Roll No. 2102086

Total No. of Questions : 09

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B.Tech. (EEE) (Sem.–5)

# DIGITAL SIGNAL PROCESSING

Subject Code : BTEC-502-18

M.Code : 78298

Date of Examination: 30-12-2023

Time : 3 Hrs.

Max. Marks : 60

**INSTRUCTIONS TO CANDIDATES :**

1. SECTION-A is COMPULSORY consisting of TEN questions carrying TWO marks each.
2. SECTION-B contains FIVE questions carrying FIVE marks each and students have to attempt any FOUR questions.
3. SECTION-C contains THREE questions carrying TEN marks each and students have to attempt any TWO questions.

## SECTION-A

1. Write briefly :

a) Discuss significance of ROC in z-transform.

b) What are the important features of DSP processors?

c) Compare digital filters and analog filters.

d) Differentiate linear convolution and circular convolution.

e) What are steps involved in the design of FIR filter.

f) Relate Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT).

g) Differentiate between FIR and IIR filter.

h) What are auto-correlation and cross-correlation in signals?

i) List properties of linear time-invariant discrete time system.

j) What is twiddle factor?



## SECTION-B

2. Design a digital filter using Bilinear Transformation technique for following system :

$$H_a(s)=\frac{3}{(s+2)(s+3)}$$

Assume T = 0.1 sec.

3. Describe Matched Ź-transformation methods for design of IIR filter.

4. Realize following digital filter using cascade form and parallel form :

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

5. Determine output of the system $h[n]=\left(\frac{1}{4}\right)^n u(n)$ for input $x[n]+\left(\frac{1}{2}\right)^n u(n)$.

6. Explain the concept of multi-rate signal processing.

## SECTION-C

7. Discuss different types of structures used in realization of FIR filter.

8. a) Discuss the memory architecture of TMS Series using a labelled diagram.

b) Compare DSP processor and general-purpose processor.

9. Find 8-point DFT of following sequence using the radix-2 decimation-in-time algorithm :

$$x[n]=\{1,0,2,0,3,0,4,0\}$$

**NOTE : Disclosure of Identity by writing Mobile No. or Making of passing request on any page of Answer Sheet will lead to UMC against the Student.**

## SECTION- A

1)

a) The Significance of ROC in Z transform is :-

i) It determine whether system is stable or unstable

ii) It also determine whether system is causal or anti causal.

b) features of DSP processor are: -

i) Instructions are executed in single cycle of clock

ii) Separate data & Program memory.

2)

| Digital filter | Analog filter. |
|---|---|
| * Its step response is Symetrical b/w upper & lower portion. | * Its step response is not symmetrical b/w upper & lower. |
| * It is less affected by noise | * It is more affected by noise. |

d)

| Linear Convolution | Circular Convolution. |
| --- | --- |
| * Multiplication of two sequence in time domain is called linear Convolution. | * Multiplication of two Sequence in ~~tim~~ frequency domain is called Circular Convolution. |
| * It deals with infinite or aperiodic signals. | * It deals with finite or periodic signals. |

e) The steps involved in design of FIR filter are :-

i) Determining Specification.

ii) Finding a Transfer Function.

iii) Choose a realization structure

iv) Implementing the filter.

f) Relate DFT & FFT

both DFT & FFT both Computing the same thing the representation in the frequency domain of a finite discrete sequence $x[n]$ of size N.

$$X[K] = \sum_{n=0}^{N-1} x[n] e^{-2\pi n K/N}.$$

on the other hand

FFT designate the family of algorithm which computes the sum in a very efficient way due to periodicity of the exponential.

g)

| FIR | IIR. |
|---|---|
| * If the impulse response of the filter falls to zero after a finite period of time. it is an FIR. | * If the impulse response exist indefinitely it is an IIR. |
| * It rely solely on the input signal. | * It rely on both input signal & previous output values. |

Auto Correlation – It measures the similarity b/w a signal & delayed version of itself.

Cross Correlation – It measures the similarity b/w two different signals.

i) The various properties of discrete LTI system are

i) Commutative property

ii) Distributive property

iii) Associative property

iv) Stability property.

j) Twiddle factor ($W_N$).

