MADE EASY

Leading Institute for ESE, GATE & PSUs

ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-3 : Analog and Digital Communication Systems [All topics]
Digital Circuit-1 + Microprocessors and Microcontroller [Part Syllabus]
Network Theory-2 + Signals and 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	48
Q.2	
Q.3	45
Q.4	7
Section-B	
Q.5	29 + 4
Q.6	19
Q.7	
Q.8	
Total Marks Obtained	148+4 = 152

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

9/4/26

• your accuracy is good.
• attempt more to maximize your marks

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.

Section A : Analog and Digital Communication Systems

1 (a) **(i)** A Double sideband suppressed carrier (DSB-SC) signal is defined as $s(t) = A\cos(\omega_c t)\, m(t)$, where $m(t)$ is the message signal with average power P_m. The signal is applied to a coherent detector where the local oscillator has a phase error of 30°, represented by $c(t) = A\cos(\omega_c t + 30°)$.

Assuming the output is passed through an ideal Low Pass Filter (LPF) with a bandwidth equal to that of the message signal.

1. Derive the expression for the output signal $y(t)$.
2. Determine the average power of the output signal $y(t)$ in terms of A and P_m.

(ii) A coherent BFSK system uses the following signalling waveforms:

$s_0(t) = \cos(2\pi f_0 t);\ 0 \le t \le T_b \;\Rightarrow$ for logic 0

$s_1(t) = \cos(2\pi f_1 t);\ 0 \le t \le T_b \;\Rightarrow$ for logic 1

The frequencies are given as $f_0 = 1000$ kHz and $f_1 = 1050$ kHz.

1. Calculate the maximum possible bit rate (R_b) such that the signals remain orthogonal.
2. If the bit rate is increased to 200 kbps, determine the minimum frequency f_1 required to maintain the orthogonality between signals.
3. Calculate the transmission bandwidth (B.W) of this BFSK system for the bit rate found in part (1), using the first-null criteria.

[6 + 6 marks]

(i) (1) Given, a DSB-SC sig, $\left[s(t) = A\cos(\omega_c t)\, m(t)\right]$

$c(t) = A\cos(\omega_c t + 30°)$

Now, $y(t) = s(t) \cdot c(t)$

$y(t) = \left[A\cos(\omega_c t) \cdot m(t)\right] \cdot A\cos(\omega_c t + 30°)$

$y(t) = A^2\, m(t)(\cos\omega_c t) \cdot (\cos[\omega_c t + 30°])$

After passing through LPF,

$y(t) = \frac{A^2}{2} m(t) \cos 30°$

$\left[\cos A \cdot \cos B \Downarrow \frac{1}{2}\left[\cos(A+B) + \cos(A-B)\right]\right]$

$y(t) = \frac{A^2}{2} m(t) \times \frac{\sqrt{3}}{2}$

$$\boxed{y(t) = \frac{\sqrt{3}A^2}{4} m(t)}$$ **.

$$P_{avg} = E(y^2(t)) = E\left[\frac{\sqrt{3}A^2}{4} m(t)\right]^2$$

$$P_{avg} = \frac{3A^4}{16} E[m^2(t)]$$

⇓ Power of message s/g

$$\boxed{P_{avg} = \frac{3A^4}{16} \times P_M.}$$ **.

(ii) Given, Logic 0 → $\cos 2\pi f_0 t$; $0 \le t \le T_b$ $[f_0 = 1000\text{KHz}]$

① Logic 1 → $\cos 2\pi f_1 t$; $0 \le t \le T_b$ $f_1 = [1050 \text{ KHz}]$

$$\Delta f = |f_0 - f_1| = |1000 - 1050| = 50\text{KHz}.$$

Now, $\Delta f = \frac{1}{2T_b} = 50\text{KHz}.$

∵ $\boxed{T_b = \frac{1}{R_b}}$

Now, $\frac{R_b}{2} = 50\text{KHz}$ ∴ $\boxed{R_b = 100 \text{ Kbps}}$ **

② To maintain orthogonality,

$$\Delta f = |f_0 - f_1| = n \times R_{b_{new}}.$$

(OR) $f_1 - f_0 = n \times R_{b_{New}}.$

$f_1 - 1000 = n \times 200 \text{ Kbps}$

$\boxed{f_1 = 1200 \text{ KHz}}$ (put n=1)

(iii) B.W of BFSK → $(f_H - f_L) + 2R_b = B.W$

A/c where $f_H = f_1$ and $f_L = f_0$

Put values we get,

$(1050 - 1000) + 2 \times 100K = B.W.$

$50 + 200K = B.W.$

$B.W = 250 KHZ$ **

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Gwd

Q.1 (b) (i) Define the Shannon-Hartley theorem for channel capacity. State the condition required for "error-free transmission" in a digital communication system.

(ii) A binary signal is transmitted through an ideal AWGN channel with infinite bandwidth. If the two-sided Power spectral density (PSD) of the channel noise is 7 mW/Hz:

1. Derive the expression for the minimum bit energy (E_b) required for error-free transmission as the bandwidth approaches infinity.
2. Calculate the numerical value of this minimum average bit energy.

[2 + 6 + 4 marks]

(i) Shannon-Hartley Theorem ⇒ $C = B \log_2\left(1+\frac{S}{N}\right)$

where $\frac{S}{N}$ is not in dB.

$C \rightarrow$ channel capacity, $B \rightarrow$ Bandwidth

(It tells us about the rate at which channel can transmit data over a communication channel)

⇒ For Error-free transmission $[C \geq R_b]$.

(ii) Given AWGN channel, B·W = ∞, $\frac{N_0}{2} = 7\times10^{-3}\ \frac{W}{Hz}$.

$$C = B\log_2\left[1+\frac{S.P}{N.P}\right]$$

S.P = sig power

N.P = Noise power.

$N.P = N_0 W$.

$S.p = C\times E_b$.

Now, $C = B\log_2\left[1+\frac{E_b\cdot C}{N_0 W}\right]$

as $B\rightarrow\infty$

As B.W approaches to ∞., $x\rightarrow 0$

$$\lim_{x\rightarrow 0}\frac{\log_2(1+x)}{x} = \frac{1}{\ln 2}.$$

$\frac{E_b}{N_0} \geq \ln 2$ (For error free transmission)

$E_b \geq N_0 \ln 2 \Rightarrow \boxed{E_b \geq 0.693\, N_0}$

$\boxed{(E_b)_{min} = N_0 \ln 2}$ **

iii) Now, $E_b \geq \ln 2 \times N_0$ where $\frac{N_0}{2} = 7 \times 10^{-3} \frac{W}{Hz}$.

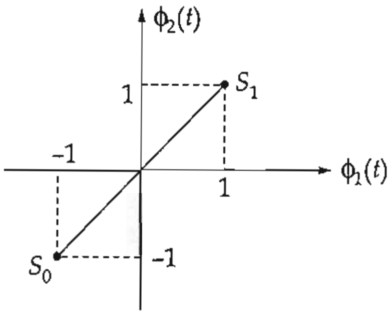
$E_b \geq 0.693 \times 14 \times 10^{-3}$

$$E_{b_{min}} = 9.702 \times 10^{-3} \ J$$

$E_{b_{min}} = 9.702 \ mJ$

Good 12

1 (c) A binary communication system uses two equiprobable signal $s_0(t)$ and $s_1(t)$. The constellation diagram for these signals in a two-dimensional orthonormal signal space (ϕ_1, ϕ_2) is shown below. The signals are transmitted over an AWGN channel with a two-sided noise Power Spectral Density (PSD) of 0.50 W/Hz.

