Saket Centre

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ESE 2024 : 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 ☐	Pune ☐	
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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	25
Q.2	0
Q.3	30
Q.4	0
Section-B	
Q.5	24
Q.6	25
Q.7	0
Q.8	14
Total Marks Obtained	118

Signature of Evaluator .... Cross Checked by ....

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

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.

- Avoid calculation mistakes
- write step by step
- Explain theory questions further

Section A : Analog and Digital Communication Systems

Q.1 (a) With the help of frequency spectrum and the graphical representation of wave specify the difference between Amplitude Modulation and Linear addition of modulating signal and carrier signal. (Assume the modulating and carrier signal to be sinusoidal)

[12 marks]

$S_{AM}(t) = A$ Let $m(t) = A_m \sin \omega_m t$

$c(t) = A_c \cos \omega_c t$

Addition of $m(t)$ and $c(t)$ $= m(t) + c(t)$

$= A_m \sin \omega_m t + A_c \cos \omega_c t$

$S_{AM}(t) = A_c [1 + K_a m(t)] \cos \omega_c t$

Let $K_a = \frac{1}{A_c}$ → when ka not give for numerical calculation. $K_a A_m = \mu$ ($\mu = \frac{A_m}{A_c}$)

$= A_c \left[1 + \frac{1}{A_c} m(t)\right] \cos \omega_c t$

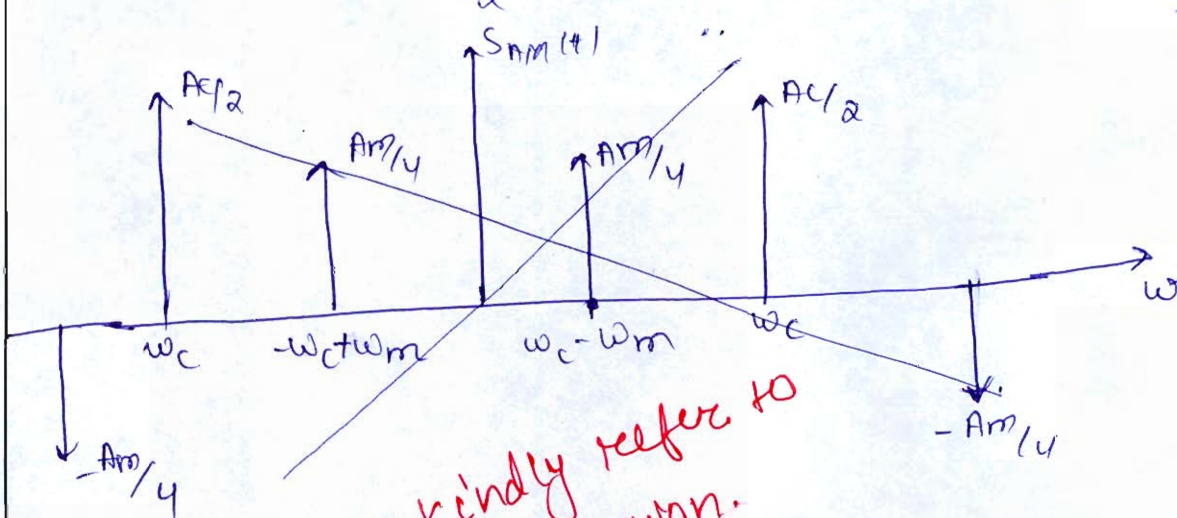
$= A_c \cos \omega_c t + m(t) \cos \omega_c t$ → $A_c m(t)$

1

$= A_c \cos \omega_c t + A_m \sin \omega_m t \cos \omega_c t$ → $A_m A_c$

$= A_c \cos \omega_c t + \frac{A_m}{2} [\sin(\omega_m + \omega_c)t + \sin(\omega_m - \omega_c)t]$ ← $\frac{A_m A_c}{2}$

$S_{AM}(t) = A_c \cos \omega_c t + \frac{A_m}{2} [\sin(\omega_m + \omega_c)t - \sin(\omega_c - \omega_m)t]$



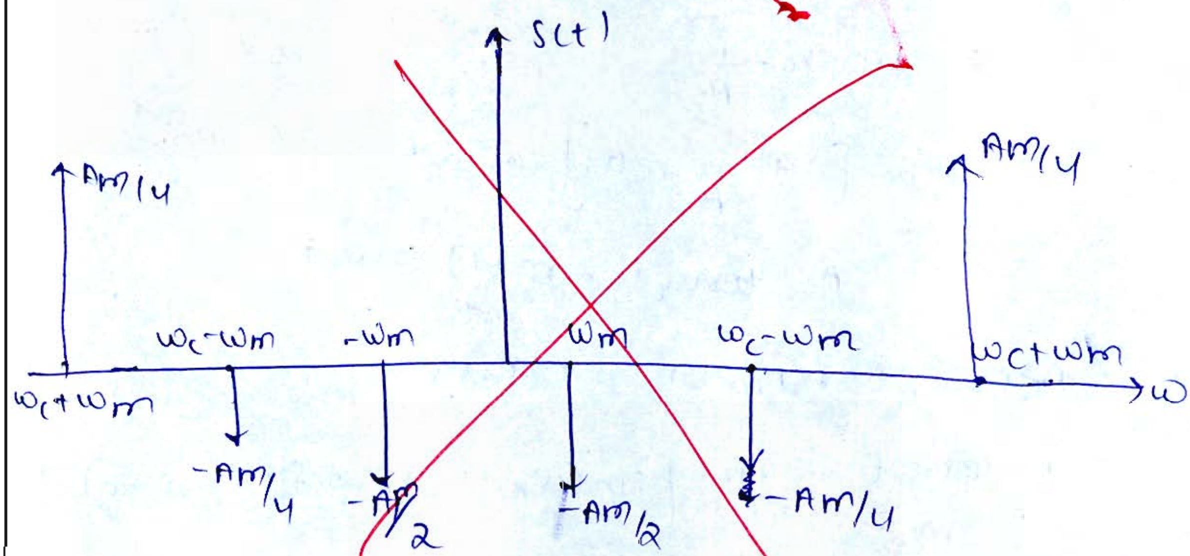
kindly refer to solution.

difference b/w $s_{AM}(t)$ and $[m(t) + c(t)] = s(t)$

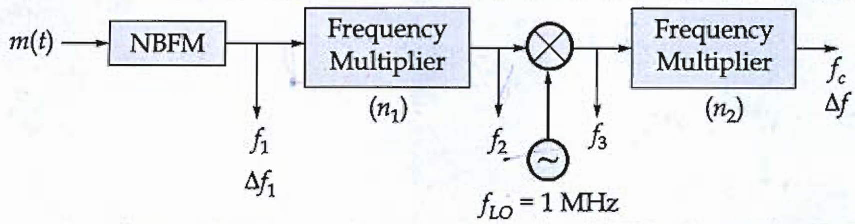
$s(t) = s_{AM}(t) - m(t) - c(t)$ → difference means not subtracting here compare between both

$= \frac{A_c \cos\omega_c t}{2} + \frac{A_m}{2}\left[\sin(\omega_m+\omega_c)t - \sin(\omega_c-\omega_m)t\right] - A_m \sin\omega_m t - A_c \cos\omega_c t$

$= \frac{A_m}{2}\sin(\omega_m+\omega_c)t - \frac{A_m}{2}\sin(\omega_c-\omega_m)t - A_m \sin\omega_m t$



Q.1 (b) Consider the block diagram of an Armstrong FM transmitter shown in the figure below:



It is given that f_1 = 175 kHz, n_1 = 16, n_2 = 32, Δf_1 = 50 Hz; then calculate

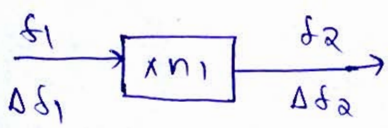
(i) The maximum frequency deviation Δf of the output FM signal.

(ii) The frequency f_3.

(iii) The possible values of carrier frequency f_c.

