SRI KRISHNA COLLEGE OF TECHNOLOGY

An Autonomous Institution, (Approved by AICTE and affiliated to Anna University)

Accredited by NAAC with "A" grade

Coimbatore, Tamil Nadu

END SEMESTER REGULAR EXAMINATIONS – APR/MAY 2023

ANSWER KEY

Regulation – 2020

Programme(s)	Semester	Course Code(s)	Course Title
B.E - EEE	VI	20EC612	Principles of Digital Signal Processing

Time: Three Hours **Max Marks: 100**

COURSE OUTCOMES:

CO1	Understand various concepts of Signals and Systems
CO2	Apply the mathematical operations on signals and systems
CO3	Apply Z Transform and Discrete Fourier Transforms techniques
CO4	Analyze various types of DSP filters using IIR and FIR filter design
CO5	Analyze the programmable digital signal processor and multi-rate Signal Processing

	PART – A (10 X 2 = 20 MARKS) ANSWER ALL QUESTIONS	BT	CO	Marks
1.	**Outline deterministic signal with an example.** Signal that can be uniquely described by ✓ an explicit mathematical expression, ✓ a table of data ✓ a well-defined rule Eg. x(n)= Asin n	U	CO1	2
2.	**State the conditions for causality and stability of a system in terms of its impulse response.** **Condition for causality** $h(n)=0$ for $n<0$ **Conditions for stability** $$\sum_{n=-\infty}^{\infty} \lvert h(n)\rvert < \infty$$	U	CO1	2
3.	**Mention the significance of correlation in signal processing. Give an example.** ➢ It is used to compare two signals. ➢ It is used in the applications in radar and sonar system where the location of the target is measured by comparing the transmitted and reflected signals. ➢ Other applications of correlation include image processing and control engineering.	U	CO2	2

<table>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4.</td><td>Represent the following finite duration sequence as a sum of weighted impulses, x(-1)=2, x(0)=4, x(1)=-1, x(2)=-2.
$x(-1)=2=2\delta(n+1)$
$x(0)=4=4\delta(n)$
$x(2)=-1=-1\delta(n-1)$
$x(2)=-2=-2\delta(n-2)$
Therefore, $x(n)= 2\delta(n+1)+4\delta(n)-1\delta(n-1)-2\delta(n-2)$.</td><td>AP</td><td>CO2</td><td>2</td></tr>
<tr><td>5.</td><td>Summarize the properties of region of convergence.
1. The ROC is a ring or disk in the z-plane centered at the origin.
2. The ROC cannot contain any poles.
3. If x(n) is a causl sequence then the ROC is the entire z-plane except at z=0.
4. If x(n) is a non-causal sequence then the ROC is the entire z-plane except at $z=\infty$.</td><td>U</td><td>CO3</td><td>2</td></tr>
<tr><td>6.</td><td>The First 5 DFT coefficients of a 8 sample sequence x(n) are X(0)=2; X(1)=0.5-j1.206, X(2)=0; X(3)=0.5-j0.206; X(4)=0. Determine the remaining DFT coefficients.
X(5)= 0.5+j0.206
X(6)=0
X(7)=0.5+j1.206</td><td>U</td><td>CO3</td><td>2</td></tr>
<tr><td>7.</td><td>Comment on the frequency responses of Chebyshev type I and type II Filters.
Type I filters exhibit equiripple behavior in the pass band and a monotonic characteristics in the stop band. Type II filters exhibit monotonic characteristics in the pass band and equiripple behavior in the stop band.</td><td>U</td><td>CO4</td><td>2</td></tr>
<tr><td>8.</td><td>Compare FIR and IIR Filters.
<table><tr><th>S. No</th><th>FIR Filter</th><th>IIR Filter</th></tr><tr><td>1</td><td>Filters have linear phase</td><td>Filters do not have linear phase</td></tr><tr><td>2</td><td>Filter is non-recursive</td><td>Filters can be realized recursively</td></tr></table></td><td>U</td><td>CO4</td><td>2</td></tr>
<tr><td>9.</td><td>Infer the need for anti-aliasing and anti-imaging filters in downsampling and upsampling of a signal respectively.
Antialiasing is needed before it is sampled to remove the aliasing of unwanted high frequency signals. The low-pass filter placed after the up sampler to remove the images created due to up sampling is anti-imaging filter.</td><td>U</td><td>CO5</td><td>2</td></tr>
<tr><td>10.</td><td>Differentiate Von Neumann and Harvard architectures.
<table><tr><th>S. No</th><th>Von Neumann Architecture</th><th>Harvard Architecture</th></tr><tr><td>1</td><td>There is common bus for data and instruction transfer.</td><td>Separate buses are used for transferring data and instruction.</td></tr><tr><td>2</td><td>It is ancient computer architecture based on stored program computer concept.</td><td>It is modern computer architecture based on Harvard Mark I relay based model.</td></tr></table></td><td>AP</td><td>CO5</td><td>2</td></tr>
</table>

PART – B (5 X 16 = 80 MARKS)

		BT	CO	Marks
11	a) Determine the values of power and energy of the following signals. Find whether the signals are power, energy or neither energy nor power signals. i) $x(n)=6\cos(\pi n/2)$	AP	CO1	10

a) (i) $x(n) = 6\cos\left(\frac{\pi n}{2}\right)$ (10 Marks)

