Saket

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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

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Delhi ☐	Bhopal ☐	Jaipur ☑	Pune ☐	
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(Saket Centre, new delhi)

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	45
Q.2	47
Q.3	
Q.4	26
Section-B	
Q.5	21
Q.6	19
Q.7	
Q.8	
Total Marks Obtained	158

Good

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

1. Good handwriting as well writing skills

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.
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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]

1(a)

let modulating signal, $m(t) = A_m \cos(2\pi f_m t)$

and carrier signal, $c(t) = A_c \cos(2\pi f_c t)$ (let $f_c >>> f_m$)

Hence general expression of AM signal is given by:-

$$S_{AM}(t) = [A_c + A_m \cos 2\pi f_m t] \cos 2\pi f_c t$$

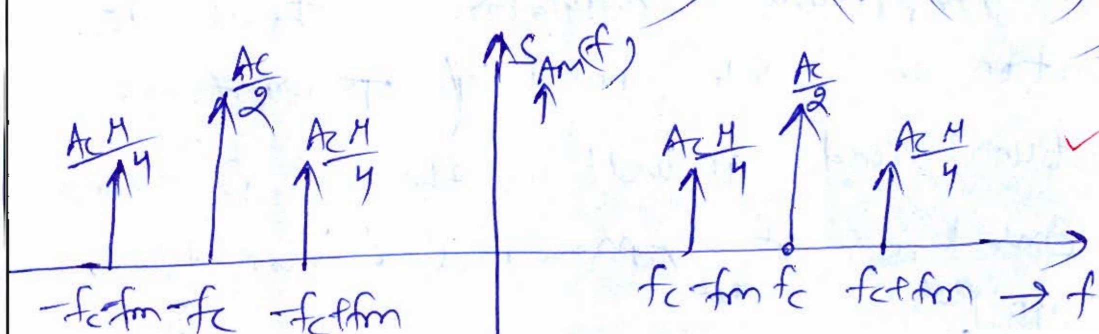
$$S_{AM}(t) = A_c [1 + \mu \cos 2\pi f_m t] \cos(2\pi f_c t) \quad \left(\text{where } \mu = \frac{A_m}{A_c}\right)$$

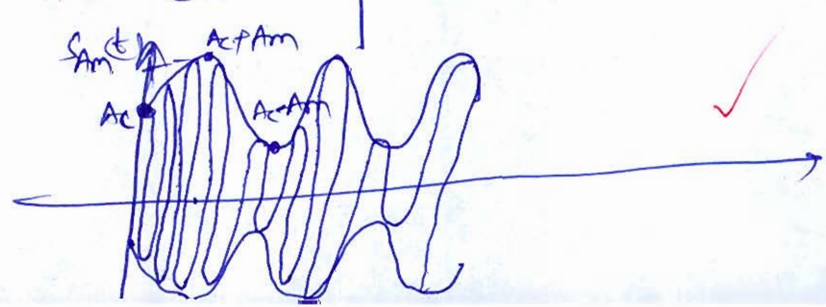
$$S_{AM}(t) = A_c \cos(2\pi f_c t) + A_c \mu \cos(2\pi f_m t) \cos(2\pi f_c t)$$

$$S_{AM}(t) = A_c \cos(2\pi f_c t) + \frac{A_c \mu}{2} [\cos 2\pi (f_c + f_m) t + \cos 2\pi (f_c - f_m) t]$$

now taking Fourier Transform both sides-

$$S_{AM}(f) = \frac{A_c}{2} [\delta(f - f_c) + \delta(f + f_c)] + \frac{A_c \mu}{4} [\delta(f - (f_c + f_m)) + \delta(f + (f_c + f_m))] + \frac{A_c \mu}{4} [\delta(f - (f_c - f_m)) + \delta(f + (f_c - f_m))]$$

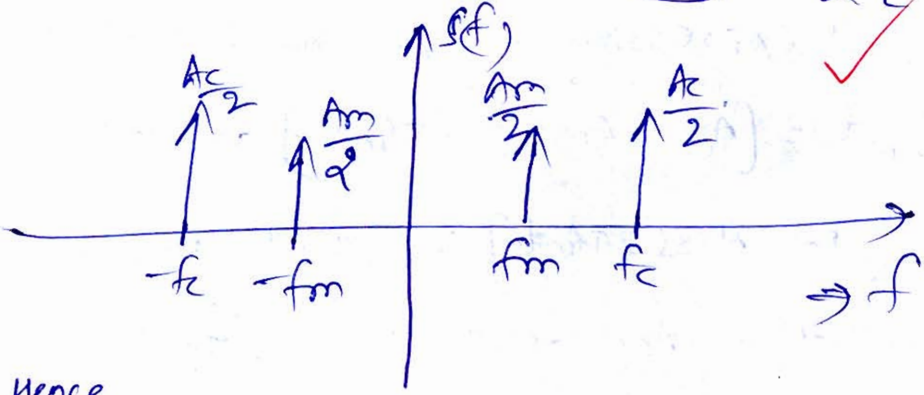




now let Linear Addition of modulating and carrier signal = $S(t) = m(t) + c(t)$

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

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



Hence in Linear Addition of modulating and carrier signal, There are impulses at carrier and modulating frequency Hence it does not form any Side Band and Also Linear Addition of m(t) and c(t) does not generate any modulated signal rather it generated another ~~modulated sign~~ sinusoidal signal.

But in Amplitude modulation, There is generation of Side Band (s ~~from~~ frequency spectrum) and as well as there is generation of Envelope of AM signal (from time-domain).

