

## **BMPC3002 SIGNALS AND SYSTEMS IN BIOMEDICAL ENGINEERING (3-0-0)**

### **Course Objective:**

This course aims to provide students with an in-depth understanding of signal processing concepts applied to biomedical systems. It covers time and frequency domain analysis, transform techniques, and digital filter structures. Emphasis is placed on interpreting and processing biomedical signals for diagnostic and research purposes in healthcare technologies.

### **Module-I: (12 Hrs)**

Introduction to Signal & Systems: Signals: Definition of Signal, Various Types of Signals and its classification, Standard Test Signals, Representation of signals in continuous and discrete domain, Basic Signal Operations - Shifting, Time Scaling and Amplitude Scaling Operations, signal sampling and quantization, discretization of continuous time signals, Sampling Theorem, Nyquist Criteria, Aliasing and Quantization as a error in Sampling Process, Reconstruction of Sampled Signals, Various types of 1D and 2D signals

Systems: Definition of System, Types of Systems and its classification, Difference between continuous and discrete time domain systems

Biomedical Aspects in Signal and Systems: Classification of Various Bio signals, Types of Biological systems, Types of 1D and 2D signals arising/captured from human body, Deciding Sampling Rate - Nyquist Criteria for various Biomedical Signals, Various Noises in Biomedical Signals

### **Module-II: (10 Hrs)**

Time Domain Analysis of Discrete Time System: Introduction of discrete time signal and systems, Properties of discrete time systems, Classification of discrete time systems, Systems characterized by Linear Time Invariance property, Convolution of LTI Systems using Mathematical method, Tabular method and Graphical method, Circular Convolution, LTI system characterized by differential equation: Homogeneous and Particular Solution of differential equation, Correlation of Signals - Cross correlation and Autocorrelation

Biomedical Case Study: Convolution of 1D and 2D signals of Biomedical origin, Correlation of signals of Biomedical origin.

### **Module-III: (10 Hrs)**

Frequency Domain Characterization of Signals & Systems by Transform Techniques

(PART-I):

Frequency Domain analysis of First and Second Order LTI Systems Z-Transform: Introduction to Z-Transform, Region of Convergence (ROC), Properties of Z – Transform, Z-Transform of Standard Sequences, one sided & Two sided Z –Transform, Solution of Differential Equation using Z-Transform, Frequency Response from poles and zero locations, Connection between Laplace Transform & Z - Transform, Inverse Z – Transform.

### **Module-IV: (08 Hrs)**

Frequency Domain Characterization of Signal & System by Transform Techniques

(PART-II):

Discrete Fourier Transform: Representation of Periodic Sequence by Fourier Series, Introduction to Discrete Fourier Transform (DFT), Properties of DFT, DFT of Standard Signals, Implementation of DFT for Frequency domain analysis of discrete signals, Linear Convolution using DFT

Fast Fourier Transform: Introduction to Fast Fourier Transform, Radix-2 FFT algorithm, Radix-2 Decimation in Time FFT (DIT-FFT), Radix -2 Decimation in Frequency FFT (DIF-FFT), Goertzel Algorithm Spectrum Power, Spectral Density and its Importance Relation between Discrete Fourier Transform (DFT) and Z- Transform, Importance of DFT and FFT as a primary tool for Biomedical Signal Analysis

### **Module-V: (08 Hrs)**

Structures for Linear Time Invariant System & system characterized by Linear Constant Coefficient Differential Equation (Structure for Digital Filters): System classification based on the impulse response – IIR & FIR system, System classification bases on output response – Recursive & Non – Recursive System

IIR Filter Structure: Direct Form I & II Realizations, Cascade combination of Second Order System, Parallel combination of Second Order Systems

FIR Filter Structure: Direct form realization, Cascade form, Frequency Sampling form and Lattice Structure, Representation and dependency of Zero-pole plot on nature of IIR/FIR systems.

**Course Outcomes (COs)**

- CO1: Identify and classify various types of signals and systems, including biomedical signals, and understand fundamental signal operations.
- CO2: Explain the concepts of sampling, quantization, aliasing, and system properties in both time and frequency domains relevant to biomedical applications.
- CO3: Apply convolution and correlation techniques to analyze biomedical signals in time domain using mathematical, graphical, and tabular methods.
- CO4: Analyze discrete-time systems using Z-Transform, DFT, and FFT, and interpret their frequency response for biomedical signal processing.
- CO5: Evaluate the behavior of LTI systems through digital filter structures (IIR & FIR) and use pole-zero plots to assess system performance in biomedical scenarios.

**Reference Books:**

1. Principles of Linear Systems and Signals , B. P. Lathi, 2nd Edition, Oxford Press (2009)
2. Signals and Systems, A. Anand Kumar, 2nd Edition, PHI Learning Private Limited
3. Signals and Systems, Alan V. Oppenheim and Alan Wilsky, 2nd Edition, Prentice Hall Signal Processing Series
4. Signals and Systems for Bioengineers - A MATLAB based Introduction, 2nd Edition, John Semmlow, Academic Press
5. Signals and Systems in Biomedical Engineering, 2nd Edition, Robert P. Northrop, 2nd Edition, CRC Press
6. Digital Signal Processing, N. G. Palan, Tech Max Publications