1.Avoid calculation errors
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ESE 2023 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-2 : Signals and Systems + Microprocessors and Microcontroller [All topics]
Network Theory-1 + Control Systems-1 [Part Syllabus]

Name ....

Roll No :

Test Centres	Student's Signature
Delhi ☐ Bhopal ☑ Jaipur ☐ Pune ☐ Kolkata ☐ Bhubaneswar ☐ Hyderabad ☐	

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. 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.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	170

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2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
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4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

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6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Section A : Signals and Systems + Microprocessors and Microcontroller

Q.1 (a) Suppose the following facts are given about the signal $x(t)$ with Laplace transform $X(s)$:

1. $x(t)$ is real and even.
2. $X(s)$ has four poles and no zeros in the finite s-plane.
3. $X(s)$ has a pole at $s = \frac{1}{2}e^{j\frac{\pi}{4}}$.
4. $\int_{-\infty}^{\infty} x(t)dt = 4$

Determine $X(s)$.

[10 marks]

If $P_1 = \frac{1}{2}e^{j\pi/4}$ then $P_2 = \frac{1}{2}e^{-j\pi/4}$ {complex conjugate}

From point ①

$x(t) = x^*(t)$ and $x(t) = x(-t)$

$\Rightarrow X(s) = X^*(-s)$ and $X(s) = X(-s)$

therefore $X(s) = X^*(-s) = X(-s)$

So P_3 would be $= -\frac{1}{2}e^{j\pi/4}$

P_4 would be $= -\frac{1}{2}e^{-j\pi/4}$

Now $X(s) = \dfrac{K}{(s-\frac{1}{2}e^{j\pi/4})(s-\frac{1}{2}e^{-j\pi/4})(s+\frac{1}{2}e^{j\pi/4})(s+\frac{1}{2}e^{-j\pi/4})}$

~~for~~ From point ④ $\int_{-\infty}^{\infty} x(t)\,dt = 4$

$\Rightarrow X(s)|_{s=0} = 4$

$X(0) = \dfrac{K}{(-\frac{1}{2}e^{j\pi/4})(-\frac{1}{2}e^{-j\pi/4})(\frac{1}{2}e^{j\pi/4})(\frac{1}{2}e^{-j\pi/4})}$

$4 = \dfrac{K}{1/16}$

$4 \times 1/16 = K$

$\frac{1}{4} = K$

Hence

$$X(s) = \frac{1/4}{\left(s-\frac{1}{2}e^{j\pi/4}\right)\left(s-\frac{1}{2}e^{-j\pi/4}\right)\left(s+\frac{1}{2}e^{-j\pi/4}\right)\left(s+\frac{1}{2}e^{j\pi/4}\right)}$$

Q.1 (b) Describe the following instructions of 8085 microprocessor:
(i) SBI (ii) SHLD (iii) RRC (iv) SPHL (v) DAD
[10 marks]

(i) SBI :- SBI stands for Substract immediate given data from the content of Accumulator. It is an immediate addressing mode

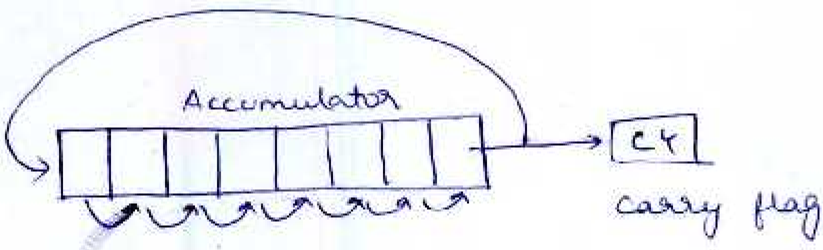
ex :- SBI 05H , means

$[A] \leftarrow [A] - [05]_H$

CY flag is internally complemented after this operation, 2's complement is used in substraction

(ii) SHLD :- It means storing the data from 'HL' pair of register to 'DE' pair of register. It is a register addressing mode.

(iii) RRC :- RRC stands for rotate content of accumulator right and LSB of accumulator is saved in CY flag



SPHL :- It is used to exchange the content of 'HL' register pair with 'SP' i.e. stack pointer register.

DAD :- It is used for 16 bit addition i.e. 'HL' content added to content of Rp
[HL] ← [HL] + Rp

Q.1 (c) Let $g_1(t) = \{[\cos(\omega_0 t)]x(t)\} * h(t)$ and $g_2(t) = \{[\sin(\omega_0 t)]x(t)\} * h(t)$,

where $x(t) = \sum_{k=-\infty}^{\infty} a_k e^{jk100t}$ is a real-valued periodic signal and h(t) is the impulse response of a stable LTI sytem.

Specify a value for ω_0 and any necessary constraints on $H(j\omega)$ to ensure that

$$g_1(t) = \text{Re}\{a_5\} \text{ and } g_2(t) = \text{Im}\{a_5\}$$

[10 marks]

Q.1 (d) Design the control word to configure the ports of 8255 (programmable peripheral interface) chip in mode 0, with port B and port C upper (PC_U) as inputs and port A and port C lower (PC_L) as outputs.

[10 marks]

Q.1 (e) Consider the following transfer function of an IIR filter:

$$H(z)=\frac{0.28z^2+0.319z+0.04}{0.5z^3+0.3z^2+0.17z-0.2}$$

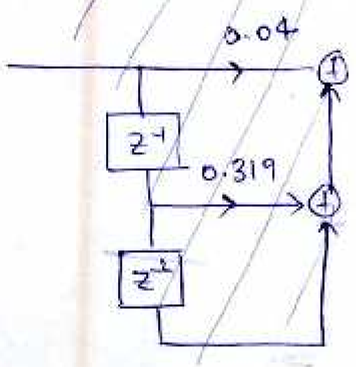
Realize this filter using direct form-I and direct form-II structures.

[10 marks]

Sol^n

$$H(z) = \frac{0.28z^2 + 0.319z + 0.04}{1 - [1.2 - 0.17z - 0.3z^2 - 0.5z^3]}$$

Direct form 1

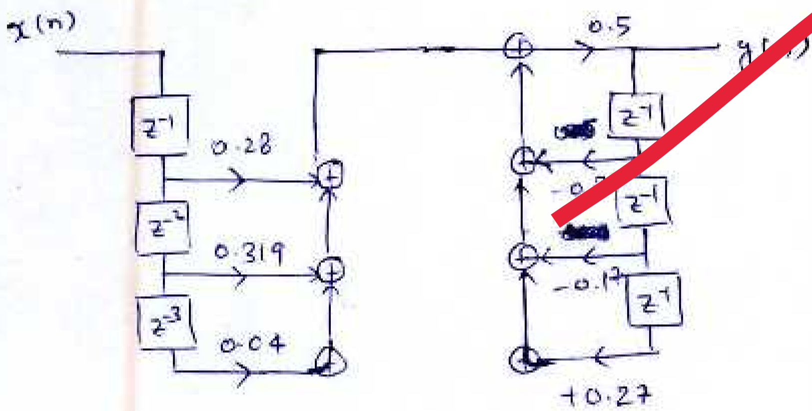


$$H(z) = \frac{\cancel{z^3}[0.28 + 0.319z^{-1} + 0.04z^{-2}]}{z^{\cancel{3}}[0.5 + 0.3z^{-1} + 0.17z^{-2} - 0.2z^{-3}]}$$

$$H(z) = \frac{0.28z^{-1} + 0.319z^{-2} + 0.04z^{-3}}{0.5 + 0.3z^{-1} + 0.17z^{-2} - 0.2z^{-3}}$$

$$= \frac{0.28z^{-1} + 0.319z^{-2} + 0.04z^{-3}}{1 - [0.5 - 0.3z^{-1} - 0.17z^{-2} + 0.2z^{-3}]}$$

Direct form - I



Direct form ②

Q.1 (f) It is required to move a block of 16-byte long data string from offset 4000 H to offset 5000 H. Write assembly language program to accomplish the above task for both 8085 and 8086 microprocessors. Assume that the block size is 10 and segment addresses are pre-initialized in case of 8086 microprocessor.