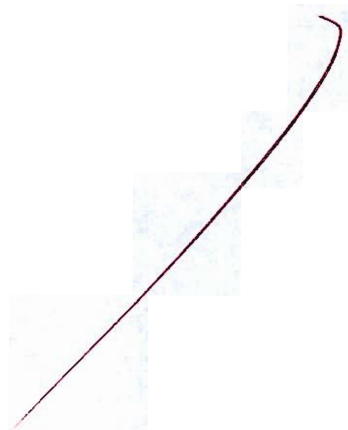


(i) Identify the signal vector s_0 and s_1 from the diagram and calculate the distance of each signal point from the origin. What does this distance represent physically?

(ii) Determine the minimum Euclidean distance (d_{min}) between the two symbols.

(iii) Calculate the Bit Error Rate (BER) of the system using an optimum threshold correlator receiver. Express your result in terms of the Q-function.

[12 marks]



Q.1 (d) (i) A sinusoidal message signal $m(t) = A_m \cos(2\pi f_m t)$ is applied to the X-plates of of a CRO, and an AM signal $s(t) = A_c[1 + \mu \cos(2\pi f_m t)] \cos(2\pi f_c t)$ is applied to the Y-plates. The resulting X-Y display is a triangle with a maximum vertical height of 4 units. The unmodulated carrier power is measured into an antenna load of 5 ohm.

1. Determine the modulation index (μ) from the given CRO display and identify the modulation state.
2. If the peak amplitude of the message signal is 10 V, calculate the total power transmitted and the power stored in the sidebands for this specific triangular pattern.
3. Calculate the Transmission efficiency (η) of this AM signal. What is the maximum possible efficiency for a standard AM wave without over-modulation?

(ii) Two random process, $X(t)$ and $Y(t)$ are related by a differentiation operation, such that $Y(t) = \dfrac{dX(t)}{dt}$. It is given that $X(t)$ is real valued wide sense stationary (WSS) process with a known auto-correlation function (ACF) denoted by $R_X(\tau)$. Determine the exact expression for the ACF of the resulting process, $R_Y(\tau)$, expressed in terms of the derivatives of $R_X(\tau)$.

[6 + 6 marks]

(i) Given $m(t) = A_m \cos 2\pi f_m t$, $s(t) = A_c[1 + \mu(\cos 2\pi f_m t)] \cos 2\pi f_c t$

↑ X - plates ↑ Y - plates

(1)

From standard AM expression,

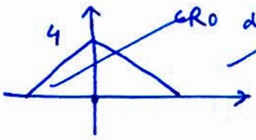
$$S_{AM}(t) = A_c\left[1 + \cos 2\pi f_m t \cdot \mu\right] \cos 2\pi f_c t$$

$$= A_c\left[1 + K_a |m(t)|_{max} \cos 2\pi f_m t\right] \cos 2\pi f_c t$$

where $|m(t)|_{max} = A_m$.

$\therefore$ $\boxed{\mu = K_a A_m}$ where $\left[K_a = \frac{1}{A_c}\right]$

~~A/c,~~ ~~$P_c = \frac{A_c^2}{2 \times R} = \frac{A_c^2}{2 \times 5} = \frac{A_c^2}{10} = P_c$~~



~~CRO display.~~

~~$\frac{A_c}{2} = 4$ units.~~

~~$A_c = 8$ units.~~

~~$K_a = \frac{1}{8}$~~ $\therefore$ ~~$\mu = \frac{A_m}{A_c}$~~

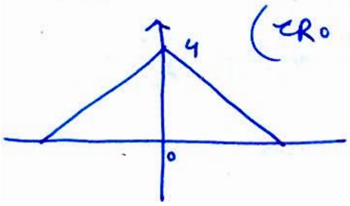
~~(2) $A_{max} = 10V = A_c(1+\mu)$~~

Now A/c , For CRO , envelope of V_{min} occurs at (0)

$$\mu = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} = 1 = 100\%.$$

($V_{min} \to 0$)

(CRO display.)



Now, since we know, $\mu = \frac{A_m}{A_c} = 1$

Given $\boxed{A_m = 10V}$ max. value of message sig. $\therefore \boxed{A_c = A_m = 10V}$

Now, $P_c = \frac{A_c^2}{2R} = \frac{(10)^2}{2\times 5} = \frac{100}{10} = 10W$

$\boxed{R = 5\Omega}$ Given

Now, $\Rightarrow \boxed{P_t = P_c\left(1 + \frac{\mu^2}{2}\right)}$

Total power transmitted

$P_t = 10\left(1 + \frac{1}{2}\right) = 10 \times 3/2 = 15W$

$P_t = P_c + P_{SB}$

$15W = 10W + P_{SB}$

$\boxed{P_{SB} = 5W}$

(OR)

$P_{SB} = \frac{P_c \mu^2}{2} = \frac{10\times 1}{2}$

$\boxed{P_{SB} = 5W}$

(3) Now $\eta = \frac{P_{SB}}{P_t} = \frac{P_c \mu^2/2}{P_c\left(1+\frac{\mu^2}{2}\right)} = \frac{\mu^2}{2+\mu^2} = \eta$ (efficiency)

Given $\mu = 1$ (Previously solved)

$\boxed{\eta = \frac{1^2}{2+1^2} = \frac{1}{3} = 33.33\%}$ **

This is the only max. η for AM sig.

$\left[\because \mu = 1\right]$ it is max. efficiency for max. value of μ.

$\Uparrow$

$[\mu_{max}]$

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(ii) Let $x(t)$ has auto correlation function $R_x(\tau)$.
and $y(t)$ has auto-correlation function $R_y(\tau)$.

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

Now,

$$R_y(\tau) = -\frac{d^2}{d\tau^2} R_x(\tau)$$

using Differentiation property.

$x(t) \longleftrightarrow R_x(\tau)$

$y(t) \longleftrightarrow R_y(\tau)$

$\frac{d}{dt} x(t) \longleftrightarrow (-1)^1 \frac{\partial^2}{\partial t^2} R_x(\tau) = y(t)$ (ACF) $= R_y(\tau)$

$R_y(\tau) = E[x(t) \cdot y(t+\tau)]$

$R_y(\tau) = E\left[\frac{d}{dt} x(t) \cdot \frac{d}{dt} x(t+\tau)\right] = E\left[\frac{d^2}{dt^2} x(t) \cdot x(t+\tau)\right]$

$R_y(\tau) = R_x''(\tau) \cdot (-1)$

$R_x''(\tau)$ is second derivate of $R_x(\tau)$

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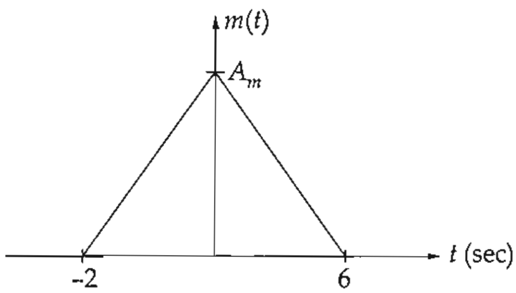
.1 (e) **(i)** The message signal $m(t)$ shown in the figure is applied separately to a frequency modulator with frequency sensitivity k_f (in Hz/V) and a phase modulator with a phase sensitivity k_p (in rad/V).