[12 marks]

NBFM → $\theta_i = \omega_c t + 2\pi k_f \int m(t)$



$f_2 = n_1 f_1$

$f_2 = 16 \times 175$

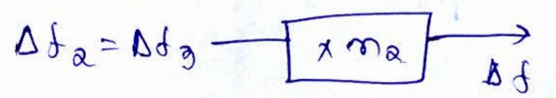
$f_2 = 2800\ KHZ$

(5)

$\Delta f_2 = n_1 \Delta f_1$

$\Delta f_2 = 16 \times 50 = 0.8\ KHZ$

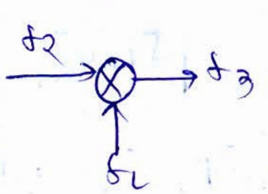
There is no effect of local oscillator frequency on frequency deviation so $\Delta f_2 = \Delta f_3$



$\Delta f = n_2 \times \Delta f_2$

$= 32 \times 0.8$

$\Delta f = 25.6\ KHZ$ ✓



⇒ $f_3 = f_2 \pm f_L$

$f_2 > f_L$ $\quad = -1000K + 2800K$

$f_3 = 18KHZ$ → 1800 KHZ

or

$f_3 = (2800 + 1000)\ KHZ$

$= 3800\ KHZ$

$f_c = n_2 f_3 = 32 \times 18$ → 1800

$f_c = 576$ KHz $= 57.6$ MHz

(i) $\Delta f = 25.6$ KHz

(ii) $f_3 = 18$ KHz ✗

(iii) $f_c = 576$ KHz ✗

Q.1 (c) The carrier $c(t) = A\cos 2\pi 10^6 t$ is angle modulated (PM or FM) by the sinusoidal signal $m(t)$. The modulation index β for frequency modulated signal and for phase modulated signal are 4.5 and 9 respectively. Also, using Carson's rule, the bandwidth for phase modulated and frequency modulated signals are 8.250 kHz and 15 kHz respectively. (Assume deviation constants are $K_p = 3$ rad/V and K_f Hz/V)

(i) Determine $m(t)$ and K_f

(ii) Write the expression of modulated signal for both phase and frequency modulated signal.

(iii) If the amplitude of $m(t)$ is decreased by a factor of two, then calculate the new modulation index for both the modulation schemes.

[12 marks]

$\beta_{FM} = 4.5$ $\quad \beta_{PM} = 9$ $\quad f_c = 10^6$ Hz

$BW_{FM} = 15$ KHz $\quad BW_{PM} = 8.250$ KHz

K_f $\quad K_p = 3$ rad/V

(i) $BW_{FM} = 2(\Delta f_{fm} + f_m) = 15K$.

$\Delta f + f_m = 7.5$ KHz

$\beta_{FM} = \frac{\Delta f_{FM}}{f_m} = 4.5$

$\Delta f = 4.5 f_m$

$\Delta f + f_m = 7.5K$

$4.5 f_m + f_m = 7.5K$

$f_m = \frac{7.5}{5.5}K$

$f_m = 1.36$ KHz

$A_m = ?$

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

$m(t) =$

(iii) $A_m' = \frac{A_m}{2}$

$[\beta_{FM}]_{new} = \frac{\Delta f}{f_m} = \frac{\beta_{old}}{2}$

$[\beta_{FM}]_{new} = \frac{4.5}{2}$

$[\beta_{FM}]_{new} = 2.25$

$[\beta_{PM}]_{new} = \frac{[\beta_{PM}]_{old}}{2}$

$= \frac{9}{2}$

$[\beta_{PM}]_{new} = 4.5$

$\Delta f = 7.5 - 1.36$

$\boxed{\Delta f_{PM} = 6.14 \text{ KHZ}}$

$S_{FM}(t) = A_c \cos[2\pi f_c t + 2\pi K_f \int m(t)]$

$\Delta\phi = 2\pi K_f \int m(t)$

$\Delta\omega = 2\pi K_f m(t)$

$\Delta f_{FM} = K_f A_m$ —— ①

for sinusoidal $m(t) \rightarrow \beta = \Delta\phi$

$\beta_{PM} = \frac{\Delta f_{PM}}{f_m}$

$BW = 2(\Delta f_{PM} + f_m)$

$9 = \frac{\Delta f}{f_m} \longrightarrow$

$\frac{8.250}{2} = \Delta f_{PM} + f_m$

$\frac{8.250}{2} = 10 f_m$

$\boxed{\Delta f_{PM} = 3.7125 \text{ KHZ}}$

$\boxed{f_m = 0.4125 \text{ KHZ}}$

$S_{PM}(t) = A_c \cos[2\pi f_c t + K_p m(t)]$

$\Delta\phi = K_p m(t)$

$\Delta\omega = K_p \frac{dm(t)}{dt}$

10

$\Delta f_{max} = \frac{K_p}{2\pi} \times A_m \times 2\pi f_m$

$3.7125 = \frac{3}{2\pi} \times A_m \times 2\pi \times 0.4125$

$\boxed{A_m = 3 \text{ Volt}}$

(i) $m(t) = 3 \cos 2\pi \times 1.36 \times 10^3 t$

$\boxed{m(t) = 3 \cos 8545.132\, t}$

from $\Delta f_{FM} = K_f A_m \Rightarrow K_f \times 3 = 6.14 \text{K}$

$\boxed{K_f = 2.046 \text{ KHZ/Volt}}$

(ii) $S_{FM}(t) = A \cos[2\pi 10^6 t + ~~12.855 \times 10^3~~ \sin 2\pi f_m t]$

1.5044 → 4.5

$S_{PM}(t) = A \cos[2\pi \times 10^6 t + 9 \cos 2\pi \times 0.4125 \times 10^3 t]$

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Q.1 (d) Compare the performance of an uncoded data transmission system with the performance of a coded system using the (7, 4) Hamming code with $d_{min} = 3$, when applied to the transmission of a binary source with rate $R = 10^4$ bits/sec. The channel is assumed to be an additive White Gaussian noise channel, the received power is 1 μW and the noise power spectral density is $\frac{N_0}{2} = 10^{-11}$ W/Hz. The modulation scheme is binary PSK. Consider $Q(3.16) = 7.86 \times 10^{-4}$ and $Q(4.14) = 1.73 \times 10^{-5}$.

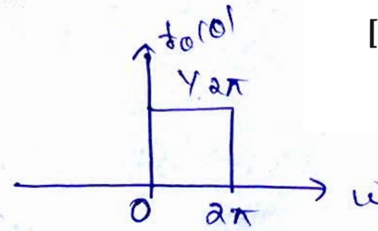
[12 marks]

Q.1 (e) Two random variables X and Y are related to another random variable θ, as $X = \sin\theta$ and $Y = \cos\theta$. If θ is uniformly distributed in the range $[0, 2\pi]$, then prove that X and Y are orthogonal, uncorrelated but not independent.

[12 marks]

- $X = \sin\theta$

$$E[X] = E[\sin\theta]$$



$$= \int_0^{2\pi} \sin\theta \, f_\theta(\theta)\, d\theta$$

$$= \int_0^{2\pi} \sin\theta \times \frac{1}{2\pi}\, d\theta = \frac{1}{2\pi}\left[-\cos\theta\right]_0^{2\pi}$$

$$E[X] = -\frac{1}{2\pi}[1-1] = 0.$$

$$\boxed{E[X] = 0}$$

9

- $Y = \cos\theta$

$$E[Y] = E[\cos\theta] = \int_0^{2\pi} \cos\theta \, f_\theta(\theta)\, d\theta$$

$$= \int_0^{2\pi} \cos\theta \times \frac{1}{2\pi}\, d\theta$$

$$= \frac{1}{2\pi}\left[\sin\theta\right]_0^{2\pi}$$

$$\boxed{E[Y] = 0}$$

- $E[XY] = E[\sin\theta\cos\theta] = E\left[\frac{\sin 2\theta}{2}\right]$

$$= \int_0^{2\pi} \frac{\sin 2\theta}{2} f_\theta(\theta)\, d\theta$$

$$= \int_0^{2\pi} \frac{\sin 2\theta}{2} \times \frac{1}{2\pi}\, d\theta$$

$$E[XY] = \frac{1}{4\pi}\left[-\frac{\cos 2\theta}{2}\right]_0^{2\pi}$$

$$= \frac{-1}{8\pi}[0-0]$$

$$E[XY] = 0$$

$$Cov(X,Y) = E[XY] - E[X]\,[Y]$$

$$= 0 - 0$$

$$= 0$$

$Cov(X,Y) = 0 \longrightarrow$ so it is uncorrelated.