[10 marks]

Q.2 (a) Find the Fourier transform for the following signals:

(i) $x_1(t) = e^{-|t|}\cos(2t)$

(ii) $x_2(t) = \dfrac{\sin(2\pi t)}{\pi(t-1)}$

(iii) $x_3(t) = \begin{cases} t^2 ; & 0 < t < 1 \\ 0 ; & \text{otherwise} \end{cases}$

(iv) $x_4(t) = (1 - |t|)u(t+1)u(1-t)$

[20 marks]

Sol^n (i) $x_1(t) = e^{-|t|}\cos 2t$

$$= e^{-t}\cos 2t\, u(t) + e^{t}\cos 2t\, u(-t)$$

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

$$= [e^{-t}u(t) + e^{t}u(-t)]\left[\frac{e^{j2t} + e^{-j2t}}{2}\right]$$

$$= \underbrace{\left(\frac{e^{-t}u(t) + e^{t}u(-t)}{2}\right)}_{k_1} e^{j2t} + \cancel{\{e^{-t}u(t)+e^{t}u(-t)\}} + \left(\frac{e^{-t}u(t)+e^{t}u(-t)}{2}\right)e^{-j2t}$$

$$k_1(t) = \frac{1}{2}\left[e^{-t}u(t) + e^{t}u(-t)\right]$$

$$k_1(\omega) = \frac{1}{2}\left[\frac{1}{1+j\omega} + \frac{1}{1-j\omega}\right] = \frac{1}{2}\cdot\frac{1-j\omega+1+j\omega}{1+\omega^2} = \frac{1}{1+\omega^2}$$

Now

$$x_1(t) = k_1(t)e^{j2t} + k_1(t)e^{-j2t}$$

$$X_1(\omega) = k_1(\omega-2) + k_1(\omega+2)$$

$$X_1(\omega) = \frac{1}{1+(\omega-2)^2} + \frac{1}{1+(\omega+2)^2}$$

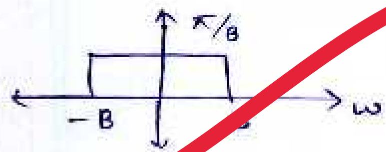
(ii) $$x_2(t) = \frac{\sin 2\pi t}{\pi(t-1)} = \frac{\sin 2\pi(t-1+1)}{\pi(t-1)} = \frac{\sin[2\pi(t-1)+2\pi]}{\pi(t-1)}$$

$$x_2(t) = \frac{\sin 2\pi(t-1)}{\pi(t-1)} = \frac{2\sin 2\pi(t-1)}{2\pi(t-1)}$$

$$x_2(t) = 2\,Sa\,2\pi(t-1)$$

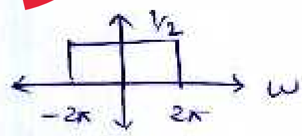
we know that

$Sa\, Bt \overset{FT}{\longleftrightarrow}$

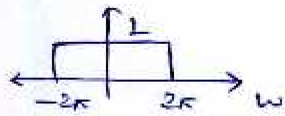


Put $B = 2\pi$

$Sa\, 2\pi t \overset{FT}{\longleftrightarrow}$

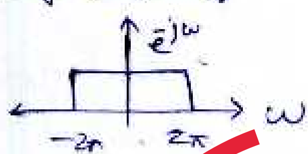


$2\, Sa\, 2\pi t \overset{FT}{\longleftrightarrow}$



using time shifting property

$2\, Sa\, 2\pi (t-1) \longleftrightarrow$



(iii) $x_3(t) = \begin{cases} t^2 & ; \; 0 < t < 1 \\ 0 & ; \; \text{otherwise} \end{cases}$

$x_3(t) = t^2 [\underbrace{u(t) - u(t-1)}]$

$= t^2 A(t)$

$A(t) = u(t) - u(t-1)$

Taking Fourier transform

$A(\omega) = \dfrac{1}{j\omega} - \dfrac{e^{-j\omega}}{j\omega}$

$= \dfrac{1 - e^{-j\omega}}{j\omega}$

$t^2 A(t) \overset{FT}{\longleftrightarrow} j^2 \dfrac{d^2 A(\omega)}{d\omega^2}$

$t^2 A(t) \longleftrightarrow (-1) \dfrac{d^2}{d\omega^2} \left[\dfrac{1 - e^{-j\omega}}{j\omega}\right]$

$t^2 A(t) \longleftrightarrow (-1) \dfrac{d}{d\omega} \left[\dfrac{(j\omega)(je^{-j\omega}) - j(1 - e^{-j\omega})}{(j\omega)^2} \right]$

$$t^2A(t) \leftrightarrow (-1)\frac{d}{d\omega}\left\{\frac{(-1)\omega e^{-j\omega} - j + je^{-j\omega}}{-\omega^2}\right\}$$

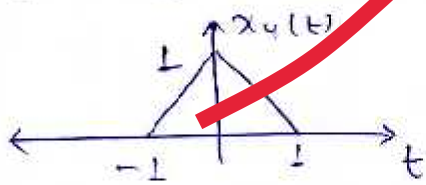
$$\leftrightarrow (-1)\left[\frac{(-\omega^2)[-e^{-j\omega} + \omega j e^{-j\omega} - j^2 e^{-j\omega}] + 2\omega(-\omega e^{-j\omega} - j + je^{-j\omega})}{\omega^4}\right]$$

$$t^2A(t) \leftrightarrow (-1)\left[\frac{\cancel{\omega^2 e^{-j\omega}} - j\omega^3 e^{-j\omega} + \cancel{j^2\omega^2 e^{-j\omega}} - 2\omega^2 e^{-j\omega} - 2j\omega + 2j\omega e^{-j\omega}}{\omega^4}\right]$$

$$t^2A(t) \leftrightarrow (-1)\left[\frac{-j\omega^3 e^{-j\omega} - 2\omega^2 e^{-j\omega} - 2j\omega + 4j\omega e^{-j\omega}}{\omega^4}\right]$$

(iv) $x_4(t) = \{1-|t|\}\, u(t+1)\, u(1-t)$

$= \{1-|t|\}\,[u(t+1) - u(t-1)]$



$x_4(t) = 1\ \text{tri}\left(\frac{t}{1}\right)$

we know that

$\text{tri}\left(\frac{t}{1}\right) \xleftrightarrow{FT} (1\cdot 1)\ Sa\ \frac{\omega}{2}$

$\text{tri}(t) \xleftrightarrow{FT} Sa\ \omega/2$

therefore

$(1-|t|)\,[u(t+1)\,u(1-t)] \xleftrightarrow{FT} Sa\ \omega/2$

Q.2 (b) Explain the following Data Transfer Schemes:
(i) Programmed data transfer schemes.
(ii) DMA data transfer scheme.