N point DFT of sequence $X(K) = \sum_{n=0}^{N-1} x(n).e^{-j2\pi Kn/N}$

$K = 0$ to $N-1$

$n = 0$ to $N-1$.

where $\boxed{e^{-j2\pi/N} = W_N}$ Twiddle factor

# SECTION - B.

Q2.

$$H_s(s) = \frac{3}{(s+2)(s+3)}$$

$T = 0.1\,s.$

A/q to BLT

$$s = \frac{2}{T}\frac{(z-1)}{(z+1)}$$

$$H(s) = H(z)\Big|_{s = \frac{2}{T}\frac{(z-1)}{(z+1)}}$$

$$H(s) = \frac{3}{s^2+5s+6} = \frac{3}{s^2+5s+6}$$

$$H(z) = \frac{3}{\left(\frac{2}{T}\frac{(z-1)}{(z+1)}\right)^2 + 5\left(\frac{2}{T}\frac{(z-1)}{(z+1)}\right) + 6}$$

$T = 0.1$

$$= \frac{3}{\left(0.2\frac{(z-1)}{(z+1)}\right)^2 + \left(\frac{(z-1)}{(z+1)}\right) + 6}$$

$$H(z) = \frac{3(z+1)^2}{0.04(z-1)^2 + z^2 - 1 + 6z^2 + 6 + 12z}$$

$$H(z) = \frac{3(z+1)^2}{0.04z^2 + 0.04 - 0.08z + z^2 + 6z^2 + 5 + 12z}$$

$$H(z) = \frac{3z^2 + 6z + 3}{7.04z^2 + 11.92z + 5.04}$$

Q3

Matched z transform for IIR filter.

It is also known as Pole-zero Mapping.

let $H_a(s) = \frac{A(s)}{B(s)}$ be transfer function of analog filter

Containing n zeroes & n poles

$$H_a(s) = \frac{(s-z_1)(s-z_2)\cdots\cdots(s-z_n)}{(s-p_1)(s-p_2)\cdots\cdots(s-p_m)}$$

$$= \frac{\prod_{k=1}^{r}(s-z_k)}{\prod_{k=1}^{m}(s-p_k)}$$

In this method an analog Pole

$$(s-p_k) \Rightarrow (1-e^{p_k t} z^{-1})$$

In this method an analog zero.

$$(s-z_k) \longrightarrow (1-e^{z_k T} \cdot z^{-1}).$$

Ex.

$$H_a(s) = \frac{(s+2)}{(s+1)(s+3)}$$

by matched Z Transform.

$$[s-(-2)] \xrightarrow{\text{for zero}} 1-e^{-2T} \cdot z^{-1}$$

for Pole

$$s-(-1) \longrightarrow 1-e^{-1} z^{-1}$$

$$s-(-3) \longrightarrow 1-e^{-3} z^{-1}$$

$$= \frac{1-e^{-2} z^{-1}}{(1-e^{-1}z^{-1})(1-e^{-3}z^{-1})}.$$

Q4.

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

Digital filter cascade.

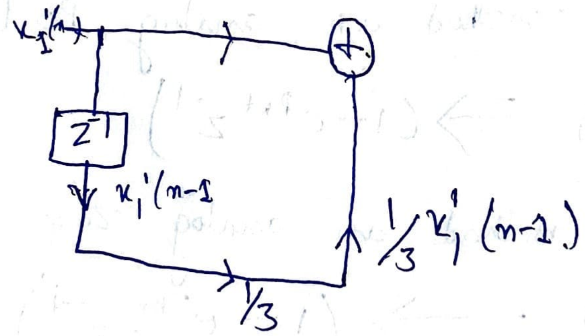
$$y(n) - \frac{3}{4}y(n-1) + \frac{1}{8}y(n-2) = x(n) + \frac{1}{3}x(n-1)$$

