GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-V

Course Title: Biomedical Digital Signal Processing
(Course Code: 4350303)

Diploma programme in which this course is offered	**Semester in which offered**
Biomedical Engineering	5th Semester

1. RATIONALE:

Biomedical digital signal processing course enables students to understand the fundamental principles of signal analysis and processing in the context of biomedical signals, represent them mathematically, convert analog biomedical signals into digital signals and understand advantages and relevance of DSP techniques into biomedical signal processing.

2. COMPETENCY:

The course content should be taught and curriculum should be implemented with the aim to develop required skills in the students so that they are able to acquire following competency:

- Perform processing on biomedical signals using basic digital signal processing techniques and represent them mathematically.

3. COURSE OUTCOMES (COs):

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

a. Classify signals and perform basic manipulations on signals.
b. Classify systems and describe LTI systems and also compute convolution sum.
c. Represent the signals in frequency domain using fourier series and fourier transform.
d. Convert analog signals to digital form while minimizing distortion and information loss.
e. Understand the block diagram of a digital signal processing system, recognize the advantages of digital signal processing over analog systems, and apply digital signal processing techniques to solve biomedical engineering problems.

4. TEACHING AND EXAMINATION SCHEME:

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	4	4	30*	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the attainment of the cognitive domain UOs required for the attainment of the COs.

***Legends: L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **CA** - Continuous Assessment; **ESE** - End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES:

The following practical outcomes (PrOs) are the subcomponents of the Course Outcomes (Cos). They are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Familiarize students with MATLAB environment for signal processing tasks, and understand the basics of signals and their importance in engineering and science.	-*	2
2	Perform basic arithmetic/mathematical expressions by using MATLAB software.	-*	2
3	Use MATLAB to study about basic functions for signal plotting in MATLAB.	-*	2
4	Write a MATLAB program to generate continuous time and discrete time sine and cosine wave.	1	4
5	Write a MATLAB program to perform basic signal operations of amplitude scaling.	1	4
6	Write a MATLAB program to generate basic singularity functions. (unit impulse, unit step, unit ramp, exponential).	1	4
7	Understand the performance of different systems.	2	2
8	Perform Linear Convolution of two sequences using MATLAB.	2	4

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
9	Write a MATLAB program to compare continuous-time and discrete-time system for a given input signal.	2	4
10	Write a MATLAB program to validate the any one property of the fourier transform for given signals.	3	4
11	Understand the performance of Digital filters.	3	2
12	Write a MATLAB program to compute and plot the trigonometric Fourier series representation of a continuous-time periodic signal.	3	4
13	Demonstrate and verify sampling theorem/ rate for given signal.	4	4
14	Write a MATLAB program to read an analog signal using the "audioread" function, and then plot the signal in the time domain.	4	4
15	Understand the performance of analog to digital conversion process.	4	4
16	Analyze various biosignals.	5	2
17	Write a MATLAB program to generate a continuous time sinusoidal signal of given frequency and duration, plot it in time domain	5	4
			56 Hrs.

_* Prerequisites to perform programs in MATLAB.

Note

*i. More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.*

*ii. The following are some **sample** 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Ability to understand given aim and develop the logic for program	40
2	Write down the program in MATLAB and produce desired results	30
3	Decode the program and correct it.	30
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to use in uniformity of practical's in all institutions across the state.

Sr.No	Equipment Name with Broad Specifications	PrO. No.
1	Desktop computers with MATLAB installed	All

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfill the development of this course competency.

a. Express the significance of signal processing in biomedical engineering applications.
b. Show concerns for the impact of artifacts in biomedical signals.
c. Commit to mastering signal processing techniques.
d. Identify the importance of continuous growth in signal processing knowledge.
e. Practice environmentally friendly methods and processes. (Environment related)

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. If required, more such UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit 1 Basics of signals and time domain analysis of signals	1.1 Define signals and explain their significance in engineering and science. 1.2 Differentiate between continuous-time and discrete-time signals, and identify their respective applications in signal processing. 1.3 Illustrate graphical and sequence method used to represent signal in time domain. 1.4 Perform basic signal operations, including amplitude scaling, time shifting, and time reversal, on given signals. 1.5 Classify signals based on determinism, periodicity, symmetry (even and odd), causality, and energy/power properties. 1.6 Explain singularity functions and represent them graphically and mathematically.	1.1 Definition and examples of signals 1.2 Continuous-time and discrete-time signals 1.3 Representation of signals in the time domain 1.4 Basic signal operations: amplitude scaling, time shifting, time reversal 1.5 Signal classification: deterministic non-deterministic, periodic and aperiodic signals, even and odd, causal and non-causal, energy and power signals. 1.6 Singularity functions: unit impulse, unit step, unit ramp, and exponential functions
Unit-II Basics of systems and LTI systems	2.1 Explain the concept of a system in the context of signal processing and engineering. 2.2 Compare continuous-time systems with discrete-time systems. 2.3 Describe various properties of systems, including static and dynamic behavior, linearity, time invariance, causality, stability, and invertibility, and categorize systems based on these properties. 2.4 Describe LTI system and impulse response. 2.5 Compute linear convolution of given two sequences.	2.1 Definition of system, continuous time and discrete time systems 2.2 Properties of systems and Classification of systems based on the properties: static and dynamic, linear and non-linear, time variant and time invariant, causal and non-causal, stable and unstable, invertible systems 2.3 Linear time invariant systems: impulse response, discrete time LTI system, the convolution sum

