VNR Vignana Jyothi Institute of Engineering and Technology

IV Year B.Tech EEE – I Sem	**L**	**T/P/D**	**C**
	3	**0**	**3**

(5EC17) PRINCIPLES OF DIGITAL SIGNAL PROCESSING

Course Prerequisites: Network Analysis, Advanced Calculus, Linear and Digital IC applications

Course Objectives

- To understand characteristics of discrete time signals and systems
- To analyze and process signals using various transform techniques
- To understand various factors involved in design of digital filters
- To understand the features of TMS24XX processors.

Course Outcomes

After completion of this course the student is able to

- Analyze and process signals in the discrete domain
- Design filters to suit specific requirements for specific applications
- Perform statistical analysis and inferences on various types of signals
- Design and control the electrical drive using different 24xx processors.

UNIT-I

INTRODUCTION

Classification of continuous time Signals & Systems. Linear shift invariant systems, stability and causality, Sampling of Continuous signals- Introduction to digital signal processing-Sampling process-Sampling theorem.

Classification of discrete time signals and sequences

UNIT – II

FOURIER ANALYSIS

Introduction toDiscrete Fourier series, Discrete Fourier Transform: Properties of Discrete Fourier Transform, linear convolution and circular convolution of sequences using DFT, Computation of DFT, Relation between DFT and Z-Transform.

Fast Fourier transform: Radix -2 decimation in time and decimation in frequency FFT algorithms, Inverse FFT.

UNIT – III

Z- TRANSFORM

Introduction to Z-transform, Properties of Z- Transform, Inverse Z- Transform, Application of Z- Transforms for Linear constant coefficient difference equations, Realization of Digital filters, system function – stability criterion.

UNIT – IV

IIR FILTERS

Analog filter approximations-Design of Butterworth Chebyshev filters, Design of IIR digital filter from analog filter using- impulse invariant and bilinear transformation techniques, design examples, realization of IIR filters-direct, canonic, cascade, and parallel forms.

UNIT – V

FIR FILTERS

Characteristics of FIR Digital Filters, Frequency response, Design of FIR filters using – Rectangular, Hamming, Bartlett- windows , frequency sampling technique, comparison of FIR and IIR filters, realization of IIR filters-direct, cascade forms. Architecture and features of TMS 320F 2407, Applications of DSP.

TEXT BOOKS:

1. Digital signal processing: principles, algorithms and applications-John G.Proakis, D.G.Manolakis, 3rd edition, PHI-2007.
2. Discrete time signal processing-A.V.Oppenheim and R.W.Schaffer,PHI,2009.
3. TMS 320F 24xx Manuals

REFERENCES:

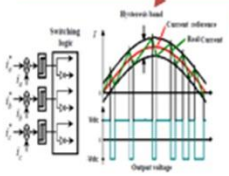
1. Digital signal processing-Fundamentals and applications-LiTan, Elsevier,2008.
2. Fundamentals of digital signal processing using MATLAB-Robert J.Schilling, Sandra L.Harris, Thomson, 2007.
3. Digital signal processing-S.Salivahanan, A.Vallavaraj, C.Gnanapriya, TMH, 2009.
4. Discrete systems and digital signal processing with MATLAB-Taan S.ElAli,CRC Press,2009.
5. P Venkata Ramani, M.Bhaskar, “Digital Signal Processor; Architecture, Programming & Application”, TataMcGrawHill-2001

Scenario Mapping on Principles of Digital Signal Processing

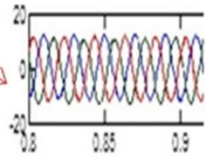
Sensorless Control of PMSM with Flux Weakening Operation for Washing Machine Application

Department of Electrical and Electronics Engineering

UNIT-I
Classification of Signals to generate PWM to control converter



Output from the Inverter

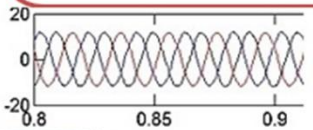


Inverter

UNIT- V
Application of DSP in Drives: Speed Control of a Washing Machinem

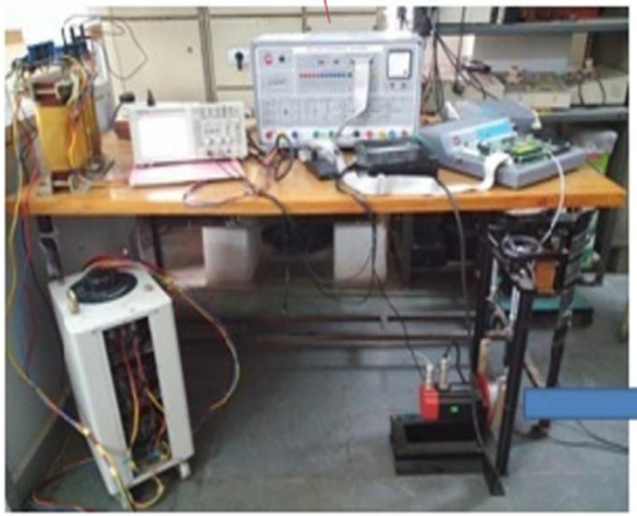
Analysis of signals in time domain using DFT & FFT to analyze harmonics which are present in the current waveform