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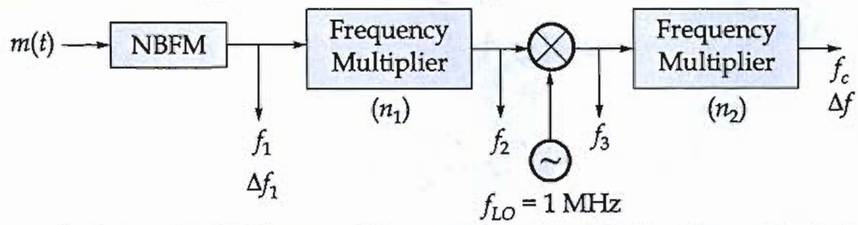
Good

.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]

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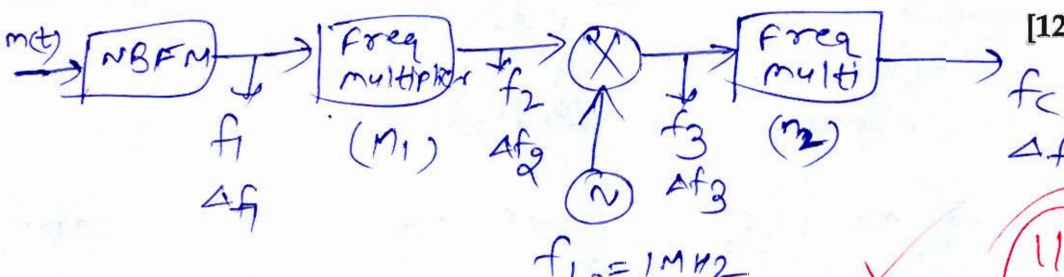

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$f_1 = 175$ KHz, $\Delta f_1 = 50$ Hz, $n_1 = 16$, $n_2 = 32$

(i) We can write, $f_2 = n_1 f_1 = 16 \times 175 \times 10^3 = 2.8$ MHz

$\Delta f_2 = n_1 \Delta f_1 = 16 \times 50 = 800$ Hz

Since $\Delta f_2 = \Delta f_3 = 800$ Hz

Hence $\Delta f = n_2 \Delta f_3 = 32 \times 800 = 25.6$ KHz

(i) Hence maximum frequency deviation $= \Delta f$

$\boxed{\Delta f = 25.6 \text{ KHz}}$

(ii) frequency, $f_3 = ?$

(a) Assume up conversion. Then $f_3 = f_2 + f_{LO}$

$f_3 = 2.8 + 1 = 3.8$ (MHz)

(b) Assume down conversion then $f_3 = f_2 - f_{LO}$

$f_3 = 2.8 - 1 = 1.8$ MHz

(iii) (a) let up conversion Then $f_3 = 3.8$ MHz

Hence $f_c = n_2 f_3 = 32 \times 3.8 = 121.6$ MHz

(b) Assume down conversion then $f_3 = 1.8$ MHz

Hence $f_c = n_2 f_3 = 32 \times 1.8$

$$f_c = 57.6 \text{ (MHz)}$$

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]

Soln

given:-

$c(t) = A\cos(2\pi 10^6 t)$

$\beta_{FM} = 4.5$, $\beta_{PM} = 9$, $(BW)_{PM} = 8.25$ KHz, $(BW)_{FM} = 15$ KHz

$K_p = 3 \frac{\text{rad}}{\text{Volt}}$, $K_f \left(\frac{\text{Hz}}{\text{Volt}}\right) = ?$

we know $\beta_{FM} = \frac{(\Delta f)_{FM}}{f_m}$ where f_m = msg frequency

~~Also $(BW)_{FM} = (\beta_{FM}+1)2f_m$~~

~~$15 \times 10^3 = (4.5+1)2f_m$~~

~~$f_m = 1.36$ (KHz)~~

(i)

We know for sinusoidal msg signal, $\beta = \Delta\phi$

where $\Delta\phi$ = maximum phase deviation

Hence $\beta_{PM} = [\Delta\phi]_{PM} = K_p A_m$ where A_m = msg Amplitude

$\Rightarrow A_m = \frac{\beta_{PM}}{K_p} = \frac{9}{3} = 3$ (Volt)

now $(BW)_{PM} = (\beta_{PM}+1)2f_m$

$8.25 \times 10^3 = (9+1)2f_m$

$$f_m = 0.4125 \text{ (KHz)}$$

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

$$m(t) = 3\cos(2\pi(412.5)t)$$

Also we know, $(BW)_{FM} = 2(\Delta f_{FM} + f_m)$

$$15\times10^3 = 2[\Delta f_{FM} + 0.4125]$$

$$\Delta f_{FM} = 7.0875\ (KHz)$$

Also we know, $\Delta f_{FM} = K_f A_m$

$$K_f = \frac{7.0875\times10^3}{3} = 2.3625\left(\frac{KHz}{Volt}\right)$$

(ii) Expression of frequency modulated signal is given by –

$$S_{FM}(t) = A\cos[2\pi 10^6 t + \beta \sin(2\pi f_m t)]$$

$$S_{FM}(t) = A\cos[2\pi\times10^6 t + 4.5\sin(2\pi(412.5)t)]$$

now Expression of phase modulated signal is given by –

$$S_{PM}(t) = A\cos[2\pi 10^6 t + \beta_{PM}\cos(2\pi f_m t)]$$

$$S_{PM}(t) = A\cos[2\pi 10^6 t + 9\cos(2\pi(412.5)t)]$$

(iii) now Amplitude of m(t) is decreased by a factor 2 Hence $A_m^q = \frac{A_m}{2} = 1.5(\text{volt})$

Hence $\beta_{PM}^q = K_p A_m^q = 3\times1.5 = 4.5$

$$\beta_{FM}^q = \frac{K_f A_m^q}{f_m} = \frac{2.3625\times10^3\times1.5}{412.5}$$

$$\beta_{FM}^q = 8.59$$

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]

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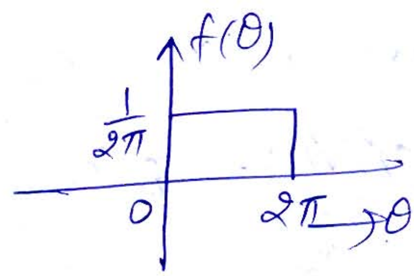
Q.1 (e) Two random variables X and Y are related to another random variable θ, as $X = \sin\theta$ and $Y = \cos\theta$. If θ is uniformly distributed in the range $[0, 2\pi]$, then prove that X and Y are orthogonal, uncorrelated but not independent.