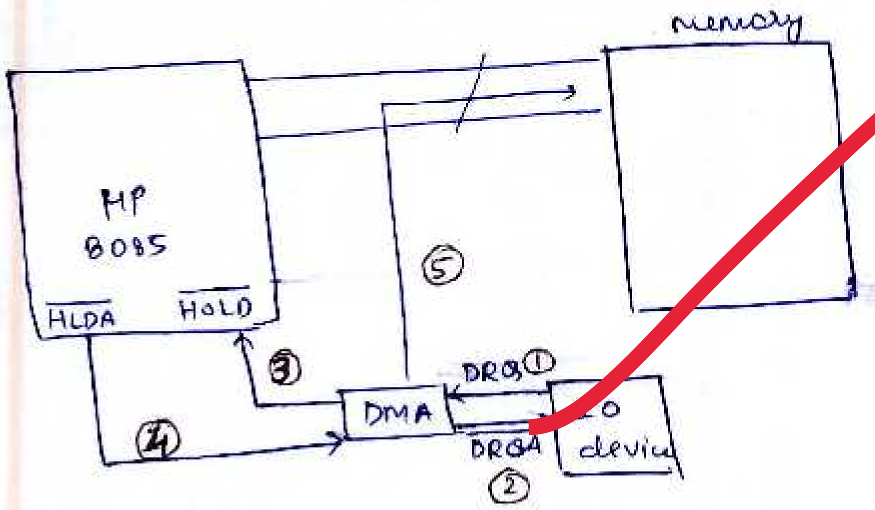
[20 marks]

(ii) DMA data transfer scheme :- when IO devices do data transfer there are 2 option available
(i) If data is less then directly with the help of μP data can be accessed or transferred to memory.
But when there is large amount of data to be transferred or accessed then IO device takes the help of DMA controller.

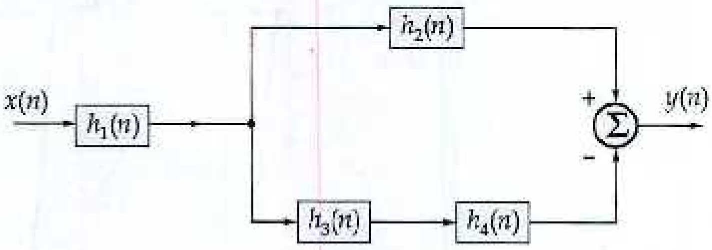
DMA sends HOLD signal to μP and μP acknowledge by HLDA signal and the address buses are transferred to DMA controller now DMA controller can access data from memory or transferred to.

DMA can transfer data in 3 modes
① Burst mode :- All data at once.
② cycle stealing mode :- when buses are idle it transfer or access data
③ Interleaved mode :- Interleaved or time share Address buses between diff I/O devices

Step 1 :- IO device sends device request to DMA (DRQ)
Step 2 :- DMA Acknowledge device request $\overline{DRQA}$
Step 3 :- DMA sends HOLD signal to μP
Step 4 :- μP acknowledge HLDA signal and address buses are transferred to DMA
Step 5 :- DMA access memory


memory
MP
8085
HLDA
HOLD
5
3
DRQ 1
DMA
IO device
4
DRQA
2

Q.2 (c) Consider the interconnection of LTI systems shown in the figure below:



$$h_1(n) = \left\{\frac{1}{2}, \frac{1}{4}, \frac{1}{2}\right\}_{\uparrow},\ h_2(n) = h_3(n) = (n+1)\,u(n) \text{ and } h_4(n) = \delta(n-2)$$

Determine the response of the system, if $x(n) = \delta(n+2) + 3\delta(n-1) - 4\delta(n-3)$. Assume that the system is initially relaxed.

[20 marks]

Sol^n

$h'(n) = h_3(n) * h_4(n)$

$= (n+1)u(n) * \delta(n-2)$

$= (n-2+1)\,u(n-2)$ $\quad \{ x(n) * \delta(n-n_0) = x(n-n_0) \}$

$= (n-1)\,u(n-2)$

$h''(n) = h_2(n) - h'(n)$

$= \underbrace{(n+1)u(n)}_{k_1(n)} - \underbrace{(n-1)u(n-2)}_{k_2(n)}$

$k_1(n) = \{\underset{\uparrow}{1}, 2, 3, 4, 5 \ldots\}$ $\quad k_2(n) = \{0, 0, 1, 2, 3, 4 \ldots\}$

$h''(n) = k_1(n) - k_2(n)$

$h''(n) = \{\underset{\uparrow}{1}, 2, 2, 2, 2, 2, \ldots\}$

$h''(n) = \delta(n) + 2u(n-1)$

$h(n) = h_1(n) * h''(n)$

$= \left[\frac{1}{2}\delta(n) + \frac{1}{4}\delta(n-1) + \frac{1}{2}\delta(n-2)\right] * \left[\delta(n) + 2u(n-1)\right]$

$h(n) = \frac{1}{2}\delta(n) + \frac{1}{2}\times 2\,u(n-1) + \frac{1}{4}\delta(n-1) + \frac{1}{4}\times 2\,u(n-2)$
$+ \frac{1}{2}\delta(n-2) + \frac{1}{2}\times 2\,u(n-3)$

$h(n) = \frac{1}{2}\delta(n) + u(n-1) + \frac{1}{4}\delta(n-1) + \frac{1}{2}u(n-2)$
$+ \frac{1}{2}\delta(n-2) + u(n-3)$

$$h(n) = \frac{1}{2}\delta(n) + \frac{1}{4}\delta(n-1) + \frac{1}{2}\delta(n-2) + u(n-1) + \frac{1}{2}u(n-2) + u(n-3)$$

Given

$$x(n) = \delta(n+2) + 3\delta(n-1) - 4\delta(n-3)$$

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

$$y(n) = \left[\frac{1}{2}\delta(n) + \frac{1}{4}\delta(n-1) + \frac{1}{2}\delta(n-2) + u(n-1) + \frac{1}{2}u(n-2) + u(n-3)\right] * \left[\delta(n+2) + 3\delta(n-1) - 4\delta(n-3)\right]$$

$$y(n) = \frac{1}{2}\delta(n+2) + \frac{1}{4}\delta(n+1) + \frac{1}{2}\delta(n) + u(n+1) + \frac{1}{2}u(n) + u(n-1) + 3\times\frac{1}{2}\delta(n-1) + 3\times\frac{1}{4}\delta(n-2) + \frac{3}{2}\delta(n-3) + 3u(n-2) + \frac{3}{2}u(n-3) + 3u(n-4) - 2\delta(n-3) - \delta(n-4) - 2\delta(n-5) - 4u(n-4) - 2u(n-5) - 4u(n-6)$$

$$y(n) = \frac{1}{2}\delta(n+2) + \frac{1}{4}\delta(n+1) + \frac{1}{2}\delta(n) + \frac{3}{2}\delta(n-1) + \frac{3}{4}\delta(n-2) - \frac{1}{2}\delta(n-3) - \delta(n-4) - 2\delta(n-5) + u(n+1) + \frac{1}{2}u(n) + u(n-1) + 3u(n-2) + \frac{3}{2}u(n-3) - u(n-4) - 2u(n-5) - 4u(n-6)$$

15

Q.3 (a) Consider a list of 50 numbers is stored in memory, starting at 6000 H in an 8085 microprocessor system. Write an assembly language program to find number of negative, zero and positive numbers from this list and store these results in memory locations 7000 H, 7001 H and 7002 H respectively.

[20 marks]

Q.3 (b) Determine the z-transform for the following sequences. Sketch the pole-zero plot and indicate the ROC.

(i) $\left(\frac{1}{2}\right)^n \{u[n]-u[n-10]\}$

(ii) $7\left(\frac{1}{3}\right)^n \cos\left[\frac{2\pi n}{6}+\frac{\pi}{4}\right]u[n]$

[20 marks]

Q.3 (c) (i) Consider a signal $m(t) = \cos \omega_0 t$, where $\omega_0 = 2\pi f_0$. Illustrate the effect of undersampling of $m(t)$ for a sampling rate of $f_s = \frac{3}{2} f_0$.

(ii) Explain briefly three 8085 microprocessor instructions, which use stack memory for their execution.

[10 + 10 marks]

Q.4 (a) **(i)** Write an 8085 assembly language program to convert a 2-digit BCD number stored at memory address 2200 H into its binary equivalent number and store the result in a memory location 2300 H.

(ii) Write an 8051 assembly language program to convert a given 8-bit binary number into its Gray Code equivalent. Explain with an example.