UNIT –III
Analysis of discrete time signal in frequency domain using Z-Transform

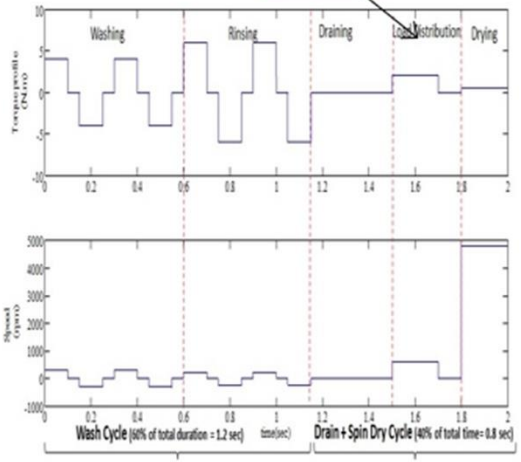


Prepared by:
Dr. N.Krishna Kumari
&
Dr. Rashmi Kapoor

UNIT -IV
IIR Filters: Removes noise from a given signal of infinite in nature
UNIT -V
IIR Filters: Removes noise from a given signal of infinite in nature



Load and Speed profile of Washing Machine



VALLURUPALLI NAGESWARA RAO VIGNANA JYOTHI INSTITUTE OF ENGINEERING AND TECHNOLOGY

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NBA Accredited CE, EEE, ME, ECE, CSE, EIE, IT -B.TechPrograms
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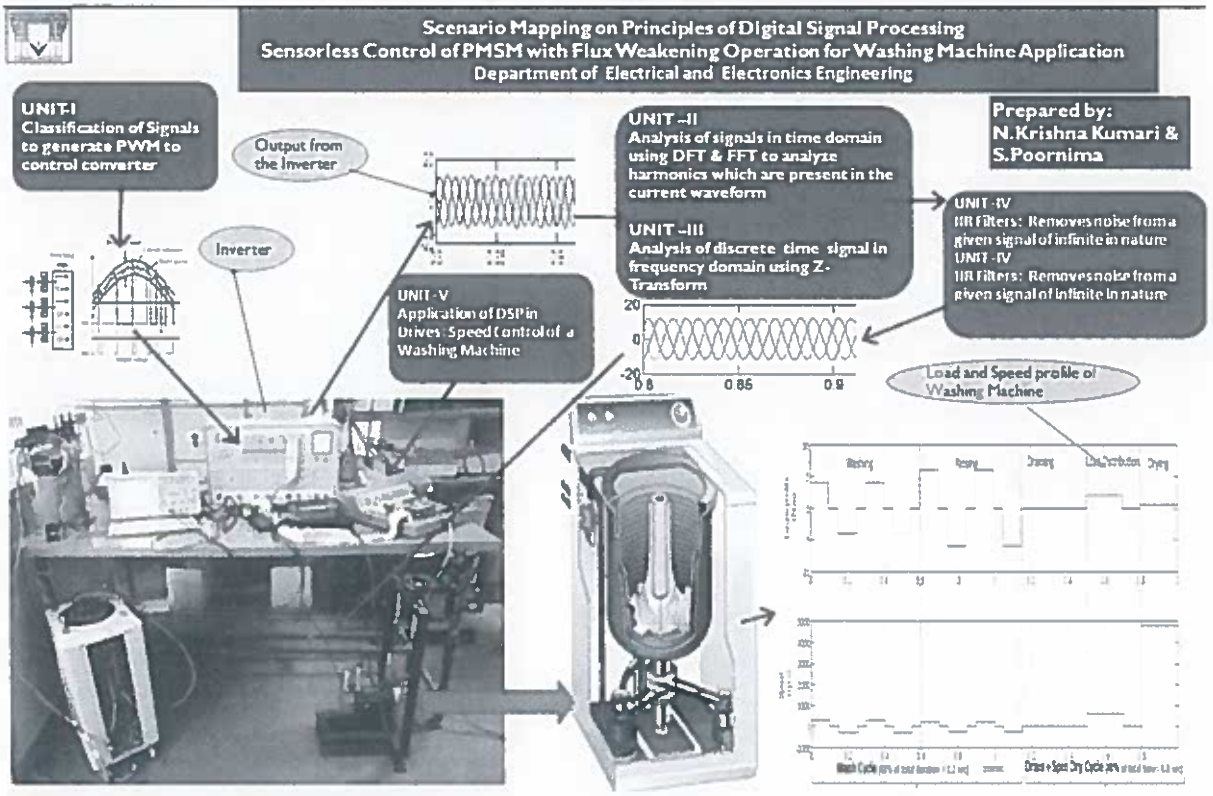
TAMASOMA JYOTIRGAMAYA
Estd.1995

