# DIGITAL SIGNAL PROCESSING AND ITS APPLICATIONS

**PROF. VIKRAM M. GADRE**
Department of Electrical Engineering
IIT Bombay

**PRE-REQUISITES :** It would help if they have an exposure to Signals and Systems, although this is not a strict pre-requisite

**INTENDED AUDIENCE :** Third Year Undergraduates/ First Year Graduate (Masters Students) INDUSTRIES APPLICABLE TO : Texas Instruments, Analog Devices, Samsung, almost any industry which works in communication and signal processing would value this training, as a core discipline.

**INDUSTRIES SUPPORT:** Texas Instruments, Analog Devices, Samsung, almost any industry which works in communication and signal processing would value this training, as a core discipline.

## COURSE OUTLINE:

The course begins with a discussion on Discrete Time signals and systems. This is followed by an introduction of the Z transform, its properties and system theoretic implications. The foundations of digital filter design and realization are built up. Practice Problems with solutions, summaries of each lecture and illustrative explanations of concepts are all additionally provided, to enhance learning.

## ABOUT INSTRUCTOR :

Prof. Vikram M. Gadre completed his B.Tech in 1989 from Electrical Engineering (CGPA 9.90 on scale of 10), Indian Institute of Technology, Delhi and Ph.D in 1994 from from Electrical Engineering, Indian Institute of Technology, Delhi. His research interests are Communication and signal processing, with emphasis on multiresolution and multirate signal processing, especially wavelets and filter banks: theory and applications

## COURSE PLAN :

**Week 1**: Lecture 1: Introduction: Digital signal processing and its objectives
Lecture 2A: Introduction to sampling and Fourier Transform
Lecture 2B: Sampling of sine wave and associate complication
Lecture 3A: Review of Sampling Theorem
Lecture 3B: Idealized Sampling, Reconstruction
Lecture 3C: Filters And Discrete System

**Week 2:** Lecture 4A: Answering questions from previous lectures.
Lecture 4B: Desired requirements for discrete system
Lecture 4C: Introduction to phasors
Lecture 4D: Advantages of phasors in discrete systems
Lecture 5A: What do we want from a discrete system?
Lecture 5B: Linearity - Homogeneity and Additivity
Lecture 5C: Shift Invariance and Characterization of LTI systems
Lecture 6A: Characterization of LSI system using it's impulse response
Lecture 6B: Introduction to convolution
Lecture 6C: Convolution: deeper ideas and understanding

**Week 3:** Lecture 7A: Characterisation of LSI systems, Convolution-properties
Lecture 7B: Response of LSI systems to complex sinusoids
Lecture 7C: Convergence of convolution and BIBO stability
Lecture 8A: Commutativity & Associativity
Lecture 8B: BIBO Stability of an LSI system
Lecture 8C: Causality and memory of an LSI system.
Lecture 8D: Frequency response of an LSI system.
Lecture 9A: Introduction and conditions of Stability
Lecture 9B: Vectors and Inner Product.
Lecture 9C: Interpretation of frequency Response as Dot Product
Lecture 9D: Interpretation of Frequency Response as Eigenvalues

**Week 4:** Lecture 10A: Discrete time fourier transform
Lecture 10B: DTFT in LSI System and Convolution Theorem.
Lecture 10C: Definitions of sequences and Properties of DTFT.
Lecture 11A: Introduction to DTFT, IDTFT
Lecture 11B: Dual to convolution property
Lecture 11C: Multiplication Property, Introduction to Parseval's theorem
Lecture 12A: Introduction And Property of DTFT
Lecture 12B: Review of Inverse DTFT
Lecture 12C: Parseval's Theorem and energy and time spectral density

**Week 5**: Lecture 13A: Discussion on Unit Step
Lecture 13B: Introduction to Z transform
Lecture 13C: Example of Z transform
Lecture 13D: Region of Convergence
Lecture 13E: Properties of Z transform
Lecture 14A: Z- Transform
Lecture 14B: Rational System
Lecture 15A: Introduction And Examples Of Rational Z Transform And Their Inverses
Lecture 15B: Double Pole Examples And Their Inverse Z Transform
Lecture 15C: Partial Fraction Decomposition
Lecture 15D: LSI System Examples

**Week 6:** Lecture 16A: Why are Rational Systems so important?
Lecture 16B: Solving Linear constant coefficient difference equations which are valid over a finite range of time
Lecture 16C: Introduction to Resonance in Rational Systems
Lecture 17A: Characterization of Rational LSI system
Lecture 17B: Causality and stability of the ROC of the system function
Lecture 18A: Recap Of Rational Systems And Discrete Time Filters
Lecture 18B: Specifications For Filter Design
Lecture 18C: Four Ideal Piecewise Constant Filters
Lecture 18D: Important Characteristics Of Ideal Filters

**Week 7:** Lecture 19A: Synthesis of Discrete Time Filters, Realizable specifications
Lecture 19B: Realistic Specifications for low pass filter. Filter Design Process
Lecture 20A: Introduction to Filter Design. Analog IIR Filter,FIR discrete-time filter, IIR discrete-time filter.
Lecture 20B: Analog to discrete transform
Lecture 20C: Intuitive transforms, Bilinear Transformation
Lecture 21A: Steps for IIR filter design
Lecture 21B: Analog filter design using Butterworth Approximation

**Week 8:** Lecture 22A: Butterworth filter Derivation And Analysis of butterworth system function
Lecture 22B: Chebychev filter Derivation
Lecture 23: Midsem paper review discussion
Lecture 24A: The Chebyschev Approximation
Lecture 24B: Next step in design: Obtain poles
Lecture 25A: Introduction to Frequency Transformations in the Analog Domain
Lecture 25B: High pass transformation
Lecture 25C: Band pass transformation

**Week 9:** Lecture 26A: Frequency Transformation
Lecture 26B: Different types of filters
Lecture 27A: Impulse invariant method and ideal impulse response
Lecture 27B: Design of FIR of length (2N+1) by the truncation method,Plotting the function V(w)
Lecture 28A: IIR filter using rectangular window, IIR filter using triangular window
Lecture 28B: Proof that frequency response of an fir filter using rectangular window function

centered at 0 is real.
**Week 10:** Lecture 29A: Introduction to window functions

Lecture 29B: Examples of window functions
Lecture 29C: Explanation of Gibb's Phenomenon and it's application

Lecture 30A: Comparison of FIR And IIR Filter's
Lecture 30B: Comparison of FIR And IIR Filter's
Lecture 30C: Comparison of FIR And IIR Filter's

Language Code.

Lecture 31A: Introduction and approach to realization (causal rational system)
Lecture 31B: Comprehension of Signal Flow Graphs and Achievement of Pseudo Assembly

**Week 11:** Lecture 32A: Introduction to IIR Filter Realization and Cascade Structure

**Week 12:** Lecture 35A: Introductory Remarks of Discrete Fourier Transform and Frequency Domain Sampling

Lecture 32B: Cascade Parallel Structure
Lecture 32C: Lattice Structure
Lecture 33A: Recap And Review of Lattice Structure, Realization of FIR Function.
Lecture 33B: Backward recursion, Change in the recursive equation of lattice.
Lecture 34A: Lattice structure for an arbitrary rational system
Lecture 34B: Example realization of lattice structure for rational system

Lecture 35B: Principle of Duality, The Circular Convolution