1. Derive the expression for the instantaneous frequency in both FM and PM cases. And obtain the maximum frequency deviation $(\Delta f)_{max}$ for both FM and PM signals.

2. Sketch the waveform of $\frac{dm(t)}{dt}$ versus t and determine its maximum absolute value i.e., $\left|\frac{dm(t)}{dt}\right|_{max}$.

3. If the maximum frequency deviation $(\Delta f)_{max}$ is kept the same in both cass, find the ratio $\frac{k_p}{k_f}$.

(ii) An AM receiver is designed to receive signals with a carrier frequency (f_c) in the range of 550 kHz to 1650 kHz. The receiver uses an intermediate frequency (f_{IF}) of 450 kHz. The local oscillator frequency (f_{LO}) is set at the higher of the two possible values for all incoming signals. A variable capacitor-based LC oscillator is used as the local oscillator.

1. Determine the tuning range of the local oscillator.

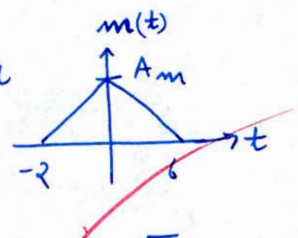
2. Calculate the required capacitance ratio $\left(\frac{C_{max}}{C_{min}}\right)$ for the local oscillator to cover this frequency range.

3. Explain the concept of "High-side Injection" and "Low-side Injection" in a superhetrodyne receiver. Why is high-side injection generally preferred in AM broadcast receivers?

[6 + 6 marks]

(1)

(1) Given

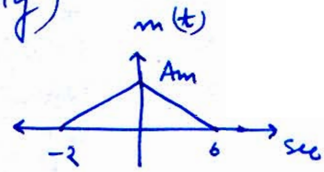


Now, K_f → frequency sensitivity in (Hz/V)

K_p → phase sensitivity in (rad/V)

$\left[f_i = f_c + K_f \cdot m(t)\right]$ [For FM sig]

$f_i = f_c + \frac{K_p}{2\pi} \frac{d}{dt}|m(t)| \Rightarrow$ (For PM sig)



$(\Delta f)_{max} = \frac{K_p}{2\pi} \left|\frac{d}{dt} m(t)\right|_{max} \rightarrow \frac{A_m}{2}$.

$\Rightarrow$ $f_i = f_c + \frac{K_p}{2\pi} \times \frac{A_m}{2} = f_c + \frac{K_p A_m}{4\pi}$ (PM sig)

$\Rightarrow$ $f_i = f_c + K_f |m(t)|_{max} = f_c + K_f A_m$ (FM sig)

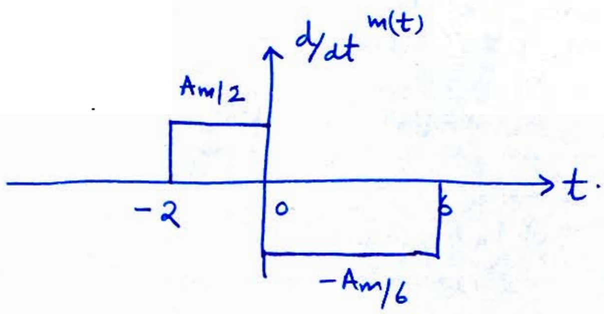
$\downarrow$

$\Delta f_{max} = K_f \times A_m$.

(2) Sketch of $\frac{d}{dt} m(t)$.

$\frac{d}{dt} m(t)$ will be $\frac{A_m}{2}$ for $-2 < t < 0$

$\frac{d}{dt} m(t)$ will be $-\frac{A_m}{6}$ for $0 < t < 6$



Max. value of $\left|\frac{d}{dt} m(t)\right| = \frac{A_m}{2}$

(3) Now, A/c Given $(\Delta f)_{max}$ is same for both PM and FM sig.

$(\Delta f)_{max}$ FM sig $= K_f \cdot A_m$.

$(\Delta f)_{max}$ PM sig $= \frac{K_p A_m}{4\pi}$ (Previously solved)

⇓

$\frac{K_p}{2\pi} \frac{d}{dt} |m(t)|_{max} = \frac{K_p}{2\pi} \times \frac{A_m}{2}$

Both are same ∴ $(\Delta f)_{PM\,max} = (\Delta f)_{FM\,max}$

$K_f A_m = \frac{K_p A_m}{4\pi}$

$$\boxed{\frac{K_p}{K_f} = 4\pi}$$ **

Excellent (2)

---

ii) Given f_c OR f_s = 550 KHz to 1650 KHz.

IF = 450 KHz.

Higher side injection → $f_{LO} = f_s + IF$ = (550 to 1650)K + 450K

(1) $f_{LO\,min} = 550 + 450 = 1000$ KHz

$f_{LO\,max} = 1650 + 450 = 2100$ KHz.

Tunning range ⇒ (1000 KHz to 2100 KHz)

(2) Now, we know, $f_{LO} = \frac{1}{2\pi\sqrt{LC}}$ → $f \propto \frac{1}{\sqrt{C}}$

$$\frac{C_{max}}{C_{min}} = \left(\frac{f_{max}}{f_{min}}\right)^2 = \left(\frac{2100}{1000}\right)^2 = 4.41$$

(3) Higher side Injection ⇒ $f_{LO} > f_s$. **

The value of local oscillator freq (f_{LO}) is kept at higher value compared to the carrier frequency.

$$f_{LO} = f_s + IF$$ **

Lower side injection ⇒ $f_{LO} < f_s$. **

The value of local oscillator freq. (f_{LO}) is kept at lower value compared to carrier freq.

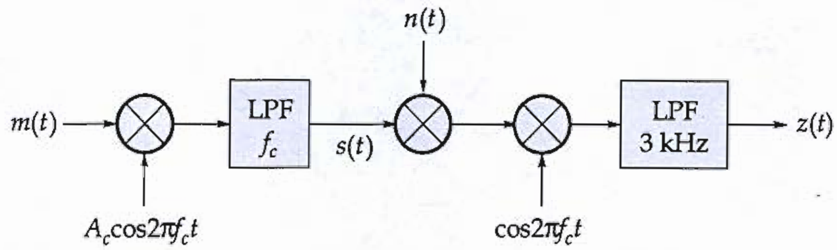
$$f_{LO} = f_s - IF$$ **

Advantage of Higher-side Injection → to be preferred.

(1) Tuning becomes easy. (capacitor ratio comes out to be small)

(2) Maintains uniform track record.

.2 (a) Consider the SSB system shown below which transmits the lower sideband modulated signal $s(t)$.



Assume that the message signal $m(t)$ has PSD of $|M(f)|^2$ and its Fourier transform

$$M(f) = \begin{cases} 0.003 & |f| \le 1.5\text{ kHz} \\ 0.001 & 1.5\text{ kHz} \le f \le 3\text{ kHz} \\ 0 & |f| > 3\text{ kHz} \end{cases}.$$

(i) Find A_c such that the power in $s(t)$ is equal to 100 mW. Also, draw the spectrum of $m(t)$, $s(t)$ and $z(t)$.