Energy, $E = \sum_{n=-\infty}^{\infty} |x(n)|^2$

$= \sum_{n=-\infty}^{\infty} 6\cos^2\left(\frac{\pi n}{2}\right)$

$= 6 \sum_{n=-\infty}^{\infty} \cdot \frac{1+\cos\left(\frac{\cancel{2}\pi n}{\cancel{2}}\right)}{2}$

$= 3 \sum_{n=-\infty}^{\infty} (1+\cos \pi n)$

$= 3\left[\sum_{n=-\infty}^{\infty} 1 + \sum_{n=-\infty}^{\infty} \cos(n\pi)\right]$

$\boxed{E = \infty}$

Power, $P = \underset{N\to\infty}{Lt} \frac{1}{2N+1} \sum_{n=-N}^{N} |x(n)|^2$

$= \underset{N\to\infty}{Lt} \frac{1}{2N+1} \cdot 3\left[\sum_{n=-N}^{N} 1 + \sum_{n=-N}^{N} \cos n\pi\right]$

$= \underset{N\to\infty}{Lt} \frac{1}{2N+1} 3\left[2N+1\right]$

$= \underset{N\to\infty}{Lt} \frac{1}{\cancel{2N+1}} \cdot 3(\cancel{2N+1})$

$\boxed{\text{Power} = 3 \text{ watts}}$

$E=\infty$, $P=3$ W (finite)

The signal is power signal.

ii) $x(n)=3(0.5)^n u(n)$

a)(ii) $x(n) = 3(0.5)^n u(n)$ (5 Marks)

$$E = \sum_{n=-\infty}^{\infty} |x(n)|^2$$

$$= \sum_{n=-\infty}^{\infty} \left|3(0.5)^n \cdot u(n)\right|^2$$

$$= \sum_{n=0}^{\infty} 9 \cdot (0.5)^{2n}$$

$$= 9 \cdot \sum_{n=0}^{\infty} (0.25)^n$$

$$= 9 \cdot \left[1 + 0.25 + (0.25)^2 + \cdots\right]$$

$$= \frac{9[1]}{1-0.25} = \frac{9}{0.75}$$

$$\boxed{E = 12 \text{ Joules}}$$

$$P = \lim_{N\to\infty} \frac{1}{2N+1} \sum_{n=0}^{N} 9 \cdot (0.25)^n$$

$$= \lim_{N\to\infty} \frac{9}{2N+1} \sum_{n=0}^{N} (0.25)^n$$

$$= \lim_{N\to\infty} \frac{9}{2N+1} \left(\frac{1-(0.25)^{N+1}}{1-0.25}\right)$$

using Geometric Sum formula.

$$= \frac{9}{\infty} \left(\frac{1-(0.25)^{\infty}}{1-0.25}\right)$$

$$= \frac{9}{\infty} \cdot 1 \text{ (approx)}$$

$$\boxed{P = 0}$$

Since $E = 12$ Joules (finite) & $P = 0$

the given signal is Energy signal.

	b) Find whether the following signals are periodic or not. If periodic, find the fundamental period and fundamental frequency. **i) x(n)=sin (nπ/3).cos(nπ/5)**	**AP**	**CO1**	**6**

b) (i) $x(n) = \sin(n\pi/3).\cos(n\pi/5)$ (3 Marks)

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

$$x(n) = \frac{1}{2}\left[\sin\left(\frac{n\pi}{3} + \frac{n\pi}{5}\right) + \sin\left(\frac{n\pi}{3} - \frac{n\pi}{5}\right)\right]$$

$$= \frac{1}{2}\left[\underbrace{\sin\left(\frac{8n\pi}{15}\right)}_{\text{term 1}} + \underbrace{\sin\left(\frac{2n\pi}{15}\right)}_{\text{term 2}}\right]$$

Term 1:

$$= \frac{8\pi N_1}{15} = 2\pi M_1$$

$$N_1 = \frac{\cancel{2\pi}(15)}{\cancel{8\pi}_{4}} M_1$$

$$N_1 = \frac{15}{4} M_1$$

for $M_1 = 4$; $N_1 = 15$

Term 2:

$$\frac{2\pi N_2}{15} = 2\pi M_2$$

$$N_2 = \frac{2\pi(15) M_2}{2\pi}$$

$$= 15\, M_1$$

for $M_2 = 1$; $N_2 = 15$.

Now, $\frac{N_1}{N_2} = \frac{15}{15} = \frac{1}{1}$ = Rational

therefore, the given signal is periodic

Fundamental period,

$$N = \frac{N_1}{N_2} = \frac{1}{1}$$

$$N = N_1 . 1 = 1 . N_2$$

$$\boxed{N = 15 \text{ Samples}}$$

fundamental frequency,

$$f = \frac{1}{N} = \frac{1}{15} \text{ rad/samples.}$$

ii) x(n)=30 cos((n/8)-π)

b) (ii) $x(n) = 30\cos\left(\frac{n}{8} - \pi\right)$ (3 Marks)

Periodicity, $x(n+N) = x(n)\ \forall n$

$$x(n+N) = 30\cos\left(\frac{n}{8} + \frac{N}{8} - \pi\right)$$

$$= 30\cos\left(\frac{n}{8} - \pi + \frac{N}{8}\right)$$

$$x(n) = 30\cos\left(\frac{n}{8} - \pi\right)$$

$\frac{N}{8}$ should be equal to integer multiple of 2π

$$\frac{N}{8} = 2\pi \times M$$

$$N = 16\pi M$$

Here N cannot be a integer for any integer value of M

$\Rightarrow x(n)$ is not aperiodic

(OR)

12.	**Check whether the following systems are dynamic, linear, time invariant, causal and stable. Justify your answers.**	**AP**	**CO1**	**16**

i) y(n)=2x(n)+1/((x(n-1))

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

Dynamic or Static (2 Marks)

The o/p y(n) depends on the past input. the system is dynamic.