Checking orthogonality
↳ for orthogonal $E[XY] = 0$ should.

So from above, we get

$\boxed{E[XY] = 0} \rightarrow$ it is orthogonal

$$E[X^2] = E[\cos^2\theta] = \int_0^{2\pi} \cos^2\theta \times \frac{1}{2\pi}\, d\theta$$

$$= \frac{1}{\pi}\int_0^{\pi/2} \cos^2\theta \, d\theta \quad = \frac{1}{2\pi}\int_0^{2\pi}\left(\frac{1+\cos 2\theta}{2}\right) d\theta = 1/2$$

$$= \frac{1}{\pi} \times \frac{\pi}{2} \times \frac{1}{2} = \frac{1}{4} \quad X \qquad \frac{2}{\pi}$$

$$E[Y^2] = E[\sin^2\theta] = \int_0^{2\pi} \sin^2\theta \times \frac{1}{2\pi}\, d\theta = \frac{1}{4} \quad X$$

$$E[X^2Y^2] = E\left[\frac{1}{4}\sin^2 2\theta\right] = \int_0^{2\pi} \frac{1}{4}\sin^2 2\theta \times \frac{1}{2\pi}\, d\theta$$

$$= \frac{1}{8\pi}\int_0^{2\pi} \frac{1-\cos 4\theta}{2}\, d\theta$$

$$= \frac{1}{16\pi}\left[[\theta]_0^{2\pi} - \left[\frac{\sin 4\theta}{4}\right]_0^{2\pi}\right]$$

$$= \frac{1}{16\pi}\left[2\pi - \frac{1}{4}\times 0\right] = \frac{1}{8}$$

So $E[XY] = E[X]\,E[Y]$

But $E[X^2Y^2] \neq E[X^2]\,[Y^2]$

So it is not independent.

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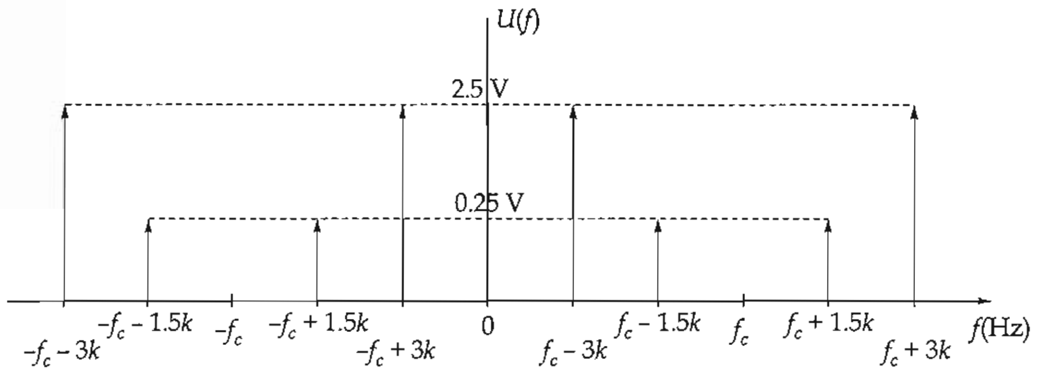
Q.2 (a) The spectrum of a Amplitude modulated signal, $U(f)$ is depicted below:



(Assume Amplitude of carrier signal, $A_C = 10$ volt)

(i) Write the expression for the AM signal $u(t)$ in time domain.. Also, determine the message signal, $m(t)$ and carrier signal, $c(t)$.

(ii) Identity the AM modulation scheme used from the given spectrum and mention some advantages of the scheme used over double side band full carrier (DSB-FC) AM modulation scheme. Also, calculate the % of power saved in the above modulation scheme as compared to DSB-FC.

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

(iv) With the help of total power dissipated, calculate the modulation index. Also calculate the bandwidth of the modulated signal.

[7 + 5 + 3 + 5 marks]

Q.2 (b) (i) The pulse rate in a DM system is 56,000 per sec. The input signal is $5 \cos(2\pi \times 1000t) + 2 \cos(2\pi \times 2000t)$ V, with t in sec. Find the minimum value of step size which will avoid slope overload distortion. What would be disadvantages of choosing a value of step-size which is larger than the minimum?

(ii) 1. Generate the CRC code for the data word 1110. The divisor polynomial is $p^3 + p + 1$.

2. Also, mention the advantage of cyclic codes.

[10 + 10 marks]

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Do not write in this margin

Q.2 (c) Discuss briefly the following parameters which are used to describe an AM receiver:

(i) Selectivity (ii) Sensitivity

(iii) Dynamic range (iv) Fidelity

[20 marks]

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Q.3 (a) **(i)** In a picture transmission, there are about 2.5×10^6 picture elements per frame. For good reproduction, 12 brightness levels are necessary. Assume all levels are equally likely to occur. Determine the channel bandwidth, without coding to transmit one picture frame every three minutes. (Assume the SNR over the channel to be 30 dB)

(ii) **1.** What do you understand by source coding? What is the purpose of the channel encoder and channel decoder?

2. Also, explain the purpose of the digital modulator and digital demodulator.

[10 + 10 marks]

(i)

$L = 12$

$R_b = n f_s$

$L = 12 \leq 2^n$

$n \geq 3.58$

$\boxed{n = 4}$

$f_s = 2.5 \times 10^6$

$R_b = 4 \times 2.5 \times 10^6 = 10^7 = 10$ Mbits/sec.

Read question carefully.

1

Channel capacity

$C \geq R_b$

$B \log_2(1 + SNR) \geq R_b$

B → channel B.W.

R_b → bit rate

SNR → Signal to Noise ratio of channel

$SNR = 10^3 = 1000$

$10^7 = B \log_2(1 + 1000)$

$10^7 = B \times 9.967$

$B = 0.1 \times 10^7$

$B = 10^6$ ~~M. Mbi~~ bits/~~sec~~ sec

$B.W = 10^6\ Hz$

(ii) ① Source coding

Source coding is used to reduce the unwanted bits. In this we provide the codes to each message signals to increase the efficiency of the transmission.

There are 2 types of source coding.

① variable length coding
② fixed length coding.

For more clarity refer to solution

7

Purpose of channel encoder →

channel encoder is used to reduce the signal noise and interference, in this signal is transmitted by encoding or we can say transmitted in discrete form.

channel decoder →

Channel decoder is used to detect or decode the incoming or received signal to to get back the original message signal.

② Purpose of Digital modulator → conversion to analog signal

Digital modulator is used to increase the frequency and reduce the antenna heights so that we can achieve long distance communication.

This definition is analog modulator

Purpose of Digital Demodulator → extract digital data from analog signal over comm channel

Digital Demodulator is used to demodulate the incoming modulated signal to get back the modulating signal.

kindly refer to solution for more clarity

(5)

Q.3 (b) An angle modulated signal with carrier frequency of 1 MHz is described by the equation:

$$S_{EM}(t) = 5\cos(\omega_c t + 20\sin 1000\pi t + 10\sin 2000\pi t)$$

Then, calculate

(i) The power of the modulated signal

(ii) The maximum frequency deviation Δf.

(iii) The maximum phase deviation $\Delta\phi$.

(iv) The bandwidth of $S_{EM}(t)$.

(v) Modulation index 'β'.

