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• Try to attempt question completely

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ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-2 : Digital Electronics + Microprocessors + Electrical Circuits-1 + Systems and Signal Processing-1

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	27
Q.2	21
Q.3	
Q.4	
Section-B	
Q.5	40
Q.6	50
Q.7	44
Q.8	
Total Marks Obtained	182

Signature of Evaluator: Sourabh kumar ....

Cross Checked by ....

IMPORTANT INSTRUCTIONS

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

DONT'S

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

DO'S

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

Section A : Digital Electronics + Microprocessors

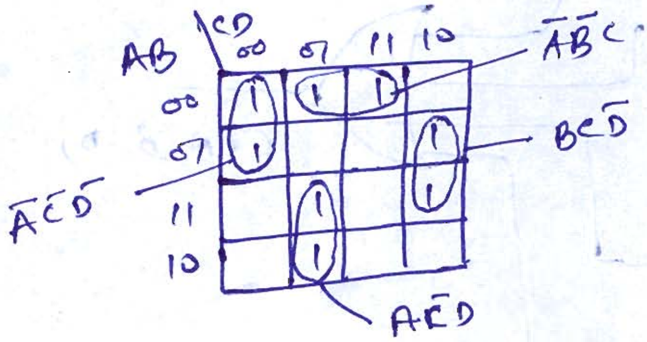
Q.1 (a) Derive a minimized POS expression for the given function and realize using NOR-gates only.

$$F(A, B, C, D) = \Sigma m(0, 1, 3, 4, 6, 9, 13, 14)$$

[12 marks]

Answer

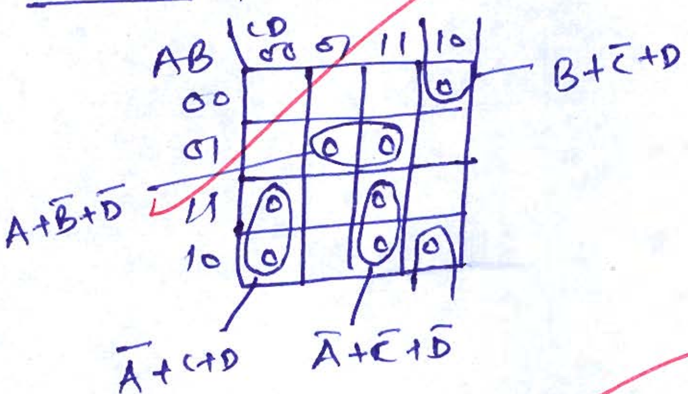
By using K-map



$f(A,B,C,D) = \bar{A}\bar{B}C + BC\bar{D} + A\bar{C}D + \bar{A}\bar{C}\bar{D}$

(SOP form)

for POS $\quad f(A,B,C,D) = \Pi M(2,5,7,8,10,11,12,15)$



$f(A,B,C,D) = (B+\bar{C}+D)\cdot(\bar{A}+\bar{C}+\bar{D})\cdot(\bar{A}+C+D)(A+\bar{B}+\bar{D})$

Now

$\overline{\overline{f(A,B,C,D)}} = \overline{\overline{\bar{A}\bar{B}C + BC\bar{D} + A\bar{C}D + \bar{A}\bar{C}\bar{D}}}$

By Implementing using NOR-gates

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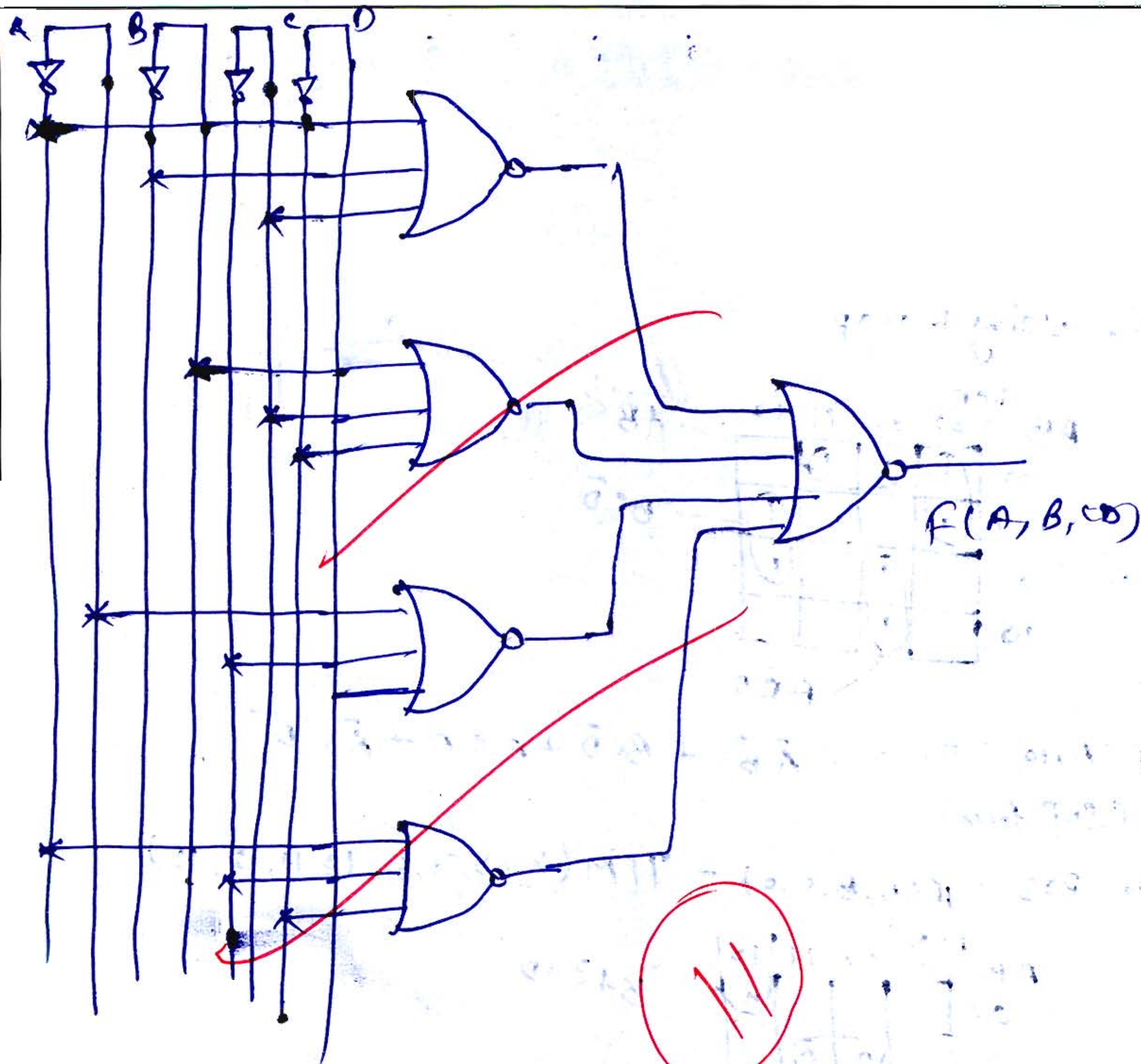

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Good Approach

Q.1 (b) Design an odd parity bit generator using four bit input.

[12 marks]

Truth table

	A	B	C	D	output Y_0
0	0	0	0	0	1
1	0	0	0	1	0
2	0	0	1	0	0
3	0	0	1	1	1
4	0	1	0	0	0
5	0	1	0	1	1
6	0	1	1	0	1
7	0	1	1	1	0
8	1	0	0	0	0
9	1	0	0	1	1
10	1	0	1	0	1
11	1	0	1	1	0
12	1	1	0	0	1
13	1	1	0	1	0
14	1	1	1	0	0
15	1	1	1	1	1

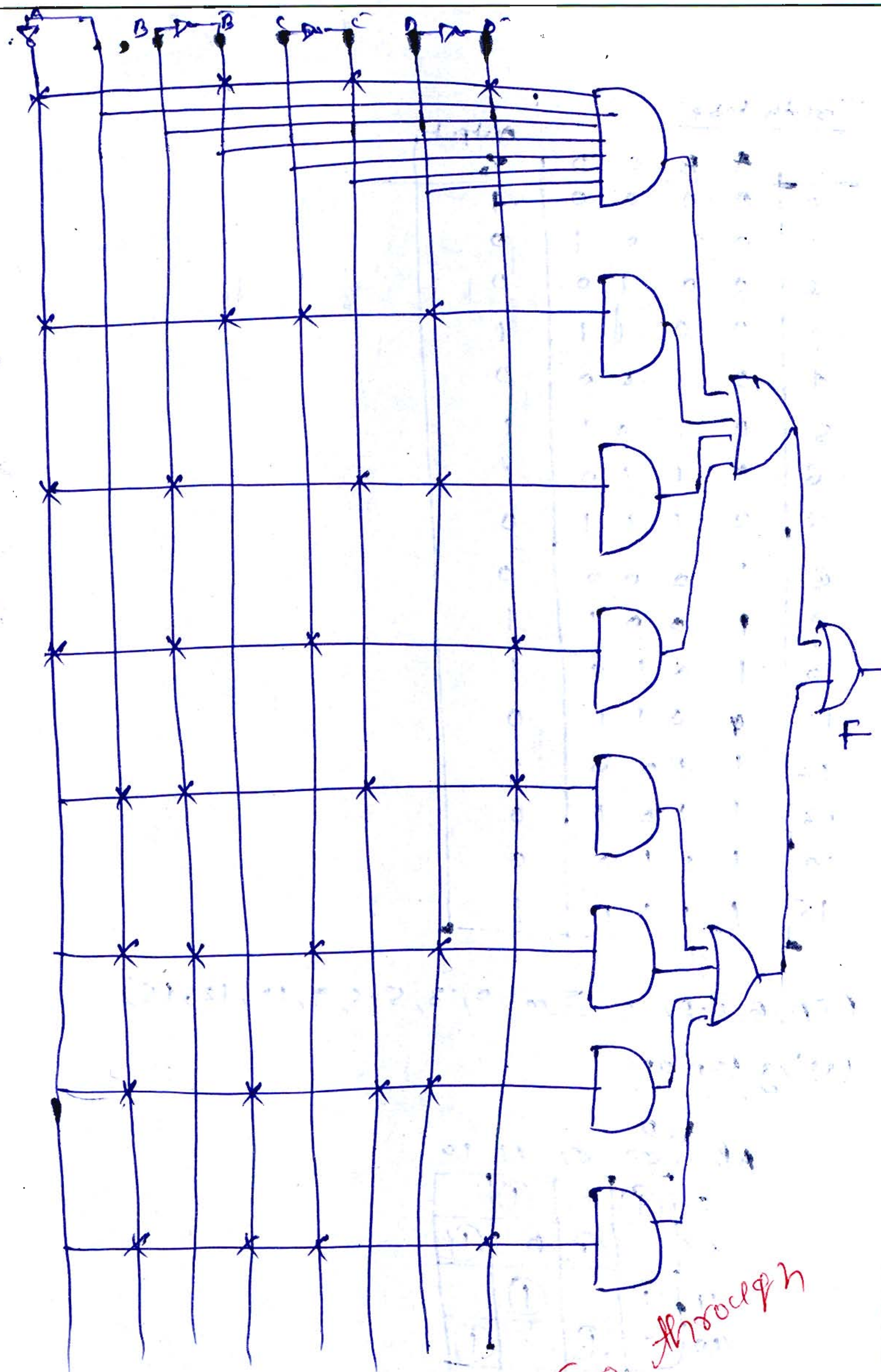
$$f(A,B,C,D) = \Sigma m(0,3,5,6,9,10,12,15)$$