Linear or Non-linear: (1 marks)

The system does not satisfy the superposition principle so it is non-linear system.

Time invariant: or variant: (2 marks)

The system is time invariant system.

Causal or Non-causal: (1 marks)

The output depend only on present & past inputs, So the system is causal

Stable: (2 marks)

$$\sum_{n=-\infty}^{\infty} |h(n)| < \infty$$

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

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

$$\sum_{n=-\infty}^{\infty} |h(n)| < \infty$$

$$\sum_{n=-\infty}^{\infty} 2\delta(n) + \frac{1}{\delta(n-1)} < \infty$$

$1 < \infty$ → So the system is stable.

	ii) y(n)=nx²(n) (ii) $y(n) = nx^2(n)$ Dynamic or static: (2 marks) The o/p y(n) depends on the input at that instant only. Therefore the system is static. Linear or Non-Linear: (1 marks) The system does not satisfy the superposition principle. so it is a Non-Linear system. Time variant or invariant system: (2 marks) The system is time variant system. Causal or Non-causal (1 marks) The output depend on present input only so the system is causal. Stable or unstable s/m: (2 marks) $\sum_{n=-\infty}^{\infty} \|h(n)\| < \infty$ $h(n) = n\delta^2(n)$ The system is stable system.			
13.	**a) Determine the convolution sum of the given two sequences using graphical method.** **x1(n)={3,2,1,2}(n=0 to 3); x2(n)={1,2,1,2}(n=-1 to 2)**	**AP**	**CO2**	**10**

$x_1(n) = \{3, 2, 1, 2\}$; $x_2(n) = \{1, 2, 1, 2\}$

Graphical method:

Step 1: The sequence $x_1(n)$ starts at $m_1 = 0$ & $x_2(n)$ starts at $m_2 = -1$. Therefore, the starting time for evaluating the output sequence $y(n)$ is

$m = m_1 + m_2$

$= 0 - 1$

$\boxed{m = -1}$ → starting value.

Length of the sequence $n = n_1 + n_2 - 1$

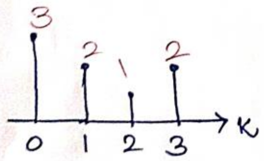
$n_1 = 4$; $n_2 = 4$

$= 4 + 4 - 1$

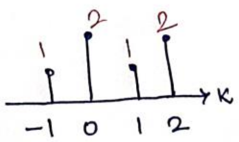
$\boxed{n = 7}$

$n = -1, 0, 1, 2, 3, 4, 5$ Ending value → 5

Step 2: Express both sequences in terms of the index k.

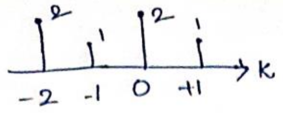


$x_1(k)$



$x_2(k)$

Step 3: Fold $x_2(k)$ to obtain $x_2(-k)$



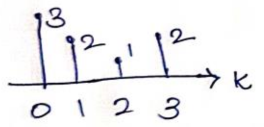
$x_2(-k)$

Step 4: Apply the shifting property and find the value of $y(n)$

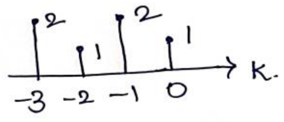
$$y(n) = \sum_{k=-\infty}^{\infty} x_1(k)\, x_2(n-k)$$

If $n = -1$

$$y(-1) = \sum_{k=-\infty}^{\infty} x_1(k)\, x_2(-1-k)$$



$x_1(k)$



$x_2(-1-k)$

$$y(-1) = \sum_{k=-3}^{3} x_1(k)\, x_2(-1-k)$$

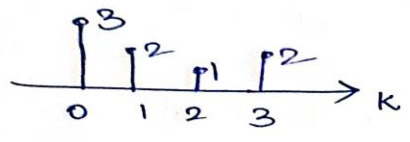
$$y(-1) = x_1(-3)\,x_2(-3) + x_1(-2)\,x_2(-2) + x_1(-1)\,x_2(-1) + x_1(0)\,x_2(0) + x_1(1)\,x_2(1) + x_1(2)\,x_2(2) + x_1(3)\,x_2(3)$$

$$= (0\cdot 2) + (0\cdot 1) + (0\cdot 2) + (3\cdot 1) + (2\cdot 0) + (1\cdot 0) + (2\cdot 0)$$