Industry Endorsement

This is to endorse that the following WIT &WIL scenario titled "Sensorless Control of PMSM with Flux Weakening Operation for Washing Machine Application" can be used as teaching–learning methodology for the subject titled **"Principles of Digital Signal Processing"** for **B.Tech IV Year** Electrical and Electronics Engineering Students.

WIT & WIL methodology is a teaching –learning process of **VNR VIGNANA JYOTHI INSTITUTE OF ENGINEERING AND TECHNOLOGY**, which would aim to bridge the gap between institutional academic systems and industry requirements. The definition of " WIT& WIL" method explained as an active methodology of teaching and learning activity with " Why am I Teaching & What I am Teaching" from Teacher's prospective. And from student's prospective "Why am I Learning & What I am Learning".



Signature of Industrial Expert

Sree Lakshmi Ratna. Y
Sr. Engineer,
United Technologies, Hyd.

Department of Electrical and Electronics Engineering

Principles of Digital Signal Processing Theory

Application/ Scenario taken:	Sensorless Control of PMSM with Flux Weakening Operation for Washing Machine Application

Introduction: This scenario focuses on a highly-integrated and digitized servo control system for permanent magnet synchronous machine (PMSM) used in washing machine, which is based on digital signal processor (DSP). The field oriented control (FOC) algorithm and sinusoidal pulse width modulation technique are implemented in the system.

Selection of Motor: As it is demanded to have good qualities of reliability, stabilization, exact orientation and speediness in radar-driven system, it is the PMSM servo system that can satisfy its requirements. PMSM motors have strengths of maintenance free, high controllability, robustness against environment, high efficiency, and high-power-factor operation. With the precision control, its potential advantages can be fully realized to accomplish the rigorous demand of speed control of washing machine. In order to meet the demanding requirements, the field oriented control (FOC) algorithm and sinusoidal pulse width modulation technique (SPWM) technique are adopted.

Application of DSP (Unit-V): The DSP used here for real-time signal sampling, processing, transformation and computation. The control system makes full use of real-time calculation capability of DSP.It is the DSP that makes the complicated real-time calculation of various transformations and SPWM algorithm possible. It employs the information of rotor angle and stator currents to perform all the computations.

Generation of Gate Signals to the Inverter (Unit-I): In Sine triangle PWM, sinusoidal signals and triangular signals are generated and compared the signals to implement PWM technique. Here sine signals are called as reference signals and triangle signals are called carrier signals. Reference signal is generated In Real time application DSP Processor **generates the signals** i.e.reference signal is generated by using parameters based on given V/F reference i.e. amplitude and frequency and carrier wave is generated with proper

switching frequency. We use semiconductor devices as switches in inverter. Output waveform of inverter will be deviated from sinusoidal shape due to presence of harmonics.

Harmonic Analysis and the use of FFT, DFT, Z-Transform and Filters (Unit-II, III, IV and V): The order of different harmonics can be found using Fast Fourier transform analysis. A FFT spectrum analyser computes the Discrete Fourier Transform (DFT), a mathematical process that transforms the input signal waveform into the components of its frequency spectrum. This analysis enables to make output more sinusoidal by eliminating dominant harmonics. Appropriate filter has to be designed to eliminate dominant harmonics from the information obtained from FFT spectrum. Digital filters will be preferred over analog filters due to customization and accuracy. Designing of digital filters (IIR and FIR filters) can be done in discrete domain using the Z-transform based on required specification.