Using K-map

AB \ CD	00	01	11	10
00	1		1	
01		1		1
11	1		1	
10		1		1

7

$$F(A,B,C,D) = \bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}CD + \bar{A}B\bar{C}D + \bar{A}BC\bar{D}$$
$$+ AB\bar{C}\bar{D} + ABCD + A\bar{B}\bar{C}D + A\bar{B}C\bar{D}$$



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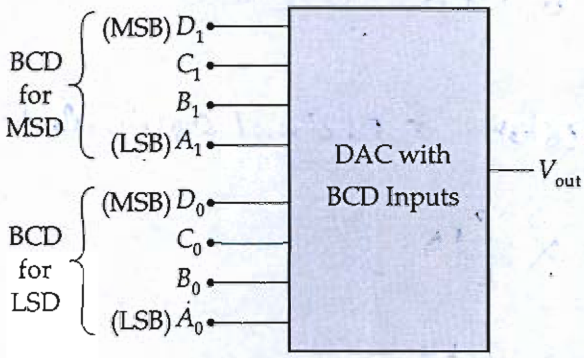
.1 (c) A digital to analog converter using BCD input code is shown in the figure below.



If the weight of A_1 is 2 V, then **find:**

(i) Step size.

(ii) Full scale output voltage.

(iii) Percentage resolution.

(iv) V_{out} for $D_1C_1B_1A_1$ = 0110 and $D_0C_0B_0A_0$ = 0100. **[12 marks]**

Answer (i)

given $A_1 = 2$ (weight)

(i) Step size $= \dfrac{V_{fs}}{2^{n}-1}$

for

D_1	C_1	B_1	A_1	D_0	C_0	B_0	A_0
0	0	0	1	0	0	0	0

So $\boxed{\text{Step size} = 2\text{ Volt}}$

(ii) full scale o/p voltage

$$2 = \frac{V_{fs}}{2^{\cancel{4}\,8}-1}$$

$$\boxed{V_{fs} = \cancel{256}\ 510\ \text{Volt}}$$

(iii) percentage Resolution

$$= \frac{1}{2^{\cancel{4}\,8}-1} \times 100$$

$$= \cancel{39.4}\ 0.3921\%$$

(iv) given $\begin{matrix} D_1 & C_1 & B_1 & A_1 & D_0 & C_0 & B_0 & A_0 \\ 0 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \end{matrix}$

$V_{out} =$ Resolution × Decimal equivalent

$V_{out} = 2 \times [100]$

$\boxed{V_{out} = 200 \text{ Volt}}$

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.1 (d) List of the functional classification of 8085 instruction set. Give one example for each class.

[12 marks]

(A) Classification of 8085 Instruction set.

(1) Data transfer Instruction

ex. MOV A, ~~08H~~ B

MVI A, 08H

(2) Logical ~~&~~ Operation Instruction

ex. — ORA, BH

— ANI, BH

— XOR, 01H

(3) Branch Instruction

ex. — CALL,

— RETURN

— JUMP

ex. CALL, 8000H

(4) STACK Instruction

ex. POP, Rp , PUSH Rp

(5) Input - Output Instruction

ex. IN, 08H

OUT 09H

(6) HLT, EI, DI, SIM, etc.

6

Go through the made easy solution

.1 (e) A bar code scanner scans the boxes being shipped from the loading dock and record all the codes in computer memory; the end of the data is indicated by the byte 00. The code 10100011 (A3H) is assigned to 19″ television sets. Write a program to count the number of 19″ television sets that were shipped from the following data set: Data: FA, 67, A3, B8, A3, A3, FA, 00. Write comments in the program.

[12 marks]

Q.2 (a) Design a 3-bit counter that goes through the states 2, 4, 5, 7, 2, 4, ... using *T*-flip flops. Assume the unused states as don't cares. Check whether the designed counter is self starting or not and there by give the complete sequence diagram for the designed counter.

[20 marks]

Answer

Truth Table

	Present state			Next state			Output		
	Q_2	Q_1	Q_0	Q_2	Q_1	Q_0	T_2	T_1	T_0
2	0	1	0	ϕ	0	0	ϕ	ϕ	0
4	ϕ	0	0	1	0	1	0	0	ϕ
5	1	0	1	1	1	1	0	1	0
7	1	1	1	0	1	0	1	0	1
2									
4									

Now

$T_2 = \Sigma m(2,7) + d(0,1,3,6)$

$T_1 = \Sigma m(2,5) + d(0,1,3,6)$

$T_0 = \Sigma m(4,7), d(0,1,3,6)$

using K-MAP

for T_2

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	X	X	X	1
1			1	X

for T_1

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	X	X	X	1
1		1		X

for T_0

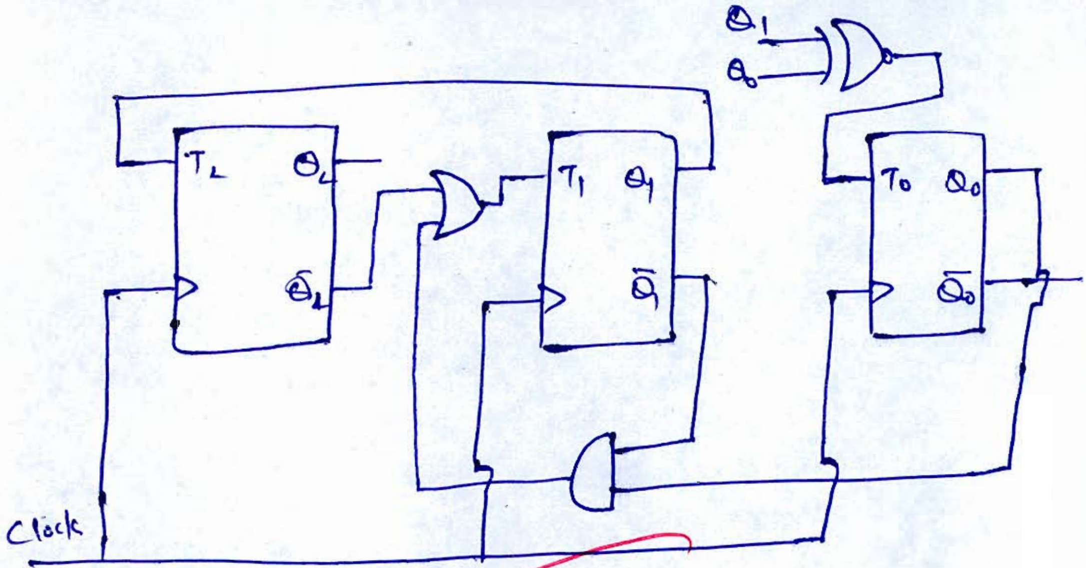
$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	X	X	X	
1	1		1	X

$\boxed{T_2 = Q_1}$

$\boxed{T_1 = \bar{Q}_2 + \bar{Q}_1 Q_0}$

$T_0 = \bar{Q}_1\bar{Q}_0 + Q_1 Q_0$

$\boxed{T_0 = Q_1 \odot Q_0}$



for checking selfstarting or Not
So counter will be start from state '2' if any unused state provided (i.e. 0, 1, 3, 6)
So Check for '0' ⇒ $Q_2 Q_1 Q_0 = 0\ 0\ 0$

So $T_2 = Q_1 = 0$

$T_1 = \bar{Q}_2 + \bar{Q}_1 Q_0 = 1 + 1.0 = 1$

$T_0 = Q_1 \odot Q_0 = 1$

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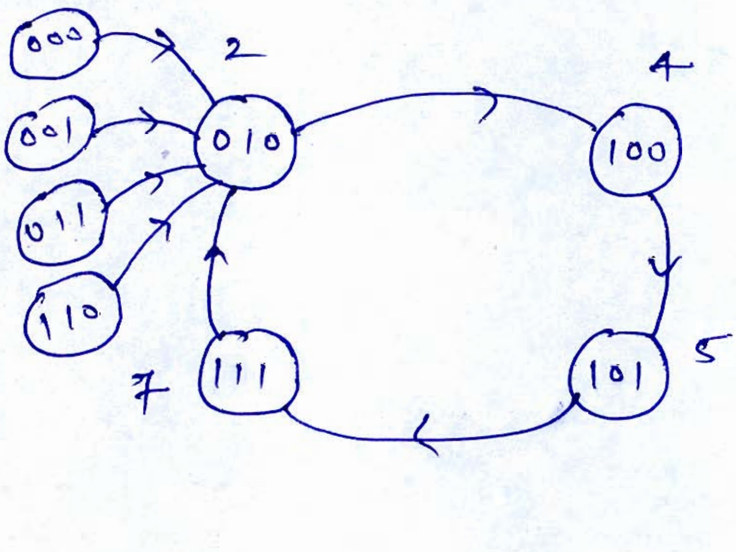
Sequence diagram