(ii) What would be the corresponding power in the demodulator output $Z(t)$ in the absence of noise?

(iii) It $n(t)$ is a white Gaussian process with $S_n(f) = \frac{N_0}{2}$, what is the noise power in the demodulator output for $N_0 = 0.0001$ mW/Hz?

(iv) Find the SNR for this system at the demodulator output.

[20 marks]

Q.2 (b) In a single integration Delta Modulation system, the voice signal bandwidth is 3.4 kHz sampled at a rate of 64 kHz, similar to PCM. The maximum signal amplitude is normalized as $A_{max} = 1$.

(i) Determine the minimum value of the step size σ to avoid slope overload.

(ii) Determine the granular noise power N_0.

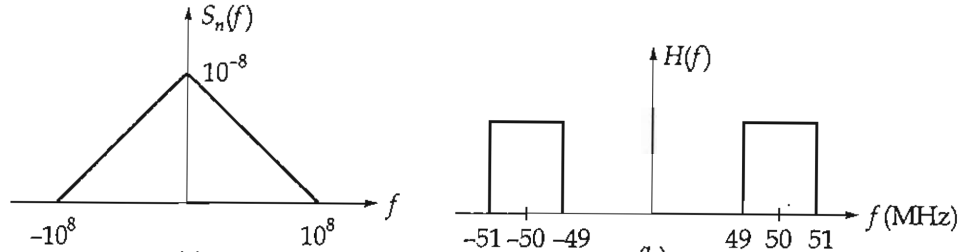
(iii) Assuming that the voice signal is sinusoidal, determine signal power S_0 and the SNR.

(iv) Assuming that the voice signal amplitude is uniformly distributed in the range (–1, 1), determine signal power S_0 and the SNR.

(v) Determine the minimum transmission bandwidth.

[20 marks]

Q.2 (c) A noise process has a power spectral density given by figure (a).



(a) (b)

$$S_n(f) = 10^{-8}\left(1 - \frac{|f|}{10^8}\right), \text{ for } |f| < 10^8 \text{ Hz}$$
$$= 0, \quad |f| > 10^8 \text{ Hz}$$

The noise is passed through an ideal bandpass filter with $H(f)$ as shown in figure (b) with a bandwidth of 2 MHz centered at 50 MHz.

(i) Find the power content of the output noise.

(ii) Write the output noise in terms of the in phase and quadrature components and find the power in each component.

(iii) Find the power spectral density of these two components.

(iv) Find the auto-correction function of the in-phase component.

[20 marks]

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Q.3 (a) **(i)** An angle modulated signal is given by the following expression
$u(t) = 5\cos[2\pi f_c t + 40\sin(500\pi t) + 20\sin(1000\pi t) + 10\sin(2000\pi t)]$

1. If $u(t)$ is a PM signal,

(a) Determine the maximum phase deviation $\Delta\phi_{max}$.

(b) If the phase deviation constant is k_p = 5 radian per volt, determine the message signal $m(t)$.

2. If $u(t)$ is a FM signal,

(a) Determine the maximum frequency deviation, Δf_{max}.

(b) If the frequency deviation constant is k_f = 10000π rad/sec per volt, determine the message signal $m(t)$.

(ii) Show that the probability of error for a BPSK transmission system in which the coherent receiver carrier has a phase error of θ is given by $P_e = Q\left[\sqrt{\frac{2E_b\cos^2\theta}{N_0}}\right]$

[12 + 8 marks]

(i)

① Given, $u(t) \Rightarrow$ PM sig.

$\phi(t)$

$u(t) = 5\cos[2\pi f_c t + 40\sin(500\pi t) + 20\sin(1000\pi t) + 10\sin(2000\pi t)]$

(a) $(\Delta\phi)_{max} = |\phi(t)|_{max} = 40 + 20 + 10$

$(\Delta\phi)_{max} = 70$ radian.

(b) Since we know, $(\Delta\phi) = K_p \cdot m(t)$

$m(t) = \frac{\phi(t)}{K_p} = \frac{\phi(t)}{5} \Leftarrow \left[K_p = 5 \frac{rad}{Volt}\right]$

$m(t) = \frac{1}{5}\left[40\sin(500\pi t) + 20\sin(1000\pi t) + 10\sin(2000\pi t)\right]$

(2) m(t) is FM sig,

(a) $\Delta f_{max} = ?$

$$f_i(t) = \frac{1}{2\pi}\frac{d}{dt}[\phi_i(t)]$$

$$f_i(t) = f_c + \frac{1}{2\pi}\left[(40\times 500\pi)\cos(500\pi t) + 20\times 1000\pi\cos(1000\pi t) + 10\times 2000\pi\cos(2000\pi t)\right]$$

$$f_i(t) = f_c + (\Delta f)_{max}.$$

$$\Delta f_{max} = \left[\frac{40\times 500\pi + 20\times 1000\pi + 10\times 2000\pi}{2\pi}\right]$$

$$(\Delta f)_{max} = 10000 + 1000 + 10000$$

$$(\Delta f)_{max} = 30,000\ Hz.$$

(b) $$f_i(t) = f_c + \frac{k_f}{2\pi}m(t)$$

$$m(t) = (f_i(t) - f_c)\times\frac{2\pi}{k_f}$$

$$m(t) = \frac{2\pi}{10000\pi}\left[10000\cos(500\pi t) + 10000\cos(1000\pi t) + 10,000\cos(2000\pi t)\right]$$

$$m(t) = 2\cos(500\pi t) + 2\cos(1000\pi t) + 2\cos(2000\pi t)$$

Ans

9

(ii) Consider, BPSK sig represented by →

$$s(t) = \pm\sqrt{\frac{2E_b}{T_b}}\cos 2\pi f_c t \quad \Leftarrow \quad \begin{bmatrix} 0 \xrightarrow{by} -A_c\cos 2\pi f_c t \\ 1 \xrightarrow{by} +A_c\cos 2\pi f_c t \end{bmatrix}$$

and provided with local oscillator as $\cos(2\pi f_c t + \theta)$

Now, we get,

$$\int_0^{T_b} \cos(2\pi f_c t)\cdot\cos(2\pi f_c t+\theta) \simeq \frac{T_b}{2}\cos\theta .$$

[Now effective energy becomes $E_b\cos^2\theta$.]

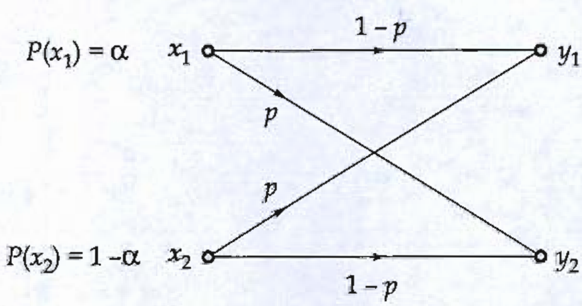
Now $P_e = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$

(Put $E_{b\,effective} = E_b\cos^2\theta$)
we get,

$$P_e = Q\left(\sqrt{\frac{2E_b\cos^2\theta}{N_0}}\right)$$

Q.3 (b) **(i)** Given a Binary Symmetric Channel (BSC) in below figure with $P(x_1) = \alpha$.