[12 marks]

Soln

given:-

$X = \sin\theta \quad , \quad Y = \cos\theta$



now $E[X] = \int_{-\infty}^{\infty} x\, f(\theta)\, d\theta$

$E[X] = \int_0^{2\pi} \sin\theta \left(\frac{1}{2\pi}\right) d\theta = \frac{1}{2\pi}\left[-\cos\theta\right]_0^{2\pi} = 0$

$E[Y] = \int_{-\infty}^{\infty} Y\, f(\theta)\, d\theta = \int_0^{2\pi} \cos\theta \left(\frac{1}{2\pi}\right) d\theta = \frac{1}{2\pi}\left[\sin\theta\right]_0^{2\pi} = 0$

$E[X^2] = \int_{-\infty}^{\infty} x^2 f(\theta)\, d\theta = \int_0^{2\pi} (\sin^2\theta)\frac{1}{2\pi}\, d\theta = \frac{1}{2\pi}\int_0^{2\pi}\left[\frac{1-\cos 2\theta}{2}\right] d\theta$

$E[X^2] = 0.5$

$E[Y^2] = \int_{-\infty}^{\infty} y^2 f(\theta)\, d\theta = \int_0^{2\pi} (\cos^2\theta)\left(\frac{1}{2\pi}\right) d\theta = \frac{1}{2\pi}\int_0^{2\pi}\left(\frac{1+\cos 2\theta}{2}\right) d\theta$

$E[Y^2] = 0.5$

(i) orthogonality

$E[XY] = E[\sin\theta\cos\theta] = E\left[\frac{\sin 2\theta}{2}\right] = \int_{-\infty}^{\infty}\left(\frac{\sin 2\theta}{2}\right) f(\theta)\, d\theta$

$E[XY] = \int_0^{2\pi}\left(\frac{\sin 2\theta}{2}\right)\left(\frac{1}{2\pi}\right) d\theta = \frac{1}{4\pi}\left[-\frac{\cos 2\theta}{2}\right]_0^{2\pi}$

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

Since $E[XY] = 0$ Hence X and Y are orthogonal to each other.

(ii) now $\text{cov}(X;Y) = E[(X-m_X)(Y-m_Y)] = E(XY) - E(X)E(Y)$

$\text{cov}(X;Y) = 0 - 0 \times 0 = 0$

Since $\text{cov}(X;Y) = 0$ Hence X and Y are said to be uncorrelated.

(iii) now Since $E(XY) = 0$ and $E(X)E(Y) = 0$

Also $E[X^2Y^2] = E(\sin^2\theta \cos^2\theta) = E\left[\frac{\sin^2 2\theta}{4}\right]$

$E[X^2Y^2] = \int_0^{2\pi} \left(\frac{\sin^2 2\theta}{4}\right)\left(\frac{1}{2\pi} d\theta\right) = \frac{1}{8\pi}\int_0^{2\pi}\left[\frac{1-\cos 4\theta}{2}\right] d\theta$

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

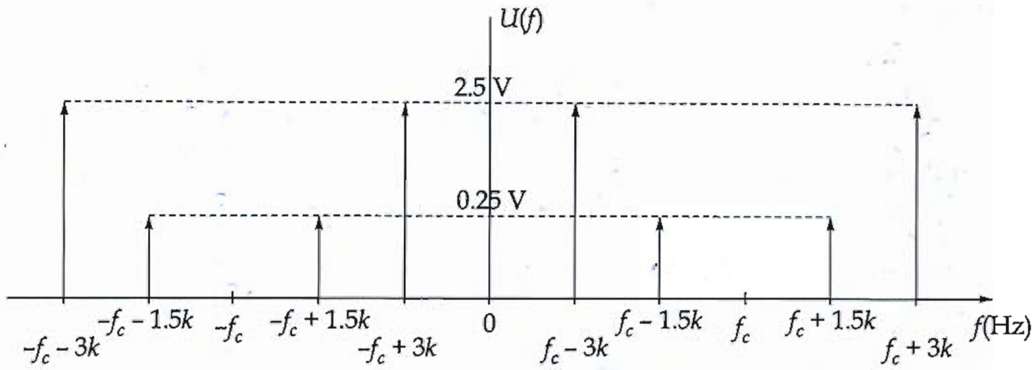
$E[X^2Y^2] = \frac{1}{16\pi}\{2\pi - 0\} = \frac{1}{8} = 0.125$

Also $E(X^2)E(Y^2) = 0.5 \times 0.5 = 0.25$

now Since $E[X^2Y^2] \neq E(X^2)E(Y^2)$ Hence X and Y are not independent.

(12) Good

.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.

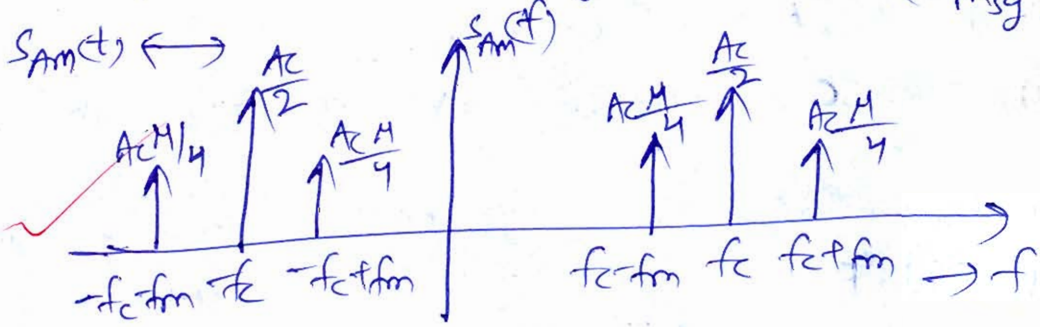
(iv) With the help of total power dissipated, calculate the modulation index. Also calculate the bandwidth of the modulated signal.