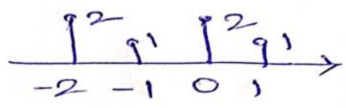
$$\boxed{y(-1) = 3}$$

If $n = 0$

$$y(0) = \sum_{k=-\infty}^{\infty} x_1(k)\, x_2(-k)$$



$x_1(k)$



$x_2(-k)$

$y(0) = 8$

If $n = 1$

$y(1) = 8$

If $n = 2$; $y(2) = 12$

If $n = 3$; $y(3) = 9$

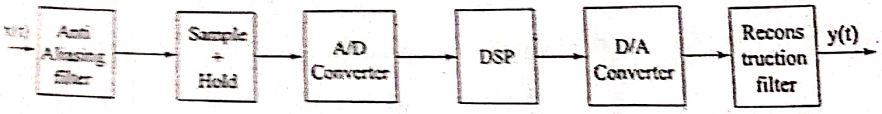
If $n = 4$; $y(4) = 4$

If $n = 5$; $y(5) = 4$

$$\boxed{y(n) = \{3, \underset{\uparrow}{8}, 8, 12, 9, 4, 4\}}$$

b) Illustrate Digital Signal Processing with the aid of neat block diagram. | U | CO2

Diagram (3 Marks)



Explanation (3 Marks)

- Sampling
- Quantization
- Sampling Theorem

(OR)

14. a) Compute the Z-Transform and the associated ROC of the following signals. | AP | CO3 | 6

i) $\delta(n-n_0)$

ii) $u(n-n_0)$

iii) $x(n)=\{1,2,3,3,2,1\}$ starting at n=-2

a) (i) $\delta(n-n_0)$ (2 marks)

Z-transform of $\delta(n-m) = z^{-m}$ All z except 0 (if $m>0$)

$\boxed{\delta(n-n_0) = z^{-n_0}}$ all z except ∞ if $(m<0)$

(ii) $u(n-n_0)$ → Apply shifting property (2 marks)

$\boxed{Z\{u(n-n_0)\} = z^{-n_0} \cdot \frac{z}{z-1}}$ $|z| > 1$, except $z=0$ if $m>0$, $z=\infty$ if $m<0$

(iii) $x(n) = \{1,2,\underset{\uparrow}{3},3,2,1\}$

$$X(z) = \sum_{n=-\infty}^{\infty} x(n) z^{-n}$$

$$= \sum_{n=-2}^{3} x(n) z^{-n}$$

$$= x(-2)z^{2} + x(-1)z^{1} + x(0)z^{0} + x(1)z^{-1} + x(2)z^{-2} + x(3)z^{-3}$$

$$\boxed{X(z) = z^{2} + 2z^{1} + 3 + 3z^{-1} + 2z^{-2} + z^{-3}}$$

X(z) converges for all values of z except at $z=0$ & $z=\infty$

b) A causal discrete time system is represented by the following difference equations, | AP | CO3 | 10

y(n)+1/4y(n-1)=x(n)+1/2x(n-1)

i) Find the system function H(z) and its corresponding ROC.
ii) Find the unit sample response h(n) of the system.

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

(i) $H(z)$

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

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

$Y(z)\left[1 + \frac{1}{4} z^{-1}\right] = X(z)\left[1 + \frac{1}{2} z^{-1}\right]$

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

$= \frac{1 + \frac{1}{4z}}{1 + \frac{1}{2z}}$

$= \frac{\frac{4z+1}{4z}}{\frac{2z+1}{2z}}$

$= \frac{4(z+1/4)}{4z} * \frac{2z}{2(z+1/2)}$

$\boxed{H(z) = \frac{(z+1/4)}{(z+1/2)}}$

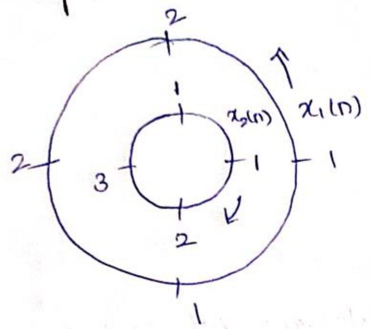
$$\begin{array}{r|l} & 1 - 0.25z^{-1} \\ \hline z + 0.5 & z + 0.25 \\ & z + 0.5 \\ \hline & -0.25 \\ & -0.25 - 0.125z^{-1} \\ \hline \end{array}$$

$h(n) = \{1, -0.25, \dots\}$

15.	a) Perform circular convolution of the following sequences using concentric circles method. x1(n)={1,2,2,1} x2(n)={1,2,3,1}	AP	CO3	8

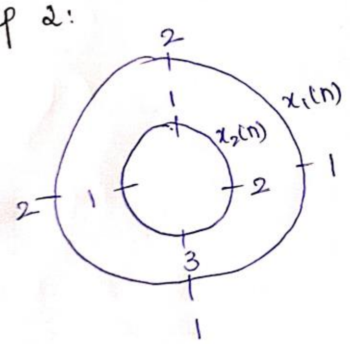
$x_1(n) = \{1,2,2,1\}$; $x_2(n) = \{1,2,3,1\}$

Step 1:



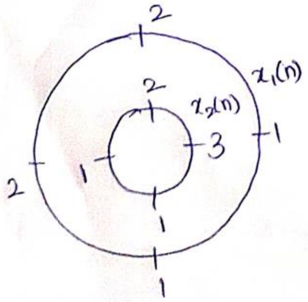
$$y(0) = \{(1\times1)+(2\times1)+(2\times3)+(1\times2)\}$$
$$= \{1+2+6+2\}$$
$$= \{11\}$$