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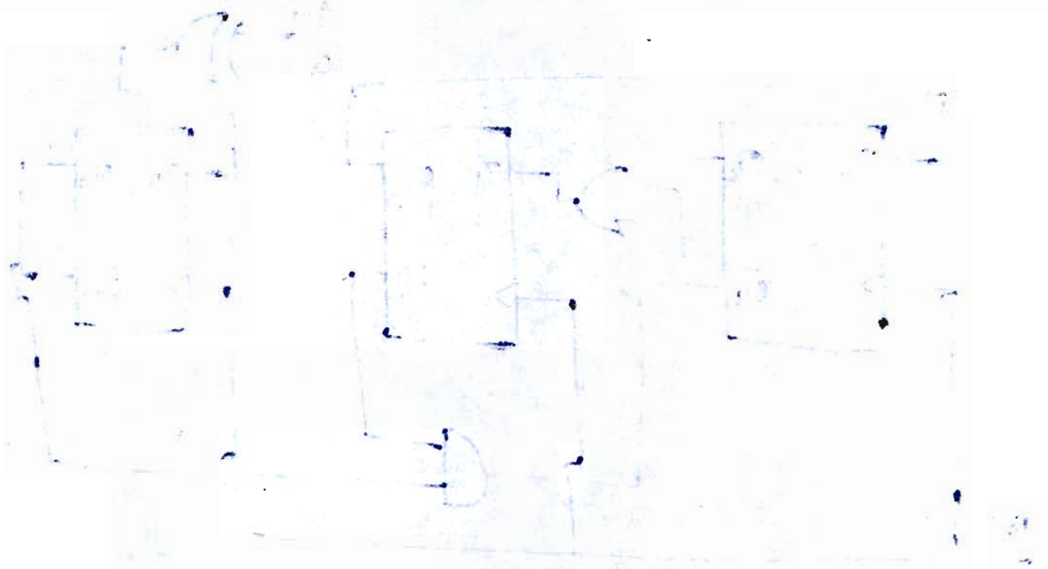

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.2 (b) (i) Calculate the delay produced by the following subroutine program of an 8085 microprocessor, which is operating with a clock frequency of 2 MHz.

```
DELAY  :  MVI B, 02H
LOOP2  :  MVI C, FFH
LOOP1  :  DCR C
          JNZ LOOP1
          DCR B
          JNZ LOOP2
          RET
```

[14 marks]

Answer

DELAY : MVI B, 02H = 10 T State

LOOP2 : MVI C, FFH = 10 T state

LOOP1 : DCR C = 4 T state

JNZ LOOP1 = 10T / 7T state.

DCR B = 4 T state.

JNZ LOOP2 = 10T / 7T state

RET = 6 T state.

Loop 2 → operates for $(FF)_H$ times

$(FF)_H = (255)_{10}$.

Loop 1 → operates for $(02)_H = (2)_{10}$

~~total time for loop 2~~

6

Total time cycle = $10T + 2\times[10T + 4T + 10T + 4T + 10T] + 6T$

Total cycle = 92 T state.

4

given f = 2 MHz

$T = \frac{1}{2\times10^{6}} = 0.5\times10^{-6}$ sec.

So total Delay = 927

$= 92 \times 0.5 \times 10^{-5}$

$\boxed{\text{total Delay} = 46\ \mu sec.}$

.2 (b) *(ii)* Explain the features of the three sources of interrupts in the 8086 microprocessor.

[6 marks]

Q.2 (c) Draw the state diagram of a modulo-4 UP/DOWN counter. Design the circuit using JK flip flops.

[20 marks]

Answer for 4-bit UP counter

	Present state				Next state				Output							
	Q_3	Q_2	Q_1	Q_0	Q_3	Q_2	Q_1	Q_0	J_3	K_3	J_2	K_2	J_1	K_1	J_0	K_0
0	0	0	0	0	0	0	0	1	0	X	0	X	0	X	1	X
1	0	0	0	1	0	0	1	0	0	X	0	X	1	X	X	1
2	0	0	1	0	0	0	1	1	0	X	0	X	X	0	1	X
3	0	0	1	1	0	1	0	0	0	X	1	X	X	1	X	1
4	0	1	0	0	0	1	0	1	0	X	X	0	0	X	1	X
5	0	1	0	1	0	1	1	0	0	X	X	0	1	X	X	1
6	0	1	1	0	0	1	1	1	0	X	X	0	X	0	1	X
7	0	1	1	1	1	0	0	0	1	X	X	1	X	1	X	1
8	1	0	0	0	1	0	0	1	X	0	0	X	0	X	1	X
9	1	0	0	1	1	0	1	0	X	0	0	X	1	X	X	1
10	1	0	1	0	1	0	1	1	X	0	0	X	X	0	1	X
11	1	0	1	1	1	1	0	0	X	0	1	X	X	1	X	1
12	1	1	0	0	1	1	0	1	X	0	X	0	0	X	1	X
13	1	1	0	1	1	1	1	0	X	0	X	0	1	X	X	1
14	1	1	1	0	1	1	1	1	X	0	X	0	X	0	1	X
15	1	1	1	1	0	0	0	0	X	1	X	1	X	1	X	1

for $J_3 = \Sigma m(7) + d(8,9,10,11,12,13,14,15)$

$K_3 = \Sigma m(15) + d(0,1,2,3,4,5,6,7)$

$J_2 = \Sigma m(3,11) + d(\cancel{0,1,2,3}, 4, 5, 6, 7, 12,13,14,15)$

$K_2 = \Sigma m(7, 15) + d(0,1,2,3,8,9,10,11)$

$J_1 = \Sigma m(1,5,9,13) + d(2,3,6,7,10,11,14,15)$

$K_1 = \Sigma m(3,7,11,15) + d(0,1,4,5,8,9,12,13)$

$J_0 = \Sigma m(0,2,4,6,8,10,12,14) + d(1,3,5,7,9,11,13,15)$

$K_0 = \Sigma m(1,3,5,7,9,11,13,15) + d(0,2,4,6,8,10,12,14)$

Now

$J_3 =$

$Q_3Q_2 \backslash Q_1Q_0$	00	01	11	10
00				
01			1	
11	X	X	X	X
10	X	X	X	X

K_3

$Q_3Q_2 \backslash Q_1Q_0$	00	01	11	10
00	X	X	X	X
01	X	X	X	X
11			1	
10				

$J_3 = Q_2 Q_1 Q_0$

$K_3 = Q_2 Q_1 Q_0$

$J_2 =$

$Q_3Q_2 \backslash Q_1Q_0$	00	01	11	10
00			1	
01	X	X	X	X
11	X	X	X	X
10			1	

$Q_3Q_2 \backslash Q_1Q_0$	00	01	11	10
00	X	X	X	X
01			1	
11			1	
10	X	X	X	X

$Q_3Q_2 \backslash Q_1Q_0$	00	01	11	10
00		1	X	X
01		1	X	X
11		1	X	X
10	X	1	X	X

$J_2 = Q_1 Q_0$

$K_2 = Q_1 Q_0$

$J_1 = Q_0$

$Q_3Q_2 \backslash Q_1Q_0$	00	01	11	10
00	X	X	1	
01	X	X	1	
11	X	X	1	
10	X	X	1	

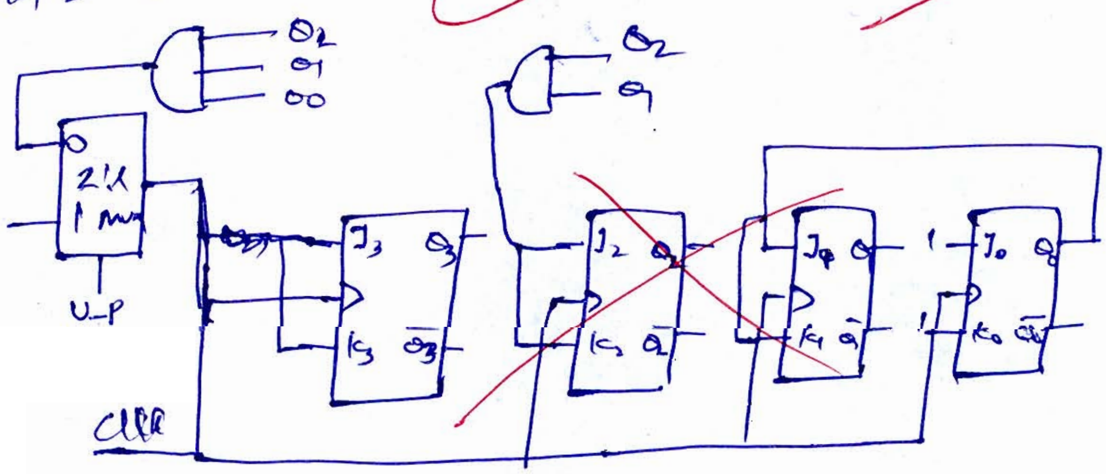
$Q_3Q_2 \backslash Q_1Q_0$	00	01	11	10
00	1	X	X	1
01	1	X	X	1
11	1	X	X	1
10	1	X	X	1

$Q_3Q_2 \backslash Q_1Q_0$	00	01	11	10
00	X	1	1	X
01	X	1	1	X
11	X	1	1	X
10	X	1	1	X

$K_0 = 1$

$J_0 = 1$

$K_1 = Q_0$



for Up-Counter U-P = 0, for Down Counter U-P = 1

5

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Q.3 (a) (i) Design a synchronous counter using *D*-flip flop that counts in the following sequence: 6, 3, 5, 0, 2, 6, 3, 5, 0, 2, 6

[10 marks]

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Q.3 (a) (ii) Explain the working of 3-bit flash type ADC.