[20 marks]

(i) $P_t = P_c\left[1 + \frac{\beta^2}{2}\right]$.

$S_{EM}(t) =$ ~~β 5 co~~ $A_c\cos[\omega_c t + \beta_1 \sin\omega_1 t + \beta_2 \sin\omega_2 t]$

$\beta_1 = 20 \qquad \beta_2 = 10$.

$\beta^2 = \beta_1^2 + \beta_2^2 = 20^2 + 10^2 = 400 + 100$

$\beta^2 = 500$

$P_t = \frac{5^2}{2}\left[1 + \frac{500}{2}\right] = \frac{25}{2}[1 + 250]$

$P_t = 3.137$ KW

(ii) $\theta_i = \omega_c t + 20\sin 1000\pi t + 10\sin 2000\pi t$

$\frac{d(\theta_i)}{dt} = \omega_i = \omega_c + 20\times1000\pi\cos(1000\pi t) + 20000\pi\cos(2000\pi t)$

$f_i - f_c = \Delta f = 10^4\cos(1000\pi t) + 10^4\cos(2000\pi t)$

write proper step by step.

$|\Delta f|_{max} = 10^4 + 10^4 = 2\times10^4 = 20\,KHz$

$\Delta f_{max} = 20\,KHz$

-ceived ...on.

(iii)

$\Delta\phi = 20\sin 1000\pi t + 10\sin 2000\pi t$.

$|\Delta\phi|_{max} = |20\sin 1000\pi t + 10\sin 2000\pi t|_{max}$

$= 20 + 10$

$|\Delta\phi|_{max} = 30\ rad$

(iv) By carson rule.

$BW = 2(\Delta f_{max} + f_{max})$

$= 2[20$

$f_{max} = \frac{2000\pi}{2\pi}$

$f_{max} = 1000 = 1KHz$.

17

$BW = 2[20+1]K$

$BW = 42KHz$

(v) Modulation index (β)

$\beta = \frac{\Delta f}{f_{max}}$

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$$\beta = \frac{20}{1}$$

$$\boxed{\beta = 20}$$

(ii) (i)

$$P_t = \frac{A_c^2}{2}$$

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

$$\boxed{P_t = 12.5 \text{ watt}}$$

Q.3 (c) The parity check matrix of a (7, 4) linear block code is given as

$$H = \left[\begin{array}{ccc|cccc} 1 & 0 & 0 & 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 \end{array}\right].$$

(i) Find the generator matrix G for this code.

(ii) Determine all possible code words corresponding to the generator matrix.

(iii) Determine the minimum distance of the code word.

(iv) Check whether [0 1 0 0 0 1 1] is a valid codeword or not.

[4 + 8 + 4 + 4 marks]

(i) $G =$

Q.4 (a) A single-tone LSB-SSB modulated signal is generated using the phase-shift method of SSB generation. However, the narrow-band carrier phase-shift network cause a phase error '$\in$' between the input phase and quadrature phase carrier. Assume message signal as $\cos(\omega_m t)$ and carrier signal as $\cos(\omega_c t)$.

(i) Draw the block diagram for the generation of LSB-SSB signal for the above case.

(ii) Find the expression for the output SSB signal with the above given conditions and sketch the frequency spectrum.

(iii) Obtain the expression for the ratio of the power in the desired to undesired sideband as a function of $\in$.

(iv) Calculate the ratio of desired to undesired power, if phase error $\in$ is 15°.

[20 marks]

Q.4 (b) In a DSB-SC system, the carrier frequency is 600 kHz and the modulating signal $m(t)$ has a uniform PSD band limited to 5 kHz. The modulated signal is transmitted over a distortionless channel having a noise with PSD, $S_n(\omega) = \dfrac{1}{\omega^2 + a^2}$ where $a = 10^6\pi$. Assume the useful signal power at the receiver input is 1 μW. The received signal is band pass-filtered, multiplied by $2\cos\omega_c t$ and then low pass filtered to obtain the output $s_0(t) + n_0(t)$. Determine the output SNR.

[20 marks]

Q.4 (c) A binary channel has the following noise characteristics:

$$P(Y/X) = \begin{bmatrix} \frac{2}{3} & \frac{1}{3} \\ \frac{1}{3} & \frac{2}{3} \end{bmatrix}$$

(i) If the input symbols are transmitted with probabilities $\frac{3}{4}$ and $\frac{1}{4}$ respectively, calculate $H(X)$, $H(Y)$, $H(X, Y)$, $H\left(\frac{Y}{X}\right)$, $H(X \mid Y)$ and $I(X, Y)$.

(ii) Find the channel capacity, efficiency and redundancy of the channel.

[20 marks]

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

Q.5 (a) **(i)** The open loop transfer function of a system is given by $G(s) = \frac{5}{s(s+2)}$. It is desired to locate the pole of this transfer function at –6 and $-2 \pm j3$ by using a suitable PID controller. Determine the suitable gains needed for PID controller to achieve the given specifications.

(ii) Design a PD controller so that the system having open loop transfer function $G(s)H(s) = \frac{1}{s(s+1)}$ will have phase margin of 40° at 2 rad/sec.

[6 + 6 marks]

(i) PID controller $G'(s) = K_P + \frac{K_I}{S} + K_D S$

T.F. $G''(s) = G(s)\, G'(s)$

$$G''(s) = \frac{5}{S(S+2)}\left[\frac{K_P S + K_I + K_D S^2}{S}\right].$$

$$G''(s) = \frac{5\left[K_P S + K_I + K_D S^2\right]}{S^2(S+2)}$$

$$T.f = \frac{G''(s)}{1+G''(s)} = \frac{5\left[K_P S + K_I + K_D S^2\right]}{S^3 + 2S^2 + 5K_P S + 5K_I + 5K_D S^2}$$

(6)

Given Poles at -6, $-2 \pm j3$

$$C.E. \rightarrow (s+6)(s+2-j3)(s+2+j3)$$

$$C.E = (s+6)\left[(s+2)^2+9\right] = (s+6)\left[s^2+4+4s+9\right]$$

$$C.E = (s+6)\left[s^2+4s+13\right]$$

$$C.E = s^3+4s^2+13s+6s^2+24s+78$$

$$C.E. = s^3+10s^2+37s+78 \quad \text{—— (ii)}$$

equation (ii) compare with following equation is

$$= s^3+(2+5K_D)s^2+5K_P s+5K_I$$

$2+5K_D=10$

$5K_D=8$

$$\boxed{K_D=1.6}$$

$5K_P=37$

$$\boxed{K_P=7.4}$$

$5K_I=78$

$$\boxed{K_I=15.6}$$

$$\text{Gain} \rightarrow G'(s) = \left[7.4+1.6s+\frac{15.6}{s}\right]$$

(ii)

$$PD \rightarrow G(s) = K_P + K_D s$$

$$G''(s) = \frac{(K_P+K_D s)}{s(s+1)}$$

$$\phi = -90^\circ - \tan^{-1}\omega + \tan^{-1}\frac{K_D\omega}{K_P}$$

(5)

$$PM = 180^\circ + \phi$$

$$40 = 90^\circ - \tan^{-1}\omega + \tan^{-1}\frac{K_D\omega}{K_P}$$

$$-\tan^{-1}\omega + \tan^{-1}\frac{K_D\omega}{K_P} = -50^\circ$$

$$\tan^{-1}\frac{\omega - \frac{K_D\omega}{K_P}}{1+\omega^2\frac{K_D}{K_P}} = 50^\circ$$

$$\omega - \frac{K_D\omega}{K_P} = 1.19 + \omega^2 \times 1.19\frac{K_D}{K_P}$$

at ω = 2 rad/sec.

