u(t) = (20 + 2\cos 3000\pi t + 10\cos 6000\pi t)\cos 2\pi f_c t$

$u(t) = 20\cos 2\pi f_c t + 2\cos 2\pi f_c t \cos 3000\pi t + 10\cos 2\pi f_c t \cos 6000\pi t$

$= 20\cos 2\pi f_c t + \cos 2\pi(101500)t + \cos(2\pi 98500)t + 5\cos(2\pi\, 103000 t) + 5\cos(2\pi\, 97000 t)$

$U(f) = 10\,[\delta(f+f_c) + \delta(f-f_c)] + \frac{1}{2}\delta(f+101500) + \frac{1}{2}\delta(f-101500) + \frac{1}{2}\delta(f-98500) + \frac{1}{2}\delta(f+98500) + \frac{5}{2}\delta(f-103000) + \frac{5}{2}\delta(f+103000) + \frac{5}{2}\delta(f-97000) + \frac{5}{2}\delta(f+97000)$

(i)



(ii) power in Carrier Component i.e $f_c = 10^5$ Hz $\Rightarrow \frac{20^2}{2} = 200$ W

power in f = 97 KHz Component $= \frac{5^2}{2} = 12.5$ Watts

power in f = 98.5 KHz Component $= \frac{1^2}{2} = 0.5$ Watts

power in f = 101.5 KHz Component $= \frac{1^2}{2} = 0.5$ Watts

power in f = 103 KHz Component $= \frac{5^2}{2} = 12.5$ Watts

In the Spectrum power will be divided equally at negative and positive frequencies

i.e. $Power_{\pm f_c} =$ ~~62.5~~ 100 Watts; $P_{f=\pm 97 KHz} = 0.25$ Watts

$P_{f=\pm 98.5 KHz} = 6.25$ Watts, $P_{f=101.5 KHz} = 0.25$ Watts $P_{103 KHz} = 6.25$ Watts

(iii) $u(t) = [20 + 2\cos 3000\pi t + 10\cos 6000\pi t] \cos 2\pi f_c t$

$= 20[1 + 0.1\cos 3000\pi t + 0.5\cos 6000\pi t] \cos 2\pi f_c t$

Comparing it with Standard multitone AM Signal

$u(t) = A_c\left[1 + \mu_1 \cos\omega_{m_1} t + \mu_2 \cos\omega_{m_2} t\right]\cos\omega_c t$

$A_c = 20$; $\mu_1 = 0.1$; $\mu_2 = 0.5$

total Modulation index $\mu_T = \sqrt{\mu_1^2 + \mu_2^2}$

$= \sqrt{0.1^2 + 0.5^2}$

$\boxed{\mu_T = 0.5099}$

(iv) power in Side bands $= 12.5 + 0.5 + 0.5 + 12.5$

$= 26$ Watts

power in Carrier $= 200$ Watts

Total power $= 200 + 26$

$= 226$ Watts

Ratio of Side band power to total power $= \frac{26}{200}$

$= 0.13$

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Q.4 (b) **(i)** A message source generates six message symbols $m_1, m_2, \ldots, m_6$ with probabilities 0.3, 0.2, 0.08, 0.25, 0.12, 0.05 respectively. Give Huffman code for these symbols. Determine the efficiency and redundancy of the code.

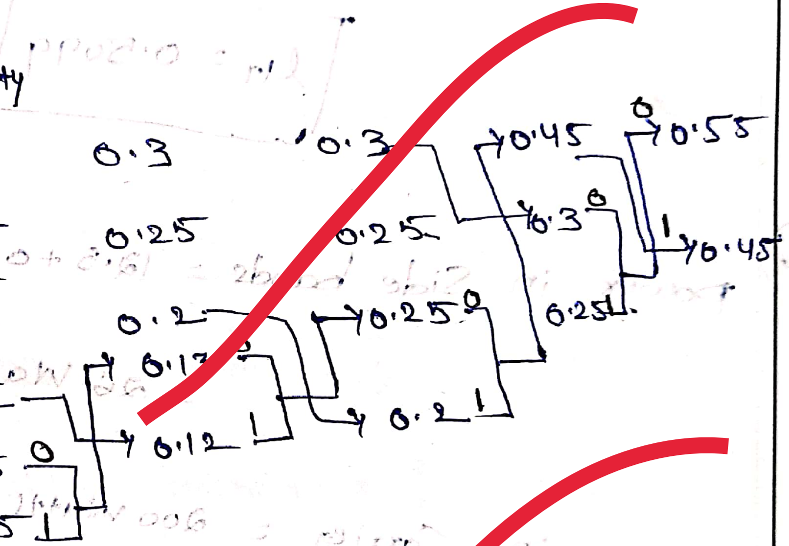
(ii) For an AM modulator with carrier frequency f_c = 200 kHz and a maximum modulating signal frequency $f_{m(\max)}$ = 6 kHz, determine,