[10 marks]

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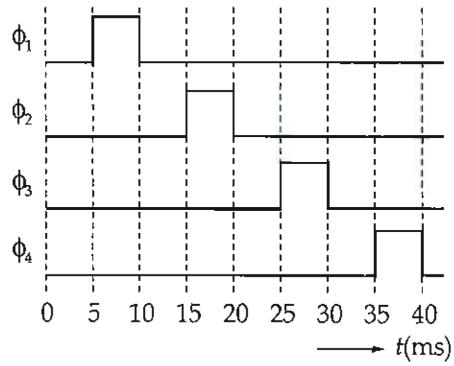
Q.3 (b) **(i)** Design a synchronous 3-bit binary up-counter using *D*-flip flops.

(ii) A stepper-motor drive circuit requires four periodic signal waveforms, each with a period of 40 ms, as shown below. By using the counter circuit obtained in part (i), design a circuit to generate the necessary signal waveforms for this stepper motor.



[10 + 10 marks]

3 (c) (i) Write a short note on the flag register of 8086 microprocessor.

[14 marks]

3 (c) (ii) Write down the purpose of each bit in SIM (Set Interrupt Mask) Instruction. Give three different functions of SIM instruction.

[6 marks]

Q.4 (a) **(i)** Write the steps involved in DMA data transfer. Also, describe the functions of 8085 pins which are used in DMA data transfer.

[10 marks]

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Q.4 (a) **(ii)** How can we generate a square wave with a variable bit rate, using microprocessor? Output should be available on a chosen port, using bit 'O'.

[10 marks]

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.4 (b) A set of five 16-bit readings of the power consumption of industrial control units is monitored by meters and stored at memory locations starting at 2050H. Each reading occupies two memory locations: the lower order byte is stored first, followed by the higher order byte. The corresponding maximum limits for each control unit are stored at memory locations starting at 2090H, also with the lower order byte stored first followed by the higher order byte. Write an 8085 assembly language program to subtract each reading from its specified maximum limit and store the difference at the same memory locations of the readings. Also provide a provision in the program to call the indicator subroutine if the reading is higher than its maximum limit and then continue checking the remaining reading.

[20 marks]

.4 (c) **(i)** Given that $(292)_{10} = 1204$ in some number system, find the base of that system.

(ii) In the following series, the same integer is expressed in different number systems. Determine the missing number of the series : 10000, 121, 100, ? , 24, 22, 20.

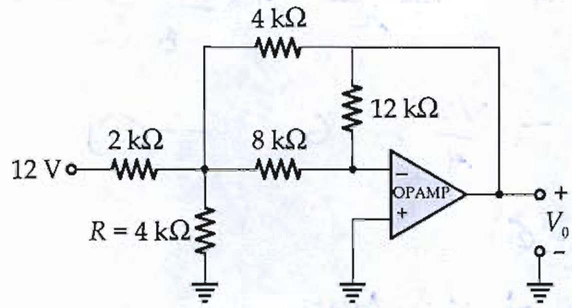
(iii) Add the binary numbers of 1101.101 and 111.011. Find its decimal equivalent.

(iv) Subtract 14 from 46 using 8-bit 2's complement arithmetic.

[5 × 4 marks]

Section B : Electrical Circuits-1 + Systems and Signal Processing-1

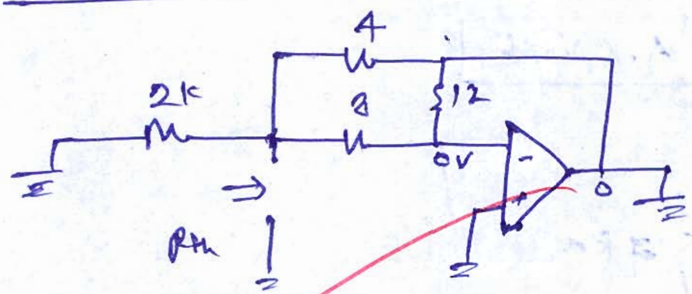
.5 (a) In the operational amplifier circuit shown in figure below, calculate the current in $R = 4\ \text{k}\Omega$ resistor, using Thevenin's theorem.



[12 marks]

Answer

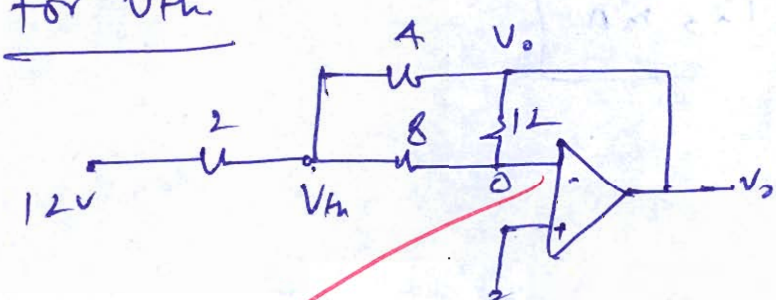
for R_{th}



$R_{th} = \cancel{2k} \ (4 \| 8) \| 2$

$\boxed{R_{th} = 8/7\ \text{k}\Omega = 1.1428\ \text{k}\Omega}$

for V_{th}



Nodal Analysis at 0V

$$\frac{0 - V_0}{12} + \frac{0 - V_{th}}{8} = 0$$

$$V_0 = -\frac{3}{2} V_{th} \quad \text{—— (1)}$$

Apply Nodal At V_{th}

$$\frac{V_{th} - 12}{2} + \frac{V_{th} - V_0}{4} + \frac{V_{th} - 0}{8} = 0$$

$$\frac{7}{8} V_{th} - \frac{V_0}{4} = 6 \quad \text{—} (2)$$

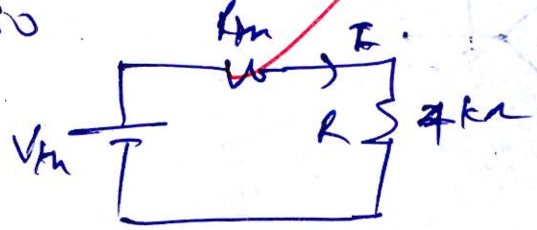
from (1) and (2)

$$7/8\, V_{th} + \frac{3}{2} \times \frac{V_{th}}{4} = 6$$

$$10 V_{th} = 48$$

$$\boxed{V_{th} = 4.8 \text{ Volt}}$$

So



5

$$I = \frac{4.8}{4 + R_{th}} = \frac{4.8}{4 + 1.1428}$$

$$\boxed{I = 0.933 \text{ mA}}$$

5 (b) The input $x[n]$ and the impulse response $h[n]$ of a discrete time LTI system are given by:

$$x[n] = u[n]$$
$$h[n] = \alpha^n u[n]; \quad 0 < \alpha < 1$$

Compute the output $y[n]$ by method of convolution.

[12 marks]

Answer

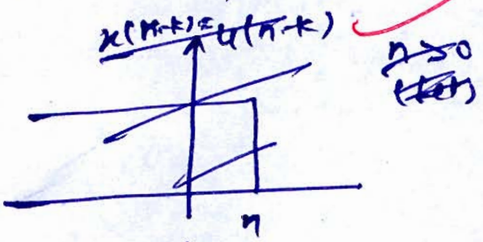
By using convolution

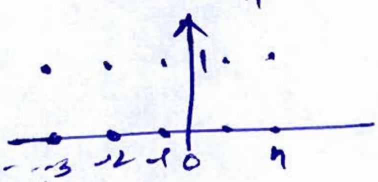
$$y(n) = \sum_{n=-\infty}^{\infty} h(k)\cdot x(n-k) = \sum_{n=-\infty}^{\infty} x(k)\, h(n-k)$$

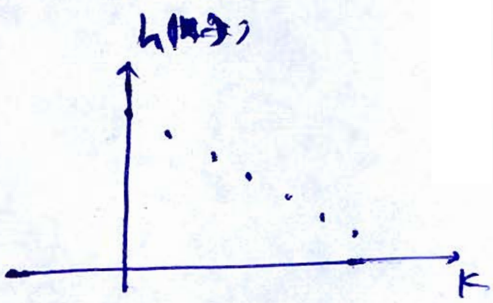
Now $x(n-k) = u(n-k)$

and $h(k) = \alpha^k u(k) \quad ; \quad 0 < \alpha < 1$

Now By plotting







11

So Case-1 $n < 0$

then

$$\boxed{y(n) = 0}$$

Good Approach

Now, case-2 $n > 0$

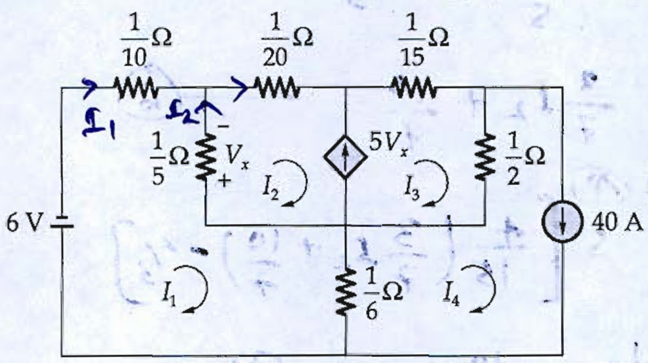
$$y(n) = \sum_{k=0}^{n} 1\cdot(\alpha)^k$$

$$\boxed{y(n) = \frac{(1-\alpha^{n+1})}{(1-\alpha)}}$$

So

$$y(n) = \begin{cases} 0 & , n < 0 \\ \dfrac{1-\alpha^{n+1}}{1-\alpha} & , n > 0 \end{cases}$$

5 (c) Find currents I_1, I_2, I_3 and I_4.