1. Show that the mutual information
$I(X\,;Y) = H(Y) + p\log_2 p + (1-p)\log_2(1-p)$
2. Calculate $I(X\,;Y)$ for $\alpha = 0.5$ and $p = 0.1$.
3. Repeat part (2)for $\alpha = 0.5$ and $p = 0.5$.

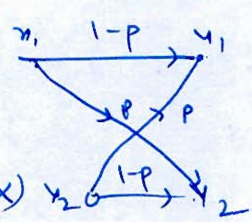


(ii) Assuming that X is a Gaussian random variable with $m = 0$ and $\sigma = 1$, find the probability density function of the random variable Y given by $Y = aX + b$.

[12 + 8 marks]

Consider a BSC, $P(x_1) = (\alpha)$

$P(x_2) = (1-\alpha)$



$I(x,y) = H(Y) + p \log_2 p + (1-p) \log_2 p.$

$$P\left(\frac{Y}{X}\right) = \begin{array}{c} \\ x_1 \\ x_2 \end{array}\begin{bmatrix} y_1 & y_2 \\ 1-p & p \\ p & 1-p \end{bmatrix} \qquad P[X] = \begin{bmatrix} (x_1) & (x_2) \\ \alpha & 1-\alpha \end{bmatrix}$$

$$P(x) \cdot P\left(\frac{Y}{X}\right) = P(X,Y)$$

$P(X,Y) = (1-p)\alpha + p(1-\alpha) + p\alpha + (1-p)(1-\alpha)$

Now,

$$H(X,Y) = + \sum P(x_1,y_1) \log_2 \frac{1}{P\left(\frac{x_1}{y_1}\right)} + P(x_1,y_2) \log_2 \frac{1}{P\left(\frac{x_1}{y_2}\right)}$$

$$+ P(x_2,y_1) \log_2 \frac{1}{P\left(\frac{x_2}{y_1}\right)} +$$

$$\sum P(x_2,y_2) \log_2 \frac{1}{P\left(\frac{x_2}{y_2}\right)}$$

Substitute values we get from

$$\boxed{I(X,Y) = H(Y) + p \log_2 p + (1-p) \log_2 (1-p)}$$

(2) If $\alpha = 0.5$ (equiprobable), $H(Y) = \log_2 2 = 1$

$I(x,y) = 1 + 0.1 \log_2(0.1) + 0.9 \log_2 0.9$

$$\boxed{I(x,y) = 0.531004406} \text{ bits.}$$

Do not write in this margin

(3) If $\alpha = 0.5$, $p = 0.5$

$H(Y)$ is still (1)

$$I(x,y) = 1 + 0.5 \log_2(0.5) + 0.5 \log_2(0.5)$$

$$\boxed{I(x,y) = 0}$$

**

(ii) Given $M_x = 0$, $\sigma_x = 1$

2

$Y = ax + b.$

$$f_x(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2a}}$$

Now $M_y = a(M_x) + b.$

$M_y = a \times 0 + b = b \leftarrow$ (Mean of Y)

Mean of Y is $\underline{b}$

Now, $\sigma_y = a^2 \, Var(X) + b^{\to 0}$

6

$\sigma_y = a^2 \times 1 + b^{\to 0} = a^2 \leftarrow$ variance of Y

Good

$$\boxed{f_y(y) = \frac{1}{\sqrt{2\pi a^2}} e^{-\frac{(x-b)^2}{2a^2}}}$$

.3 (c) (i) A DPCM system uses a linear predictor with a single tap. The normalized autocorrelation function of the input signal for a lag of one sampling interval is 0.75. The predictor is designed to minimize the prediction error variance. Determine the processing gain attained by the use of this predictor.

(ii) Show that the signal $V(t) = \sum_{i=1}^{N} [\cos \omega_c t \cdot \cos(\omega_i t + \theta_i) - \sin \omega_c t \cdot \sin(\omega_i t + \theta_i)]$ is an SSB signal. It is USB or LSB? Write an expression for the missing sideband. Obtain an expression for the total DSB-SC signal.

[12 + 8 marks]

(ii) Given, $v(t) = \sum_{i=1}^{N} \cos w_c t \cdot \cos(\omega_i t + \theta_i) - \sin w_c t \cdot \sin(\omega_i t + \theta_i)$ is an SSB sig.

$\cos A \cos B - \sin A \sin B = \cos(A + B)$

We get, $v(t) = \sum \cos(w_c t + \omega_i t + \theta_i)$

Since it is like $\cos 2\pi (f_c + f_m) t$.

$\therefore$ It is USB

$A_c \cos 2\pi (f_c + f_m) t$ comparing to this we got,

USB

$$v(t) = \sum_{i=1}^{N} \cos 2\pi [f_c + (f_i t + \theta_i)]$$

$f_c + f_m$

USB

Missing S.B is LSB.

6

$$v(t) = \sum_{i=1}^{N} \cos [w_c t - (w_i t + \theta_i)]$$

LSB

(like $f_c - f_m$)

Q.4 (a) (i) Consider the (5, 1) repeating code, with the generator matrix as

$G = [1 \;\; 1 \;\; 1 \;\; 1 \;\; 1 \;\vdots\; 1]$

Evaluate the syndrome S for the following error pattern.

1. All five possible single error patterns.
2. All 10 possible double error patterns.

(ii) The auto-correlation function of an ergodic random process $x(t)$ is given by the expression:

$$R_X(\tau) = \frac{25\tau^2 + 36}{6.25\tau^2 + 4}$$

1. Find the mean value (μ_X) and the mean square value ($E[X^2(t)]$) of the process.
2. Determine the variance (σ_X^2) of the process $X(t)$.
3. Comment on the physical significance of $R_X(0)$ and $R_X(\infty)$ for a stationary random process.

[12 + 8 marks]

3

• $R_X(0)$ means Avg. power ≐

$\left[R_X(0) = \frac{36}{4} = 9\,W.\right]$

2

$R_X(\tau)$ means power at ∞ time instant

$R_X(\infty) = \dfrac{25 + \frac{36}{\tau^2}}{6.25 + \frac{4}{\tau^2}} = \dfrac{25}{6.25} = \dfrac{25 \times 100}{625}$ = 4

⇓

4W.

2

incomplete soln

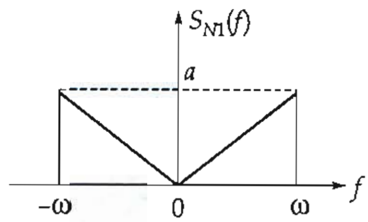
Q.4 (b) (i) A pair of noise processes $n_1(t)$ and $n_2(t)$ are related by

$$n_2(t) = n_1(t)\cos(2\pi f_c t + \theta) - n_1(t)\sin(2\pi f_c t + \theta)$$

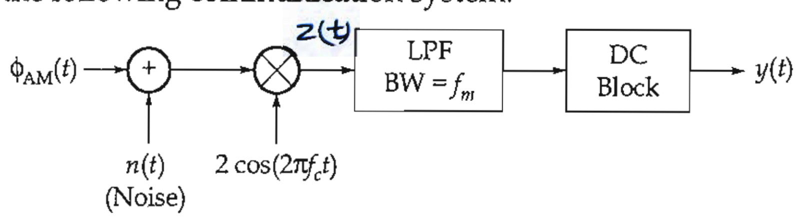
Where f_c is a constant and θ is a random variable, whose probability density function is given by

$$f_\theta(\theta) = \begin{cases} \frac{1}{2\pi}, & 0 \le \theta \le 2\pi \\ 0, & \text{otherwise} \end{cases}$$

The noise process $n_1(t)$ is stationary and its power spectral density is as shown in figure. Find and plot the corresponding power spectral density of $n_2(t)$.