1. Frequency limits for the upper and lower sidebands.
2. Bandwidth
3. Upper and lower side frequencies produced when the modulating signal is a single frequency 2 kHz tone.

[10 + 10 marks]

(i)

Symbols	Probability
m_1	0.3
m_4	0.25
m_2	0.2
m_5	0.12
m_3	0.08
m_6	0.05



Codes	length
$m_1 \Rightarrow 00$	2
$m_2 \Rightarrow 11$	2
$m_3 \Rightarrow 1000$	4
$m_4 \Rightarrow 01$	2
$m_5 \Rightarrow 101$	3
$m_6 = 1001$	4

Average length $L = \sum P_i L_i$

$L = 0.3\times 2 + 0.2\times 2 + 4\times 0.08 + 2\times 0.25 + 3\times 0.12 + 0.05\times 4$

$L = 2.38$ bits

$H(x) = -\sum_i P(x_i) \log_2 P(x_i)$

$= -\left[0.3\log_2(0.3) + 0.2\log_2(0.2) + 0.08\log_2(0.08) + 0.25\log_2 0.25 + 0.12\log_2(0.05) + 0.05\log_2 0.05\right]$

$= 2.36$

Effeinciey, $\eta = \frac{H}{H(x)} \frac{H(x)}{L} = \frac{2.36}{2.38} = 0.991$

$\eta = 99\%$

Redundancy $= 1 - \eta = 0.008$

(ii) Given $f_c = 200 KHz$; $f_{m\,max} = 6 KHz$

(1) upper Side band $= f_c + f_m$

$= 200 + 6$

$= 206 KHz$

limits of upper Side band ⇒ 200 KHz - 206 KHz

lower Side band $= f_c - f_m$

$= 200 - 6 = 194 KHz$

limits of lower Side band ⇒ 194 KHz - 200 KHz

2) Bandwidth of AM $= 2 f_m(max)$

$= 2 \times 6 KHz$

$(BW)_{Am} = 12 KHz$

3) if $f_m = 2 KHz$

upper Side band $= f_c + f_m = 200 + 2$

$f_{USB} = 202 KHz$

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Lower Side band $f_{LSB} = f_c - f_m$

$= 200 - 2$

$f_{LSB} = 198\ kHz$

20

Q.4 (c) A single-tone modulating signal $m(t) = A_m \cos(2\pi f_m t)$ is used to generate the VSB signal

$$S(t) = \frac{1}{2} a A_m A_c \cos[2\pi(f_c + f_m)t] + \frac{1}{2} A_m A_c (1-a)\cos[2\pi(f_c - f_m)t]$$

where 'a' is a constant, less than unity, representing the attenuation of the upper side frequency.

(i) Find the quadrature component of the VSB signal $S(t)$.

(ii) The VSB signal, plus the carrier $A_c \cos(2\pi f_c t)$, is passed through an envelope detector. Determine the distortion produced in recovering the message signal.

(iii) What is the value of constant 'a' for which this distortion reaches its worst possible condition?

[20 marks]

(i) $S(t) = \frac{1}{2} a A_m A_c \cos(2\pi(f_c + f_m)t) + \frac{1}{2} A_m A_c (1-a) \cos[2\pi(f_c - f_m)t]$

$= \frac{1}{2} a A_m A_c \cos 2\pi(f_c + f_m)t - \frac{1}{2} a A_m A_c \cos(2\pi(f_c - f_m)t + \frac{1}{2} A_m A_c \cos 2\pi(f_c - f_m)t$

(ii)

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Section B : Signals and Systems-1 + Microprocessors and Microcontroller-1 + Network Theory-2 + Control Systems-2

Q.5 (a) Consider a system described by the differential equation $\ddot{y}(t)+2y(t)+3\dot{y}(t)=x(t)$ with $x(t)=3e^{-4t}$, $y(0)=3$ and $\dot{y}(0)=4$. Find its Z.I.R and Z.S.R.