[14 + 6 marks]

Q.4 (b) Let $x_1(t)$ represent the input to an LTI system, where $x_1(t) = \sum_{k=-\infty}^{\infty} \alpha^{|k|} e^{jk\frac{\pi}{4}t}$ for $0 < \alpha < 1$.

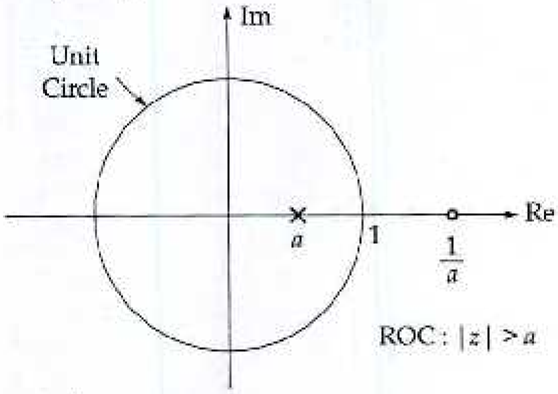
The frequency response of the system is

$$H(j\omega) = \begin{cases} 1 \ ; & |\omega| < W \\ 0 \ ; & \text{otherwise} \end{cases}$$

What is the minimum value of W so that the average energy in the output signal will be at least 90% of that in the input signal?

[20 marks]

Q.4 (c) **(i)** A discrete time system with the pole-zero pattern shown below is referred to as a first order all-pass system, since the magnitude of the frequency response is constant regardless of frequency.



Show that $\left|H(e^{j\omega})\right|$ is constant.

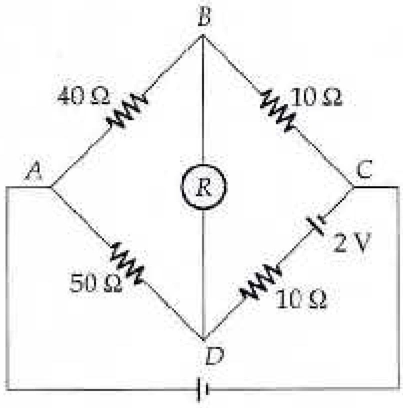
(ii) What is BSR mode in 8255?
Write the BSR control words for the following cases:

1. PC_0 to be set
2. PC_7 to be reset
3. PC_1 to be set
4. PC_7 to be set

[10 + 10 marks]

Section B : Network Theory-1 + Control Systems-1

Q.5 (a) In the circuit shown below:

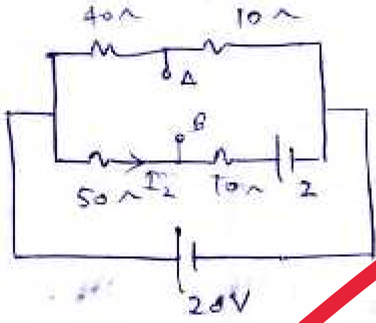


Determine the current through $R = 18\ \Omega$ using Thevenin's theorem.

[10 marks]

$V_A = \frac{20 \times 10}{50} = 4$ volt

$\cancel{V_B = \frac{(20-2)10}{60} = 3 \text{ Volt}}$



Applying KVL

$20\text{ V} = 50 I_2 + 10 I_2 + 2$

$\frac{18}{60} = I_2$

$0.3\text{ A} = I_2$

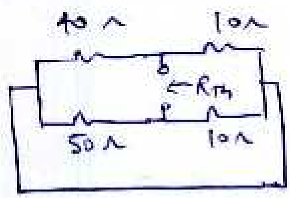
$I_2 = \frac{20 - V_B}{50}$

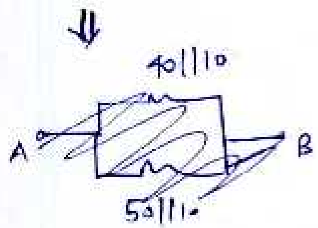
$V_B = 20 - 50 I_2$

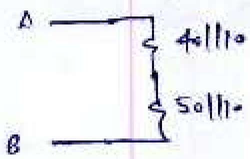
$V_B = 5$ volt

$$V_{Th} = V_A - V_B$$
$$= 4 - 5$$
$$= -1 \text{ Volt}$$

For R_{th}

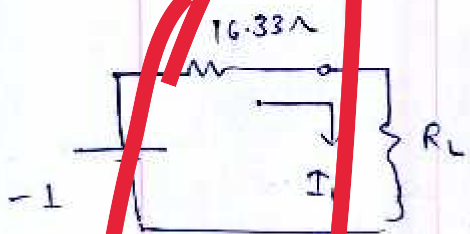






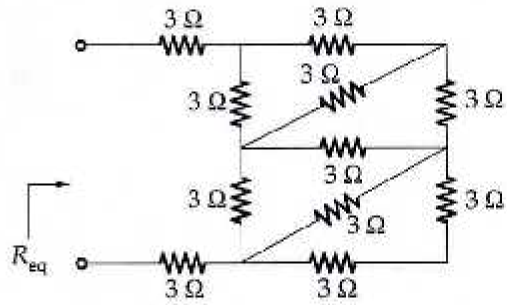
$$R_{th} = 40\|10 + 50\|10$$
$$= \frac{400}{50} + \frac{500}{60}$$
$$= 8 + 8.33$$
$$= 16.33\ \Omega$$

Thevenin equivalent ckt is



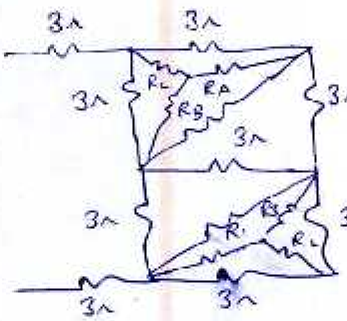
$$I_L = \frac{-1}{16.33 + R_L}$$
$$= \frac{-1}{16.33 + 18}$$
$$\boxed{I_L = -0.0291\ A}$$

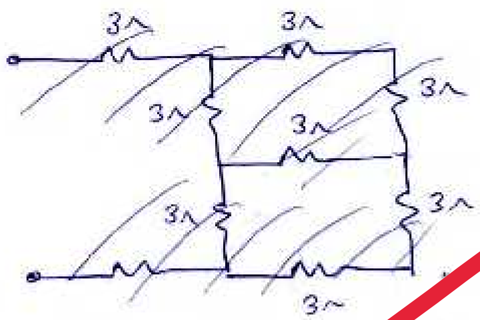
Q.5 (b) For the circuit shown below, find the equivalent resistance, R_{eq}



[10 marks]

~~# There are two balanced bridge therefore ckt will be redrawn as~~

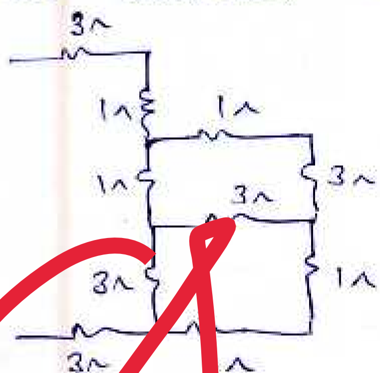


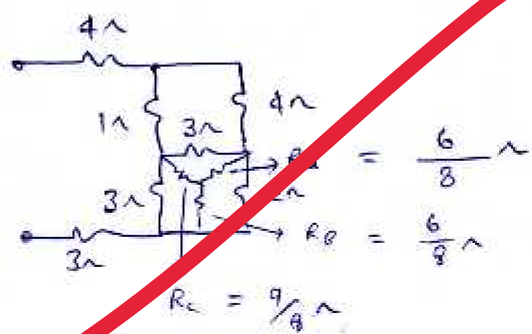


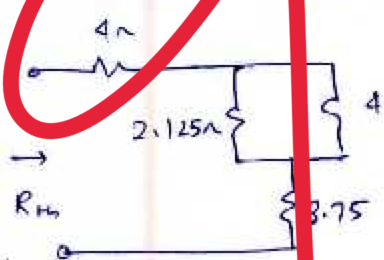
→ using delta to star conversion

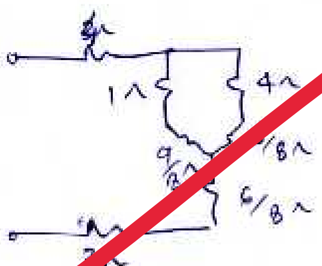
$R_A = R_B = R_C = R_1 = R_2 = R_3 = 1\Omega$

→ ckt redrawn as









$R_{th} = 4 + (4.75 \| 2.125) + 3.75$

$= 7.75 + 1.468$

$R_{th} = 9.218\,\Omega$

Q.5 (c) What are Gain Margin and Phase Margin? Discuss briefly about their importance in design of control system.