[12 marks]

Answer

KVL in loop ①

$$6 + \frac{1}{10}I_1 - V_x + \frac{1}{6}(I_1 - I_4) = 0$$

$$6 + \frac{4}{15}I_1 - \frac{1}{6}I_4 = V_x \quad \text{—— ①}$$

from circuit $\boxed{I_4 = 40A}$

And $\quad V_x = \frac{1}{5}(I_2 - I_1) \quad$ —— ②

And $\quad I_3 - I_2 = 5V_x \quad$ —— ③

Apply KVL in inner loop

$$\cancel{\frac{1}{20}I_2 + \frac{1}{15}} \cdot \quad \frac{1}{20}(I_1 + I_2) + \frac{1}{15}(5V_x + I_3) + \frac{1}{2}I_3 = 0$$

$$\frac{1}{20}I_1 + \frac{1}{20}I_2 + \frac{1}{5}V_x + \frac{17}{30}I_3 = 0 \quad \text{—— ④}$$

from ①

$$6 + \frac{4}{15}I_1 - \frac{1}{6} \times 40 = V_x$$

$$V_x = \frac{4}{15}I_1 - \frac{2}{3} \quad \text{—— ⑤}$$

from ② and ⑤

$$\frac{4}{15}I_1 - 2/3 = \frac{1}{5}I_2 - \frac{1}{5}I_1$$

$$\frac{7}{15} I_1 = \frac{1}{5} I_2 + 2/3$$

$$I_1 = \frac{3}{7} I_2 + \frac{10}{7} \quad \text{——— (6)}$$

from (3) and (4)

$$I_3 - I_2 = 5\left[\frac{4}{15}\left(\frac{3}{7} I_2 + \frac{10}{7}\right) - 2/3\right]$$

$$I_3 = \frac{11}{7} I_2 - \frac{10}{7} \quad \text{——— (7)}$$

from (4)

$$\frac{1}{20}\left[\frac{3}{7} I_2 + \frac{10}{7}\right] + \frac{1}{20} I_2 + \frac{1}{5}\left[\frac{4}{15} I_1 - 2/3\right] + \frac{17}{30}\left[\frac{11}{7} I_2 - \frac{10}{7}\right] = 20$$

$$\frac{1}{20}\left[\frac{3}{7} I_2 + \frac{10}{7}\right] + \frac{1}{20} I_2 + \frac{1}{5}\left[\frac{4}{15}\left\{\frac{3}{7} I_2 + \frac{10}{7}\right\} - \frac{2}{3}\right] + \frac{17}{30}\left[\frac{11}{7} I_2 - \frac{10}{7}\right] = 20$$

$$\frac{517}{525} I_2 = \frac{167}{210}$$

$$\boxed{I_2 = 0.8075 \text{ Amp.}}$$

then

$$I_3 = \frac{11}{7} \times 0.8075 - \frac{10}{7}$$

$$\boxed{I_3 = -0.1595 \text{ Amp.}}$$

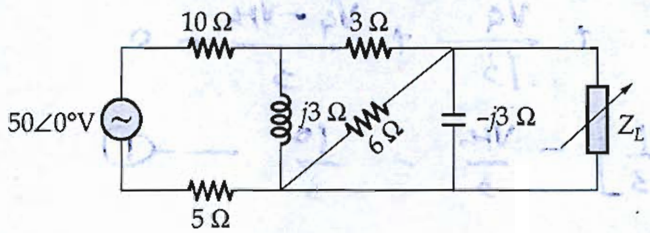
and

$$I_1 = \frac{3}{7} \times 0.8075 + \frac{10}{7}$$

$$\boxed{I_1 = 1.7746 \text{ Amp.}}$$

3

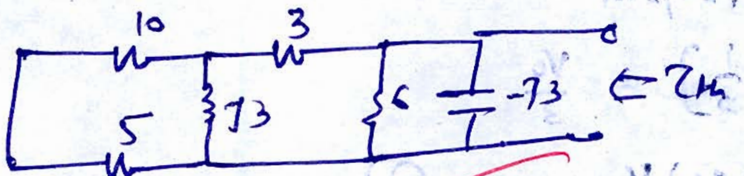
.5 (d) Find the impedance Z_L so that maximum power can be transferred to it in the network shown below. Also, find the maximum power delivered to load Z_L.



[12 marks]

By using thevenin theorem

Z_{th} calculation



$Z_{th} = \left[\left[(-j3 \| 6) + 3\right] \| j3\right] \| 15$

$Z_{th} = \left((4.2 - j2.4) \| j3\right) \| 15$

$Z_{th} = (2.1 + j2.7) \| 15$

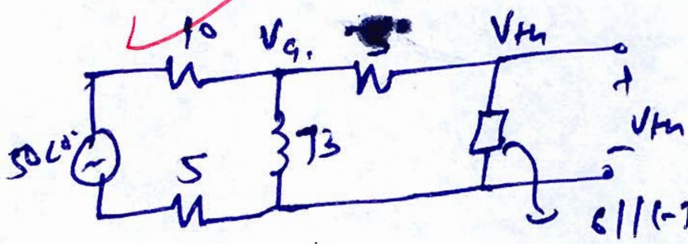
$\boxed{Z_{th} = 2.16 + j2.027}$

So for maximum power transfer to Z_L

$Z_L = R_{th} - jX_{th} = (Z_{th})^*$

$\boxed{Z_L = 2.16 - j2.027}\ \Omega$

Now V_{th} calculation



$6 \| (-j3) = 1.2 - j2.4$

Nodal Analysis at V_A

$$\frac{V_A - 50\angle 0}{15} + \frac{V_A}{j3} + \frac{V_A - V_{th}}{3} = 0$$

$$V_A\left[\frac{2}{5} - j\frac{1}{3}\right] - \frac{V_{th}}{3} = \frac{10}{3} \quad \text{——} (1)$$

Apply Nodal at V_{th}

$$\frac{V_{th} - V_A}{3} + \frac{V_{th}}{1.2 - j2.4} = 0$$

$$V_{th}\left[\frac{1}{2} + j\frac{1}{3}\right] = \frac{V_A}{3}$$

$$V_A = (1.5 + j1)\, V_{th} \quad \text{——} (2)$$

from (1) and (2)

$$(1.5 + j1)\, V_{th}\left(2/5 - j1/3\right) - \frac{V_{th}}{3} = 10/3$$

$$\boxed{V_{th} = 5.48\angle 9.46^\circ}$$

11

Maximum power transfer

$$P_{max} = \frac{(V_{th})^2}{4R_{th}}$$

$$P_{max} = \frac{(5.48)^2}{4 \times 2.16}$$

$$\boxed{P_{max} = 3.47 \text{ Watt}}$$

Good Approach

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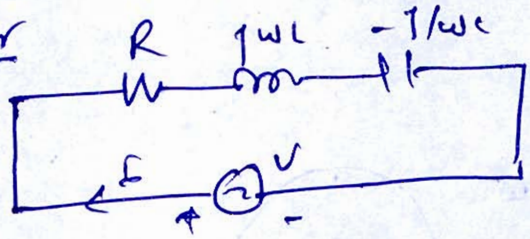
.5 (e) Show that the resonant frequency ω_0 of an R-L-C series circuit is geometric mean of ω_1 and ω_2, the lower and upper half-power frequencies respectively.

[12 marks]

Answer



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

At Resonance

$$j\omega L = 1/\omega C \Rightarrow \omega_0 = \frac{1}{\sqrt{LC}}$$

at Half power frequency

$$\omega L - \frac{1}{\omega C} = \pm R$$

at ω_1

$$\omega_1 L - \frac{1}{\omega_1 C} = R$$

$$\omega_1^2 LC - \omega_1 RC - 1 = 0$$

$$\omega_1^2 - \omega_1 R/L - 1/LC = 0$$

$$\omega_1 = \frac{R/L \pm \sqrt{(R/L)^2 + 4/LC}}{2} \quad \text{--- (1)}$$

at $\omega = \omega_2$

$$\omega_2 L - \frac{1}{\omega_2 C} = -R$$

$$\omega_2^2 LC + \omega_2 RC - 1 = 0$$

$$\omega_2^2 + R/L\,\omega_2 - 1/LC = 0$$

$$\omega_2 = \frac{-R/L \pm \sqrt{(R/L)^2 + 4/LC}}{2} \quad \text{--- (2)}$$

By multiplying eqn (1) and (2)

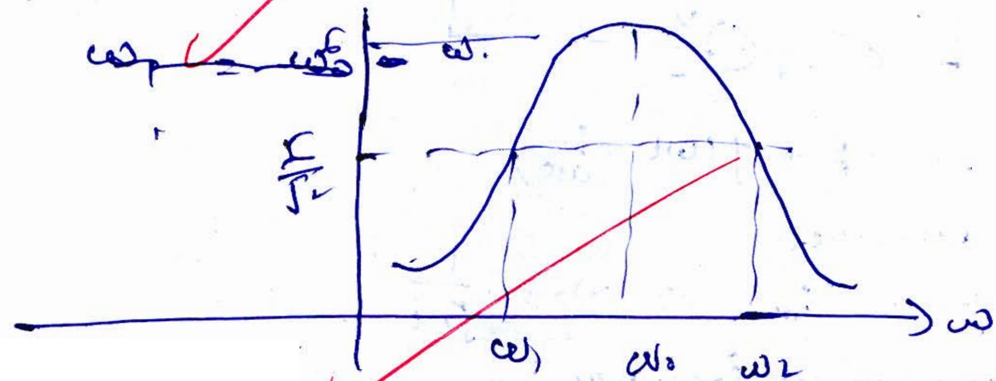
$$\boxed{\omega_0 = \sqrt{\omega_1 \omega_2}}$$

So

$$\boxed{\omega_0 = \frac{1}{\sqrt{LC}}} \text{ rad/sec}$$

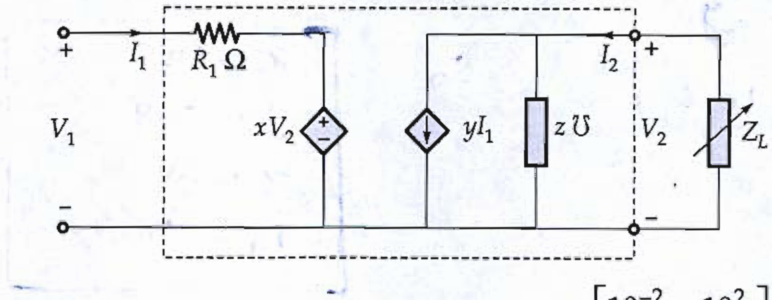
or

$\omega_p = \omega_0$



10

(a) Consider a two port network shown in figure below,



If transmission parameters matrix of the network is $\begin{bmatrix} 10^{-2} & 10^{2} \\ 0 & 10^{-1} \end{bmatrix}$.