[12 marks]

for ZIR ; $x(t)=0$

$\ddot{y}(t)+2y(t)+3\dot{y}(t)=0$

apply unilateral Laplace transform.

$s^2Y(s)-sy(0)-\dot{y}(0)+3(sY(s)-y(0))+2Y(s)=0$

$Y(s)[s^2+3s+2]=3s+4$

$Y(s)=\frac{3s+4}{s^2+3s+2}=\frac{3s+4}{(s+1)(s+2)}=\frac{A}{s+1}+\frac{B}{s+2}$

$A=(s+1)Y(s)\Big|_{s=-1}=\frac{3(-1)+4}{(-1+2)}=1$

$B=(s+2)Y(s)\Big|_{s=-2}=\frac{3(-2)+4}{-2+1}=2$

$Y(s)=\frac{1}{s+1}+\frac{2}{s+2}$

$y(t)=e^{-t}u(t)+2e^{-2t}u(t)$

for ZSR ; $y(0)=0$; $\dot{y}(0)=4$ $X(s) = \frac{3}{s+4}$

$(s^2+4s+3)Y(s) = \frac{3}{s+4}$ $A = Y(s)(s+4)\Big|_{s=-4} = \frac{3}{(-4+3)(-4+1)} = -1$

$Y(s) = \frac{3}{(s+4)(s+3)(s+1)}$ $B = Y(s)(s+3)\Big|_{s=-3} = -1.5$

$C = Y(s)(s+1)\Big|_{s=-1} = 0.5$

$Y(s) = \frac{-1}{s+4} - \frac{1.5}{s+3} + \frac{0.5}{s+1}$

$y(t) = -e^{-4t}u(t) - 1.5e^{-3t}u(t) + 0.5e^{-t}u(t)$

Q.5 (b) Describe the following instructions of 8086:

(i) LDS R_d, M
(ii) AAM
(iii) DAS
(iv) CLI

[12 marks]

i) LDS Rd, M

Used to load DS Register and Other provided Register from the memor

[DS] ← [M] & [Rd] ← [M]

(ii) AAM

Used to adjust ASCII codes after Multiplicication

AAM:- ASCII adjust for multiplication

(iii) DAS :-

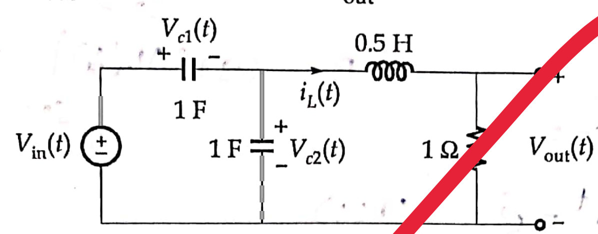
Decimal after Subtraction

This instruction is used to adjust decimal after Subtraction

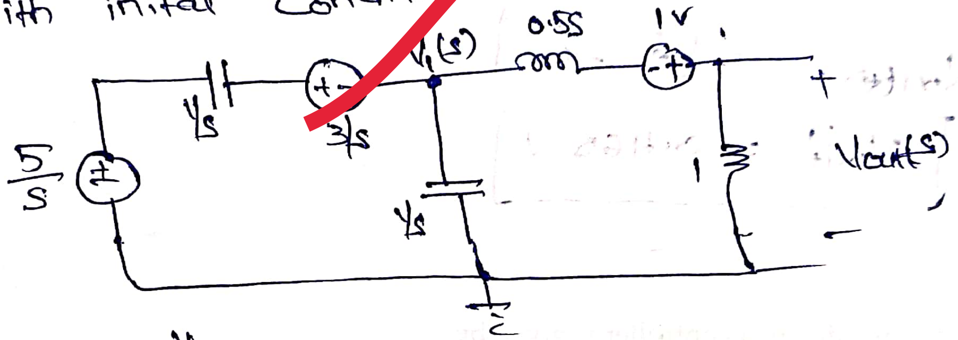
CLI :- Clear Interrupt.