$2\left[1-\frac{K_D}{K_P}\right] = 1.19 + 4.76\frac{K_D}{K_P}$ —(1)

at $\omega_{gc} = 2$ rad/sec $|G'| = 1$

$\frac{\sqrt{K_P^2 + K_D^2\omega^2}}{\omega\sqrt{\omega^2+1}} = 1$

$\sqrt{\frac{K_P^2 + K_D^2 \times 4}{4\times 5}} = 1$

$K_P^2 + 4K_D^2 = 20$

$K_P^2 + 4[0.12K_P]^2 = 20$

$K_P^2[1+0.0576] = 20$

$K_P = 4.35$

$2 - \frac{2K_D}{K_P} - 4.76\frac{K_D}{K_P} = 1.19$

$6.76\frac{K_D}{K_P} = 0.81$

$\frac{K_D}{K_P} = 0.12$

$K_D = 0.521$

$G'(s) = 4.35 + 0.521s$

Q.5 (b) Write short notes on the following with respect to 8085 microprocessor:

(i) Maskable and non-maskable interrupts.

(ii) Vectored and non-vectored interrupts.

(iii) Edge triggered and level triggered interrupts.

(iv) Priority based interrupts.

[12 marks]

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Q.5 (c) Consider the following relations:

$$y(t) = x(t) * h(t) \quad ; \quad g(t) = x(3t) * h(3t)$$

Where "*" indicates the convolution. If the signal $g(t)$ can be represented as $g(t) = ay(bt)$, then determine the values of a and b without using any transform.

[12 marks]

We know the property

If $y(t) = x_1(t) * x_2(t)$.

then $x_1(at) * x_2(at) = \frac{1}{|a|} y(at)$

good

11

Given:

$g(t) = x(3t) * h(3t)$

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

$x(at) * h(at) = \frac{1}{|a|} y(at)$

Put $a = 3$.

$x(3t) * h(3t) = \frac{1}{3} y(3t)$

$g(t) = \frac{1}{3} y(3t)$ — (1)

equation (1) compare with given in question

$g(t) = a\,y(bt)$

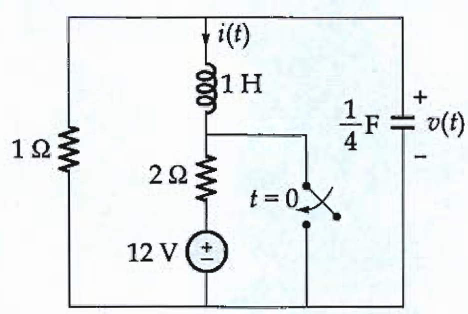
we get

$a = \frac{1}{3}$ $b = 3$

Q.5 (d) Explain all registers of 8086 Microprocessor.

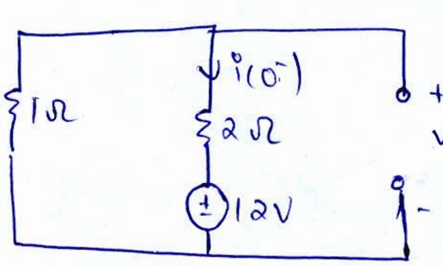
[12 marks]

Q.5 (e) For the given circuit, find $i(t)$ and $v(t)$ for $t > 0$.



[12 marks]

at $t = 0^-$, switch → open.



$i(0^-) = \frac{-12}{3}$

$i(0^-) = -4\ A$

$-v_c(0^-) + 2\,i(0^-) + 12 = 0$

$v_c(0^-) = -8 + 12$

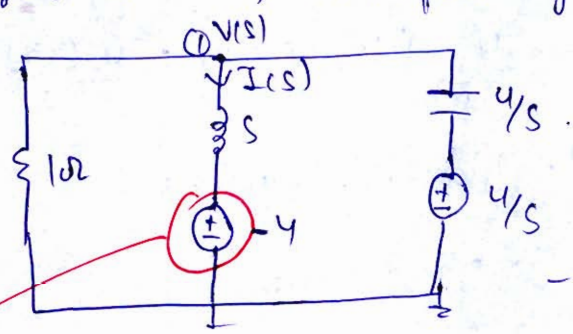
$v_c(0^-) = 4$ Volt

(3)

Inductor dacs not allow sudden change in cwrent so $i(0^-) = i(0^+) = -4A$

$v_c(0^-) = v_c(0^+) = 4V$ → capacitor doesn't allo w sudden change in voltage for $t > 0$, Transforming into Laplace

Kindly Refer to solution for more clarity



applying Nodal Analysis at Node 1.

$$\frac{V(s)}{1} + \frac{V(s)+4}{s} + \frac{V(s) - 4/s}{4/s} = 0.$$

$$V(s)\left[1 + \frac{1}{s} + \frac{s}{4}\right] = 1 - \frac{4}{s} = \frac{s-4}{s}.$$

$$V(s)\left[\frac{4s + 4 + s^2}{4s}\right] = \frac{s-4}{s}$$

$$V(s) = \frac{4(s-4)}{s^2+4s+4} = \frac{4(s-1)}{(s+2)^2}$$

$$V(s) = \frac{4}{s+2} - \frac{12}{(s+2)^2}$$

Taking Inverse laplace Transform

$$\boxed{V(t) = 4e^{-2t} - 12t\,e^{-2t}} \quad t > 0$$

$$I(s) = \frac{V(s)+4}{s}.$$

$$I(s) = \frac{4(s-1)}{s(s+2)^2} + \frac{4}{s} = \frac{4s - 4 + 4(s^2+4s+4)}{s(s+2)^2}$$

$$I(s) = \frac{4s - 4 + 4s^2 + 16s + 16}{s(s+2)^2} = \frac{4s^2 + 20s + 12}{s(s+2)^2}$$

$$I(s) = \frac{4(s^2+5s+3)}{s(s+2)^2} = \frac{A}{s} + \frac{B}{(s+2)^2} + \frac{C}{s+2}$$

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$A = \lim_{s \to 0} \frac{s I(s)}{s} = 3$

$B = \lim_{s \to -2} (s+2)^2 I(s) = \frac{4}{(-2)}[4-10+3] = \frac{4(-3)}{-2} = 6$

$C = \lim_{s \to -2} \frac{d}{ds} \frac{4}{s}(s^2+5s+3) = \frac{4}{s}(2s+5) + \frac{-4(s^2+5s+3)}{s^2}$

$= -2 - 4 + 10 - 3 = 1$

$I(s) = \frac{3}{s} + \frac{6}{(s+2)^2} + \frac{1}{(s+2)}$

Taking ILT

$i(t) = 3 + 6t e^{-2t} + e^{-2t}$ $t > 0$

Q.6 (a) A control system is represented by the state equation given below:

$\dot{x}(t) = Ax(t)$

If the response of the system is $x(t) = \begin{bmatrix} e^{-t} \\ -2e^{-t} \end{bmatrix}$ when, $x(0) = \begin{pmatrix} 1 \\ -2 \end{pmatrix}$ and $x(t) = \begin{pmatrix} e^{-2t} \\ -e^{-2t} \end{pmatrix}$

when $x(0) = \begin{pmatrix} 1 \\ -1 \end{pmatrix}$.

Calculate the system matrix A and state transition matrix for the system.

[20 marks]

Q.6 (b) Consider an initially relaxed causal LTI system characterized by the following difference equation:

$$y(n)-\frac{3}{4}y(n-1)+\frac{1}{8}y(n-2) = 2x(n)$$

(i) Find the frequency response $H(e^{j\omega})$ and the impulse response $h(n)$ of the system.

(ii) Find the response $y(n)$, if the input to this system is $x(n) = \left(\frac{1}{4}\right)^n u(n)$.