[10 marks]

→ Gain Margin :- It tells about the max gain which we can provide to system till it becomes unstable. It is the gain found mathematically at that frequency at which the phase is 180° (ie phase cross over frequency)

→ Phase margin :- It is the maximum phase which we can incorporate in our system before it becomes unstable. For PM phase is calculated at gain cross over frequency ie the frequency at which the gain is 1 or 0dB.

→ Gain margin and phase margin are tools to design our system considering the stability ~~___~~ wrt gain and phase of system. GM and PM gives us a glimpse of relative stability of system ie how much extra gain and phase our system can tolerate to work properly.

Q.5 (d) Determine the range of real valued system constant K for which the system with following characteristic equation is stable.

$$s^4 + Ks^3 + 2s^2 + (K+1)s + 10 = 0$$

[10 marks]

Sol^n

s^4	1	2	10
s^3	K	$K+1$	0
s^2	$\frac{2K-K-1}{K} = \frac{K-1}{K}$	10	0
s	$\dfrac{\left(\frac{K-1}{K}\right)(K+1) - 10K}{\frac{K-1}{K}}$	0	0
1	10		

For stability all the coefficient of 1st column must be +ve / same sign

$K > 0$ —①

$\frac{K-1}{K} > 0$

$K > 1$ —②

$\left(\frac{K-1}{K}\right)(K+1) - 10K > 0$

$\frac{K^2-1}{K} > 10K$

$K^2 - 1 > 10K^2$

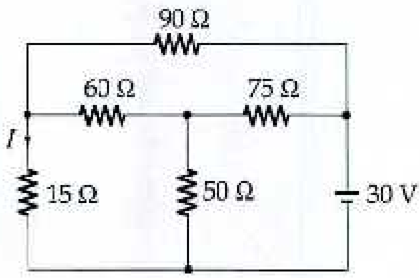
$-1 > 9K^2$

$\sqrt{-1/9} > K$ {imaginary value}

$\boxed{\text{Hence system is not stable for any value of } K}$

Do not write in this margin

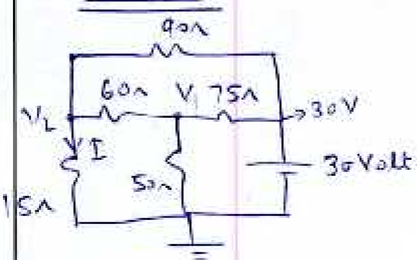
Q.5 (e) State reciprocity theorem and verify it with respect to 30 V source and current *I* in the network given below:



[10 marks]

→ Reciprocity theorem states that in a reciprocal network the ratio of response to excitation remains constant.

Case - 1



KCL at node V_1

$$\frac{30-V_1}{75} = \frac{V_1-V_2}{60} + \frac{V_1}{50}$$

$$\frac{30}{75} = V_1\left[\frac{1}{60}+\frac{1}{50}+\frac{1}{75}\right] - \frac{V_2}{60}$$

$$\frac{30}{75} = \frac{V_1}{20} - \frac{V_2}{60} \quad \text{— (A)}$$

KCL at node V_2

$$\frac{V_1-V_2}{60} + \frac{30-V_2}{90} = \frac{V_2}{15}$$

$$V_1\left[\frac{1}{60}\right] + V_2\left[-\frac{1}{60}-\frac{1}{90}-\frac{1}{15}\right] = -\frac{30}{90}$$

$$\frac{V_1}{60} - V_2\left[\frac{3+2+12}{180}\right] = -1/3$$

$$\frac{V_1}{60} - V_2\left(\frac{17}{180}\right) = -1/3$$

$0.016V_1 - 0.094V_2 = -0.33$ — (B)

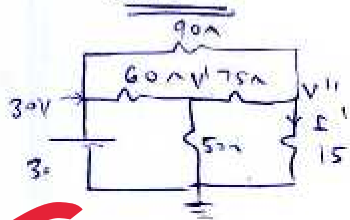
on solving (A) and (B)

$V_1 = 39/4 = 9.75$ V

$V_2 = 21/4 = 5.25$ V

$I = \frac{V_2}{15} = 0.35A$

Case - 2



KCL at node V'

$$\frac{30-V'}{60} = \frac{V'}{50} + \frac{V'-V''}{75}$$

$$\frac{1}{2} = V'\left[\frac{1}{50}+\frac{1}{60}+\frac{1}{75}\right] - \frac{V''}{75}$$

$$\frac{1}{2} = 0.05V' - 0.0133V'' \quad \text{— (C)}$$

KCL at node V''

$$\frac{30-V''}{90} = \frac{V''}{15} - \frac{V'-V''}{75}$$

$$\frac{1}{3} = -\frac{V'}{75} + V''\left[\frac{1}{90}+\frac{1}{15}+\frac{1}{75}\right]$$

$$\frac{1}{3} = -0.0133V' + 0.0911V'' \quad \text{— (D)}$$

on solving (C) and (D)

$V' = 11.7166$ Volt

$V'' = 5.3$ Volt

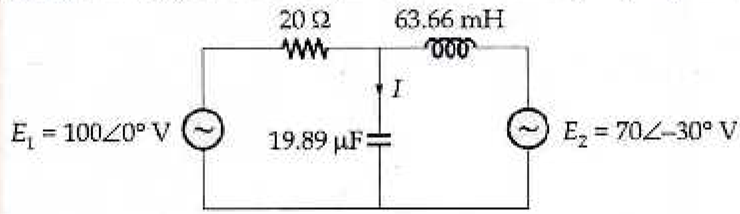
$I' = \frac{5.3}{15}$

$\boxed{I' = 0.35\ A}$

$\boxed{I = I'}$ verified

Do not write in this margin

Q.5 (f) For the circuit shown in below figure, if the frequency of supply is 50 Hz, determine the current I flowing through the 19.89 μF capacitor using superposition theorem.



