Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

(A constituent unit of MAHE, Manipal)

DEPARTMENT OF MECHATRONICS

V SEMESTER B.TECH. (MECHATRONICS)

END SEMESTER EXAMINATIONS, DECEMBER 2023

SUBJECT: DIGITAL SIGNAL PROCESSING [MTE 3151]

(06/12/2023)

Time: 3 Hours **MAX. MARKS: 50**

Instructions to Candidates:

- Answer **ALL** the questions.
- *Data not provided, may be suitably assumed*

Q. No		M	CO	PO	LO	BL
`1A.	Consider an LTI system, initially at rest, described by the difference equation $y(n) = 2y(n-1) + 5y(n-3) + 2x(n) - x(n-1) + 3x(n-2)$ i) Determine the transfer function of the system. ii) Construct the direct form I and direct form II realization of this system and comment on the requirement of delay elements for the realization	5	3	2	2	3
1B.	A linear phase digital filter with transfer function $H(\omega)$ shown as follows is desired: $x(n) = \begin{cases} 1 & \omega \leq \frac{\pi}{4} \\ 0 & \frac{\pi}{4} \leq \omega \leq \pi \end{cases}$ i) Identify whether it a low-pass, high-pass, band-pass, or band-stop filter. Justify your answer ii) Sketch the spectrum of its transfer function iii) Determine the impulse response $h(n)$ from $H(\omega)$	3	3	2	1	4
1C.	Consider 2 real sequences $x_1[n] = \{1\ 2\ 3\ 0\}$, $x_2[n] = \{1\ 3\ 2\ 1\}$. Let $X_1(K)$ and $X_2(K)$ be 4-point DFTs of $x_1[n]$ and $x_2[n]$ respectively. Another sequence $x_3[n]$ is derived by taking 4-point inverse DFT of $X_3(K) = X_1(K)\ X_2(K)$. Find the value of $x_3[2]$	2	2	2	5	4
2A.	For the given specifications of digital IIR filter, determine the optimal order of the filter. Lower stopband edge =25Hz Lower passband edge =100Hz	4	3	3	2	4

	Upper stopband edge =225Hz Upper passband edge =150Hz Stopband attenuation= 18dB Passband ripple =3dB Sampling frequency =500Hz					
2B.	Given a concert recording with interference at a frequency of 2.2 kHz, design a digital filter with a length of 5 and a sampling frequency of 8 kHz to specifically eliminate unwanted signals within the frequency range of 2 kHz to 2.4 kHz. Evaluate the specifications required to design this filter effectively for the purpose of signal cleanup in the recorded music.	**3**	**3**	**3**	**2**	**4**
2C.	An FIR digital filter has the transfer function $H(z) = \frac{1}{2}(1 + z^{-1})(1 - z^{-1})$ i) Sketch the pole-zero diagram of this system. ii) Sketch $\lvert H(e^{jw})\rvert$ and determine the 3db cutoff frequency. iii) Identify whether it a low-pass, high-pass, band-pass, or band-stop filter. Justify your answer.	**3**	**3**	**3**	**3**	**4**
3A.	A filter needs to be designed to filter the low frequency disturbance and enhance the quality of signal transmission in a wireless communication system operating in a noisy environment, ensuring efficient data transfer while minimizing interference. The digital specifications of the required filter are given below. (Use bilinear transformation) Stop band ripple $\leq 15\ dB$ Pass band edge = 150Hz Pass band attenuation > 1dB Stop band edge =100Hz Sampling frequency =1kHz	**5**	**3**	**3**	**5**	**5**
3B.	Compute $H(z)$ using the impulse invariant technique for the analog system function $H(s) = \frac{1}{(s+1)(s^2 - 8s + 15)}$ Assume $T = 1s$.	**3**	**3**	**2**	**2**	**3**
3C.	Design the transfer function of 5th order LPF using Butterworth approximation.	**2**	**3**	**2**	**2**	**5**
4A.	Design a digital Butterworth filter that satisfies the following constraints using bilinear transformation. Assume $T = 2s$. $0.8 \leq \lvert H(e^{jw})\rvert \leq 1, \quad 0 \leq w \leq 0.2\pi$ $\lvert H(e^{jw})\rvert \leq 0.2, \quad 0.4\pi \leq w \leq \pi$	**5**	**3**	**3**	**2**	**5**
4B.	Convert the analog filter with transfer function $H_a(s)$ to digital filter using bilinear transformation.	**3**	**3**	**3**	**2**	**3**

	$H_a(s) = \frac{(s+0.1)}{(s+0.1)^2+16}$					
4C.	During frequency transformation using bilinear transformation, there occurs a nonlinear relationship between the analog and digital frequencies. Identify this effect and recommend effective strategies or techniques to mitigate these distortions while ensuring the accurate preservation of analog filter specifications in practical digital filter design.	**2**	**3**	**2**	**2**	**4**
5A.	Discuss the architectural improvements and steps can be taken to develop an efficient, low-power, high-speed FFT implementation that minimizes computational complexity and memory usage, enabling faster processing in applications like signal processing, image processing, communication systems, and bio-robotics.	**5**	**4**	**3**	**3**	**4**
5B.	EEG (electroencephalogram) is a non-invasive technique used to measure the brain's electrical activity by detecting the voltage fluctuations on the scalp. Describe the various signal processing methods which could be adopted for analyzing such signals. Comment on the various applications for which those signal processing methods could be employed and the safety and risk factor involved in it.	**3**	**4** **5**	**3**	**3**	**4**
5C.	Construct the cascade realization of this system and comment on the requirement of multipliers, adders and delay elements for the realization $H(z) = \frac{1-z^{-1}}{(1+3z^{-1})(1+5z^{-1})}$	**2**	**3**	**2**	**2**	**4**