Convolution (Unit-II): Parameters of reference wave phasor corresponding to referenced speed such as amplitude, phase and frequency can be computed using Fourier transforms with linear and circular convolution**.**

Dr. N. Krishna Kumari

Dr. Rashmi Kapoor

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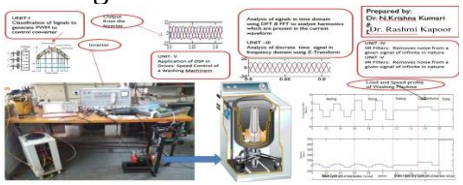
Course Name: Principle of Digital Signal Processing Year /Sem: IV/Isem

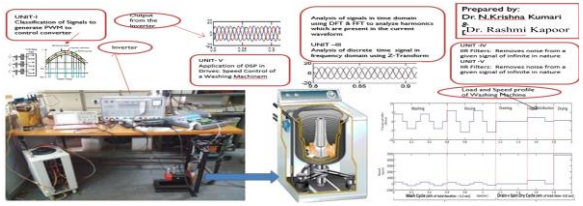
Course Code: 5EC17 Course coordinator: Dr. Rashmi Kapoor

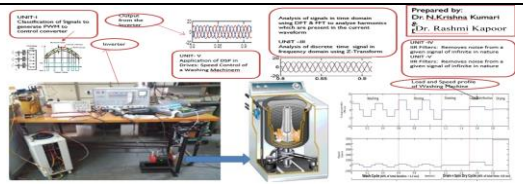
Lecture No.	Content of Syllabus	Wit & WIL SCENERIO Mapping	Teaching Plan			
			Lecture Dates	Delivery Methodologies	Learning Resourses/Reference	Course Outcomes
1.	PDSP -Scenario explanation	Sensor less control of PMSM for washing machine 	20/8/2020	DM8		CO1, CO2, CO3,CO4

The scenario chosen to map the PDSP syllabus is sensor less control of Permanent magnet synchronous motor with flux weakening control for washing machine application. To operate washing machine in various modes, the motor need to be operated in various modes and at various speeds. To control the modes of operation of motor an inverter is used. An inverter can be controlled by pulse width modulation technique. For which a sinusoidal signal is compared with a constant signal to generate the PWM pulses for inverter. Various types of continuous and discrete time signals are covered in first unit. For proper operation of motor the output of the inverter should be free from any harmonic components. So Fourier transform and Z transform can be used for frequency domain analysis of the inverter output, that are covered in second and third unit of the syllabus.

If any noise signal is detected filters can be used to suppress these noise components. These filters are covered in forth and fifth unit of the syllabus.

UNIT-1 INTRODUCTION



Lecture No.	Content of Syllabus	Wit & WIL SCENERIO Mapping	Teaching Plan			
			Lecture Dates	Delivery Methodologies	Learning Resourses/Reference	Course Outcomes
2	Characteristics of Signals (Energy , Power and its characteristics)	 Fig.1	20/8/2020	DM1,DM4	T1,T5	CO1,CO3
3.	Representation of Signals		21/8/2020	DM1	T1,T5	CO1,CO3
4.	Representation of Signals	 Fig.2	27/8/2020	DM1,DM4,DM8	T1,T5	CO1,CO3
5.	Operations on Signals		28/8/2020	DM1	T1,T5	CO1,CO3
6.	Operations on Signals		29/8/2020	DM1,DM8,DM4	T1,T5	CO1,CO3
7.	Characteristics of systems and		3/9/2020	DM1,DM4	T1,T5	CO1,CO3

	its verification					
8.	Classification of discrete time systems		4/9/2020	DM1,DM4,DM8	T1,T5	CO1,CO3
9.	Introduction to convolution Linear convolution		5/9/2020	DM1,DM4,DM8	T1,T5	CO1,CO3
10.	Sampling and aliasing		10/9/2020	DM1,DM4,DM8	T1,T5	CO1,CO3
11	Sampling theorem		11/9/2020	DM1,DM4,DM8	T1,T5	CO1,CO3
Brief Description: knowledge of various discrete time signals will help us to understand how the PWM can be implemented on a digital signal processor using a triangular discrete time signal and discrete time unit step signals or a sine and triangular signal if SPWM implementation is required. As motor input as well as inverter gate signal both should be continuous time signals the processors output need to be converted to analog signal. For proper reconstruction of the signal sampling frequency should be chosen very carefully that understanding will be given by sampling theorem. Figure 2 is the real time set up of a Digital signal processor generating PWM pulses.						