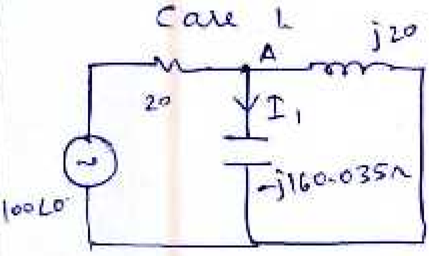
[10 marks]

Sol^n

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi \times 50 \times 19.89 \times 10^{-6}} = 160.035\,\Omega$$

$$X_L = \omega L = 2\pi \times 50 \times 63.66 \times 10^{-3} = 20\,\Omega$$

Case 1



KCL at node A

$$\frac{100 - V_A}{20} = V_A\left[\frac{1}{j20} + \frac{1}{-j160.035}\right]$$

$$\frac{100}{20} = V_A\left[\frac{1}{20} + \frac{1}{j20} - \frac{1}{j160.035}\right]$$

$$5 = V_A\left[\frac{1}{20} - \frac{j}{20} + \frac{j}{160.035}\right]$$

$$5 = V_A\left[0.05 - j0.05 + j\,0.00624\right]$$

$$5 = V_A\left[0.05 - 0.04375j\right]$$

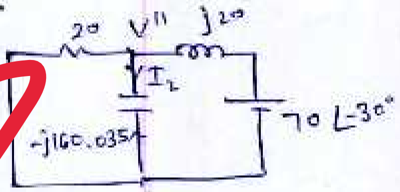
$$V_A = 75.25\angle 0.72 \rightarrow \text{in radian}$$

$$I_1 = \frac{V_A}{-j160.035}$$

$$= \frac{75.25\angle 0.72}{\ldots}$$

$$\boxed{I_1 = 0.470\angle 2.29}$$

Case - 2



KCL at node V''

$$\frac{70\angle -30^\circ - V''}{j20} = \frac{V''}{20} + \frac{V''}{-j160.035}$$

$$3.5\angle{-120^\circ} = V''\left[\frac{1}{20} + \frac{j}{160.035} \mp \frac{j}{20}\right]$$

$$3.5\angle{-120^\circ} = V''\left[0.05 + 0.00624j - 0.05i\right]$$

$$3.5\angle{-120^\circ} = V''\left[0.05 - 0.04375j\right]$$

$$V'' = 52.68\angle{-78.81^\circ}$$

$$I'' = \frac{V''}{-j160.035} = 0.329\angle 11.18^\circ$$

$$= 0.329\angle 0.195 \rightarrow \text{in radian}$$

$$I = I_1 + I''$$

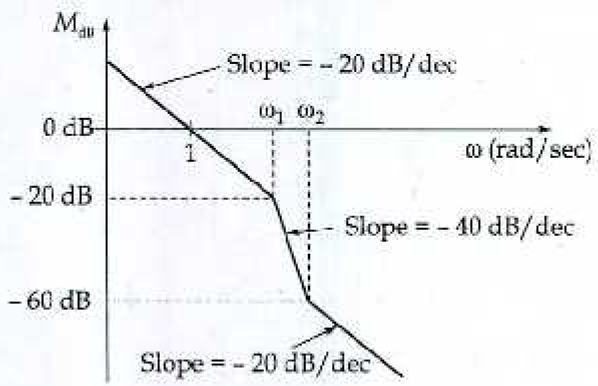
← in radian

$$= 0.[illegible]\angle[illegible] + 0.329\angle 0.195$$

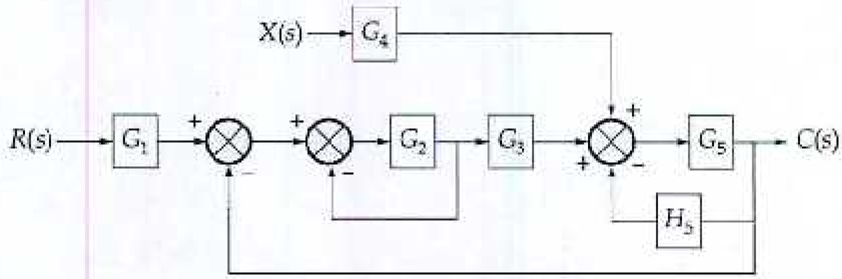
$$\boxed{I = 0.417\angle 1.54}$$

in radian

Q.6 (a) (i) Determine the transfer function corresponding to the following Bode plot:



(ii) Using block diagram reduction technique, find the transfer function from each input to the output C(s) for the system shown below:



[10 + 10 marks]

(i) Pole $= 0, \omega_1,$ $TF = \dfrac{K\left(\frac{s}{\omega_2}+1\right)}{s\left(\frac{s}{\omega_1}+1\right)}$

zero $= \omega_2$

$$-20\,dB/decade = \frac{0-(-20)}{\log 1 - \log \omega_1}$$

$$-20 = \frac{20}{\log 1/\omega_1}$$

$$\log \omega_1 = 1$$

$$\boxed{\omega_1 = 10}$$

$$\frac{-20+60}{\log \frac{\omega_1}{\omega_2}} = 40$$

$$1 = \log \frac{\omega_2}{\omega_1}$$

$$\omega_2 = 10\omega_1$$

$$\omega_2 = 100$$

~~T/F~~ Also

$$|M|_{dB} = 20\log K - 20\log\omega$$

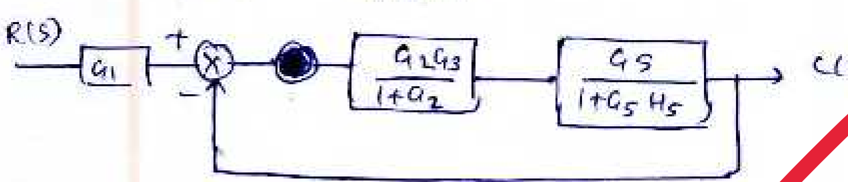
at $\omega = 1$ $|M| = 0\,dB$

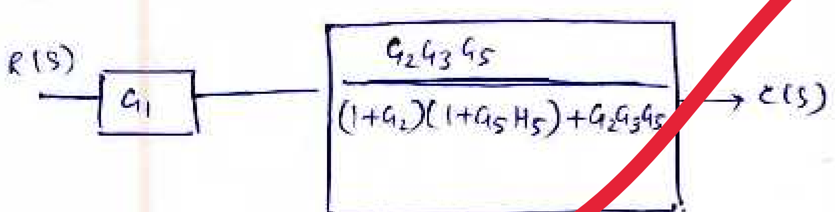
$$0 = 20\log K - 20\log 1$$

$$\boxed{K = 1}$$

$$\boxed{TF = \frac{\frac{s}{100}+1}{s\left(\frac{s}{10}+1\right)}}$$

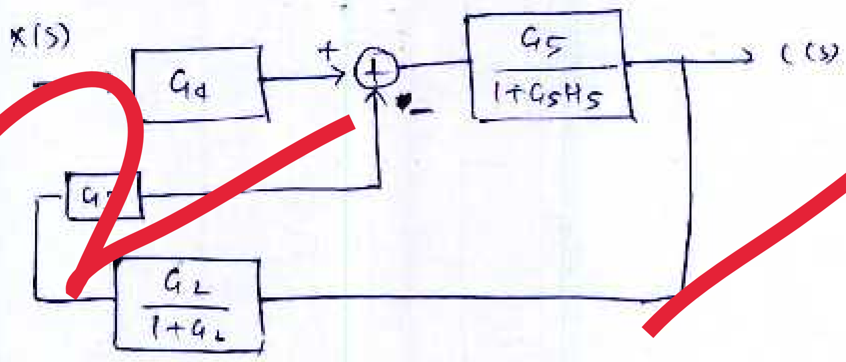
(ii) For $\left.\dfrac{C(s)}{R(s)}\right|_{X(s)=0}$