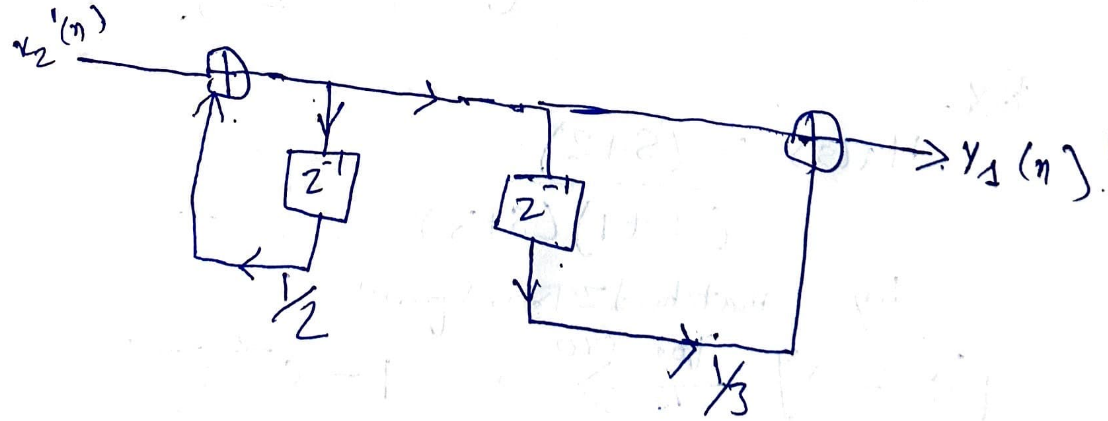
$$Y(z) - \frac{3}{4}Y(z)z^{-1} + \frac{1}{8}Y(z)z^{-2} = X(z) + \frac{1}{3}X(z)z^{-1}$$

$$\frac{Y(z)}{X(z)} = \frac{(1+\frac{1}{3}z^{-1})}{(1-\frac{3}{4}z^{-1}+\frac{1}{8}z^{-2})} \Rightarrow \frac{(1+\frac{1}{3}z^{-1})}{(1-\frac{1}{2}z^{-1})} \;\&\; H(z) = \frac{1}{(1-\frac{1}{4}z^{-1})}$$

$$\frac{1+\frac{1}{3}z^{-1}}{(1-\frac{1}{4}z^{-1})}, \quad \frac{1}{(1-\frac{1}{2}z^{-1})}$$

$x_1'(n) =$



Q5).

Concept of 'Multirate signal processing.

* Multirate signal processing is a technique in DSP that deals with signals having different sampling rates.

* It allow us to process signal that are acquired or need to be output at different frequencies.

Its breakdown.

* Multiple Sampling Rates → The key idea behind MRSP is using multiple sampling rate at the processing system. Signal are often obtained at a specific rate depending on the source or application

* Core Operation : Up Sampling & Down Sampling

Down Sampling (Decimation) → It reduces the Sampling rate of a signal.

Up Sampling (Interpolation) → It increases the Sampling rate of signal.