[7 + 5 + 3 + 5 marks]

14M

(i) given: $A_C = 10$ volt

Standard AM spectrum is given as below (for sinusoidal msg signal)



by comparing given AM spectrum with standard AM spectrum, we can write -

$$\frac{A_c \mu_1}{4} = 0.25 \Rightarrow \mu_1 = \frac{4 \times 0.25}{10} = 0.1$$

Also $$\frac{A_c \mu_2}{4} = 2.5 \Rightarrow \mu_2 = \frac{4 \times 2.5}{10} = 1$$

Also There is not any carrier component present in given AM spectrum.

Also $f_{m_1} = 1.5K$ and $f_{m_2} = 3K$, Also $\mu_t^2 = \mu_1^2 + \mu_2^2 = (0.1)^2 + (1)^2 = 1.01$

now we can write

$$y(f) = 0.25\left[\delta(f-(f_c+1.5K)) + \delta(f+(f_c+1.5))\right] + 2.5\left[\delta(f-(f_c+3K)) + \delta(f+(f+3K))\right] + 0.25\left[\delta(f-(f_c-1.5K)) + \delta(f+f_c-1.5K)\right] + 2.5\left[\delta(f-(f_c-3K)) + \delta(f+(f_c-3K))\right]$$

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, taking inverse fourier Transform –

$$y(t) = 0.5\cos(2\pi(f_c+1.5K)t) + 0.5\cos(2\pi(f_c-1.5K)t) + 5\cos(2\pi(f_c+3K)t) + 5\cos(2\pi(f_c-3K)t)$$

now carrier signal, $c(t) = A_c\cos(2\pi f_c t) = 10\cos(2\pi f_c t)$

message signal, $m_1(t) = A_{m_1}\cos(2\pi f_{m_1} t) = 1\cos(2\pi(1.5\times10^3)t)$

and $m_2(t) = A_{m_2}\cos(2\pi f_{m_2} t) = 10\cos(2\pi(3\times10^3)t)$

(ii) given modulation scheme is double side band suppressed carrier. (DSB-SC)

Advantage of DSB-SC over DSB-FC :-

(a) in DSB-SC, power is saved in comparision of DSB-FC.

(b) generation of DSB-SC is easier in comparision of DSB-FC.

% of power saved in DSB-SC as compared to DSB-FC $= \dfrac{P_c}{P_c\left[1+\frac{\mu_t^2}{2}\right]} \times 100(\%)$

4

$$= \left(\frac{2}{2+\mu_t^2}\right)\times 100\ (\%)$$

$$= \frac{2}{2+1.01}\times 100\ (\%)$$

$$= 66.44\ (\%) \longrightarrow \text{Answer}$$

1

(iii) ~~power in~~ Carrier power, $P_c = \dfrac{A_c^2}{2} = 50$ watt

power in $(f_c+1.5K)$ frequency $= \dfrac{(0.5)^2}{2} = 0.125$ watt

$\rightarrow (0.25)^2$

power in $(f_c + 3K)$ frequency $= \frac{(5)^2}{2} = 12.5$ (watt)

power in $(f_c - 1.5K)$ frequency $= \frac{(0.5)^2}{2} = 0.125$ (watt) 0.25

power in $(f_c - 3K)$ frequency $= \frac{(5)^2}{2} = 12.5$ (watt)

(iv) Total power dissipated $= P_{total} = (0.125)2 + (12.5)2$

$P_{total} = 25.25$ (watt)

5

now we know, $P_{total} = P_c \frac{\mu_t^2}{2}$ (for DSB-SC for multitone)

Hence $\mu_t = \sqrt{\frac{2P_{total}}{P_c}} = \sqrt{\frac{2 \times 25.25}{50}} = 1.0049$

(μ_t = modulation index for multitone DSB-SC)

now bandwidth of modulated signal $= 2f_{m_2} = 2 \times 3 = 6$ KHz

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]

soln given:- for DM system, pulse Rate = data Rate $= R_b = 56000$ bits per sec

input signal, $m(t) = 5\cos(2\pi \times 1000t) + 2\cos(2\pi \times 2000t)$ (volt)

To avoid slope overload errors,

$$\frac{\Delta}{T_s} \geq \left|\frac{dm(t)}{dt}\right|_{max} \quad \text{——} (1)$$

$$\frac{dm(t)}{dt} = \frac{d}{dt}\left[5\cos(2\pi \times 1000t) + 2\cos(2\pi \times 2000t)\right]$$

$$\frac{dm(t)}{dt} = -10\pi \times 1000 \sin(2\pi \times 1000t) - 4\pi \times 2000 \sin(2\pi \times 2000t)$$

now $\left|\frac{dm(t)}{dt}\right|_{max} = 10\pi \times 1000 + 4\pi \times 2000 = 10000\pi + 8000\pi$

$$\left|\frac{dm(t)}{dt}\right|_{max} = 18000\pi$$

Hence from equation (1) -

$$\Delta f_s \geq \left|\frac{dm(t)}{dt}\right|_{max}$$

where $f_s = R_b = 56000$ (bps)

(9)

$$\Delta \geq \frac{18000\pi}{56000}$$

$$\Delta \geq 1.00979$$

Hence $\boxed{\Delta_{min} = 1.00979 \text{ (volt)}}$ → To avoid slope overload error

if we choose step size larger than minimum step size than granular distortion will occur in DM system.

(ii) (1) data word = 1110

divisor polynomial $= p^3 + p + 1$

divisor polynomial codeword = 1011

Hence we will append 3 zeros in the data word.

```
            11
1011 ) 1110000
   ⊕   1011
       ~~0~~101000
   ⊕    1011
       ~~000~~100
```

⊕ ≡ modulo-2 operation

~~Hence CRC code = 100~~

Remainder = 100

Hence CRC Code = 1110100

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(2) advantage of cyclic codes :-

cyclic codes are used to detect errors in a bitstream.

cyclic codes are generated with the help of Hamming codes.

cyclic codes are prefix free codes and gives better coding efficiency.