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Course Name: Principle of Digital Signal Processing Year /Sem: IV/Isem

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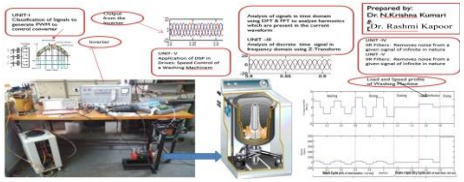
1.	PDSP -Scenario explanation	Sensor less control of PMSM for washing machine 	20/8/2020	DM8		CO1, CO2, CO3,CO4

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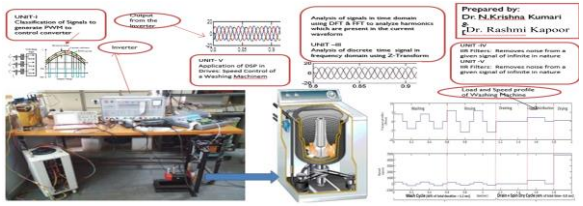
If any noise signal is detected filters can be used to suppress these noise components. These filters are covered in forth and fifth unit of the syllabus.

UNIT-1 INTRODUCTION



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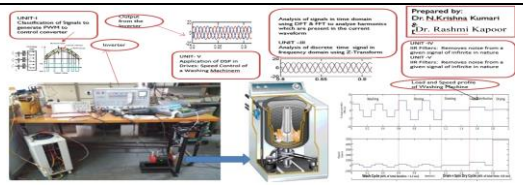
2	Characteristics of Signals (Energy , Power and its characteristics)	 Fig.1	20/8/2020	DM1,DM4	T1,T5	CO1,CO3
3.	Representation of Signals		21/8/2020	DM1	T1,T5	CO1,CO3
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5.	Operations on Signals		28/8/2020	DM1	T1,T5	CO1,CO3
6.	Operations on Signals		29/8/2020	DM1,DM8,DM4	T1,T5	CO1,CO3
7.	Characteristics of systems and		3/9/2020	DM1,DM4	T1,T5	CO1,CO3

	its verification					
8.	Classification of discrete time systems		4/9/2020	DM1,DM4,DM8	T1,T5	CO1,CO3
9.	Introduction to convolution Linear convolution		5/9/2020	DM1,DM4,DM8	T1,T5	CO1,CO3
10.	Sampling and aliasing		10/9/2020	DM1,DM4,DM8	T1,T5	CO1,CO3
11	Sampling theorem		11/9/2020	DM1,DM4,DM8	T1,T5	CO1,CO3
Brief Description: knowledge of various discrete time signals will help us to understand how the PWM can be implemented on a digital signal processor using a triangular discrete time signal and discrete time unit step signals or a sine and triangular signal if SPWM implementation is required. As motor input as well as inverter gate signal both should be continuous time signals the processors output need to be converted to analog signal. For proper reconstruction of the signal sampling frequency should be chosen very carefully that understanding will be given by sampling theorem. Figure 2 is the real time set up of a Digital signal processor generating PWM pulses.						

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Course Name: Principle of Digital Signal Processing
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Dr. Rashmi Kapoor

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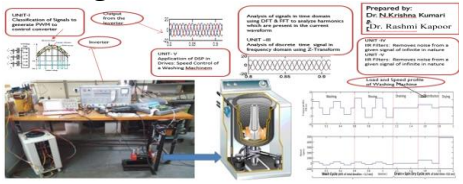
1.	PDSP -Scenario explanation	Sensor less control of PMSM for washing machine 	19-09-2020	DM8		CO1, CO2, CO3,CO4

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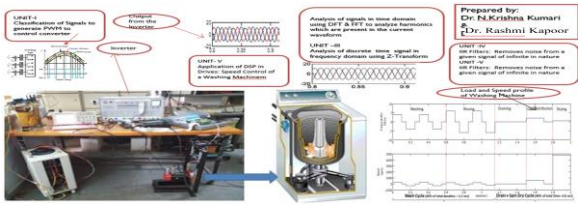
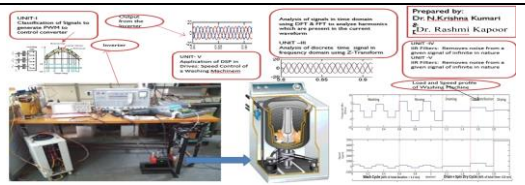
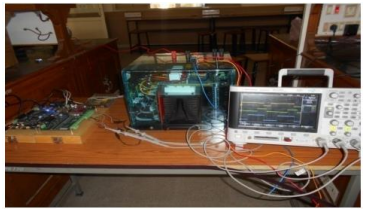
If any noise signal is detected filters can be used to suppress these noise components. These filters are covered in fourth and fifth unit of the syllabus.