Step 2:



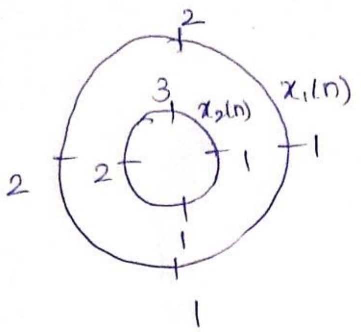
$$y(1) = \{(1\times2)+(2\times1)+(2\times1)+(1\times3)\}$$
$$= \{2+2+2+3\}$$
$$= \{9\}$$

Step 3:



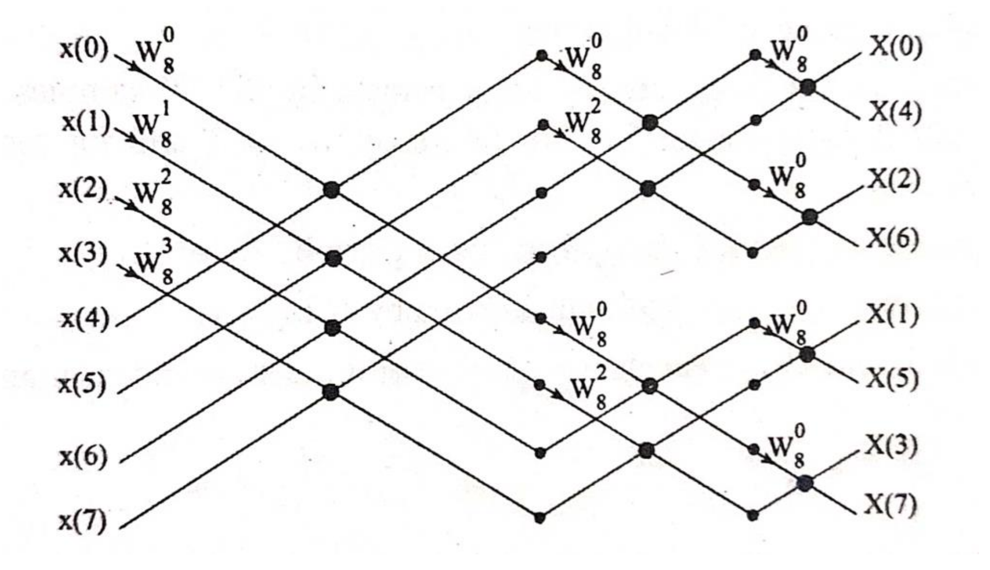
$$y(2) = \{(1\times3)+(2\times2)+(2\times1)+(1\times1)\}$$
$$= \{3+4+2+1\}$$
$$= \{10\}$$

Step 4:



$$y(3) = \{(1\times1)+(2\times3)+(2\times2)+(1\times1)\}$$
$$y(3) = \{1+6+4+1\}$$
$$y(3) = \{12\}$$

$$\boxed{y(n) = \{11, 9, 10, 12\}}$$

	b) Deduce the signal flow graph of radix-2 Decimation in frequency FFT algorithm for N=8. 	**AP**	**CO3**	**8**
	(OR)			
16.	**Using DFT-IDFT method, Determine the response of the system with impulse response h(n)={1,2,1} for the input x(n)={3,2}.** x(n)={3,2} h(n)= { 1,2,1} Length of y(n)= 3+2-1=4 x(n)= {3,2,0,0} h(n)= {1,2,1,0} **4 marks** $X(k) = \sum_{n=0}^{3} x(n)e^{\frac{-j2\pi nk}{4}}$ k=0,1,2,3 $X(k) = \sum_{n=0}^{3} x(n)e^{\frac{-j\pi nk}{2}}$ $X(0) = x(0) + x(1) + x(2) + x(3)$ =3+2=5 $X(1) = \sum_{0}^{3} x(n)e^{\frac{-j\pi n}{2}}$ $= x(0) + x(1)e^{\frac{-j\pi}{2}} + x(2)e^{\frac{-j\pi}{1}} + x(3)e^{\frac{-3j\pi}{2}}$ =3+2(-j) =3-2j $X(2) = \sum_{0}^{3} x(n)e^{\frac{-j2\pi n}{2}}$ $= x(0) - x(1)$	**AP**	**CO3**	**16**

=3-2
=1

$$X(3) = \sum_{0}^{3} x(n) e^{\frac{-j3\pi n}{2}}$$

$$= x(0) + x(1) e^{\frac{-j3\pi}{2}}$$

=3+2j

X(k)= {5, 3-2j,1, 3+2j}

h(n)= { 1,2,1,0} **4 marks**

$$H(k) = \sum_{n=0}^{3} h(n) e^{\frac{-j\pi nk}{2}}$$ k=0,1,2,3

H(0)=1+2+1+0=4

$$H(1) = \sum_{n=0}^{3} h(n) e^{\frac{-j\pi n}{2}}$$

$$= h(0) e^{\frac{-j\pi x 0}{2}} + h(1) e^{\frac{-j\pi x 1}{2}} + h(2) e^{\frac{-j\pi x 2}{2}} + h(3) e^{\frac{-j\pi x 3}{2}}$$