2

Refer solution

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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]

Solu^n

AM Receiver parameters –

(i) Selectivity :- selectivity of AM Receiver is the ability of a receiver to detect weak signals and amplifying those signals. selectivity of TRF receivers is HIGH in comparison of superheterodyne receivers since for TRF receivers gain is High. gain should be increased to improve selectivity of a receiver but when gain is increased then system will become unstable.

(ii) Sensitivity :-

Sensitivity of a Receiver is the ability of a receiver to increase signal to noise Ratio of weak signals. To increase signal to noise Ratio of weak signal, we are using companding Technique (A-law and μ-law).

(iii) dynamic Range :-

dynamic Range of a Receiver is the Amplitude variation from peak to peak of a Received signal in the Receiver. dynamic Range of a Receiver should be low for minimum error [quantization]. Hence dynamic Range of a superhetero-dyne Receiver is Low in comparison of TRF receivers.

iv) fidelity :-

Fidelity of a Receivers is the ablity of a Receivers To Reproduce all the frequency component present in message signal. To increase Fidelity of a Receiver we are using gang tuning capacitor. for large Range of gang tuning capacitor, fidelity will be High but cost will be High.

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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]

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]

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]

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.

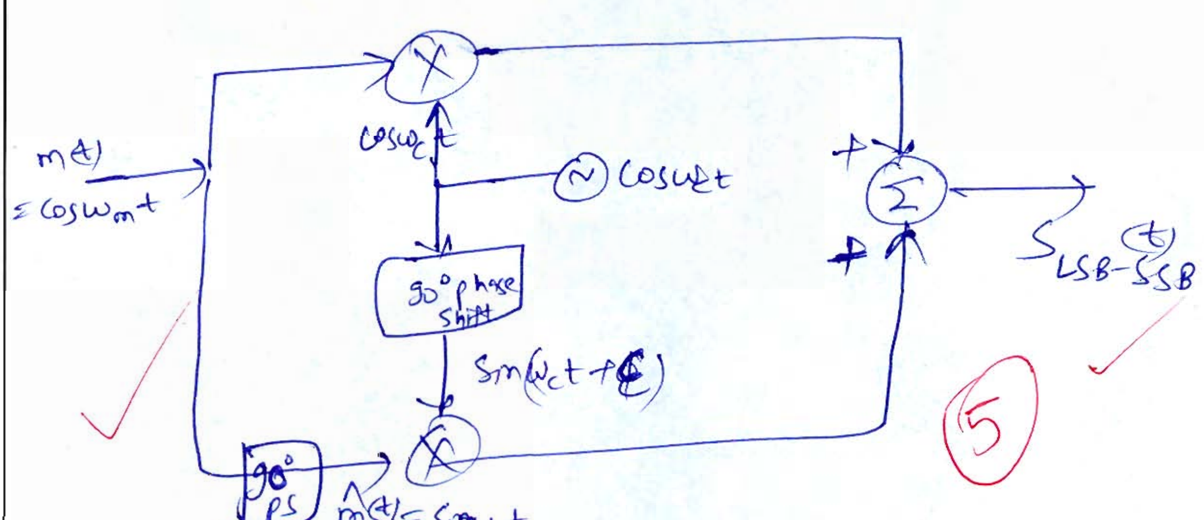
(iii) Obtain the expression for the ratio of the power in the desired to undesired sideband as a function of $\in$.

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

[20 marks]

Sol^n

(i) Block diagram for generation of LSB - SSB



(ii) $S_{LSB-SSB}(t) = \cos\omega_m t \cos\omega_c t + \sin\omega_m t \sin(\omega_c t + \epsilon)$

$S_{LSB-SSB}(t) = \frac{1}{2}[\cos(\omega_c + \omega_m t) + \cos(\omega_c - \omega_m)t]$

$+ \frac{1}{2}[\cos((\omega_c - \omega_m)t + \epsilon) - \cos((\omega_c + \omega_m)t + \epsilon)]$

take fourier Transform

(2)

$$S_{LSB-SSB}(f) = \frac{\pi}{2}\left[\delta\left(\omega - (\omega_c + \omega_m)\right) + \delta\left(\omega + (\omega_c + \omega_m)\right)\right]$$

$$+ \frac{\pi}{2}\left[\delta\left(\omega - (\omega_c - \omega_m)\right) + \delta\left(\omega + (\omega_c - \omega_m)\right)\right]$$

$$+ \frac{\pi}{2}\,\delta\,\omega - \omega_c + \omega_m .$$

incomplete

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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]

Solution given :-

$f_c = 600$ KHz

~~$f_m = 5$ KHz $= W$~~

$f_m = W =$ msg Bandwidth $= 5$ KHz

noise PSD, $S_n(\omega) = \dfrac{1}{\omega^2 + a^2}$; $a = 10^6\pi$ ✓

useful signal power, $P_{in} = S_i = 1\,\mu W$ ✓

input noise power, $n_i = \dfrac{1}{2\pi}\displaystyle\int_{-W}^{W} S_n(\omega)\, d\omega$ (1)

$n_i = \dfrac{1}{2\pi}\displaystyle\int_{-W}^{W} \left(\dfrac{1}{\omega^2 + a^2}\right) d\omega$

$$n_i = \frac{1}{2\pi(2a)} \int_{-W}^{W} \frac{2a}{a^2+\omega^2} d\omega$$

$$n_i = \frac{1}{4\pi a} \left[\tan^{-1}\left(\frac{\omega}{a}\right) \right]_{-W}^{W}$$

$$n_i = \frac{1}{4\pi(10^6\pi)} \left[\tan^{-1} \frac{5\times10^3(2\pi)}{10^6\pi} - \tan^{-1}\left(\frac{-5\times10^3\times2\pi}{10^6\pi}\right) \right]$$

$$n_i = \frac{1}{4\times10^6\pi^2} \left(\tan^{-1} 0.01 + \tan^{-1} 0.01 \right)$$

$$n_i = \frac{2\times0.57\times\pi}{180\times4\times10^6\times\pi^2} = 5.039\times10^{-10} \text{ (watt)}$$

Hence output noise power, $n_o = 2n_i$

$$\boxed{n_o = 1.007\times10^{-9} \text{ (watt)}}$$

Refer solution

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 $H(X)$, $H(Y)$, $H(X, Y)$, $H\left(\frac{Y}{X}\right)$, $H(X|Y)$ and $I(X, Y)$.