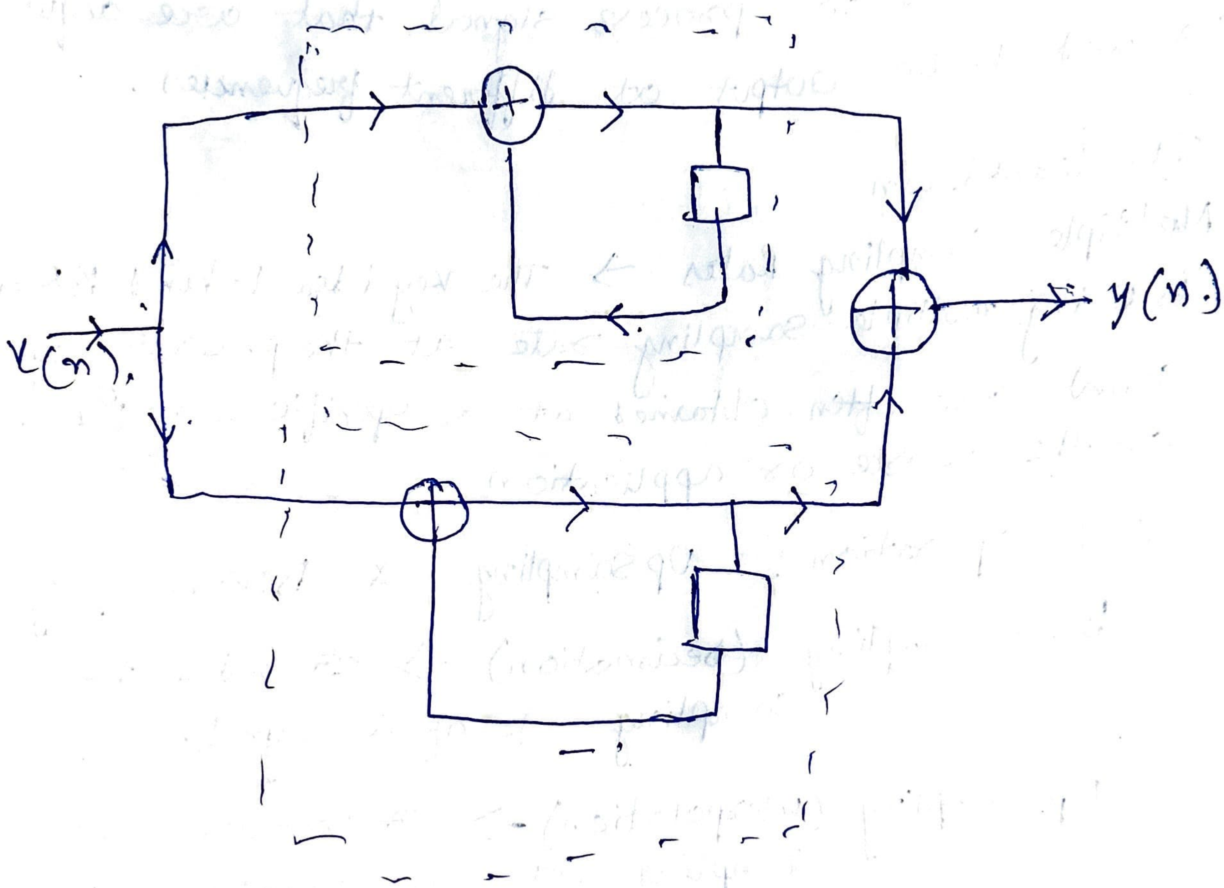
* Application. – MRSP has various applications in DSP.

* Sampling Rate conversion

* Signal processing efficiency

* other applications like audio/video encoding filter design for real time signal processing system

Parallel.



# SECTION – C

Q7 Structure for FIR. reliazations are :-

FIR system is describe by diff eq$^n$

$$y(n) = \sum_{K=0}^{M-1} b_K x(n-K)$$

$$H(z) = \sum_{K=0}^{M-1} b_K z^{-K}.$$

& the unit sample response ($h(n)$) of FIR System is identical to the coeff $\{b_K\}$

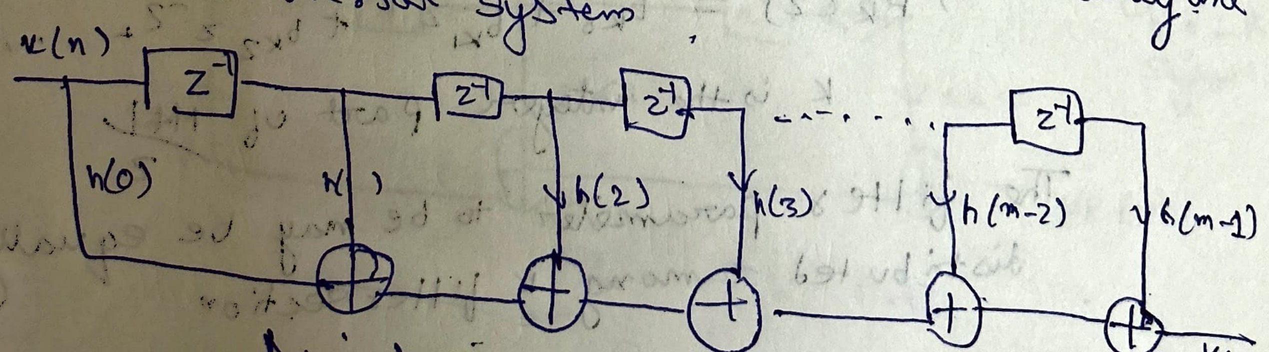
$$h(n) = \begin{cases} b_n & 0 \le n \le M-1 \\ 0 & \text{otherwise} \end{cases}$$