=1+2(-j)+1x(-1)
=-2j

$$H(2) = \sum_{n=0}^{3} h(n) e^{\frac{-j\pi n x 2}{2}}$$

$$= \sum_{n=0}^{3} h(n) e^{-j\pi n}$$

$$= h(0) + h(1) e^{-j\pi} + h(2) e^{-j\pi 2} + h(n) e^{-j\pi 3}$$

=1+2(-1)+1
=0

$$H(3) = \sum_{n=0}^{3} h(n) e^{\frac{-j\pi n x 3}{2}}$$

$$= h(0) + h(1) e^{\frac{-j\pi x 3}{2}} + h(2) e^{\frac{-j\pi 2 x 3}{2}} + h(3) e^{\frac{-j\pi 3 x 3}{2}}$$

= 1+2(j)+1(-1)
=2j

H(k)= {4, -2j, 0,2j}

Y(k)= X(k). H(k) **2 marks**
={5, 3-2j,1, 3+2j}.{4, -2j, 0,2j}

	={20,-4-6j, 0,-4+6j} $y(n) = \frac{1}{4}\sum_{k=0}^{3} Y(k)e^{\frac{j2\pi nk}{4}}$ $=\frac{1}{4}\sum_{k=0}^{3} Y(k)e^{\frac{j\pi nk}{2}}$ **6 marks** y(0) $=\frac{1}{4}\{Y(0)+Y(1)+Y(2)+Y(3)\}$ =1/4{20-4-6j-4+6j} =1/4{12}=3 $y(1) = \frac{1}{4}\sum_{k=0}^{3} Y(k)e^{\frac{j2\pi k}{4}}$ $=\frac{1}{4}\left\{Y(0)+Y(1)e^{\frac{j2\pi}{4}}+Y(2)e^{\frac{4j\pi x}{4}}+Y(3)e^{\frac{j6\pi k}{4}}\right\}$ =1/4{20+(-4-6j)(j)+0+(-4+6j)(-j)} =1/4{20-4j+6+4j+6} =8 $y(2) = \frac{1}{4}\sum_{k=0}^{3} Y(k)e^{\frac{j4\pi k}{4}}$ $= \frac{1}{4}\{Y(0)+Y(1)e^{\frac{j\pi}{1}}+Y(2)e^{\frac{j2\pi k}{1}}+Y(3)e^{\frac{j3\pi k}{1}}\}$ =1/4{20+(-4-6j)(-1)+ (-4+6j)(-1)} =7 $y(3) = \frac{1}{4}\sum_{k=0}^{3} Y(k)e^{\frac{j3\pi k}{2}}$ $= \frac{1}{4}\{Y(0)+Y(1)e^{\frac{3j\pi}{2}}+Y(2)e^{\frac{j3\pi k}{1}}+Y(3)e^{\frac{j9\pi k}{2}}\}$ =1/4{20+(-4-6j)(-j)+(-4+6j)(j)} =2 y(n)= {3,8,7,2}			

17.	**Butterworth Digital Filter** Given $\frac{1}{\sqrt{1+\varepsilon^2}} = 0.8$ from which $\varepsilon = 0.75$, $\frac{1}{\sqrt{1+\lambda^2}} = 0.2$ from which $\lambda = 4.899$ $\omega_s = 0.6\pi$ rad; $\omega_p = 0.2\pi$ rad $\frac{\omega_s}{\omega_p} = \frac{\Omega_s T}{\Omega_p T} = \frac{\Omega_s}{\Omega_p} = \frac{0.6\pi}{0.2\pi} = 3$ $N = \frac{\log \lambda/\varepsilon}{\log 1/k} = \frac{\log \frac{4.899}{0.75}}{\log 3} = 1.71$ Approximating to nearest higher values we have $N = 2$. For $N = 2$ the transfer function of normalized Butterworth filter is $H(s) = \frac{1}{s^2 + \sqrt{2}s + 1}$ $\Omega_c = \frac{\Omega_p}{(\varepsilon)^{1/N}} = \frac{0.2\pi}{(0.75)^{1/2}} = 0.231\pi$ $H_a(s) = H(s)\Big\vert_{s \to s/0.231\pi}$ $= \frac{0.5266}{s^2 + 1.03s + 0.5266}$ $= \frac{0.516j}{s + 0.51 + j0.51} - \frac{0.516j}{s + 0.51 - j0.51}$ $= \frac{0.516j}{s - (-0.51 - j0.51)} - \frac{0.516j}{s - (-0.51 + j0.51)}$ **Using Bilinear transform** **6 marks** $H(z) = \frac{0.084(1 + z^{-1})^2}{1 - 1.028z^{-1} + 0.3651z^{-2}}$	AP	CO4	16
	(OR)			
18.	**High Pass Filter Using Hanning Window:** $h_d(n) = \frac{1}{2\pi}\int_{-\pi}^{\pi} H_d(e^{j\omega})e^{j\omega n}d\omega$ **4 marks** $= \frac{1}{2\pi}\left[\int_{-\pi}^{-\frac{\pi}{2}} 1.\ e^{j\omega n}d\omega + \int_{\frac{\pi}{2}}^{\pi} 1.\ e^{j\omega n}d\omega\right]$ $= \frac{1}{2\pi}\left[\left(\frac{e^{j\omega n}}{jn}\right)_{-\pi}^{\frac{-\pi}{2}} + \left(\frac{e^{j\omega n}}{jn}\right)_{\frac{\pi}{2}}^{\pi}\right]$ $= \frac{1}{2j\pi n}\left\{\left[e^{-j\frac{\pi}{2}n} - e^{-j\pi n}\right] + \left[e^{j\pi n} - e^{j\frac{\pi}{2}n}\right]\right\}$ $h_d(n) = \frac{1}{2\pi}\int_{-\pi}^{\pi} H_d(e^{j\omega})e^{j\omega n}d\omega$ **4 marks**	AP	CO4	16