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

[20 marks]

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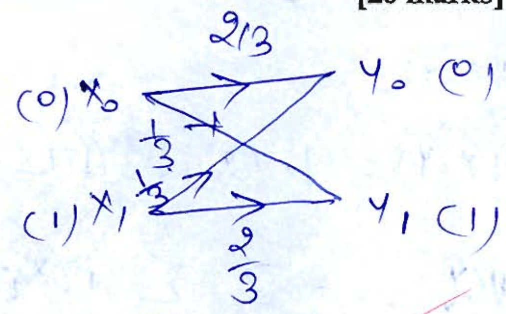
$$\left[P\left(\frac{Y}{X}\right)\right] = \begin{matrix} & y_0 & y_1 \\ x_0 & \frac{2}{3} & \frac{1}{3} \\ x_1 & \frac{1}{3} & \frac{2}{3} \end{matrix}$$



(i) given:- $P(0) = \frac{3}{4}$, $P(1) = \frac{1}{4}$

$$H(X) = -\sum_{i=1}^{2} P(x_i) \log_2 P(x_i)$$

$$H(X) = -\left[\frac{3}{4}\log_2\frac{3}{4} + \frac{1}{4}\log_2\frac{1}{4}\right]$$

$$H(X) = 0.3112 + 0.5 = 0.8112 \text{ (bits/symbol)}$$

now joint probability matrix is given by-

$$[P(X, Y)] = [P(X)]_d \left[P\left(\frac{Y}{X}\right)\right] = \begin{bmatrix} 0.75 & 0 \\ 0 & 0.25 \end{bmatrix} \begin{bmatrix} \frac{2}{3} & \frac{1}{3} \\ \frac{1}{3} & \frac{2}{3} \end{bmatrix}$$

$$[P(X;Y)] = \begin{bmatrix} \frac{1}{2} & \frac{1}{4} \\ \frac{1}{12} & \frac{1}{6} \end{bmatrix}$$

Hence $P(y_0) = \frac{1}{2} + \frac{1}{12} = \frac{6+1}{12} = \frac{7}{12}$

$P(y_1) = \frac{1}{4} + \frac{1}{6} = \frac{6+4}{24} = \frac{10}{24} = \frac{5}{12}$

now $H(Y) = -\sum_{i=1}^{2} P(y_i) \log_2 P(y_i)$

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

$H(Y) = 0.4536 + 0.5263 = 0.9799$ bits/symbol

$$H(X,Y) = -\sum_{i=1}^{2}\sum_{j=1}^{2} P(x_i, y_j)\log_2 P(x_i, y_j)$$

$$H(X,Y) = -\left[\frac{1}{2}\log_2\frac{1}{2} + \frac{1}{4}\log_2\frac{1}{4} + \frac{1}{12}\log_2\frac{1}{12} + \frac{1}{6}\log_2\frac{1}{6}\right]$$

$H(X,Y) = 0.5 + 0.5 + 0.2987 + 0.4308$

$H(X,Y) = 1.7295$ (bits/symbol)

$$H\left(\frac{Y}{X}\right) = -\sum_{i=1}^{2}\sum_{j=1}^{2} P(x_i, y_j)\log_2 P\left(\frac{y_j}{x_i}\right)$$

$$H\left(\frac{Y}{X}\right) = -\left[\frac{1}{2}\log_2\frac{2}{3} + \frac{1}{4}\log_2\frac{1}{3} + \frac{1}{12}\log_2\frac{1}{3} + \frac{1}{6}\log_2\frac{2}{3}\right]$$

$H\left(\frac{Y}{X}\right) = 0.2925 + 0.3962 + 0.1320 + 0.0975$

$H\left(\frac{Y}{X}\right) = 0.9182$ (bits/symbol)

now we know, $H(X,Y) = H(Y) + H\left(\frac{X}{Y}\right)$

Hence $H\left(\frac{X}{Y}\right) = H(X,Y) - H(Y) = 1.7295 - 0.9799$

$H\left(\frac{X}{Y}\right) = 0.7496$ (bits/symbol)

Also we know $I(X;Y) = H(X) - H\left(\frac{X}{Y}\right)$

$I(X;Y) = 0.8112 - 0.7496 = 0.0616$ (bits/symbol)

(ii) C_S = Channel capacity $= 1 + P\log_2 P + (1-P)\log_2(1-P)$

$C_S = 1 + \frac{1}{3}\log_2\frac{1}{3} + \frac{2}{3}\log_2\frac{2}{3} = 1 + 0.5283 + 0.3899$

$C_S = 1.9182$ (bits/symbol)

efficiency, $\eta = \frac{I(X;Y)}{C_s} = \frac{0.0616}{1.9182} = 0.032$

redundancy $= 1-\eta = 1-0.032 = 0.968$

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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]

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]

soln (i) maskable interrupts :- These are the interrupt signals which ~~cannot be~~ can be masked. i.e RST 7.5, RST 6.5, RST 5.5 ~~and~~

We can ignore these interrupts during excution of a urgent program.

for masking of interrupt we ~~~~ are using SIM instruction.

(2)

non-maskable interrupt :- These are the interrupts which cannot be ignored or masked. i.e Trap

(ii) Vectored interrupts :- These are the interrupt which have specific vectored address in memory.