1) Direct form Structure.

for the non-recursive system i.e FIR (i.e present O/P is independent of past o/ps).

$$y(n) = \sum_{K=0}^{M-1} h(K)x(n-K).$$

which involve M-1 memory location for storing M-1 previous I/Ps & M multiplication & M-1 additions o/p. O/P resembles a tapped delay line or a transversal system



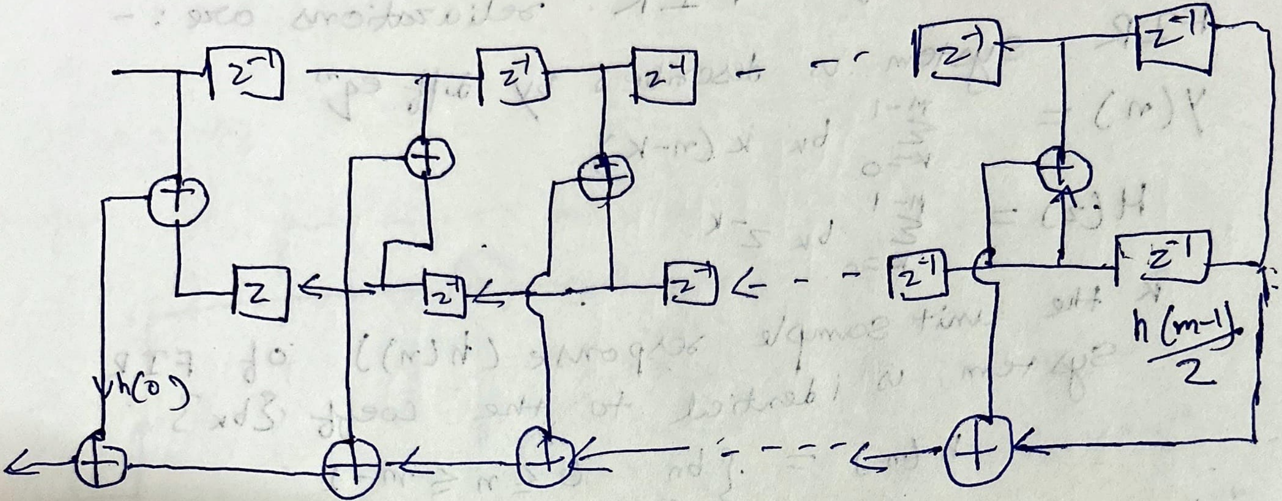

Direct form relization.

for linear phase FIR system the unit sample response $h(n)$ satisfy either symetry or asymmetry condition i.e

$$h(n) = \pm h(M-1-n)$$

hence the no of multiplication is reduces from M to M/2 for even n to $(m-1)/2$ for M odd.

for M odd




$$y(n) = h(0)\{x(n) + x(n-(M-1))\} + h(1)\{[x(n-1) + x(n-(M-2))]$$
$$+ \cdots \cdots h\left(\tfrac{M}{2}-1\right)\left\{x\left(n-\left(\tfrac{M}{2}-1\right)\right)\right\}.$$