(ii) For the following communication system:



where, $\phi_{AM}(t) = A_c[1 + \cos(2\pi f_m t)]\cos(2\pi f_c t)$

$$n(t) = n_c(t)\cos(2\pi f_c t) - n_s(t)\sin(2\pi f_c t)$$

Noise power, $= \overline{n_c^2(t)} = \overline{n_s^2(t)} = 2N_0 f_m$

1. Analyze the system and write an equation for the output signal $y(t)$.
2. Write the equation for the signal-to-noise ratio at the output.
3. Let $A_c = 10$ V, $f_m = 10$ kHz and $N_0 = 10\ \mu$W/Hz. Find the signal-to-noise ratio.

[12 + 8 marks]

after passing from LPF and DC blocked we get.

⇒ O/P $y(t) = s(t) + n(t)$ (LPF + DC blocked.)

2

$y(t) = \frac{A_c \mu}{2}$

⇒ $\frac{S}{N} = \frac{A_c^2 \mu^2}{4 N_0 f_m} = \frac{10 \times 10 \times \mu^2}{4 \times 10 \times 10^{-6} \times 10 \times 10^3}$

Incomplete soln

Q.4 (c) **(i)** An FM signal $x_c(t) = A_c \cos\left[\omega_c t + \int_{-\infty}^{t} m(t)dt\right]$ is applied to a high-pass RC filter, where $RC << \frac{1}{\omega}$ with ω representing the FM signal frequency band. Show if an envelope detector after the filter can demodulate the FM signal.

(ii) Consider a chain of $(n - 1)$ regenerative repeaters, with a total of n sequential decisions made on a binary PCM wave, including the final decision made at the receiver. Assume that any binary symbol transmitted through the system has an independent probability P_1 of being inverted by any repeater. Let P_n represent the probability that a binary symbol is in error after transmission through the complete system.

1. Show that $P_n = \frac{1}{2}\left[1-(1-2P_1)^n\right]$.

2. If P_1 is very small and n is not too large, what is value of P_n?

[12 + 8 marks]

$$S_{FM}(t) = A_c \cos\left[2\pi f_c(t) + 2\pi k_f \int_{-\infty}^{\infty} m(t)\,dt\right]$$

Standard FM slg.

Solving we get, Using (E.D)

$$(E.D)_{o/p} = A_c\sqrt{1+\beta^2}$$ where $\beta = \frac{k_f A_m}{f_m}$

$\delta f = k_f A_m$

[It justified we can get the m(t) message slg back.].

1

incompleteso/n

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

Q.5 (a) In the following base number systems, solve the equations for the value of 'X'.

(i) $(70)_8 + (122)_6 = (211)_X$

(ii) $(131)_{12} = (X)_8 + (78)_9$

[6 + 6 marks]

(i) $(70)_8 + (122)_6 = (211)_X$

$7\times8^1 + 0\times8^0 + 1\times6^2 + 2\times6^1 + 2\times6^0 = 106$

$56 + 0 + 36 + 12 + 2 = 106$

$56 + 50 = 106$

$(211)_X = 2x^2 + x + 1 = 2x^2 + x + 1 = 106$

Solve for $x = \frac{-1 \pm 29}{4}$

$X = 7$

6

Do not write in this margin

(ii) $(131)_{12} = (x)_8 + (78)_9$.

$1\times12^2 + 3\times12^1 + 1\times12^0 = 181 = (131)_{12}$

$9^1\times7 + 8\times9^0 = 71$

$181 = (x)_8 + 71$

$(x)_8 = 110$

$110 \div 8 = 13$ Remainder = 6.

$13 \div 8 = 1$ Remainder = 5

$1 \div 8 = 0$ Remainder = 1

$x = 156$

6

Correct

.5 (b) A parallel RLC circuit has the following values:

$R = 8$ kΩ, $L = 0.2$ mH, $C = 8$ μF and $V = 10 \sin \omega t$(V).

Calculate:

(i) Resonant frequency, ω_0.

(ii) 3 dB frequencies, ω_1 and ω_2.

(iii) Q and BW.

(iv) Power dissipated at ω_0, ω_1 and ω_2.

[12 marks]

Given $R = 8\,K\Omega$, $L = 0.2\,mH$, $C = 8\,\mu f$, $V = 10\sin(\omega t)\,V$.

(1) $\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.2\times10^{-3} \times 8\times10^{-6}}} = 25000$ rad/sec.

(2) 3-dB freq, ω_1, ω_2 is given as.

$\omega_1 = \omega_0 - \frac{BW}{2}$, $\omega_2 = \omega_0 + \frac{B.W}{2}$

From (3), $\omega_1 = 25000 - \frac{15.625}{2} = 24,992.1875$ rad/sec

$\omega_2 = 25000 + \frac{15.625}{2} = 25007.8125$ rad/sec.

(3) $Q = R\sqrt{\frac{C}{L}} = 8\times10^{3} \times \sqrt{\frac{8\times10^{-6}}{0.2\times10^{-3}}} = 1600$

12

$B.W = \frac{\omega_0}{Q} = \frac{25000}{1600} = 15.625$ rad/s.

(4) $P_{max} = \frac{V_{rms}^2}{R} = \frac{\left(\frac{10}{\sqrt{2}}\right)^2}{8K} = \frac{100}{4\times8K} = \frac{100}{32K}$

$= 6.25\,mW$.

(at w_1 and w_2) → half power freq.

$\Rightarrow P_{w_1} = P_{w_2} = \frac{P_{max}}{2} = \frac{6.25}{2} = 3.125\,mW$.

.5 (c) The coefficients of a 7-point FIR filter are listed below. Draw a realization diagram for the filter such that a minimum number of multiplications is required for each output computation.

$h(0) = -0.3$

$h(1) = 0.4$

$h(2) = 0.2$

$h(3) = 0.5$

$h(4) = 0.2$

$h(5) = 0.4$

$h(6) = -0.3$

Also find out the order of the filter and the type of the FIR filter structure.

[12 marks]

Q.5 (d) Write a program for an 8085 microprocessor to calculate the sum of series of numbers. The length of series is stored in the memory location 1100H and the sequence is stored starting from location 2100H. Assume the sum to be 8-bit number without any carry and store the result in location 3200H.

[12 marks]

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Q.5 (e) (i) Define the following terms:

1. Setup time.
2. Hold time.

(ii) Convert the following number from base 9 to base 11, $(18.6)_9 = (?)_{11}$

[6 + 6 marks]

⇒ Setup Time ⇒ It is defined as minimum amount of time (before) the active clock edge during which the data i/p sig must be stable at the i/p of flip-flop or register.