~~i.e RST0, RST1, RST2, RST3,~~

There are two kind of vectored interrupt

(a) Hardware interrupt
i.e TRAP, RST 7.5, RST 6.5, RST 5.5

(2)

(b) Software vectored interrupt
i.e RST0, RST1, RST2, RST3, etc.

Non-vectored interrupt :- These are the interrupt which donot have specific vectored address in memory. i.e INTR

(iii) Edge Triggered :- Edge Triggered are the interrupt which can be activated on rising edge clock signal.
i.e TRAP, RST 7.5

(2)

Level Triggered :- These are interrupt which can be activated on level triggering of clock signal.
i.e TRAP, RST 6.5, RST 5.5, INTR.

(iv) Priority based interrupts :-

(3)

There are 5 priority hardware interrupts which are TRAP, RST 7.5, RST 6.5, RST 5.5 and INTR.

TRAP Has Highest priority and INTR Has Lowest priority.

priority ordering-

TRAP > RST 7.5 > RST 6.5 > RST 5.5 > INTR

Try to add Diagrams wherever possible.

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]

Soln

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

taking fourier Transform both sides-

$Y(\omega) = X(\omega)\, H(\omega)$ —— (1)

now consider

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

taking fourier Transform both sides-

$$G(\omega) = \left[\frac{1}{3} X\left(\frac{\omega}{3}\right)\right]\left[\frac{1}{3} H\left[\frac{\omega}{3}\right]\right]$$

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$$G(\omega) = \frac{1}{9} X\left(\frac{\omega}{3}\right) H\left(\frac{\omega}{3}\right) \text{ —— (2)}$$

now from eqn (1), $Y(\omega) = H(\omega) X(\omega)$

replace $\omega \to \frac{\omega}{3}$

$$Y\left(\frac{\omega}{3}\right) = H\left(\frac{\omega}{3}\right) X\left(\frac{\omega}{3}\right) \text{ —— (3)}$$

putting eqn (3) in eqn (2) -

$$G(\omega) = \frac{1}{9} Y\left(\frac{\omega}{3}\right)$$

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now taking inverse Fourier Transform

$$g(t) = \frac{1}{3} y(3t) = a\, y(bt)$$

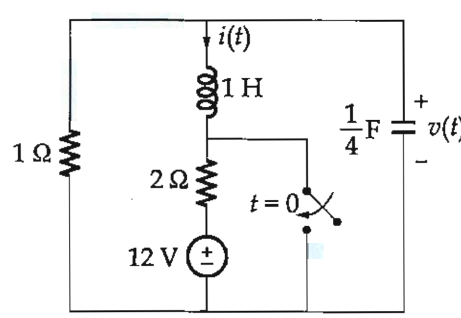
Hence by comparing –

$$a = \frac{1}{3} \quad \text{and} \quad b = 3$$

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]

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]

Solu^n

~~solution~~

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]

Soluⁿ

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

taking DTFT both sides -

$$Y(e^{j\omega}) - \frac{3}{4} e^{-j\omega} Y(e^{j\omega}) + \frac{1}{8} e^{-j2\omega} Y(e^{j\omega}) = 2X(e^{j\omega})$$

$$Y(e^{j\omega})\left[1 - \frac{3}{4}e^{-j\omega} + \frac{1}{8}e^{-j2\omega}\right] = 2X(e^{j\omega})$$

$$\frac{Y(e^{j\omega})}{X(e^{j\omega})} = H(e^{j\omega}) = \frac{2}{1-\frac{3}{4}e^{-j\omega}+\frac{1}{8}e^{-j2\omega}}$$

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

now from partial fraction we can write-

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

where $A = \frac{2}{1-\frac{1}{2}\times 4} = -2$

$B = \frac{2}{1-\frac{1}{4}\times 2} = 4$

(10)

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

now taking inverse DTFT both sides-

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

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

$$X(e^{j\omega}) = \sum_{n=-\infty}^{\infty} x(n)e^{-j\omega n} = \sum_{n=0}^{\infty}\left(\frac{1}{4}\right)^n e^{-j\omega n}$$

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

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

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

from partial fraction -

$$Y(e^{j\omega}) = \frac{A}{1-\frac{1}{2}e^{-j\omega}} + \frac{B}{1-\frac{1}{4}e^{-j\omega}} + \frac{C}{(1-\frac{1}{4}e^{-j\omega})^2}$$

$$2 = A(1-\tfrac{1}{4}e^{-j\omega})^2 + B(1-\tfrac{1}{2}e^{-j\omega})(1-\tfrac{1}{4}e^{-j\omega}) + C(1-\tfrac{1}{2}e^{-j\omega})$$

3

Comparing both sides -

$A + B + C = 2$ — ①

$\frac{A}{16} + \frac{B}{8} = 0 \Rightarrow A = -2B$ — ②

$-\frac{A}{2} - \frac{3}{4}B - \frac{C}{2} = 0$ — ③

on solving eqn ①, ② and ③ -

$C = -2$

$B = -4$

$A = 8$

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

taking inverse DTFT

$y(n) = 8(\frac{1}{2})^n u(n) - 4(\frac{1}{4})^n u(n) - 2\,(n)(\frac{1}{4})^n u(n)$ $(n+1)$

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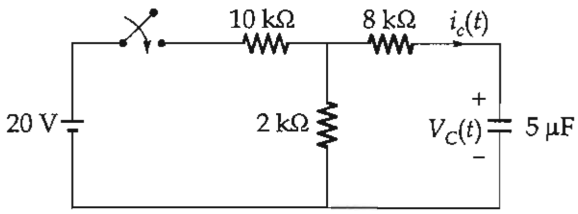
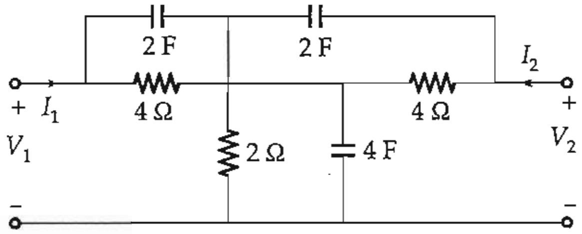
Q.6 (c) **(i)** In the network shown in figure, the switch closes at $t = 0$. The capacitor is initially uncharged. Find $V_C(t)$ and $i_c(t)$.