Then, calculate:

(i) parameters of the circuit: R_1, x, y and z.

(ii) the value of load impedance (Z_L), for maximum power transfer.

(iii) maximum power transfer to load for $V_1 = 0.1$ volt.

[20 marks]

Answer (i) given $\begin{pmatrix} V_1 \\ I_1 \end{pmatrix} = \begin{pmatrix} 10^{-2} & 10^{2} \\ 0 & 10^{-1} \end{pmatrix} \begin{pmatrix} V_2 \\ -I_2 \end{pmatrix}$

from above circuit

$V_1 = I_1 R_1 + x V_2$ — (1)

and

$I_2 = y I_1 + V_2 z$ — (2)

$V_1 = 10^{-2} V_2 + 10^{2} I_2$ — (A)

$I_1 = -10^{-1} I_2$ — (B)

from (2)

$I_1 = \frac{1}{y}[I_2 - V_2 z] = -V_2 \frac{z}{y} + \frac{1}{y} I_2$ — (3)

By comparing (B) and (3)

$z/y = 0$, $\frac{1}{y} = -10^{-1} \Rightarrow \boxed{y = -10}$

and $\boxed{z = 0}$

from (1) and (3)

$V_1 = R_1\left[-V_2 \frac{z}{y} + \frac{1}{y} I_2\right] + x V_2$

$V_1 = \left(x - \frac{R_1 z}{y}\right) V_2 + \frac{R_1}{y} I_2$ — (4)

from (A) and (4)

$\frac{R_1}{y} = -100 \Rightarrow R_1 = -100\,y = -100 \times (-10)$

$\boxed{R_1 = 1000}\ \Omega$

Do not write in this margin

and $x - \frac{R_1 2}{y} = 10^{-2}$

$\boxed{x = 10^{-2}}$ So $\boxed{\begin{array}{l} x = 10^{-2} \\ y = -10 \\ \tau = 0 \\ R_1 = 100\Omega \end{array}}$

(ii) for maximum power transfer, using thevenin theorem,

for Z_{th}, $V_1 = 0$

so from (A)

$V_1 = 0 = 10^{-2} V_2 - 10^2 I_2$

So $\frac{V_2}{I_2} = \frac{10^2}{10^{-2}} = 10^4$

So $Z_{th} = -\frac{V_2}{I_2} = -10^4$

$\boxed{Z_{th} = -10\,k\Omega}$

18

Good Approach

(iii) for V_{th} calculation, given $V_1 = 0.1$ Volt

$I_2 = 0$

So from (B) $I_1 = 0$

So $V_1 = 10^{-2} V_2$

$V_2 = V_{th} = 100 V_1 = 100 \times 0.1 = 10$ Volt

$\boxed{V_{th} = 10 \text{ Volt}}$

$P_{max} = \frac{V_{th}^2}{4R_{th}} = \frac{(10)^2}{4 \times 10 \times 10^3}$

$\boxed{P_{max} = 2.5 \text{ mVolt}}$

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Q.6 (b) **(i)** The transfer function relating the input $x(t)$ to the output $y(t)$ of a system is given by $G(s) = \dfrac{1}{(s+3)}$. A unit-step input is applied to the system at time $t = 0$. Assuming that $y(0) = 3$, find the value of $y(t)$ at time $t = 1$.

[12 marks]

Answer $G(s) = \dfrac{1}{s+3}$, $x(t) = u(t)$

$X(s) = 1/s$

$Y(s) = G(s) \cdot X(s) = \dfrac{1}{s(s+3)}$

$Y(s) = \dfrac{1/3}{s} - \dfrac{1/3}{s+3}$

By taking Inverse laplace

$y(t) = \left(1/3 - 1/3 e^{-3t}\right) u(t)$

given at $t=0$ $y(0) = 3$

So $\boxed{y(t) = \left(1/3 - 1/3\, e^{-3t}\right) u(t) + 3\delta(t)}$

Now ~~at~~ $y(t)$ at $t = 1$

$y(1) = \left(\frac{1}{3} - \frac{1}{3} e^{-3}\right) + 0$

$\boxed{y(1) = 0.3167}$

7

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Q.6 (b) (ii) Consider the signal $f(t) = 1 + 2\cos(\pi t) + 3\sin\left(\frac{2\pi}{3}t\right) + 4\cos\left(\frac{\pi}{2}t + \frac{\pi}{4}\right)$, where t is in seconds. Find its fundamental time period.

(iii) For a periodic signal $v(t) = 30\sin 100t + 10\cos 300t + 6\sin\left(500t + \frac{\pi}{4}\right)$, find the fundamental frequency in rad/s.

[6 + 2 marks]

Answer

$$f(t) = 1 + 2\cos\pi t + 3\sin\left(\frac{2\pi}{3}t\right) + 4\cos\left(\pi/_2 t + \pi/_4\right)$$

$\omega_1 = \pi$ $\quad \omega_2 = \frac{2\pi}{3}$ $\quad \omega_3 = \pi/2$

Now

$$HCF\,[\omega_1, \omega_2, \omega_3] = \omega_0$$

$$\omega_0 = \frac{HCF}{LCM}\left[\frac{\pi, 2\pi, \pi}{1, 3, 2}\right]$$

$$\boxed{\omega_0 = \frac{\pi}{6}}$$ rad/sec. fundamental frequency

$$\boxed{T_0 = \frac{2\pi}{\omega_0} = \frac{2\pi}{\pi/6} = 12 \text{ sec}}$$

8

Good Approach

(iii)

$$v(t) = 30\sin 100t + 10\cos 300t + 6\sin(500t + \pi/_4)$$

$\omega_1 = 100$ $\quad \omega_2 = 300$ $\quad \omega_3 = 500$

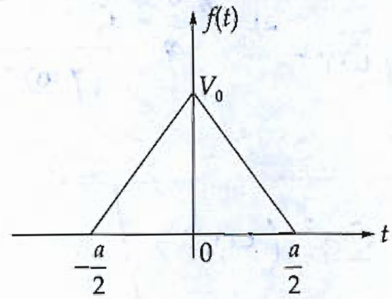
$$\omega_0 = HCF\,[\omega_1, \omega_2, \omega_3]$$

$$\omega_0 = HCF\,[100, 300, 500]$$

$$\boxed{\omega_0 = 100 \text{ rad/sec.}}$$

5 (c) (i) The figure shows a triangular pulse which is zero for all time except $-\frac{a}{2} \leq t \leq \frac{a}{2}$. For this pulse:

1. determine the Fourier transform,
2. sketch the continuous amplitude spectrum.



[12 marks]

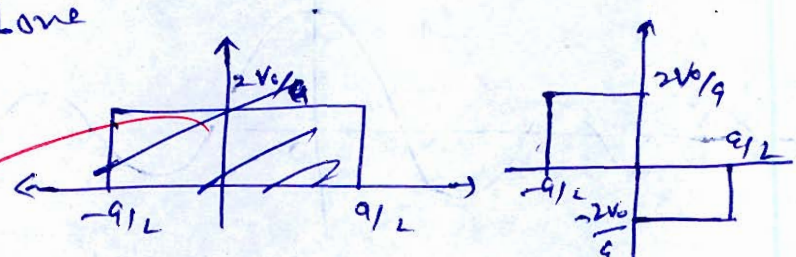
Answer(i)

$$f(t) = \frac{2V_0}{a} t + V_0 \quad ; \quad -a/2 < t < 0$$

$$= -\frac{2V_0}{a} t + V_0 \quad ; \quad 0 < t < a/2$$

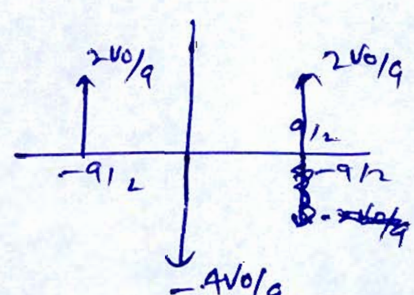
By Derivating alone

$f'(t) = x(t) =$



Again Derivating (f'(t))

$f''(t) = x'(t) = y(t) =$



So

By taking fourier transform

$$(j\omega)^2 F(\omega) = Y(\omega) \quad \text{--- (1)}$$

and

$$y(t) = \frac{2V_0}{a} \delta(t + a/2) - \frac{4V_0}{a} \delta(t) + \frac{2V_0}{a} \delta(t - a/2)$$

taking fourier transform

$$Y(\omega) = \frac{2V_0}{a} e^{ja/2\omega} - \frac{4V_0}{a} + \frac{2V_0}{a} e^{-ja/2\omega} \quad \text{--- (2)}$$

from ① and ②

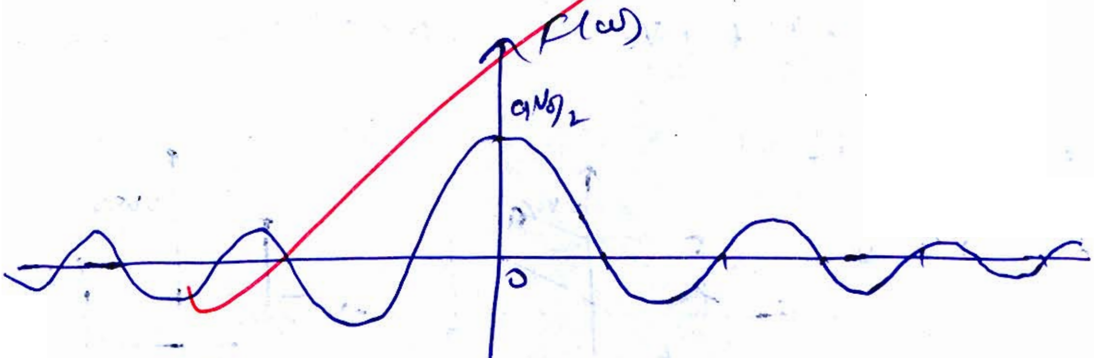
$$F(\omega) = \frac{V(\omega)}{(j\omega)^2} = \frac{1}{(j\omega)^2}\left[\frac{2V_0}{a}e^{+ja/2\omega} - \frac{4V_0}{a} + \frac{2V_0}{a}e^{-ja/2\omega}\right]$$

$$F(\omega) = \frac{2V_0}{a}\frac{e^{ja/2\omega}}{(j\omega)^2} + \frac{2V_0}{a}\frac{e^{-ja/2\omega}}{(j\omega)^2} - \frac{4V_0}{a(j\omega)^2}$$

so

$$\boxed{F(\omega) = \frac{aV_0}{2} Sa^2(\omega a)}$$

(ii) Amplitude spectrum



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(c) **(ii)** Using duality property show that the Fourier transform of $\left[\dfrac{1}{1+j2\pi t}\right]$ is equal to $e^{f}u(-f)$ where $u(t)$ is the unit step.