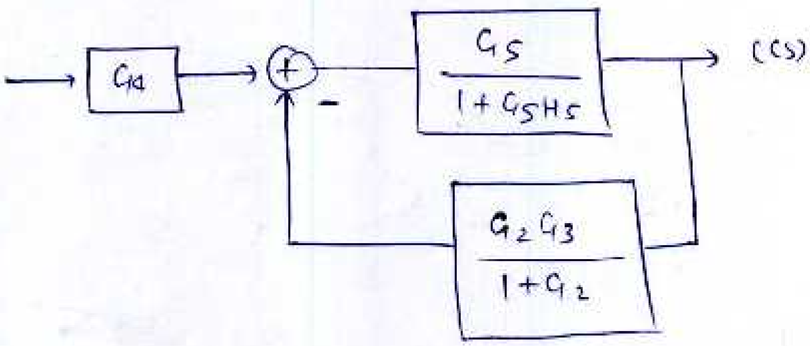


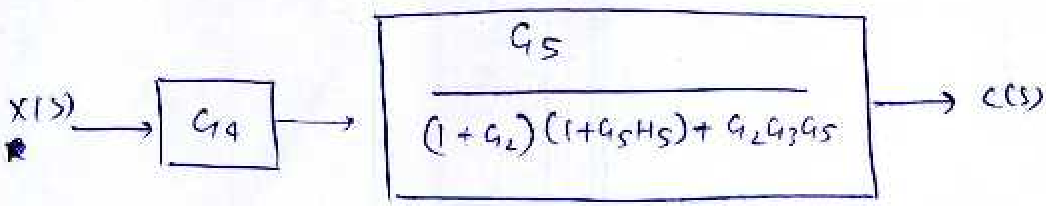


$$\frac{C(s)}{R(s)} = \frac{G_1G_2G_3G_5}{(1+G_2)(1+G_5H_5)+G_2G_3G_5}$$

for $\left.\dfrac{C(s)}{X(s)}\right|_{R(s)=0}$







$$\boxed{\frac{C(s)}{X(s)} = \frac{G_4 G_5}{(1+G_2)(1+G_5H_5)+G_2G_3G_5}}$$

Q.6 (b) The characteristic equation of a closed loop system is given by,

$$s^6 + s^5 - 2s^4 - 3s^3 - 7s^2 - 4s - 4 = 0$$

Determine the stability of the system using Routh stability criterion. While formulating Routh table, if any difficulty arise, then show two different methods to overcome the difficulty and also determine all the roots of the characteristic equation.

[20 marks]

s^6	1	-2	-7	-4
s^5	1	-3	-4	0
s^4	$\frac{(-2)+3}{1} = 1$	$\frac{-7+4}{1} = -3$	-4	0
s^3	$0 \to 4$	$0 \to -6$	0	
s^2	$\frac{-12+6}{4} = -1.5$	-4		
s	$\frac{9+16}{-1.5} = -16.67$	0		
1	-4			

AE

$q(s) = s^4 - 3s^2 - 4$

$q'(s) = 4s^3 - 6s$

After auxiliary equation there is sign change hence system is unstable

Method 1

while formulating routh table there is one full row becomes zero. Inorder to overcome this we make equation taking coefficient of preceding row and we call it as Auxilary eq^n and then we differentiate the auxilary equation and put the coefficient of differentiated eq^n in the zero row.

As in our case auxilary eq^n was

$$q(s) = s^4 - 3s^2 - 4$$

$$q'(s) = 4s^3 - 6s$$

Method 2

Another way is to put $s = z^{-1}$ in the characteristic equation and then solve the Routh table to overcome the zero row problem

→ AE equation

$$s^4 - 3s^2 - 4 = 0$$

$$x^2 - 3x - 4 = 0$$

$$x = 4, -1$$

$$s^2 = 4, -1$$

$$s = \pm 2, \pm j$$

Four roots are $2, -2, +j, -j$

$= (s+2)(s-2)(s+j)(s-j)$

$= (s^2-4)(s^2+1)$

$= s^4+s^2-4s^2-4$

$= s^4-3s^2-4$

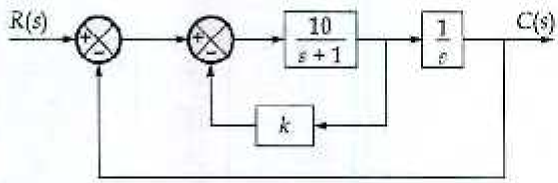
$$
\begin{array}{r}
s^2+s+1 \\
s^4-3s^2-4 \,\big)\, s^6+s^5-2s^4-3s^3-7s^2-4s-4 \\
s^6 \quad -3s^4 \quad -4s^2 \\
- \quad + \quad + \\
\hline
s^5+s^4-3s^2-3s^3-4s-4 \\
s^5 \quad -3s^3 \quad -4s \\
- \quad + \quad + \\
\hline
s^4-3s^2-4 \\
s^4-3s^2-4 \\
\hline
0
\end{array}
$$

CE $= (s^4-3s^2-4)(s^2+s+1)$

roots $= -2, 2, j, -j, -\frac{1}{2}+0.86j, -\frac{1}{2}-0.86j$

15

Q.6 (c) Consider the system shown below:



Sketch the root loci of the system as the gain k varies from zero to infinity. Determine the value of k such that the closed loop poles have the damping ratio $\xi = 0.7$.

[20 marks]

$$G'(s) = \frac{\frac{10}{s+1}}{1 + \frac{10K}{s+1}} \cdot \frac{1}{s} = \frac{10}{s(s+1+10K)}$$

$$TF = \frac{G'(s)}{1+G'(s)} = \frac{10}{s^2 + s + 10Ks + 10}$$

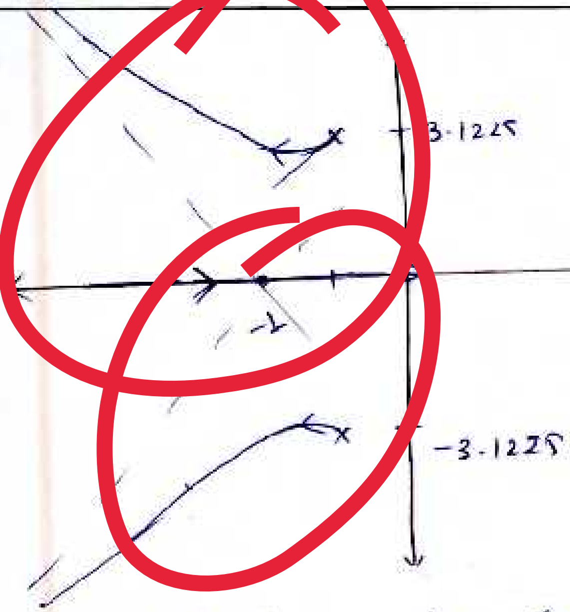
$$= \frac{10}{s^2+s+10 + 10Ks}$$

$$= \frac{10}{s^2+s+10\left[1 + \frac{10Ks}{s^2+s+10}\right]}$$

$$G''(s) = \frac{10Ks}{s^2+s+10}$$

Poles $= -0.5 + 3.1225i$, $-0.5 - 3.1225i$

zero $= 0$



$\phi_D = 180 - \phi \qquad \phi = \Sigma\phi_p - \Sigma\phi_z$

$\phi_p = 90^\circ \qquad \phi_z = 180 - \tan^{-1}\frac{3.125}{0.5}$

$\phi_z = 99.1^\circ$

$\phi_D = 180 - [90 - 99.1^\circ]$

$= 189^\circ$

$\sigma = \frac{\text{Real part of poles} - \text{Real part of zeros}}{P - Z}$

$= \frac{-0.5 - 0.5 - 0}{2-1}$

$= -1$

$CE = s^2 + s + 10 + 10Ks$

$= s^2 + s(1+10K) + 10$

$\omega_n = \sqrt{10}$

$2\eta\omega_n = 1 + 10K$

$2 \times 0.7 \times \sqrt{10} = 1 + 10K$

$\boxed{K = 0.342}$

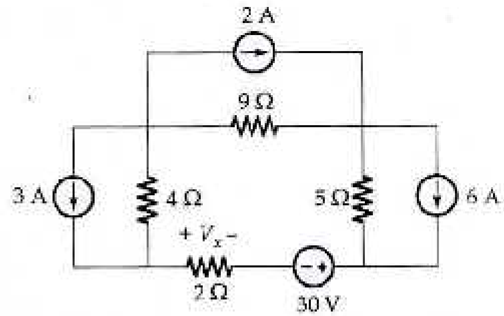
Q.7 (a) The open-loop transfer function of a system with unity negative feedback is given by,

$$G(s) = \frac{(s+1)(s+2)}{s^3(s+10)(s+20)}$$

Draw the polar plot of the system by showing all the salient points.