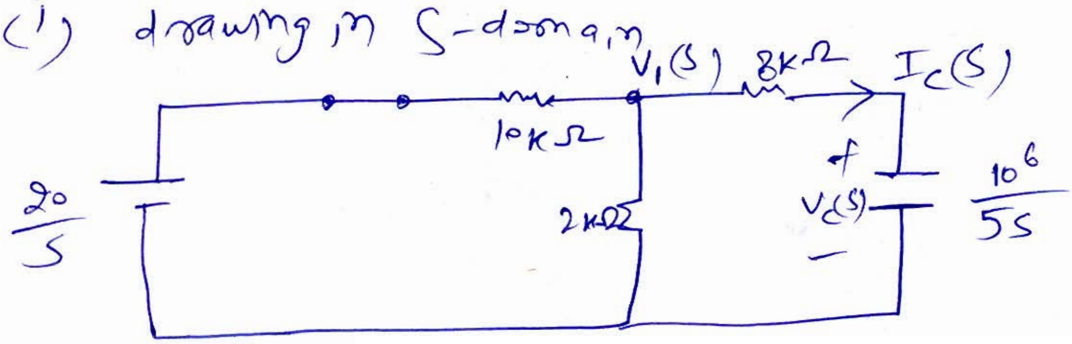
(ii) Find Y-parameters for the network shown in figure.



[10 + 10 marks]

Sol^n

(i) drawing in S-domain



Apply KCL at node (1) –

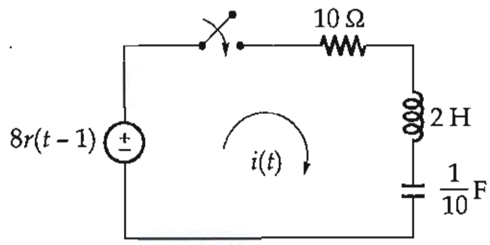
(1)

$$\frac{V_1(S) - \frac{20}{S}}{10000} + \frac{V_1(S)}{2000} + \frac{V_1(S)}{8000 + \frac{10^6}{5S}} = 0$$

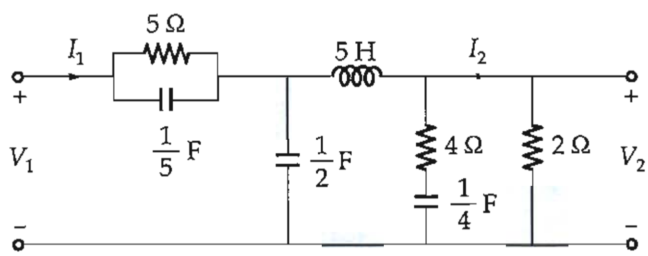
$$\frac{V_1(S)\left[8000 + \frac{10^6}{5S}\right] - 20\left(8000 + \frac{10^6}{5S}\right)}{10000\left[8000 * \frac{10^6}{5S}\right]}$$

incomplete solution

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]

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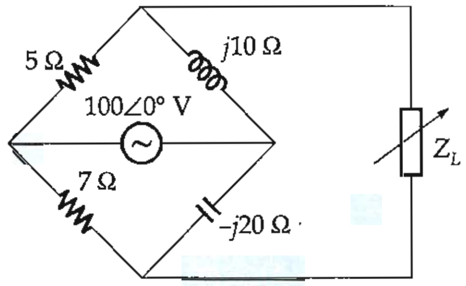
Q.7 (c) A control system has a transfer function given by $G(s) = \dfrac{s+3}{(s+1)(s+2)^2}$. Using the method of parallel decomposition, draw the state diagram with minimum number of integrators. Also obtain the state model.

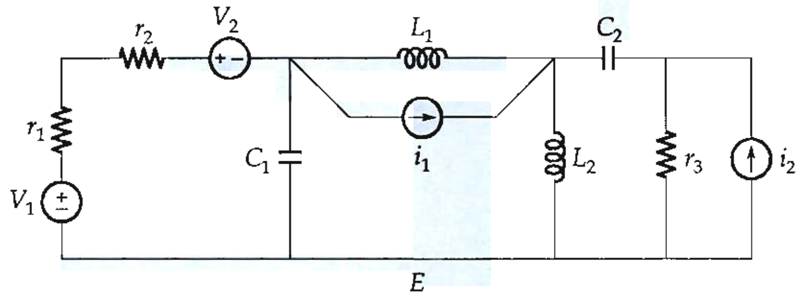
[20 marks]

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

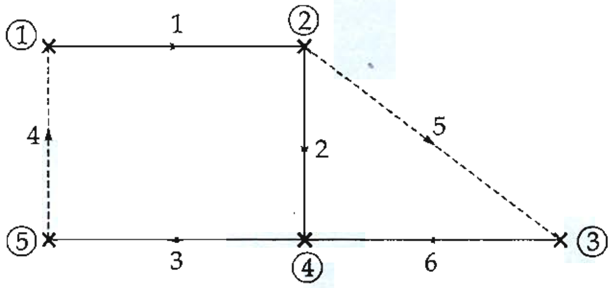


[15 marks]

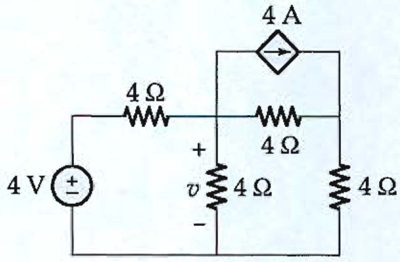
Q.8 (b) **(i)** Draw the oriented graph of network shown and obtain the incidence matrix.



(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]

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]

oooo

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work

8.25 = 10 x 2 fm

fm =

$-\frac{1}{511}[1-1]$