[8 marks]

Answer

As we know

$$e^{-at} f(t) \longrightarrow \frac{1}{a+j\omega}$$

putting $a=1$

$$e^{-t} u(t) \longrightarrow \frac{1}{1+j\omega}$$

By using Duality Property

$$e^{-t} u(t) \longrightarrow \frac{1}{1+j\omega} = \frac{1}{1+j2\pi f}$$

$f=t$ $\quad$ $t=-f$

$$\frac{1}{1+j2\pi t} \rightleftharpoons e^{f} u(-f)$$

So

$$\boxed{e^{f} u(-f) \rightleftharpoons \frac{1}{1+j2\pi t}}$$

7

Note: Duality property

$$f(t) = e^{-at} u(t) \rightleftharpoons F(\omega)$$

$$F(t) \rightleftharpoons 2\pi f(-\omega)$$

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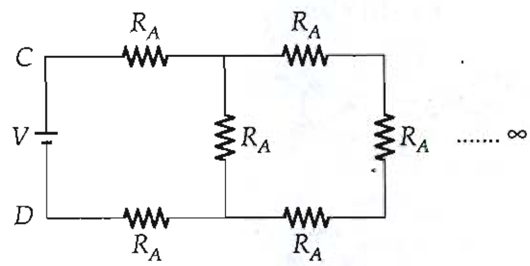
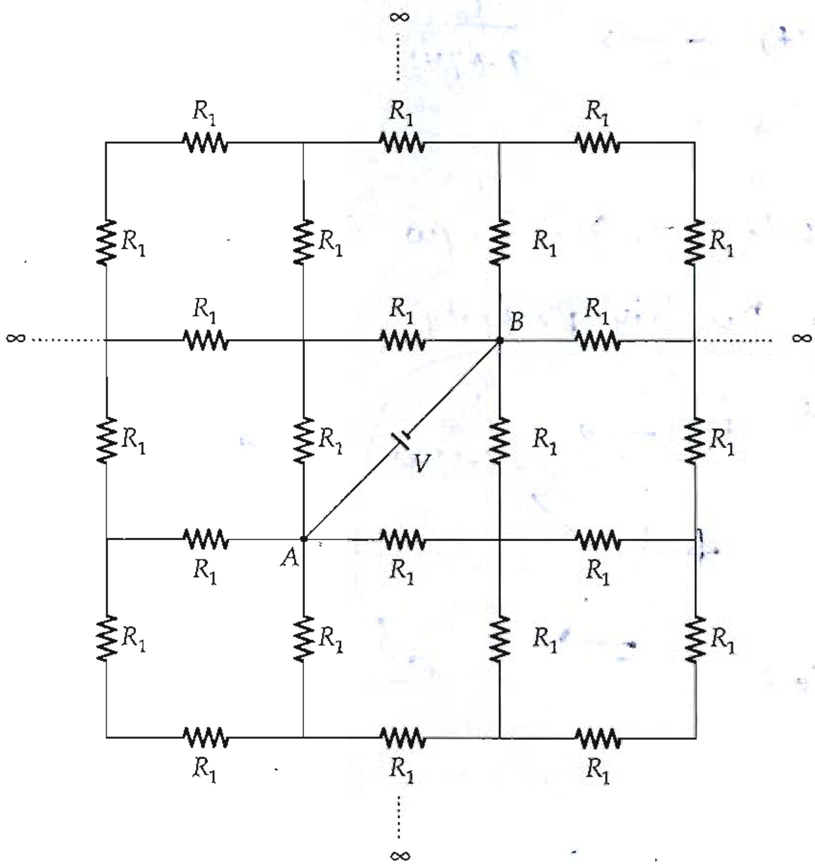
Q.7 (a) For the networks shown in figure below,



Network (i)

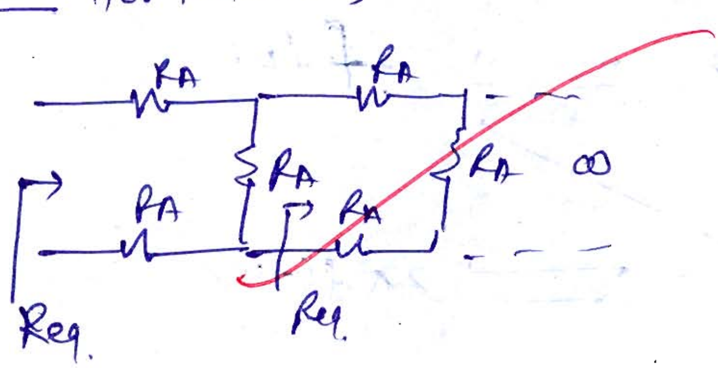


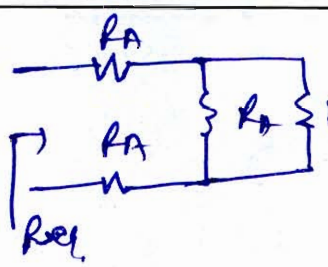
Network (ii)

On applying 10 V voltage source across terminal CD and AB respectively in network (i) and (ii), we get same power delivered by the source. Derive the relationship between the resistance present in network (i) and (ii). And also calculate the power delivered by the source for $R_A = 10\ \Omega$.

[20 marks]

Answer for Network (i)





$$\Rightarrow R_{eq.} = \frac{R_A \times R_{eq}}{R_A + R_{eq}} + 2R_A$$

So

$$R_{eq}^2 + R_A R_{eq.} = R_A \times R_{eq.} + 2R_A(R_A + R_{eq})$$

$$R_{eq}^2 - 2R_A^2 - 2R_A R_{eq.} = 0$$

By solving.

$$R_{eq.} = (1 \pm \sqrt{3}) R_A$$

So $R_{eq} = (1+\sqrt{3}) R_A \Rightarrow \boxed{R_{eq} = 2.73\,\Omega\, R_A}$

given $R_A = 10\,\Omega$

$V = 10$ volt

So power delivered by 10 V source for $R_A = 10\,\Omega$

$$P = \frac{V^2}{R_{eq.}} = \frac{(10)^2}{2.73 \times R_A} = \frac{100}{27.3}$$

$$\boxed{P = 3.66 \text{ Watt}}$$

8

In complete Solution

Q.7 (b) Consider a signal $x(t)$ with Fourier transform $X(j\omega)$. Suppose we are given the following facts :

1. $x(t)$ is real and non-negative.
2. $F^{-1}\{(1 + j\omega)X(j\omega)\} = Ae^{-2t}u(t)$, where A is independent of t.
3. $\int_{-\infty}^{\infty} |X(j\omega)|^2 \, d\omega = 2\pi$

Determine a closed-form expression of $x(t)$.

[20 marks]

Answer

from (2)

$$F^{-1}\left[(1+j\omega)\,X(j\omega)\right] = Ae^{-2t}u(t)$$

By taking fourier transform Both side

$$(1+j\omega)X(j\omega) = \frac{A}{2+j\omega}$$

$$X(j\omega) = \frac{A}{(1+j\omega)(2+j\omega)}$$

$$X(j\omega) = \frac{A}{1+j\omega} - \frac{A}{2+j\omega}$$

By taking Inverse fourier transform

$$\boxed{x(t) = Ae^{-t}u(t) - Ae^{-2t}u(t)} \quad \text{--- (1)}$$

from (3) given

$$\int_{-\infty}^{\infty} |X(j\omega)|^2 d\omega = 2\pi$$

we know that By parsvel theorem

$$\frac{1}{2\pi}\int_{-\infty}^{\infty} |X(j\omega)|^2 d\omega = \int_{-\infty}^{\infty} |x(t)|^2 dt = 1 \quad \text{--- (2)}$$

So from (1) and (2)

$$\int_0^\infty |(Ae^{-t} - Ae^{-2t})|^2 \, dt = 1$$

$$A^2 \int_0^\infty (e^{-2t} + e^{-4t} - 2e^{-3t}) \, dt = 1$$

$$A^2 \left[\frac{e^{-2t}}{-2} + \frac{e^{-4t}}{-4} - \frac{2e^{-3t}}{-3} \right]_0^\infty = 1$$

$$A^2 \left[0 + 0 - 0 - \left\{ -\frac{1}{2} - \frac{1}{4} + \frac{2}{3} \right\} \right] = 1$$

$$\boxed{A = \sqrt{12}} \text{ —— } (3)$$

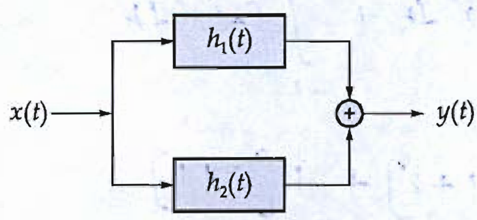
from (3) and (1)

$$\boxed{x(t) = \sqrt{12} \left[e^{-t} - e^{-2t} \right] u(t)}$$

18

Good Approach

(c) (i) Consider the parallel combination of two LTI systems shown in the figure,



The impulse responses of the systems are

$h_1(t) = 2\delta(t+2) - 3\delta(t+1);$

$h_2(t) = \delta(t-2)$

If the input $x(t)$ is a unit step signal, then find the energy of $y(t)$.