[20 marks]

(i) $y(n) - \frac{3}{4} y(n-1) + \frac{1}{8} y(n-2) = 2x(n)$

applying DTFT

$Y(e^{j\omega}) - \frac{3}{4} e^{-j\omega} Y(e^{j\omega}) + \frac{1}{8} e^{-2j\omega} Y(e^{j\omega}) = 2X(e^{j\omega})$

$Y(e^{j\omega}) \left[1 - \frac{3}{4} e^{-j\omega} + \frac{1}{8} e^{-2j\omega}\right] = 2X(e^{j\omega})$

$$H(e^{j\omega}) = \frac{Y(e^{j\omega})}{X(e^{j\omega})} = \frac{2}{1-\frac{3}{4}e^{-j\omega}+\frac{1}{8}e^{-2j\omega}}$$

$$H(e^{j\omega}) = \frac{2}{1 - \frac{1}{4}e^{-j\omega} - \frac{1}{2}e^{-j\omega} + \frac{1}{8}e^{-2j\omega}}$$

$$H(e^{j\omega}) = \frac{2}{1 - \frac{1}{4}e^{-j\omega} - \frac{1}{2}e^{-j\omega}\left[1 - \frac{1}{4}e^{-j\omega}\right]}$$

$$H(e^{j\omega}) = \frac{2}{(1 - \frac{1}{4}e^{-j\omega})(1 - \frac{1}{2}e^{-j\omega})}$$

good

10

$$H(e^{j\omega}) = \frac{-2}{1 - \frac{1}{4}e^{-j\omega}} + \frac{4}{1 - \frac{1}{2}e^{-j\omega}}$$

Taking IDTFT

$$\boxed{h(n) = -2\left(\frac{1}{4}\right)^n u(n) + 4\left(\frac{1}{2}\right)^n u(n)}$$

(ii) $x(n) = \left(\frac{1}{4}\right)^n u(n)$

Taking DTFT

$$X(e^{j\omega}) = \frac{1}{1 - \frac{1}{4}e^{-j\omega}}$$

2

$y(n) = x(n) * h(n)$

$Y(e^{j\omega}) = X(e^{j\omega})\, H(e^{j\omega})$

$$Y(e^{j\omega}) = \frac{1}{\left[1 - \frac{1}{4}e^{-j\omega}\right]} \times \frac{2}{\left[1 - \frac{1}{4}e^{-j\omega}\right]\left[1 - \frac{1}{2}e^{-j\omega}\right]}$$

$$Y(e^{j\omega}) = \frac{8}{1 - \frac{1}{2}e^{-j\omega}} - \frac{2}{\left[1 - \frac{1}{4}e^{-j\omega}\right]^2}$$

?

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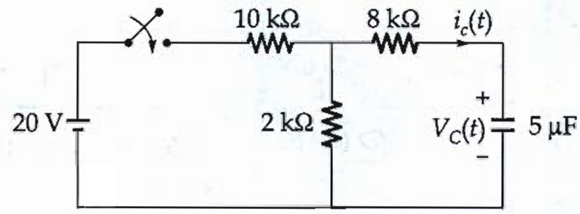
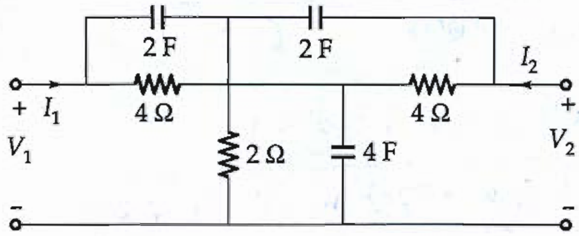
Q.6 (c) (i) In the network shown in figure, the switch closes at $t = 0$. The capacitor is initially uncharged. Find $V_C(t)$ and $i_c(t)$.



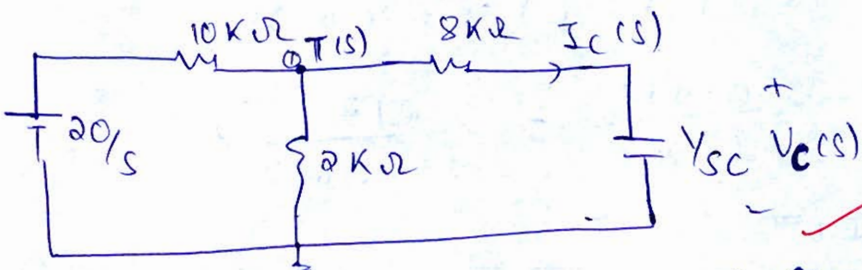
(ii) Find Y-parameters for the network shown in figure.



[10 + 10 marks]

(i) capacitor is initially uncharged → $V_C(0^-) = 0$.
$i_C(0^-) = 0$.

for $t > 0$, Transforming into laplace circuit.



applying Nodal analysis at Node ①.

4

$$\frac{T(S) - 20/s}{10K} + \frac{T(S)}{2K} + \frac{T(S)}{8K + 1/SC} = 0.$$

$$T(S)\left[\frac{1}{10K} + \frac{1}{2K} + \frac{1}{8K + 1/SC}\right] = \frac{20}{S \times 10K} = \frac{2}{S \times 10^3}$$

$$T(S)\cdot\left[\frac{1}{10K} + \frac{1}{2K} + \frac{1}{8K + \frac{200K}{S}}\right] = \frac{2}{S \times 10^3}$$

$$T(S)\left[\frac{6}{10} + \frac{S}{200 + 8S}\right] = \frac{2}{S}$$

$$T(S)\left[\frac{1200 + 48S + 10S}{2000 + 80S}\right] = \frac{2}{S}$$

$$T(s) = \frac{2(2000+80s)}{s(1200+58s)}$$

$$I_c(s) = \frac{T(s)}{8K + \frac{200K}{s}} = \frac{s\,T(s)}{8sK+200K}$$

$$I_c(s) = \frac{1}{8sK+200K} \times \frac{2(2000+80s)}{(1200+58s)}$$

$$= \frac{2(250+10s)}{(sK+200K)(600+29s)}$$

(25)

$$I_c(s) = \frac{(250+10s)\;1/29}{(s+200)\left(s+\frac{600}{29}\right)} \times 10^3 \; m$$

(25)

$$I_c(s) = \frac{0.034(250+10s)}{(s+200)(s+20.689)} \times 10^{-3}$$

$$I_c(s) = \frac{0.332}{s+200} - \frac{0.213}{s+20.689} \times 10^{-3}$$

Taking ILT

$$\boxed{i_c(t) = 0.332\,e^{-200t} - 0.213\,e^{-20.689t}} \; mA \quad t>0$$

$$V_c(s) = I_c(s) \times \frac{1}{sC}$$

$$= \frac{0.034(250+10s)}{(s+200)(s+20.689)} \times \frac{10^{-3}}{s \times 50\times10^{-6}} \; 10^{-3}$$

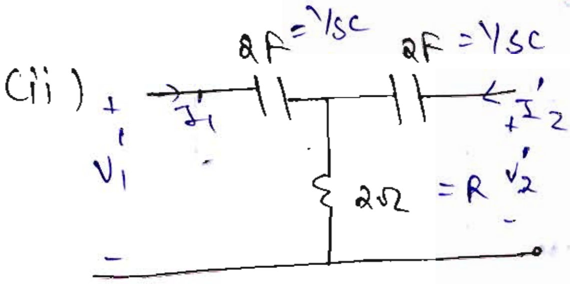
$$V_c(s) = \frac{0.68(250+10s)}{s(s+200)(s+20.689)}$$

$$V_c(s) = \frac{0.04}{s} - \frac{0.033}{s+200} + \frac{0.2056}{s+20.689}$$

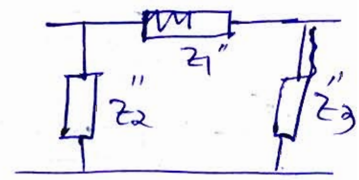
Taking ILT

$$v_c(t) = 0.04 - 0.033\,e^{-200t} + 0.2056\,e^{-20.689t} \quad t>0$$

(ii)