UNIT-2 Fourier Analysis



Lecture No.	Content of Syllabus	Wit & WIL SCENERIO Mapping	Teaching Plan			
			Lecture Dates	Delivery Methodologies	Learning Resourses/Reference	Course Outcomes
1.	Introduction to Discrete Fourier series		19-09-2020			CO1,CO 3
2	Discrete Fourier Transform		24-09-2020	DM1,DM4	T1,T5	CO1,CO 3
3.	Properties of			DM1	T1,T5	CO1,CO 3

	Discrete Fourier Transform	Fig.1	25-09-2020			
4.	linear convolution with problems	 Fig.2	26-09-2020	DM1,DM4,DM8	T1,T5	CO1,CO 3
5.	circular convolution with problems		01-10-2020	DM1	T1,T5	CO1,CO 3
6.	Computation of DFT		03-10-2020	DM1,DM8,DM4	T1,T5	CO1,CO 3
7.	Relation between DFT and Z-Transform		08-10-2020	DM1,DM4	T1,T5	CO1,CO 3
8.	DFT based problems		09-10-2020	DM1,DM4,DM8	T1,T5	CO1,CO 3
9.	Introduction to Fast Fourier Transform		15-10-2020	DM1,DM4,DM8	T1,T5	CO1,CO 3
10.	Radix -2 decimation in time and decimation in		16-10-2020	DM1,DM4,DM8	T1,T5	CO1,CO 3

	frequency FFT algorithms					
11	DIFFT based Problems		17-10-2020	DM1,DM4,DM8	T1,T5	CO1,CO 3

Convolution and correlation of signals are very important in communication. Convolution is a mathematical way of combining two signals to form a third signal. Correlation, which is similar to convolution, compares two signals to determine the degree of similarity between them. The determination of linear convolution of two signals by various methods, determination of periodic convolution of signals using various methods, cross correlation and autocorrelation of signals, power spectral density and energy spectral density are covered in Chapter 2.

Discrete-time Fourier transform (DTFT) is a method of representing a discrete-time signal in frequency domain. It is popular for digital signal processing because using this the complicated convolution operation of two sequences in time domain can be converted into a much simpler operation of multiplication in frequency domain. The DTFT, its properties and its use in the analysis of signals are explained in Chapter 2. The Fourier series representation of a periodic discrete-time sequence is called discrete Fourier series (DFS). The discrete Fourier transform (DFT) is a sampled version of DTFT.

The discrete Fourier series and its properties, the DFT and its properties, performing linear and circular convolutions using DFT, inverse discrete Fourier transform (IDFT) are also discussed in Chapter 2.

Fast Fourier Transform (FFT), a method developed by Cooley and Turkey is an algorithm for computing the DFT efficiently. The efficiency is achieved by adopting a divide and conquer approach which is based on decomposition of an N-point DFT into successively smaller DFTs and then combining them to give total transform. The computation of DFT by decimation-in-time (DIT) FFT algorithm and decimation-in-frequency (DIF) FFT algorithm, and computation of IDFT also by DIT FFT algorithm and DIF FFT algorithm and computation of DFT when N is a complex number by DIT FFT algorithm and DIF FFT algorithm are discussed in Chapter 2.

Convolution and correlation of signals are very important in communication. Convolution is a mathematical way of combining two signals to form a third signal. Correlation, which is similar to convolution, compares two signals to determine the degree of similarity between them. The determination of linear convolution of two signals by various methods, determination of periodic convolution of signals using various methods, cross correlation and autocorrelation of signals, power spectral density and energy spectral density are covered in Chapter 2.

Here convolution of Sinusoidal signal with PWM technique is convoluted with a triangular signal. The processed signal after this is given as a gate pulses to an Inverter. Which the required voltages are generated and are given to the motor. Figure 2 is the real time set up of a Digital signal processor generating PWM pulses.

Computation of these signals are performed using Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT) Techniques

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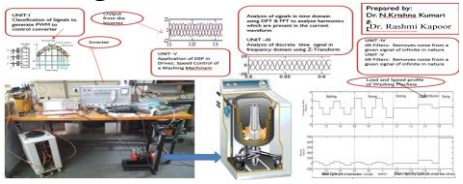
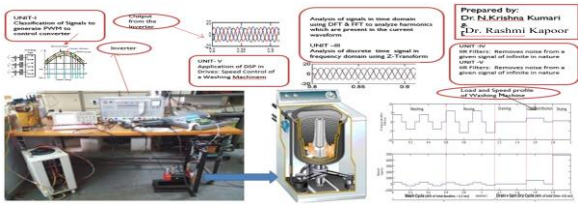
Course Name: Principle of Digital Signal Processing
Course Code: 5EC17