[10 marks]

Answer

$$h(t) = h_1(t) + h_2(t)$$

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

$$x(t) = u(t)$$

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

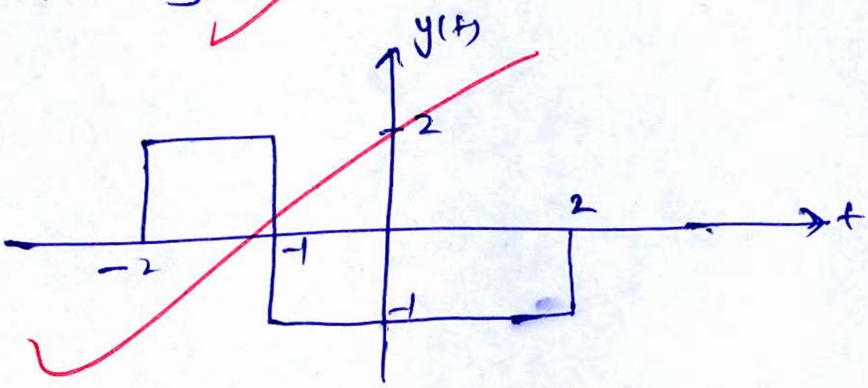
$$y(t) = [\delta(t-2) + 2\delta(t+2) - 3\delta(t+1)] * u(t)$$

$$y(t) = u(t-2) + 2u(t+2) - 3u(t+1)$$

$$\boxed{y(t) = 2u(t+2) - 3u(t+1) + u(t-2)}$$

[Note:- $u(t) * \delta(t-t_0) = u(t-t_0)$]

By plotting $y(t)$



Energy of $y(t)$

$$E_{y(t)} = \int_{-2}^{2} [y(t)]^2 dt$$

$$E_{y(t)} = \int_{-2}^{-1} (2)^2 dt + \int_{-1}^{2} (-1)^2 dt$$

$$= 4[-1+2] + 1[2+1]$$

$$\boxed{E_{y(t)} = 7 \text{ Joule}}$$

9

Good Approach

c) (ii) The exponential Fourier series representation of a continuous-time periodic signal $x(t)$ is defined as $x(t) = \sum_{k=-\infty}^{\infty} a_k e^{jk\omega_o t}$, where ω_o is the fundamental angular frequency of $x(t)$ and the coefficients of the series are a_k. The following information is given about $x(t)$ and a_k.

1. $x(t)$ is real and even, having a fundamental period of 6.
2. The average value of $x(t)$ is 2.
3. $a_k = \begin{cases} k, & 1 \le k \le 3 \\ 0, & k > 3 \end{cases}$

Find the average power of the signal $x(t)$.

[10 marks]

Answer

$$x(t) = \sum_{k=-\infty}^{\infty} a_k e^{jk\omega_0 t}$$

$T = 6$

① $x(t)$ is real and even i.e.

$$\boxed{a_k = a_{-k}}$$

② Average value of $x(t) = 2$

$$\boxed{a_0 = 2}$$

$a_1 = 1$	$a_{-1} = a_1 = 1$
$a_2 = 2$	$a_{-2} = a_2 = 2$
$a_3 = 3$	$a_{-3} = a_3 = 3$

Average power of $x(t)$ is

$$= a_0^2 + 2\sum_{k=1}^{3} a_k^2$$

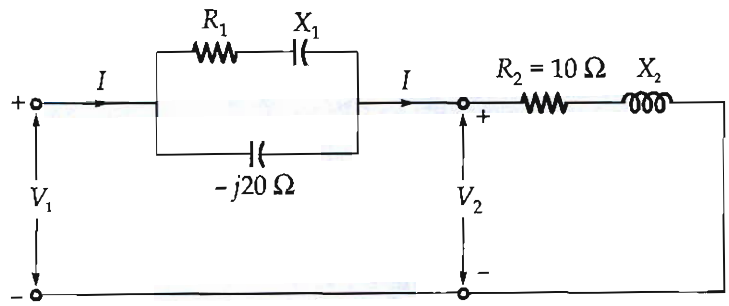
$$= 4 + 2(1+4+9)$$

$$\boxed{P = 32}$$

9

Good Approach

a) In the circuit shown in the figure below, $|V_1| = 200$ V, $V_2 = 200\angle 0°$ V and $|I| = 12$ A. The total power absorbed by the circuit is 1.8 kW. Find R_1, X_1 and X_2.



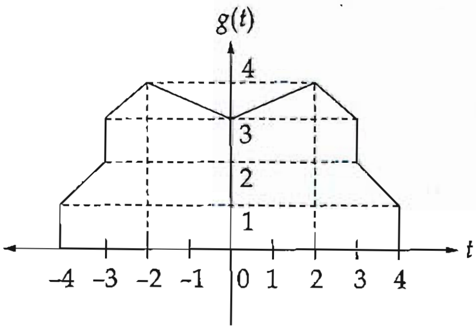
[20 marks]

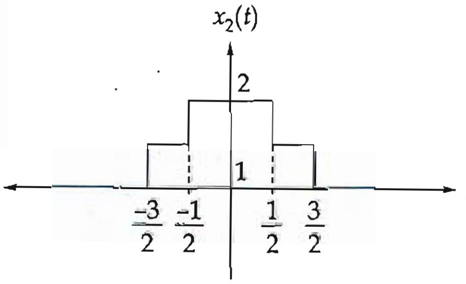
Q.8 (b) (i) Consider a continuous-time LTI system for which the input $x(t)$ and output $y(t)$ are related by $y''(t) + y'(t) - 2y(t) = x(t)$.

1. Find the system function $H(s)$.
2. Determine the impulse response $h(t)$ for each of the following three cases : (1) The system is causal, (2) The system is stable, (3) The system is neither causal nor stable.

[13 marks]

Q.8 (b) **(ii)** The response of an LTI system to an input signal $x_1(t) = u(t+1) - u(t-1)$ is denoted as $g(t)$, as illustrated in the figure below. If a new input $x_2(t)$ is applied to the same system, resulting in an output $y(t)$. Determine the value of the output at $t = 0$.



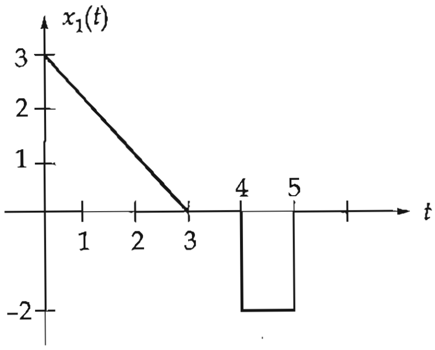


[7 marks]

Consider a continuous-time LTI system with an impulse response $h(t)$ defined as a rectangular pulse of amplitude A and duration $T(0 < t < T)$. When the system is subjected to an input $x_1(t)$ given below, it produces an output $y_1(t)$. It is observed that $y_1(5) = 0$.

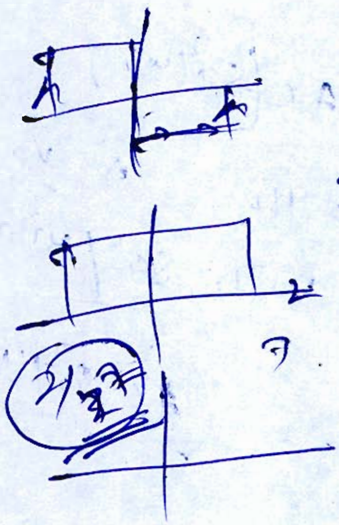
Furthermore, when the input is $x_2(t) = \sin\left(\frac{\pi t}{3}\right)u(t)$, the output $y_2(t)$ at $t = 9$ is equal to 9.

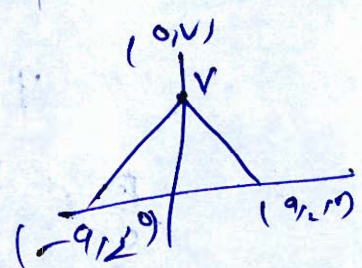
Determine the value of the product $A \times T$.



[20 marks]

Space for Rough Work





$$y - 0 = \frac{v-0}{0+9/2}\left(t+9/2\right)$$

$$y = \frac{2v}{9}\left(t+9/2\right)$$

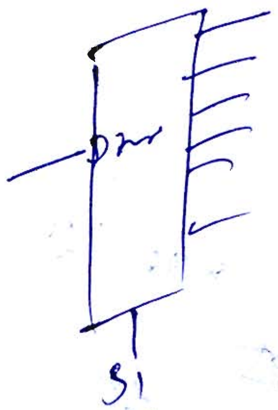
$$v = \frac{2v}{9}t + v$$

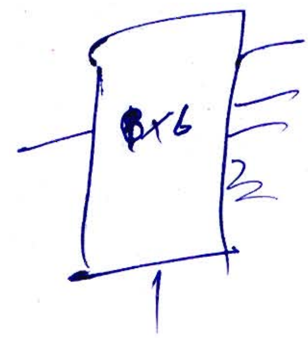
$$y - v = \frac{0-v}{9/2-0}\left(t-0\right)$$

$$y - v = -\frac{2v}{9}t$$

$$\boxed{y = -\frac{2v}{9}t + v}$$

Space for Rough Work





$A \, c \, [Sa^2(\frac{\omega c}{2})$

$A = V_0$

$c = 9/2$

$\frac{V_0 a/2 \; Sa^2(\omega a)}{A \, c \; Sa^2(\frac{\omega c}{2})}$

$V_0(s^2 + 3s) = $ ... $s^2 Y(s) - y(0) + 3[Y(s) + y_0]$

$Q_3 Q$	J	K
0 0	0	X
0 1	1	X
1 0	X	1
1 1	X	0

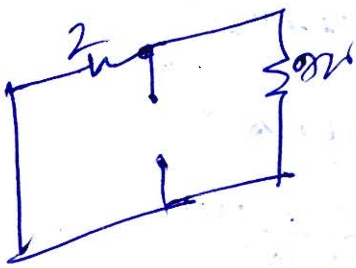
$y(t) = e \; \frac{1}{3}(1 - e^{-3t})$

$\frac{A}{s} + \frac{B}{s+3}$

$A(s+3) + Bs = 1$

$A = 1/3$

$B = -1/3$



	$Q_2 Q_1 Q_0$	
0 0 0	0 1 1	0 1 1
	3	

$A(2 + j\omega) + B(1 + j\omega) = A$

$\boxed{P = A}$ $Q = -A$