used to Clear the interrupt enable flag to 0; i.e disable INTR interrupt

Q.5 (c) Consider the circuit below in which $V_{in}(t) = 5u(t)$ V, $V_{c1}(0^-) = 3$ V, $V_{c2}(0^-) = 0$ V and $i_L(0^-) = 2$ A. Find $V_{out}(t)$ and also obtain V_{out} at $t = 1$ sec. **[12 marks]**



Replacing the Circuit in Laplace domain With inital Conditions



KCL at V_1

$$\frac{V_1 - \frac{5}{s} + \frac{3}{s}}{1/s} + \frac{V_1}{1/s} + \frac{V_1 + 1}{1 + 0.5s} = 0$$

$$s\left(V_1 - \frac{2}{s}\right) + V_1 s + \frac{V_1 + 1}{0.5s + 1} = 0$$

$$2sV_1 - 2 + \frac{V_1}{0.5s + 1} + \frac{1}{0.5s + 1} = 0$$

$$V_1\left(2s + \frac{2}{s+2}\right) = 2 - \frac{2}{s+2}$$

$$V_1 \frac{(2s^2 + 4s + 2)}{s+2} = \frac{2s + 4 - 2}{s+2}$$

$$V_1 = \frac{2s+2}{2s^2 + 4s + 2} = \frac{s+1}{s^2 + 2s + 1} = \frac{1}{s+1}$$

$$V_{out}(s) = \frac{1}{1 + 0.5s} \times V_1 = \frac{2}{s+2} \times \frac{1}{s+1}$$

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$V_{out}(s) = \frac{A}{s+2} + \frac{B}{s+1}$ $A = (s+2)V_{out}(s)\big|_{s=-2} = -2$

$B = (s+1)V_{out}(s)\big|_{s=-1} = \frac{2}{2-1} = 2$

$= \frac{2}{s+1} - \frac{2}{s+2}$

$V_{out}(t) = 2\left[e^{-t} - e^{-2t}\right]u(t)$

at $t = 1$

$V_{out}(t) = 2\left[e^{-1} - e^{-2}\right]$

$V_{out} = 0.465$

Q.5 (d) The transfer function of a controller is given by,

$$G_c(s) = \frac{10s+4}{s}$$

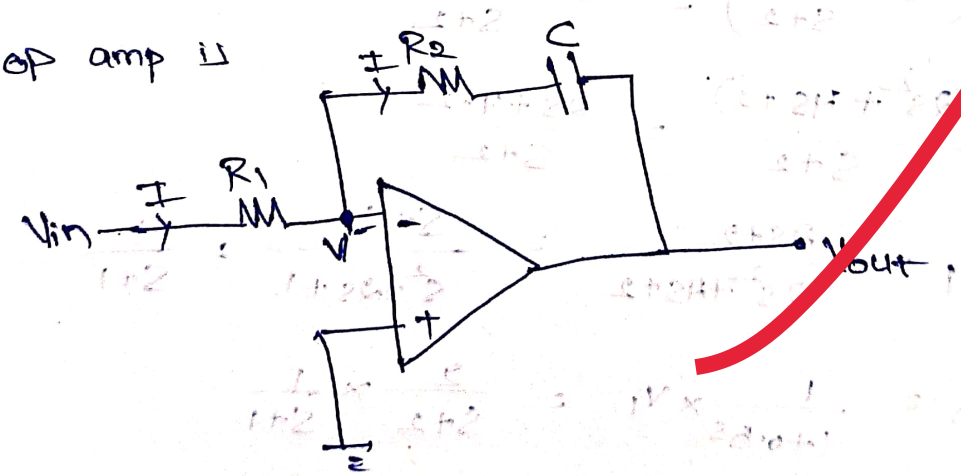
If this controller is realised using an operational amplifier, then find the other parameters of the controller assuming the capacitor value of 25 µF.