Cascade form structure

We know system function $h(z)$ of FIR system

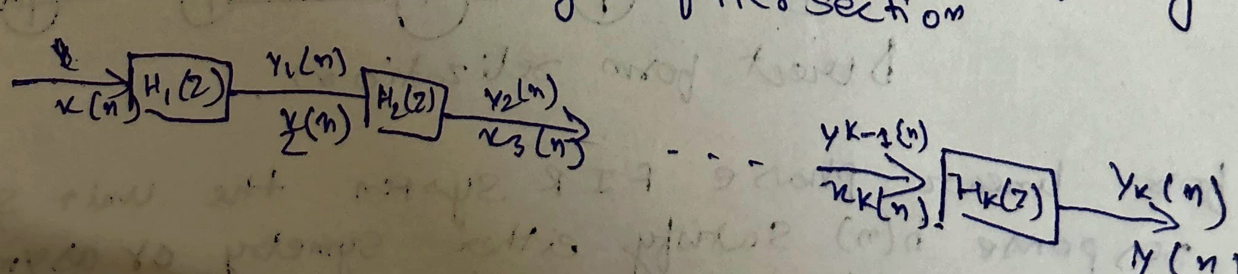
$$H(z) = \sum_{K=0}^{M-1} b_K z^{-K}.$$

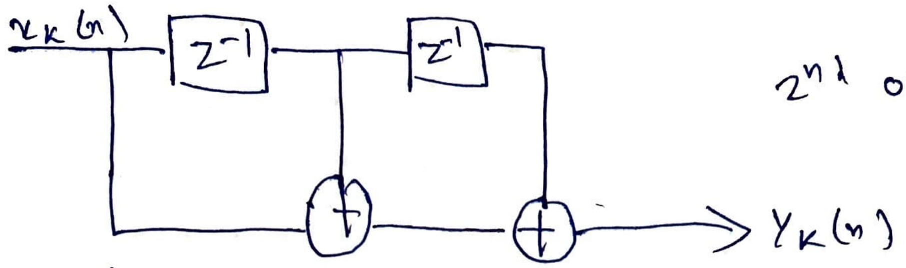
factor $H(z) = \prod_{K=1}^{K} H_K(z)$

where, $H_K(z) = b_{K0} + b_{K1} z^{-1} + b_{K2} z^{-2} + \cdots\cdots$

K is the integer part of $\frac{M+1}{2}$.

The filter parameter to be may be equally distributed among K filter section






2nd order

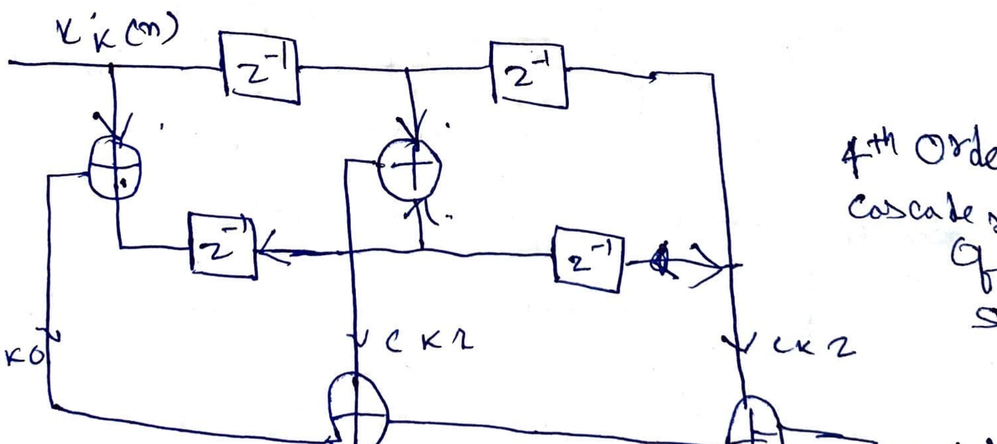
for linear phase FIR filter
the symmetry is $h(n)$ implies that the zeroes of $H(z)$ also exhibit a form of symmetry.

Then 4th order FIR system is

$$H_k(z) = C_{k0}(1-z_k z^{-1})(1-z_k^{*} z^{-1})\left(1-z^{-1}\frac{1}{z_k}\right)\left(1-\frac{z^{-1}}{z_k^{*}}\right)$$