3

⇒ Hold time ⇒. It is defined as. minimum amount of time (after) the active clock edge during the data i/p stage must be stable.

(ii) $(18.6)_9 = (\ ?\ )_{11}$

Convert base 9 to 11

$(18.6)_9$

$\Downarrow$

$1 \times 9^1 + 8 \times 9^0 = 9 + 8 = 17$ (Integer part)

$6 \times 9^{-1} = \frac{6}{9} = \frac{2}{3} = 0.666....$ (Decimal part)

$(17.666)_{10}$

Now convert to base 11

$17 \div 11 = 1$ Remainder = 6

$1 \div 11 = 0$ Remainder = 1

(16)

$0.666 \times 11 = 7.333$

$0.333 \times 11 = 3.666$

$0.666 \times 11 = 7.33$

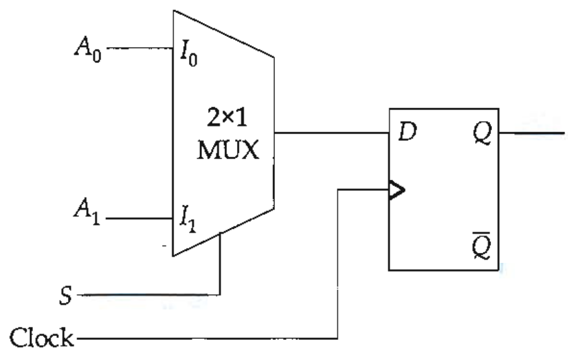
(.737)

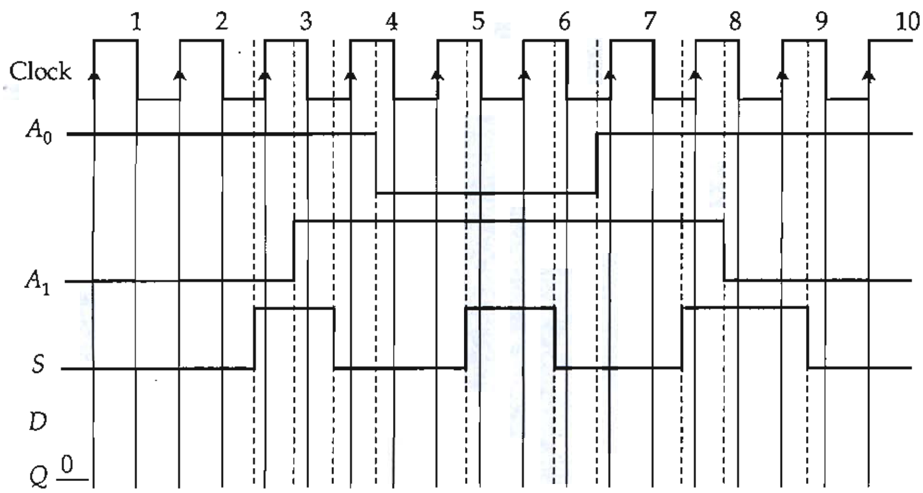
Ans ⇒ $(16.737)_{11}$

6

2

.6 (a) Consider the sequential circuit shown below:





Draw the timing diagram for the input D and output Q of the above MUX operated D-flip-flop.

[20 marks]

Now, o/p of (2×1) Mux...

6

$\bar{S}A_0 + SA_1$ = o/p of mux

Now $D = \bar{S}A_0 + SA_1$

Now, $Q_{n+1} = \bar{Q}_n A_0 + Q_n A_1$

when, $Q = 0$ we get, $Q_{n+1} = A_0$

when, $Q = 1$ we get, $Q_{n+1} = A_1$

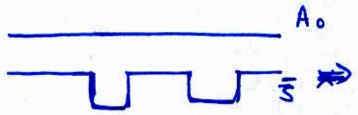
$0 \rightarrow 1 \rightarrow 0$ (Freq. Divider)

Now, we got:

Input D = o/p of Mux.

$$D_{in} = \bar{S}A_0 + SA_1$$

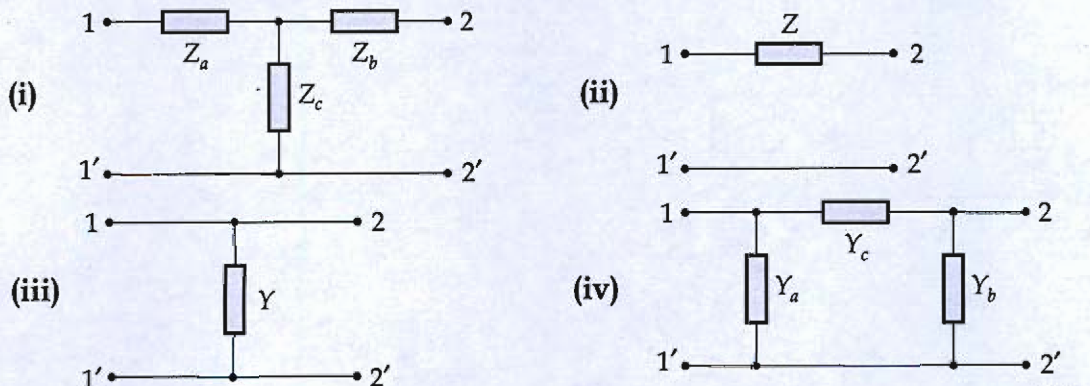
for interval $\bar{S}A_0$



Same as:

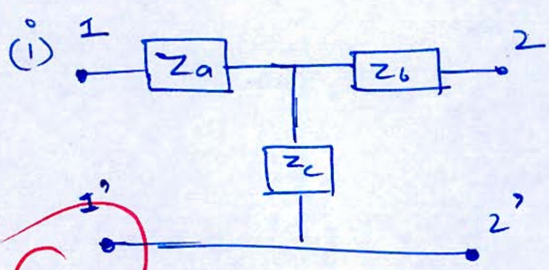
Timing diagram?

.6 (b) Find the z and y parameter for the networks shown in figure below:



[20 marks]

(i)



T-N/W

$$[Z] = \begin{bmatrix} Z_a+Z_c & Z_c \\ Z_c & Z_b+Z_c \end{bmatrix}$$

10

$Z_{11} = Z_a + Z_c$

$Z_{22} = Z_b + Z_c$

$Z_{12} = Z_{21} = Z_c$

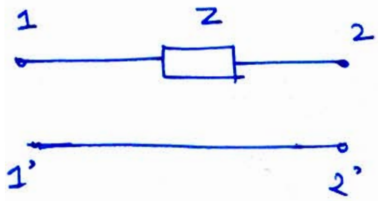
don't write here

$$[Y] = [Z]^{-1} = \frac{1}{(Z_a+Z_c)(Z_b+Z_c) - Z_c^2} \begin{bmatrix} Z_b+Z_c & -Z_c \\ -Z_c & Z_a+Z_c \end{bmatrix}$$

Let x

$$[Y] = \begin{bmatrix} \frac{Z_b+Z_c}{x} & -\frac{Z_c}{x} \\ \frac{-Z_c}{x} & \frac{Z_a+Z_c}{x} \end{bmatrix}$$

(ii)