⇒



$$Z_2'' = \frac{1}{sC} + R + \frac{R/sC}{1/sC}$$

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

$$Z_2'' = 4 + \frac{1}{2s} = \frac{8s+1}{2s}$$

$$Z_1'' = \frac{1}{sC} + \frac{1}{sC} + \frac{1/s^2C^2}{R}$$

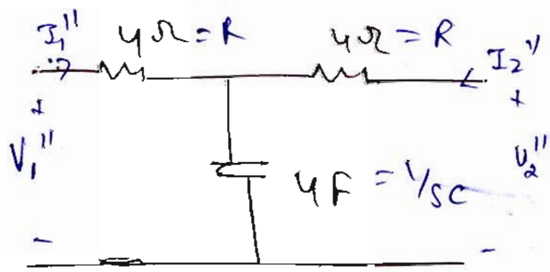
$$Z_1'' = \frac{2}{sC} + \frac{1}{s^2C^2R}$$

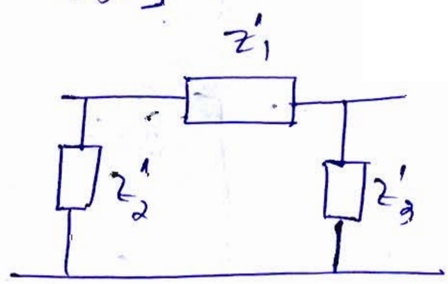
$$Z_1'' = \frac{1}{s} + \frac{1}{8s^2} = \frac{8s+1}{8s^2}$$

$$Z_3'' = R + \frac{1}{sC} + \frac{R/sC}{1/sC} = \frac{8s+1}{2s}$$

$$[Y_t'] = \begin{bmatrix} Z_1+Z_2 & Z_1 \\ Z_1 & Z_1+Z_3 \end{bmatrix} = \begin{bmatrix} \frac{8s+1}{s^2} + \frac{8s+1}{2s} & \frac{8s+1}{8s^2} \\ \frac{8s+1}{8s^2} & \frac{8s+1}{8s^2} + \frac{8s+1}{2s} \end{bmatrix}$$

$$[Y_t'] = \begin{bmatrix} \frac{(s+2)(8s+1)}{2s^2} & \frac{8s+1}{8s^2} \\ \frac{8s+1}{8s^2} & \frac{1+4s}{8s^2} \end{bmatrix}$$





$$Z_1' = 4 + 4 + \frac{16}{1/4s} = 8 + 64s$$

$$Z_2' = 4 + \frac{1}{4s} + \frac{1/s}{4} = 4 + \frac{1}{4s} + \frac{1}{4s} = 4 + \frac{1}{2s} = \frac{8s+1}{2s}$$

$$Z_3' = 4 + \frac{1}{4s} + \frac{1/s}{4} = \frac{8s+1}{2s}.$$

$$[Y'] = \begin{bmatrix} \frac{1}{8+64s} + \frac{2s}{8s+1} & \frac{1}{8+64s} \\ \frac{1}{8+64s} & \frac{1}{8+64s} + \frac{2s}{8s+1} \end{bmatrix}$$

$$[Y'] = \begin{bmatrix} \frac{2s+1/8}{8s+1} & \frac{1}{8(8s+1)} \\ \frac{1}{8(8s+1)} & \frac{\frac{1}{8}+2s}{8s+1} \end{bmatrix}$$

$$[Y''] = \begin{bmatrix} \frac{8s^2+2s}{8s+1} & \frac{8s^2}{8s+1} \\ \frac{8s^2}{8s+1} & \frac{2s+8s^2}{8s+1} \end{bmatrix}.$$

$$[Y] = [Y'] + [Y'']$$

$$= \begin{bmatrix} \frac{2s+\frac{1}{8}+8s^2+2s}{8s+1} & \frac{8s^2+1/8}{8s+1} \\ \frac{\frac{1}{8}+8s^2}{8s+1} & \frac{\frac{1}{8}+2s+2s+8s^2}{8s+1} \end{bmatrix}$$

(9)

$$= \begin{bmatrix} \frac{8s^2+4s+0.125}{8s+1} & \frac{8s^2+0.125}{8s+1} \\ \frac{8s^2+0.125}{8s+1} & \frac{8s^2+4s+0.125}{8s+1} \end{bmatrix}$$

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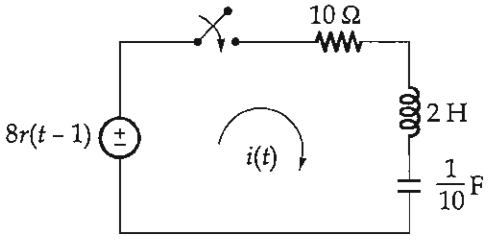
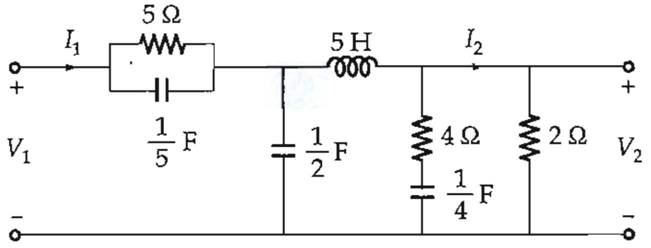
Q.7 (a) (i) For the network shown, determine the current $i(t)$ when the switch is closed at $t = 0$ with zero initial conditions.



(ii) Determine the voltage ratio $\frac{V_2}{V_1}$, current ratio $\frac{I_2}{I_1}$, transfer impedance $\frac{V_2}{I_1}$ and driving point impedance $\frac{V_1}{I_1}$ for the network shown in figure.



[5 + 15 marks]

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Q.7 (b) **(i)** The Fourier transform of the signal $x(t)$ is given by,

$$X(\omega) = \frac{d}{d\omega}\left[4\sin(4\omega)\frac{\sin(\omega/4)}{\omega}\right]$$

By using the properties of Fourier transform, determine and plot the signal $x(t)$.

(ii) Given that $x(t)$ has the Fourier transform $X(\omega)$. Express the Fourier transform of the following signals in terms of $X(\omega)$:

$$x_1(t) = x(1-t) + x(-1-t)$$

$$x_2(t) = x(3t-6)$$

$$x_3(t) = \frac{d^2}{dt^2}x(t-1)$$

[10 + 10 marks]

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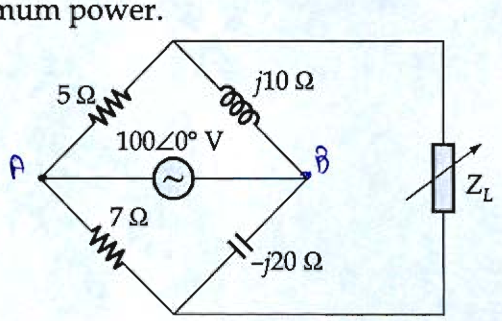
Q.7 (c) A control system has a transfer function given by $G(s) = \dfrac{s+3}{(s+1)(s+2)^2}$. Using the method of parallel decomposition, draw the state diagram with minimum number of integrators. Also obtain the state model.

[20 marks]

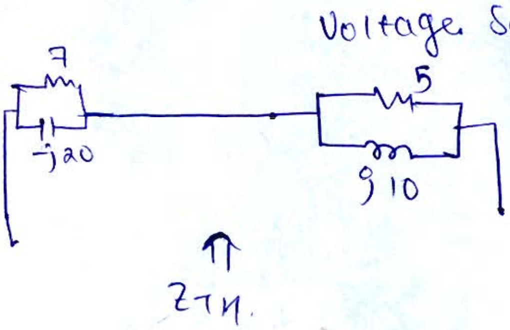
Q.8 (a) Find the value of Z_L for maximum power transfer in the network shown and also, calculate the maximum power.