$$= \frac{1}{2\pi}\left[\int_{-\pi}^{-\frac{\pi}{2}} 1.\ e^{j\omega n} d\omega + \int_{\frac{\pi}{2}}^{\pi} 1.\ e^{j\omega n} d\omega\right]$$

$$= \frac{1}{2\pi}\left[\left(\frac{e^{j\omega n}}{jn}\right)_{-\pi}^{\frac{-\pi}{2}} + \left(\frac{e^{j\omega n}}{jn}\right)_{\frac{\pi}{2}}^{\pi}\right]$$

$$= \frac{1}{2j\pi n}\left\{\left[e^{-j\frac{\pi}{2}n} - e^{-j\pi n}\right] + \left[e^{j\pi n} - e^{j\frac{\pi}{2}n}\right]\right\}$$

$$h_d(n) = \frac{1}{\pi n}\left\{\frac{\left[e^{-j\frac{\pi}{2}n} - e^{-j\pi n}\right]}{2j} + \frac{\left[e^{j\pi n} - e^{j\frac{\pi}{2}n}\right]}{2j}\right\}$$

$$\frac{1}{\pi n}\left\{-\sin\frac{\pi}{2}n + \sin n\pi\right\}$$

$$= \frac{\left\{\sin n\pi - \sin\frac{\pi}{2}n\right\}}{\pi n}$$

Order of the filter N=9

FIR filter is symmetric

Truncation

4 marks

$$h_d(n) = h_d(n) \text{ for } |n| \le \frac{N-1}{2}$$

= 0, Otherwise

$$\frac{N-1}{2} = \frac{9-1}{2} = 4$$

n range -4 to 4

n=0,

$$h_d(0) = \frac{\sin 0x\pi}{\pi x0} - \frac{\sin\frac{\pi}{2}x0}{\pi x0}$$

$$\frac{\sin 0x\pi}{\pi x0} = \frac{0}{0}$$

$$\frac{\sin\frac{\pi}{2}x0}{\pi x0} = \frac{0}{0}$$

$\frac{0}{0}$ is indeterminate form

$$h_d(0) = 1 - \frac{1}{2} = \frac{1}{2}$$

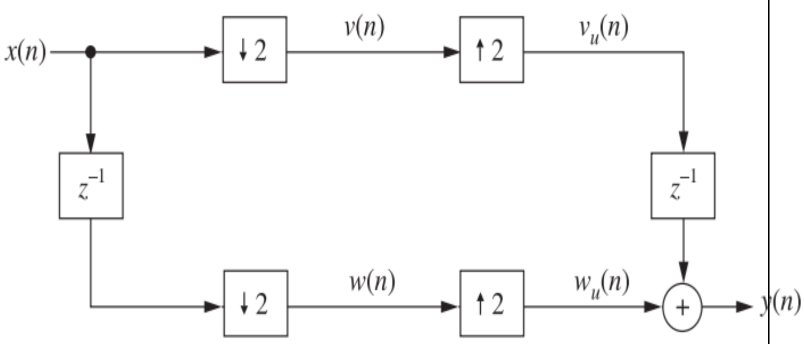
Filter coefficients are symmetrical about n=0,

h(n)= h(-n)

For n=1,

$$h_d(1) = h_d(-1) = \frac{\sin 1x\pi}{\pi x1} - \frac{\sin\frac{\pi}{2}x1}{\pi x1} = -0.3183$$