[12 marks]

$G_c(s) = \frac{10s+4}{s} = 10 + \frac{4}{s} = K_P + \frac{K_I}{s} \rightarrow (1)$

given Controller is a P-I Controller

the transfer function of PI Controller using op amp is



by applying Virtual Short $V^- = V^+ = 0$

KCL at V^-

$$\frac{V_{in}}{R_1} = \frac{0 - V_{out}}{R_2 + \frac{1}{sC}}$$

$$\frac{V_{in}}{R_1} = \frac{-V_{out}(sC)}{sCR_2 + 1}$$ We can neglect negative sign

$$\frac{V_{out}}{V_{in}} = \frac{sCR_2 + 1}{R_1 sC}$$

$$= \frac{R_2}{R_1} + \frac{1}{sR_1C} \rightarrow (2)$$

Comparing (1) & (2)

$K_p = \frac{R_2}{R_1} = 10$; $\frac{1}{R_1C} = K_I = 4$

$R_2 = 10R_1$; $R_1C = \frac{1}{4}$

$R_1 = \frac{1}{4 \times 25 \times 10^{-6}}$

$R_2 = 10 \times 10$

$R_2 = 100\,k\Omega$

$R_1 = 10\,k\Omega$

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Q.5 (e) Write a 8085 program to find 2's complement of the number stored in memory location 9000 H, and store the result in memory location 9001 H. Also give the flow chart of the program and calculate execution time of program if operating frequency is 5 MHz.

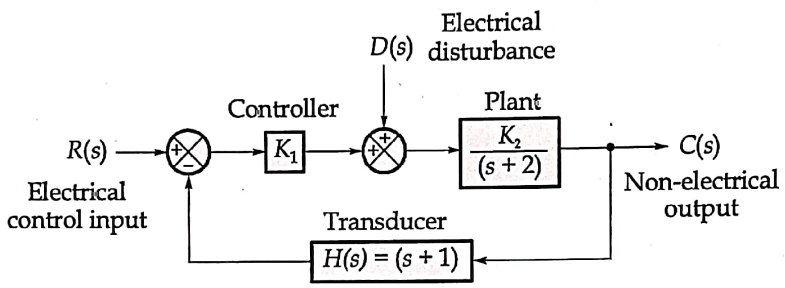
[12 marks]

Q.6 (a) **(i)** Explain all the basic machine cycles of 8085 microprocessor and differentiate between instruction cycle (IC) and machine cycle (MC).

(ii) Draw the timing diagram of OUT instruction for 8085 microprocessor.

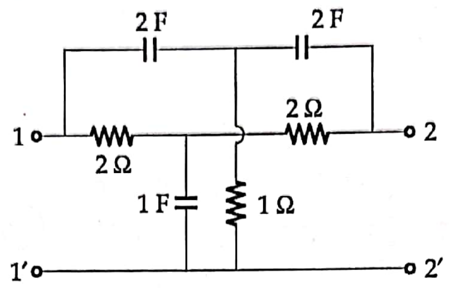
[10 + 10 marks]

Q.6 (b) For the system shown in the figure below, both the electrical control input and the disturbance are unit step signals. Find the sensitivity of the steady-state error for changes in K_1 and in K_2 individually, when $K_1 = 100$ and $K_2 = 0.10$.

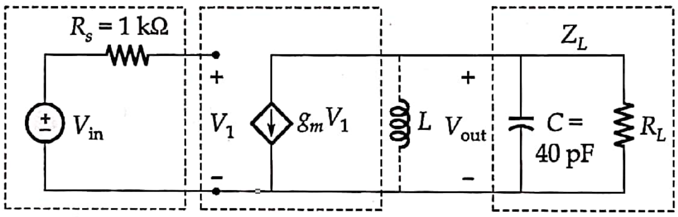


[20 marks]

Q.6 (c) **(i)** Determine the Y parameters of given network.



(ii) Below given figure displays an amplifier model containing a VCCS with $g_m = 2$ mS (milli-Siemens) and $R_L = 20$ kΩ. The applied sinusoidal voltage $V_{in}(j\omega)$ has a magnitude of 0.1 V at 10 MHz. The load is modeled by the parallel combination of R_L and the 40-pF capacitor. The capacitance accounts for such real-world phenomena as wiring capacitance, the device input capacitance, and other embedded capacitances. This capacitance cannot be removed from the circuit and often has deleterious effects on the amplifier performance.



1. With the load connected directly as shown (without L), find the magnitude of the output voltage.
2. If an inductance L is connected across the load to tune out the effect of the capacitance, find the value of L and the resulting $|V_{out}|$. What is the impact on the amplifier gain?

[8 + 12 marks]

Q.7 (a) (i) Explain the addressing modes of 8086 with one example each.