[15 marks]

Calculating Z_{TH}

Voltage Source → Short circuited.



$$Z_{TH} = [7 \,||\, (-j20)] + [5 \,||\, (j10)]$$

$$Z_{TH} = \frac{-140j}{7-j20} + \frac{50j}{5+10j}$$

$$\boxed{Z_{TH} = 10.236 - 0.1826j} \ \Omega$$

$$\boxed{Z_{TH} = 10.2377 \angle -1.022^\circ}$$

for maximum Power Transfer

$$Z_L = Z_{TH}^*$$

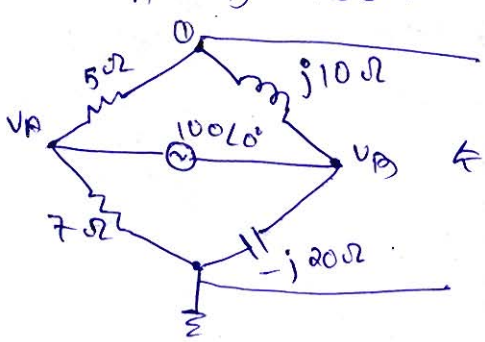
$$Z_L = 10.236 + 0.1826j$$

Power $= |I_L|^2 R_L$

$R_L = 10.236$.

Calculating V_{TH}.

$V_A - V_B = 100\ V$



← V_{TH}.

KCL at Node①

$$\frac{V_{TH}-V_A}{5} + \frac{V_{TH}-V_B}{j10} = 0$$

$$V_{TH}\left[\frac{1}{5}+\frac{1}{j10}\right] = \frac{V_A}{5} + \frac{V_B}{j10} \quad —①$$

at Node A and B Super Node

$V_A - V_B = 100$

$$\frac{V_A - V_{TH}}{5} + \frac{V_A}{7} + \frac{V_B - V_{TH}}{j10} + \frac{V_B}{-j20} = 0.$$

$$V_A\left[\frac{1}{5}+\frac{1}{7}\right] + V_B\left[\frac{1}{j10} - \frac{1}{j20}\right] = V_{TH}\left[\frac{1}{5}+\frac{1}{j10}\right]$$

$$0.343\, V_A - 0.05j\, V_B = V_{TH}\,[0.2 - 0.1j]$$

$$0.343\,[100 + V_B] - 0.05j\, V_B = V_{TH}\,(0.2 - 0.1j]$$

$$34.3 + V_B\,[0.343 - 0.05j] = V_{TH}\,[0.2 - 0.1j] \quad —②$$

from eq^n①

$$20 + V_B\,[0.5 + 0.1j] = V_{TH}\,[0.2 + 0.1j]$$

2 ← 0.2 - -

$$V_B = \frac{V_{TH}\,[0.2 + 0.1j] - 20}{0.5 - 0.1j}$$

Put in ②.

$$3.43 + \frac{V_{TH}(0.2 + 0.1j)(0.343 - 0.05j) - 20(0.343 - 0.05j)}{0.5 - 0.1j} = V_{TH}\,(0.2 - 0.1j)$$

$$-10.147 - 0.715j = V_{TH}\,[0.0678 - 0.175j]$$

Do not write in this margin

$V_{TH} = 54.2 \angle -107.147^\circ$

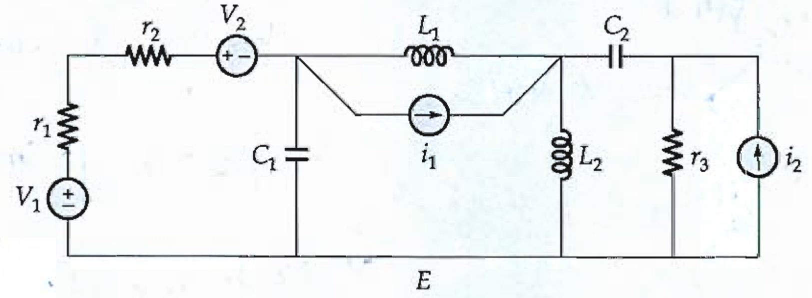
$|I_L| = \frac{|V_{TH}|}{|Z_{TH} + Z_L|} = \frac{54.2}{20.472} = 2.6475$

max. Power $= I_L^2 R_L$

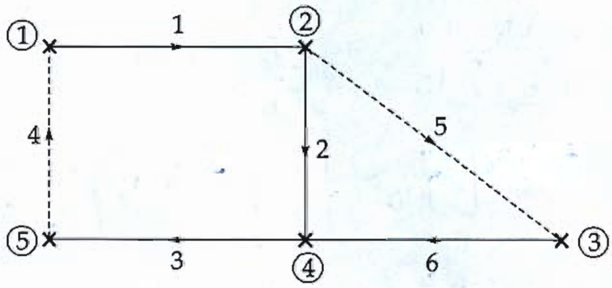
$= (2.647)^2 \times 10.236$

$P_{max} = 71.747$ watt

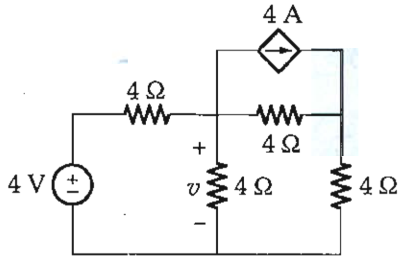
Q.8 (b) (i) Draw the oriented graph of network shown and obtain the incidence matrix.



(ii) Obtain the cutset matrix for the graph shown below:

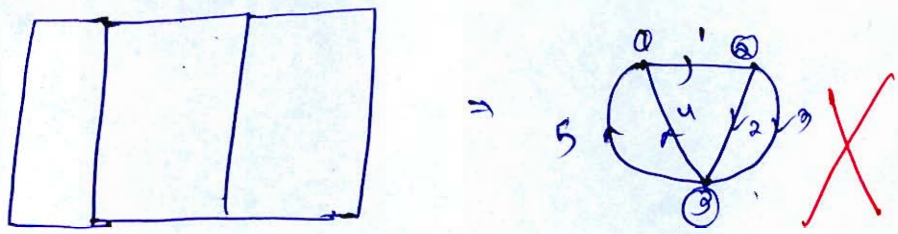


(iii) For the network shown in figure, write down the f-cutset matrix, obtain the KCL equilibrium equations in matrix form and calculate v.



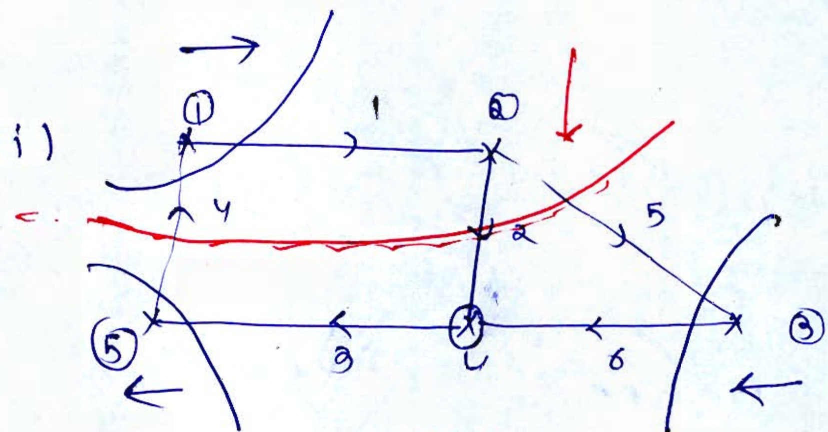
[5 + 5 + 15 marks]

(i)



Tree.

(ii)



2

Q.8 (c) (i) Write an 8085 assembly language program to store the content of its flag register in the memory location 3000 H.

(ii) Write an 8085 assembly language program to clear 150 consecutive bytes starting from memory location 2400 H.

(iii) Describe the following instructions of 8085 microprocessor:
1. SBI 2. SHLD 3. RAR 4. SPHL 5. DAD

[5 + 5 + 10 marks]

(iii) (1) SBI
↳ Subtract Immediately with Borrow

SBI Instruction means Subtract the content & Borrow from the Accumulator content and store it into Accumulator.

(2) SHLD
Stor the content present in HL pair Register. explain

5

(3) RAR
Rotate the content of Accumulator in Right through carry.

kindly Refer to solution for more clarity

(4) SPHL
Point out the stack Pointer at the address present in HL pair. explain

(5) DAD
Decrement the content of accumulator.

add register pair to H and L registers.

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OOOO

Space for Rough Work

Space for Rough Work

Space for Rough Work

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