	$h_d(2) = h_d(-2) = \frac{\sin 2x\pi}{\pi x 2} - \frac{\sin\frac{\pi}{2}x2}{\pi x 2} = 0$ $h_d(3) = h_d(-3) = \frac{\sin 3x\pi}{\pi x 3} - \frac{\sin\frac{\pi}{2}x3}{\pi x 3} = -0.1061$ $h_d(4) = h_d(-4) = \frac{\sin 4x\pi}{\pi x 4} - \frac{\sin\frac{\pi}{2}x4}{\pi x 4} = 0$ **4 marks** Hanning window sequence $w_{Hn}(n) = 0.5 + 0.5\cos\frac{2\pi n}{N-1}$ for $\frac{-(N-1)}{2} \leq n \leq \frac{(N-1)}{2}$ = 0, otherwise $w_{Hn}(n) = 0.5 + 0.5\cos\frac{2\pi n}{8}$ for $-4 \leq n \leq 4$ = 0, otherwise $w_{Hn}(0) = 0.5 + 0.5\cos\frac{2\pi x 0}{8} = 1$ $w_{Hn}(-1) = w_{Hn}(1) = 0.5 + 0.5\cos\frac{2\pi}{8} = 0.8535$ $w_{Hn}(-2) = w_{Hn}(2) = 0.5 + 0.5\cos\frac{2\pi x 2}{8} = 0.5$ $w_{Hn}(-3) = w_{Hn}(3) = 0.5 + 0.5\cos\frac{2\pi x 3}{8} = 0.1464$ $w_{Hn}(-4)w_{Hn}(4) = 0.5 + 0.5\cos\frac{2\pi x 4}{8}$ =0 **4 marks** $h(n) = h_d(n)w_{Hn}(n) \quad for -4 \leq n \leq 4$ = 0, otherwise $h(0) = h_d(0)w_{Hn}(0)$ =0.5x1=0.5 $h(-1) = h(1) = h_d(1)w_{Hn}(1) = -0.3183x0.8535 = 0.2717$ $h(-2) = h(2) = h_d(2)w_{Hn}(2)$ =0x0.5=0 $h(-3) = h(3) = h_d(3)w_{Hn}(3) = -0.1061x0.1464 = -0.0155$ $h(-4) = h(4) = h_d(4)w_{Hn}(4)$ =0x0=0			
19.	**Multi-rate System:** after down sampling x(n) $v(n) = x(2n)$	**AP**	**CO5**	**16**



If we up sample $v(n)$ by 2, we get

$$v_u(n) = v\left(\frac{n}{2}\right) = \begin{cases} x(n), & \text{for } n = 0, \pm 2, \pm 4, \ldots \\ 0, & \text{otherwise} \end{cases}$$

If we delay $x(n)$ and down sample, we get

$$w(n) = x(2n - 1)$$

If we up sample $w(n)$, we get

$$w_u(n) = w\left(\frac{n}{2}\right) = \begin{cases} x(n-1), & \text{for } n = 0, \pm 2, \pm 4, \ldots \\ 0, & \text{otherwise} \end{cases}$$

$$y(n) = v_u(n-1) + w_u(n)$$

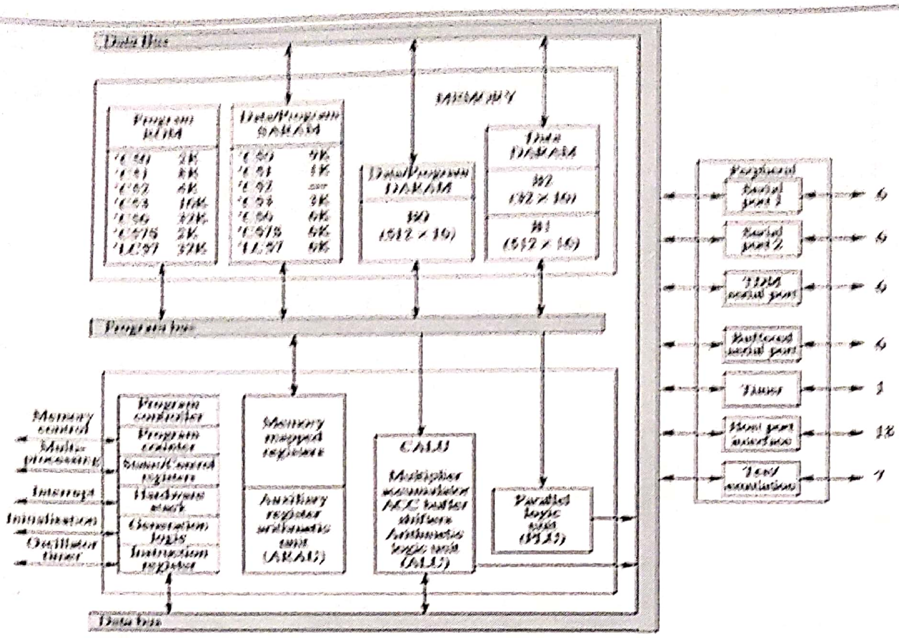
$$v_u(n) = \{x(0), 0, x(2), 0, x(3), \ldots\}$$

(OR)

20.	**Architecture of TMS320C5X** **4 marks**	**AP**	**CO5**	**16**

- The TMS320C5X generation of the Texas instruments TMS320C50 digital signal processor is fabricated with CMOS IC technology. It is a fixed point, 16-bit processor running at 40 MHz.
- The single instruction execution time is 50 nsec.
- Its architectural design is based on the combination of advanced Harvard architecture, on-chip peripherals and on-chip memory.
- The TMS320C50 has a programmable memory map which can vary for each application.
- On-chip memory includes 10K words of the RAM and 2K words of the ROM.

4 marks



4 marks

The salient features required for efficient performance of DSP operations are:

(i) Multiplier and Multiplier Accumulator
(ii) Modified Bus Structure and Memory Access Schemes
(iii) Multiple Access Memory
(iv) Multiported Memory
(v) Very Long Instruction Word (VLIW) Architecture
(vi) Pipelining
(vii) Special Addressing Modes
(viii) On-Chip Peripherals

Applications **4 marks**

- It is used in seismic data processing.
- It is used in statistical signal processing.
- It is used in voice recognition systems.
- It is used in digital images (HD).

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