[20 marks]

Q.7 (b) Consider the circuit shown in the figure below:

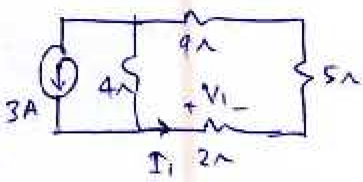


(i) Find the voltage V_x using superposition theorem.

(ii) Check the result obtained in part (i) using source transformation technique.

[15 + 5 marks]

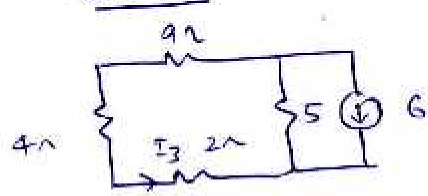
(i) Case - 1



$$I_1 = \frac{3 \times 4}{4 + 16} = \frac{12}{20}$$

$$= 0.6\,A$$

Case - 3

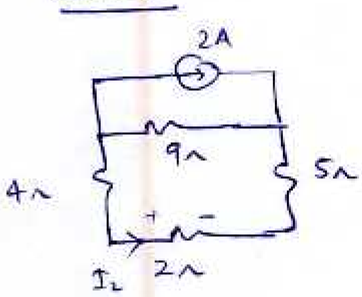


$$I_3 = \frac{(-6)(5)}{5 + 15}$$

$$= \frac{-30}{20}$$

$$I_3 = -1.5\,A$$

Case - 2

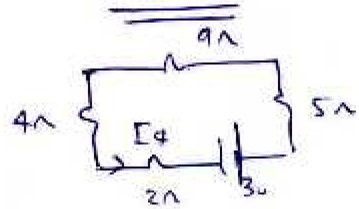


$$I_2 = \frac{(-2)(9)}{9 + 11}$$

$$= \frac{-18}{20}$$

$$I_2 = -0.9\,A$$

Case - 4



$$I_4 = \frac{30}{20}$$

$$= 1.5\,A$$

$$I_{net} = I_1 + I_2 + I_3 + I_4$$

$$= 0.6 - 0.9 - 1.5 + 1.5$$

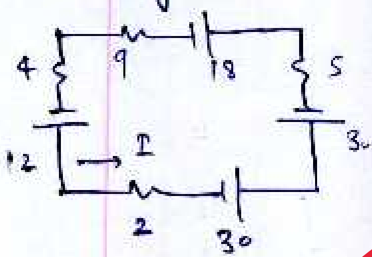
$$= -0.3$$

$$V_x = I_{net} \times 2$$

$$= (-0.3)\,2$$

$$\boxed{V_x = -0.6\ \text{volt}}$$

using source transformation



$$I = \frac{\cancel{3}0 + 12 - \cancel{3}0 - 18}{20}$$

$$= -6/20$$

$$I = -0.3$$

$$V_x = I \times 2$$

$$= -0.3 \times 2$$

$$\boxed{V_x = -0.6 \text{ Volt}}$$

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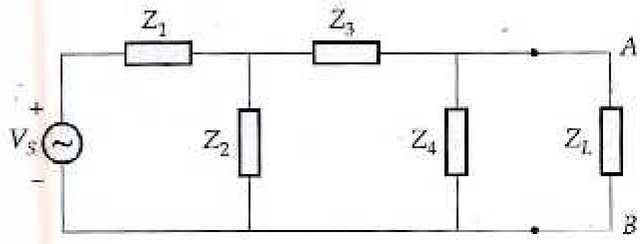
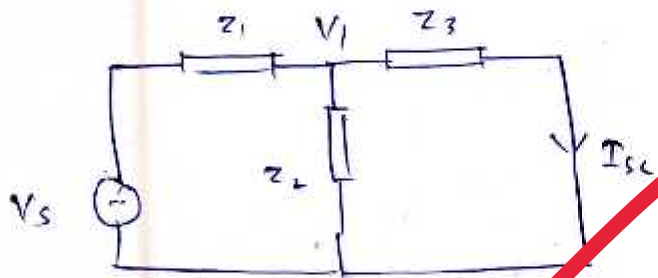
Q.7 (c) Find the current through Z_L in the network shown in figure below, using Norton's theorem.



$Z_1 = 1 + j3\ \Omega$
$Z_2 = 2 + j3\ \Omega$
$Z_3 = 3 + j2\ \Omega$
$Z_4 = 1 + j2\ \Omega$
$Z_L = 1 - j3\ \Omega$
$V_S = 40 + j0\ \Omega$

[20 marks]



$$\frac{V_s - V_1}{Z_1} = \frac{V_1}{Z_L} + \frac{V_1}{Z_3}$$

$$\frac{V_s}{Z_1} = V_1\left[\frac{1}{Z_1} + \frac{1}{Z_L} + \frac{1}{Z_3}\right)$$

$$V_s\left[\frac{1}{10} - \frac{3j}{10}\right] = V_1\left[\frac{1}{10} - \frac{3j}{10} + \frac{2}{13} - \frac{3j}{13} + \frac{3}{13} - \frac{2}{13}j\right]$$

$$V_s[0.1 - 0.3j] = V_1[0.4846 - j\,0.6846]$$

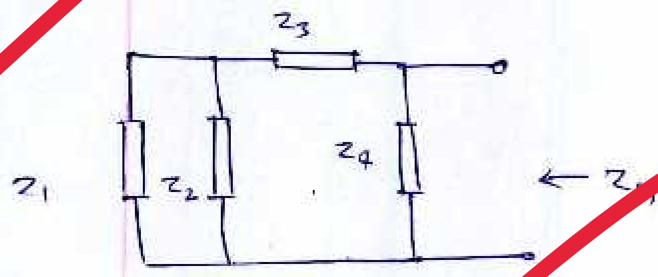
$$40 \times 0.411 \angle{-18.43^\circ} = V_1$$

$$I_{sc} = \frac{V_1 \times 40}{Z_3}$$

$$= \frac{40 \times 0.411 \angle{-18.43^\circ}}{0.230 - 0.15i}$$

$$\boxed{I_{sc} = 60 \angle 51.54^\circ}$$

For Z_{th}



$$Z_{th} = \left(\frac{Z_1 Z_2}{Z_1+Z_2} + Z_3\right) \parallel Z_4$$

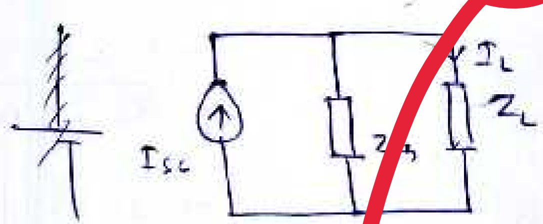
$$= \left(\frac{-7+9i}{3+j6} + 3+j2\right) \parallel (1+4i)$$

$$= \frac{\left(\frac{56}{15} + \frac{53}{15}i\right)(1+4i)}{\frac{56}{15} + \frac{53}{15}i + 1+4i}$$

$$= \frac{-3.33+11i}{\frac{71}{15} + \frac{83}{15}i}$$

$$\boxed{Z_{th} = 0.85 + 1.33i}$$

$$I_L = \frac{I_{sc}\, Z_{th}}{Z_{th} + Z_L}$$



$$= \frac{60 \angle 51.54^\circ\,(0.85+1.33i)}{1.85 - 1.67i}$$

$$= (60 \angle 51.54^\circ)(0.632 \angle 99.5^\circ)$$

$$\boxed{I_L = 37.98 \angle 151.04^\circ}$$

Do not write in this margin

Q.8 (a) Sketch the Nyquist plot for a unity negative feedback control system with open loop transfer function $G(s) = \dfrac{Ks^3}{(s+1)(s+2)}$ and determine the stability condition.

[20 marks]