(ii) Obtain the physical address and effective address for different addressing modes of 8086 with the contents of register as given below:

Offset = 1000 H; [AX] = 5000 H; [BX] = 2000 H; [SI] = 3000 H; [BP] = 5000 H;

[DI] = 4000 H; [SP] = 6000 H, [DS] = 7000 H

1. Register indirect addressing mode (assuming DI).
2. Based addressing mode (assuming BX)
3. Based index addressing mode (assuming DX).
4. Based index with displacement addressing mode (assuming BX).

[14 + 6 marks]

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Q.7 (b) A system is described by the following state and output equations:

$$\frac{dx_1(t)}{dt} = -3x_1(t) + x_2(t) + 2u(t)\ ; \quad \frac{dx_2(t)}{dt} = -2x_2(t) + u(t)\ ; \quad y(t) = x_1(t)$$

If $u(t)$ is the input and $y(t)$ is the output, then find the system transfer function and state transition matrix of the above system.

[20 marks]

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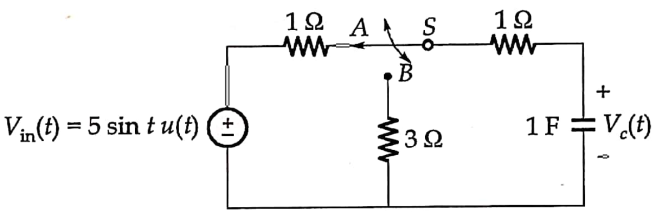
Q.7 (c) In the circuit given below $V_{in}(t) = 5 \sin t\, u(t)$ V and $V_c(0^-) = 0$. The switch is initially in position A. The switch 'S' moves from position 'A' to position 'B' at $t = 1s$ and from position 'B' to position 'A' at $t = 2s$, where it remains for all subsequent time. Find $V_c(t)$ for $t \geq 0$.



[20 marks]

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Q.8 (a) Determine the unilateral Laplace transform of the signals given below. Specify the property used, if any, in each step.

(i) $x(t) = [u(t-1) + u(-t-4)] * e^{-2t}u(t-1)$

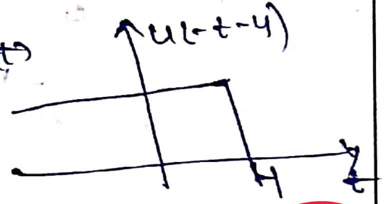
(ii) $x(t) = t \cdot \frac{d}{dt}\left[e^{-t} \cdot \cos t\, u(t) + e^{-(t+1)}u(-(t+1))\right]$

[10 + 10 marks]

(i) $x(t) = [u(t-1) + u(-t-4)] * e^{-2t}u(t-1)$

let $x_1(t) = u(t-1) + u(-t-4)$ $u(-t-4) = u(-(t+4))$

Unilateral laplace transform of $x_1(t)$



$X_1(s) = \int_{0^-}^{\infty} x_1(t) e^{-st} dt$

$= \int_0^{\infty} u(t-1) dt + \int_0^4 e^{-st} dt$

$X_1(s) = \frac{e^{-s}}{s} + \frac{1}{s}\left[1 - e^{-4s}\right]$

$x_2(t) = e^{-2t}u(t-1)$, $e^{-2t}u(t) \leftrightarrow \frac{1}{s+2}$

$= e^{-2(t-1)} \cdot e^{-2} u(t-1)$ $e^{-2(t-1)}u(t-1) \leftrightarrow \frac{e^{-s}}{s+2}$

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$$X_2(s) = e^{-2}\frac{e^{-s}}{s+2}$$

$x(t) = x_1(t) * x_2(t)$

by Convolution property

$X(s) = X_1(s)\cdot X_2(s)$

$$= \frac{1}{s}\left[e^{-s}+1-e^{-4s}\right] \times \frac{e^{-2}e^{-s}}{s+2}$$

$$X(s) = \frac{e^{-2}\left[e^{-2s}+e^{-s}+e^{-5s}\right]}{s(s+2)}$$

ii) $x(t) = t\frac{d}{dt}\left[e^{-t}\cos t\, u(t) + e^{-(t+1)}u(-(t+1))\right]$

$x_1(t) = e^{-(t+1)}u(-(t+1))$

$u(-(t+1))$

$$X_1(s) = \int_0^1 e^{-(t+1)} e^{-st}$$

$$= e^{-1}\int_0^1 e^{-(s+1)t}\,dt = e^{-1}\frac{1}{s+1}\left[1-e^{-(s+1)}\right]$$