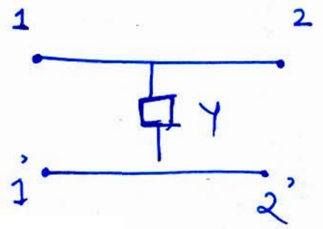
$$[Z] = \begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix}$$

Now, $[Y] = [Z]^{-1}$

$$[Y] = \frac{1}{(1-0)} \begin{bmatrix} 1 & -Z \\ 0 & 1 \end{bmatrix}$$

$$[Y] = \begin{bmatrix} 1 & -Z \\ 0 & 1 \end{bmatrix}$$

(iii)

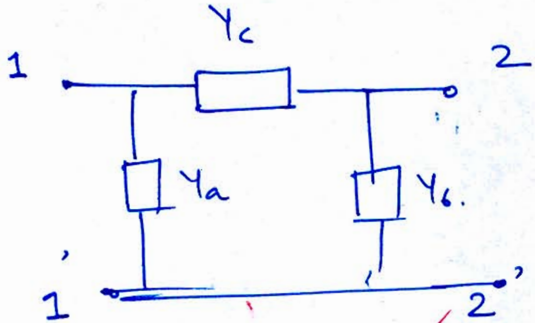


$$[Z] = \begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix}$$

$\therefore [Y] = [Z]^{-1}$

$$[Y] = \frac{1}{(1-0)} \begin{bmatrix} 1 & 0 \\ -Y & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -Y & 1 \end{bmatrix}$$

(iv)



For π - N/W

$$[Y] = \begin{bmatrix} Y_a + Y_c & -Y_c \\ -Y_c & Y_b + Y_c \end{bmatrix}$$

$Y_{11} = Y_a + Y_c$

$Y_{22} = Y_b + Y_c$

$Y_{12} = Y_{21} = -Y_c$

Now = $[Z] = [Y]^{-1}$

$$[Z] = \frac{1}{(Y_a+Y_c)(Y_b+Y_c) - Y_c^2} \begin{bmatrix} Y_b+Y_c & Y_c \\ Y_c & Y_a+Y_c \end{bmatrix}$$

$$Z_{11} = \frac{(Y_b+Y_c)}{(Y_a+Y_c)(Y_b+Y_c) - Y_c^2}$$

Let $x = (Y_a+Y_c)(Y_a+Y_b) - Y_c^2$

$$Z_{12} = \frac{Y_c}{x} \qquad Z_{22} = \frac{Y_a+Y_c}{x}$$

$$Z_{21} = \frac{Y_c}{x}$$

$$[Z] = \begin{bmatrix} \frac{Y_b+Y_c}{x} & \frac{Y_c}{x} \\ \frac{Y_c}{x} & \frac{Y_a+Y_c}{x} \end{bmatrix}$$

Do not write in this margin

Q.6 (c) (i) Explain the various addressing modes in 8086 microprocessor.

(ii) Consider the following subroutine program of an 8085 microprocessor, which is operating with a clock frequency of 2 MHz:

```
        MVI B, DATA_8 bit
LOOP:   DCR B
        JNZ LOOP
        RET
```

Let "N" is the decimal equivalent of the DATA_8 bit stored in B register. By analyzing the above program, derive an expression for the overall time delay produced by the subroutine. Using the result obtained, determine the value of "N" required to produce the overall time delay of 70 μs.

[10 + 10 marks]

Various Addressing Mode available in 8086 are :-

(1) Direct Addressing Mode ⇒ Here, transfer of information is directly taken place

Eg → LDA

(2) Indirect Addressing Mode..

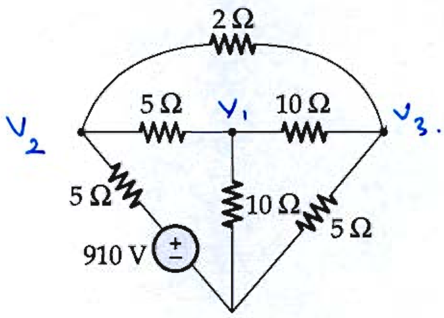
(3) Implicit Addressing Mode.

(3) Register Indirect Addressing Mode.

3

5) Register Base Indexed Addressing mode.

(a) For the below resistive network, write a cut-set schedule and derive equilibrium equations for node voltages. Also, calculate values of branch voltages and branch currents.



[20 marks]

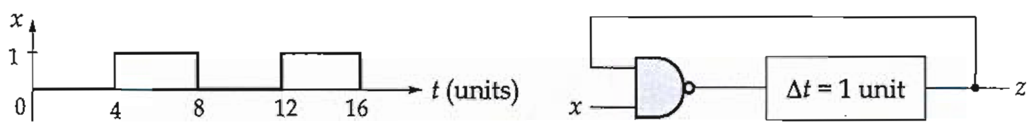
Nodal at V_2, we get

$$\frac{V_2 - 910}{5} + \frac{V_2 - V_1}{5} + \frac{V_2 - V_3}{2} = 0$$

Q.7 (b) Given $X(K) = \{255, 48.63 + j166.05, -51 + j102, -78.63 + j46.05, -85, -78.63 - j46.05, -51 - j102, 48.63 - j166.05\}$. Determine $x(n)$ using Inverse DIF FFT technique.

[20 marks]

Q.7 (c) **(i)** Consider the circuit shown in the figure below:



The input to the circuit is a periodic square wave with period 8 units. Plot the output z for 16 units of time.

(ii) Derive a minimised POS expression for the given function.

$f(A, B, C, D, E) = \prod M(0, 2, 4, 11, 14, 15, 16, 20, 24, 30, 31)$

[10 + 10 marks]

Do not write in this margin

(a) Given is the list of 50 different numbers which are stored in consecutive memory locations starting from 1000H. Write a program to search the given byte which is stored in the register 'C'. If the byte is found, then store the location of the byte in memory location 1100H and 1101H. If the byte is not found, then store the value 00H at 1100H and 1101H. Also, draw the flow chart for the given program which is to be written for 8085 microprocessor.

[20 marks]

(b) **(i)** In a linear circuit consisting of $R = 9\ \Omega$ and $L = 8$ mH, a current, $i = 5 + 100\sin(1000t + 45°) + 100\sin(3000t + 60°)$A is flowing. Find the equation of applied voltage.

(ii) Calculate the impedance consisting of R and L and the power factor of a circuit whose expression for voltage and current are
$v(t) = 250\sin 314t + 50\sin(942t + 30°)$(V) and
$i(t) = 17.7\sin(314t - 45°) + 1.583\sin(942t - 41.6°)$(A).

[10 + 10 marks]

Q.8 (c) (i) Design a combinational circuit with three inputs x, y and z and three outputs A, B and C. When the binary input is 0, 1, 2 and 3, the binary output is one greater than the input. When the binary input is 4, 5, 6 and 7, then the binary output is two less than the input.

(ii) The 8085-microprocessor system has an external crystal of 5 MHz connected between its $X1$ and $X2$ pin terminals. Calculate the time taken by the processor to execute the following delay program.

```
DELAY : MVI  D, 10 H
Loop 2: LXI  B, 2030 H
Loop 1: DCX  B
        MOV  A, C
        ORA  B
        JNZ  Loop 1
        DCR  D
        JNZ  Loop 2
        RET
```

[10 + 10 marks]

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Space for Rough Work

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