$$= C_{k0} + C_{k1} z^{-1} + C_{k2} z^{-2} + C_{k1} z^{-3} + z^{-4}$$

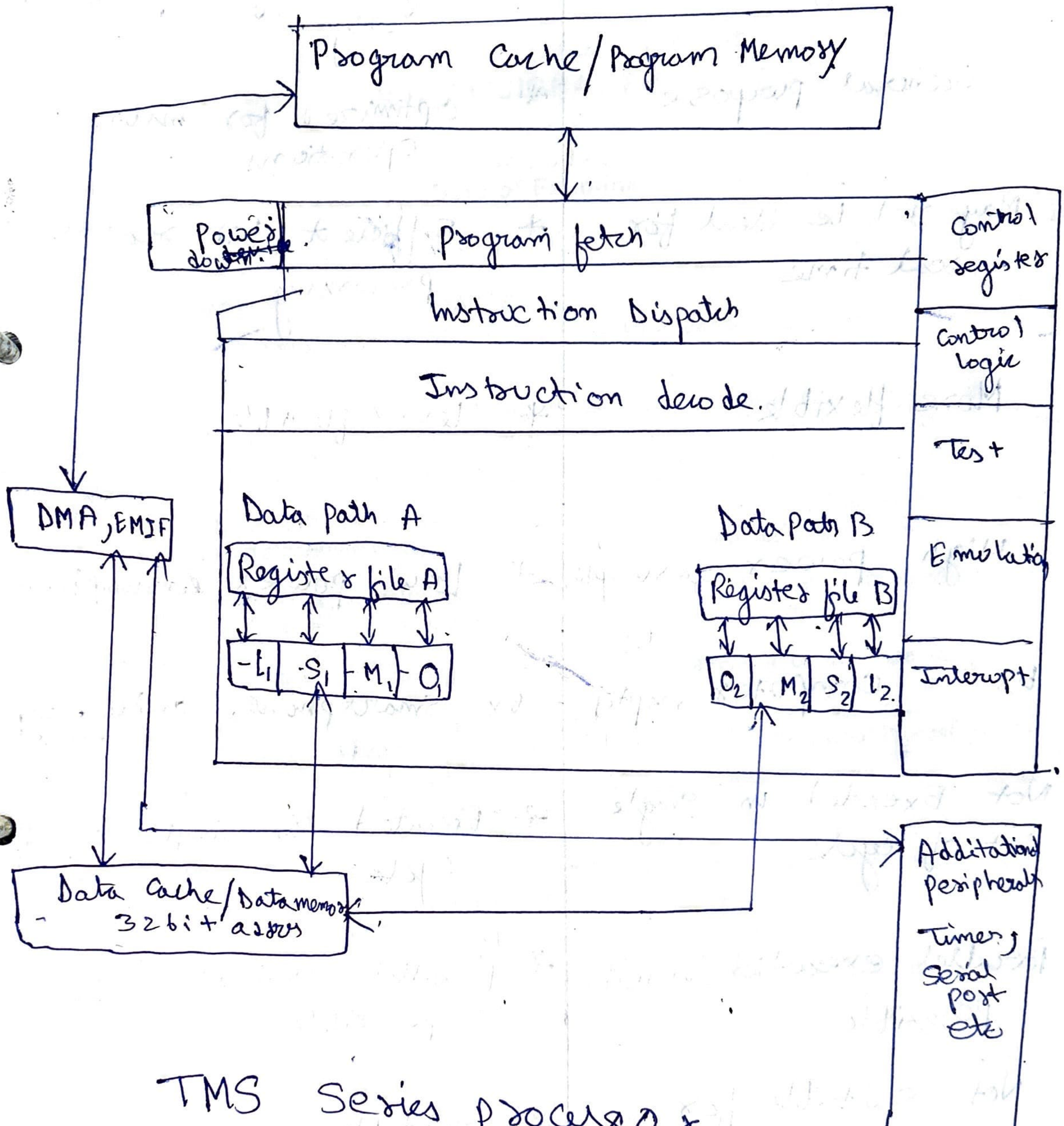
$C_{k1}$ & $C_{k2}$ is function of $z_k$




4th order Cascade realization of FIR System.

Q8)

a).




TMS Series processor

b)

| General purpose. | DSP processor |
|---|---|
| * Wide range of tasks. | * Digital signal processing only |
| * General purpose. | * optimized for math operations |
| * May not be ideal for real time | * Efficient for real time processing |
| * More flexible | * less flexible |
| * High power consumption | * Low power consumption |
| * Ex - Computer, laptop. | Ex Smartphones, audio equipment |
| * Not Executed in single set of cycle. | * Executed in Single set of cycle. |
| * Parallel execution is not possible | * Parallel execution is possible. |
| * Not Suitable for array processing | * Suitable for array processing |
| * It has only ALU. | * It has 3 separate ALU, MAC & Shifter. |