$$= e^{-1} = \frac{1}{s+1}\left[e^{-1}+e^{-s}e^{-2}\right]$$

$$e^{-t}u(t)\cos t \leftrightarrow \frac{s}{(s+1)^2+1}$$

$$\frac{d}{dt}\left[e^{-t}\cos t\, u(t) + e^{-(t+1)}u(-(t+1))\right]$$

$$= s\left[\frac{s}{(s+1)^2+1} + \frac{e^{-1}+e^{-4s}}{s+1} + \frac{e^{-1}+e^{-s}e^{-2}}{s+1}\right.$$

from differentiation in frequency domain property $t\,x(t) \leftrightarrow -\frac{d}{ds}X(s)$

$$X(s) = -\frac{d}{ds}\left[\frac{s^2}{(s+1)^2+1} + \frac{s(e^{-1} - e^{-s}.e^{-2})}{s+1}\right]$$

Q.8 (b) A series circuit consists of a 300 Ω non-inductive resistor, a 7.95 μF capacitor and a 2.06 H inductor of negligible resistance.

If the supply voltage is

$v(t) = 250\sqrt{2}\sin(314t + 30°)$ V, calculate

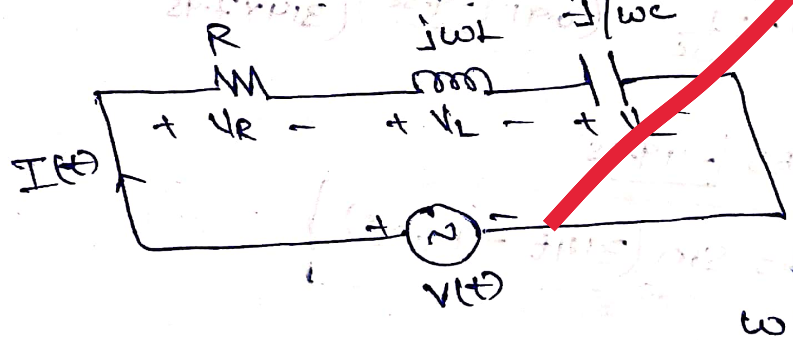
(i) the circuit current,

(ii) the voltage drop across each component in the circuit,

(iii) the power consumed in the circuit.

[5 + 10 + 5 marks]

(i) Given circuit can be drawn as



$\omega = 314$ rad/sec

$$Z = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

$$= 300 + j\left(314 \times 2.06 - \frac{10^6}{314 \times 7.95}\right)$$

$$= 300 + j\,246.24 = 388.11 \angle 39.38°$$

$$I(t) = \frac{V(t)}{Z} = \frac{V(t)}{388.11\angle 39.38^\circ} = \frac{250\sqrt{2}\angle 30^\circ}{388.11\angle 39.38}$$

$$= 0.91\angle -9.38^\circ$$

$$\therefore I(t) = 0.91 \sin(314t - 9.38^\circ) \text{ Amp}$$

(ii) $V_R = I(t) \cdot R = 0.91 \sin(314t - 9.38^\circ) \times 300$

$$= 273 \sin(314t - 9.38^\circ) \text{ Volts}$$

$$V_R = 273\angle -9.38^\circ \text{ V}$$

$$V_L = I(t) \cdot j\omega L = (0.91\angle -9.38^\circ)(314 \times 2.06\angle 90^\circ)$$

$$= 285.74\angle +80.62^\circ \text{ Volts}$$

$$V_L(t) = 285.74 \sin(314t + 80.62^\circ)$$

$$V_c = I(t) \cdot \frac{-j}{\omega C} = (0.91\angle -9.38)\left(\frac{10^6}{314 \times 7.95}\angle -90^\circ\right)$$

$$= 364.53\angle -99.38^\circ$$

$$V_c(t) = 364.53 \sin(314t - 99.38^\circ)$$

(iii) Power Consumed $S = V(t) I^*(t)$

$= \frac{250\sqrt{2}}{\sqrt{2}} \angle 30^\circ \times \frac{0.91}{\sqrt{2}} \angle 9.38^\circ$

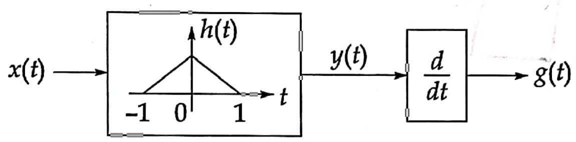
$= 160.86 \angle 39.38$ VA

Total power $S = (124.33 + j102.05)$ VA

Active power $P = 124.33$ Watts

Reactive power $Q = 102.05$ VAR

Q.8 (c) (i) Consider an LTI system has the impulse response $h(t)$ shown in figure below:



If the input $x(t) = \delta(t-1) + \delta(t-2) + \delta(t-3)$, then sketch output $g(t)$.