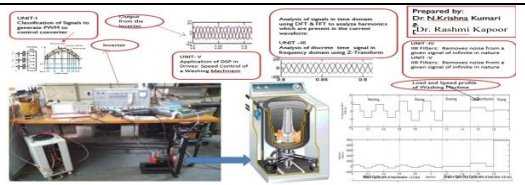
Year /Sem: IV/Isem
Course coordinators: Dr.N.Krishna Kumari
Dr. Rashmi Kapoor

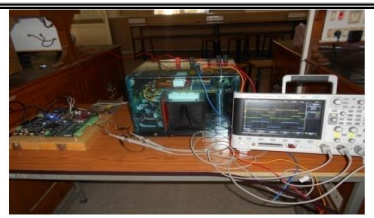
Lecture No.	Content of Syllabus	Wit & WIL SCENERIO Mapping	Teaching Plan			
			Lecture Dates	Delivery Methodologies	Learning Resourses/Reference	Course Outcomes
1.	PDSP -Scenario explanation	Sensor less control of PMSM for washing machine 	9/12/2020	DM8		CO1, CO2, CO3,CO4

The scenario chosen to map the PDSP syllabus is sensor less control of Permanent magnet synchronous motor with flux weakening control for washing machine application. To operate washing machine in various modes, the motor needs to be operated in various modes and at various speeds. To control the modes of operation of motor an inverter is used. An inverter can be controlled by pulse width modulation technique. For which a sinusoidal signal is compared with a constant signal to generate the PWM pulses for inverter. Various types of continuous and discrete time signals are covered in first unit. For proper operation of motor, the output of the inverter should be free from any harmonic components. So, Fourier transform and Z transform can be used for frequency domain analysis of the inverter output, that are covered in second and third unit of the syllabus.
If any noise signal is detected filters can be used to suppress these noise components. These filters are covered in fourth and fifth unit of the syllabus.

UNIT-3 Z-Transform

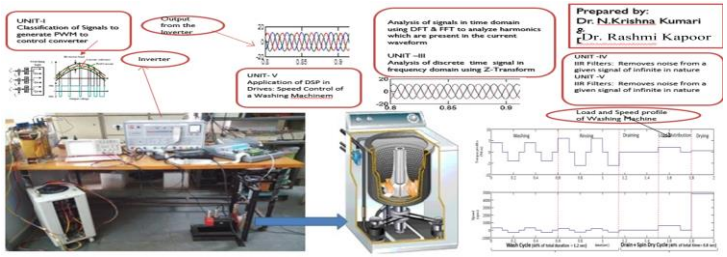


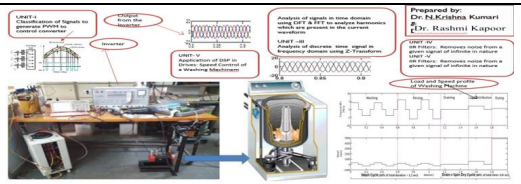
Lecture No.	Content of Syllabus	Wit & WIL SCENERIO Mapping	Teaching Plan			
			Lecture Dates	Delivery Methodologies	Learning Resourses/Reference	Course Outcomes
1.	Introduction to Z-transform	 Fig.1	9/12/2020	DM1,DM4	T1,T5	CO1,CO3
2.	Properties of Z-Transform		10/12/2020	DM1	T1,T5	CO1,CO 3
3.	Inverse Z-Transform		11/12/2020	DM1,DM4,DM8	T1,T5	CO1,CO 3
4.	Application of Z- Transforms for Linear constant		12/12/2020	DM1	T1,T5	CO1,CO 3

	coefficient difference equations	 Fig.2				
5.	Different types of realization of Digital filters		16/12/2020	DM1,DM8,DM4	T1,T5	CO2,CO 3
6.	Cascaded realization of Digital filters with problems		17/12/2020	DM1,DM4	T1,T5	CO2,CO 3,CO4
7.	Parallel realization of Digital filters with problems		18/12/2020	DM1,DM4,DM8	T1,T5	CO2,CO 3,CO4
8.	Direct realization of Digital filters with problems		19/12/2020	DM1,DM4,DM8	T1,T5	CO2,CO 3,CO4
9.	Canonic realization of Digital filters with problems		29/12/2020	DM1,DM4,DM8	T1,T5	CO2,CO 3,CO4
10.	Inverse Z-		30/12/2020	DM1,DM4,DM8	T1,T5	CO1,CO 3

	Transform					
Z-transform is a very powerful mathematical technique for analysis of discrete-time systems. Unilateral and bilateral Z-transform, inverse Z-transform, ROC and its properties, properties and theorems of Z-transform and solution of difference equations using Z-transform are introduced in Chapter 3. Realization of a discrete-time system means obtaining a network corresponding to the difference equation or transfer function of the system. Various methods of realization of discrete-time systems are described in Chapter 3. Also, Realization of Digital Infinite Impulse Response (IIR) and Finite Impulse Response Filter (FIR) are dealt in detail.						