(ii) A voltage waveform $V(t)$ has a period $T = 2$ second, its Fourier series coefficient values are:

$C_0 = 1, C_1 = 2j, C_2 = 2,$

Obtain the value of $V(t)$ at $t = 0$.

[10 + 10 marks]

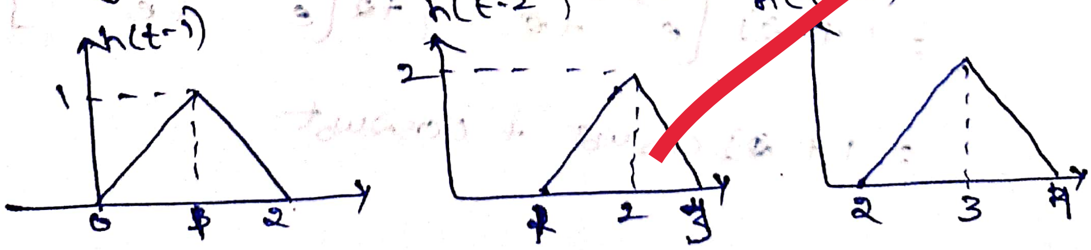
(i) $y(t) = h(t) * x(t)$

$= h(t) * (\delta(t-1) + \delta(t-2) + \delta(t-3))$

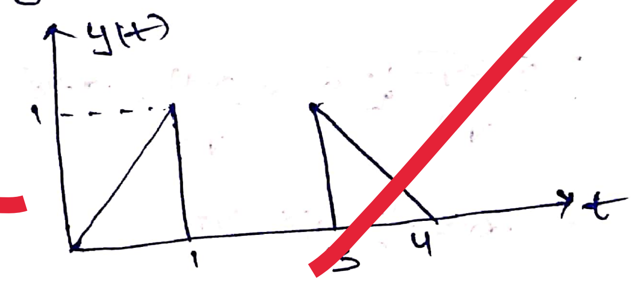
$= h(t) * \delta(t-1) + \delta(t-2) * h(t) + h(t) * \delta(t-3)$

$[\because x(t) * \delta(t-t_0) = x(t-t_0)]$

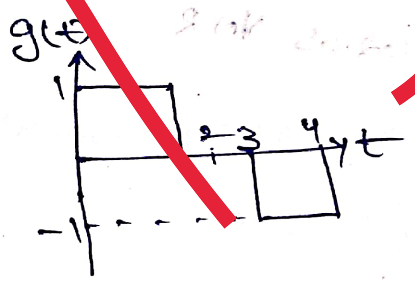
$\therefore y(t) = h(t-1) + h(t-2) + h(t-3)$



$y(t)$ can be drawn as



$g(t) = \frac{d}{dt} y(t)$



ii) Given $T = 2$ secs

$C_0 = 1$; $C_1 = 2j$; $C_2 = 1$

for odd signals C_0 will be zero ; but $C_0 \neq 0$

assuming $V(t)$ is even signal

i.e $C_k = C_{-k}$

$C_{-2} = 2j$; $C_{-1} = 2j$

$V(t)$ can be written as

$V(t) = 1 + 2j e^{-j\omega_0 t} + 2j e^{j\omega_0 t} + 2 e^{-j2\omega_0 t} + e^{j2\omega_0 t}$

$= 1 + 2j\left[e^{-j\omega_0 t} + e^{j\omega_0 t}\right] + 2\left[e^{-j2\omega_0 t} + e^{j2\omega_0 t}\right]$

$= 1 + 2j \cos\omega_0 t + \cos 2\omega_0 t$

$V(t) = 1 + j\cos\omega_0 t + \cos 2\omega_0 t$

at $t = 0$

$V(t) = 1 + j\cos(0) + \cos(0)$

$V(t) = (2 + j)$

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