UNIT-IV IIR Filters



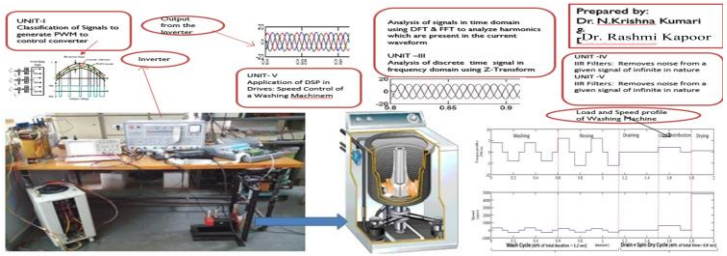
Lecture No.	Content of Syllabus	Wit & WIL SCENERIO Mapping	Teaching Plan			
			Lecture Dates	Delivery Methodologies	Learning Resourses /Reference	Course Outcomes
1	Introduction to designing of Analog Filter	 Fig.1	31/12/2020	DM1,DM4	T1,T5	CO2
2.	Designing of Butterworth filter for FFT with problems		6/1/2021	DM1	T1,T5	CO2
3.	Designing of Chebyshev filter For FFT with problems		7/1/2021	DM1,DM4,DM8	T1,T5	CO2
4.	Design of IIR		8/1/2021	DM1	T1,T5	CO2

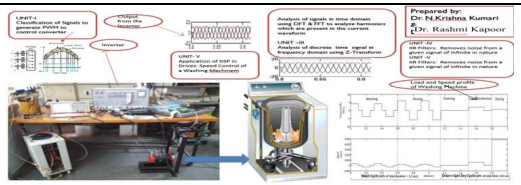
	digital filter impulse invariant techniques with problems					
5.	Design of IIR digital filter bilinear transformation techniques with problems		9/1/2021	DM1,DM8,DM4	T1,T5	CO2
6.	Realization of IIR filters with Direct realization		20/1/2021	DM1,DM4	T1,T5	CO2
7.	Realization of IIR filters with Canonic realization		21/1/2021	DM1,DM4,DM8	T1,T5	CO2
8.	Realization of IIR filters with Cascade and parallel realization		22/1/2021	DM1,DM4,DM8	T1,T5	CO2
9.	Realization of IIR filters to impulse invariant techniques with problems		23/1/2021	DM1,DM4,DM8	T1,T5	CO2
10	Realization of		27/2/2021	DM1,DM4,DM8	T1,T5	CO2

	IIR filters to bilinear transformation techniques with problems					

Brief Description: During the complete process signal passes through various stages and different devices, that adds noise to the signal. These noise component that are different frequency components can be removed by using filters, before using the signal as control parameter. Present chapter deals with designing and realization of infinite impulse response digital filters. Since analog filters are already known , conversion of analog filter to digital filters by using different techniques has been discussed. The suppression of noise from the signal improves the overall performance of the system.

UNIT-V FIR Filters



Lecture No.	Content of Syllabus	Wit & WIL SCENERIO Mapping	Teaching Plan			
			Lecture Dates	Delivery Methodologies	Learning Resourses /Reference	Course Outcomes
1	Characteristics of FIR filters, frequency response	 Fig.1	28/1/2021	DM1,DM4	T1,T5	CO2
2.	Fourier series method for design of FIR filter		29/1/2021	DM1	T1,T5	CO2
3.	Window techniques for		30/1/2021	DM1,DM4,DM8	T1,T5	CO2

	design of FIR filters					
4.	Problems on Window techniques.		3/2/2021	DM1	T1,T5	CO2
5.	Frequency sampling technique for filter design		4/2/2021	DM1,DM8,DM4	T1,T5	CO2
6.	Realization of FIR filters problems		5/2/2021	DM1,DM4	T1,T5	CO2
7.	Realization of IIR filters with Canonic realization		10/2/2021	DM1,DM4,DM8	T1,T5	CO2
8.	Realization of IIR filters with Cascade and parallel realization		11/2/2021	DM1,DM4,DM8	T1,T5	CO2

Brief Description: During the complete process signal passes through various stages and different devices, that adds noise to the signal. These noise component that are different frequency components can be removed by using filters, before using the signal as control parameter. Present chapter deals with designing and realization of finite impulse response digital filters. Since analog filters are already known, conversion of analog filter to digital filters by using different techniques has been discussed. The suppression of noise from the signal improves the overall performance of the system.