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit-III Frequency domain representation of signal	3.1 Describe and apply the concept of Fourier series to represent continuous-time and discrete-time periodic signals, both in trigonometric form and complex (exponential) form. 3.2 Enlist various properties of Fourier to simplify signal analysis and signal processing tasks.	3.1 Fourier series representation of continuous time and discrete time periodic signals: trigonometric fourier series, complex or exponential form of fourier series 3.2 Properties of fourier transform
Unit-IV Analog to digital conversion	4.1 Explain the block diagram and key components of the analog to digital conversion process, including signal sampling, quantization, and encoding. 4.2 Describe the concept of sampling and the sampling theorem, including the Nyquist rate and Nyquist criteria. 4.3 Explain aliasing and its effect on signal reconstruction. 4.4 Explain the process of quantization and its significance. 4.5 Explain quantization error.	4.1 Analog to digital conversion block diagram 4.2 Introduction to sampling, sampling theorem, nyquist rate, nyquist criteria, effect of under sampling-aliasing 4.3 Quantization and encoding: quantization levels, quantization error
Unit-V Digital signal processing and applications in biomedical engineering	5.1 Explain the components and flow of a digital signal processing system using block diagram. 5.2 Enlist various advantages of digital signal processing systems over analog systems, including flexibility, accuracy, noise immunity, ease of implementation, and the ability to handle complex algorithms. 5.3 Describe importance and significance of digital signal processing in biomedical engineering, particularly in the removal of artifacts.	5.1 Block diagram of digital signal processing system 5.2 Advantages of digital signal processing systems over analog system processing 5.3 Applications of DSP in biomedical engineering: removal of artefacts.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Basics of signals and time domain analysis of signals	10	4	8	4	16
II	Basics of systems and LTI systems	8	4	8	2	14
III	Frequency domain representation of signals.	8	4	6	4	14
IV	Analog to digital conversion	8	4	8	2	14
V	Digital signal processing and applications in biomedical engineering	8	6	6	0	12
Total		**42**	**22**	**36**	**12**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*

Note*:*

This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions to assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may slightly vary from above table.

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course. Students should perform following activities in group (or individual) and prepare reports of about 5 pages for each activity. They should also collect/record physical evidence for their (student's) portfolio which may be useful for their placement interviews:

a) Discuss real world examples of signals and systems
b) Illustrate relevance of DSP in various fields in today's world.
c) Demonstrate manipulations of different given signals.
d) Use a guitar tuner or mobile apps to demonstrate frequency analysis and identify the fundamental frequency and harmonics of musical notes.
e) Convert any real world analog signal into digital using A to D conversion process.
f) Make group projects to detect features of ECG/EEG/EMG signals.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/subtopics.
b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4 means*** different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) Show animation/ video related to course content.
e) Co-relating the importance of content of this course with other courses/ practical applications. (Example: Real world application of DSP in day to day life, image processing used in mobile phones, digital displays which shows speed/weight/temperature/pressure in digital forms etc.)
f) Introduce E-waste recycling technology among the students.
g) Guide students on how to address issues on environment and sustainability

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-projects are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain a dated work diary consisting of individual contributions in the project work and give a seminar presentation of it before submission. The duration of the micro project should be about **12-14** ***(fourteen to sixteen) student engagement hours*** during the course. The students ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

a) Generate and plot basic signals (sine, square, triangle) using MATLAB or Python. Explore how changing parameters (frequency, amplitude) affects the signal's appearance.
b) Create a program to scale the amplitude of a given signal by a user-defined factor. Plot the original and scaled signals.
c) Develop a MATLAB program to add an echo effect to an audio signal. Adjust parameters like delay and amplitude scaling to customize the echo.
d) Use MATLAB to visualize and analyze a simple biomedical signal (e.g., ECG or EEG).

e) Explore simple signal compression techniques to compress audio or image signals.
f) Create a simple tone generator using MATLAB or Python that produces different audio tones (sine, square, triangle) based on user input for frequency and duration.
g) Write a program to add two sinusoidal signals of different frequencies and visualize the resulting waveform.
h) Develop a tool to detect the dominant frequency of an audio signal using basic peak detection techniques.
i) Calculate and compare the energy of different audio signals to understand the concept of energy in signals.
j) Analyze a complex audio signal to identify its harmonic components and plot the harmonics separately.
k) Write a program to time-shift an audio signal by a specified amount of time.
l) Demonstrate the process of signal sampling and reconstruct the continuous signal from its discrete samples using MATL.

13. SUGGESTED LEARNING RESOURCES:

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	"Digital Signal Processing"	John G. Proakis and Dimitris G. Manolakis	Pearson Prentice Hall, the University of Michigan, ISBN: 9780131873742, 0131873741
2	"Signals and Systems"	Alan V. Oppenheim, Alan S. Willsky, and S. Hamid Nawab	Prentice Hall, New Jersey, ISBN: 0-13-814757-4
3	"Digital Signal Processing"	S. Salivahanan, A. Vallavaraj, and C. Gnanapriya	McGraw-Hill Education (India) Pvt Limited, ISBN: 007463996X, 9780074639962
4	"Digital Signal Processing: A Computer-Based Approach"	Sanjit K. Mitra	McGraw-Hill Higher Education, ISBN: 0072513780, 9780072513783

14. SOFTWARE/LEARNING WEBSITES

- www.dspguide.com
- www.coursera.in
- www.edx.org

- ocw.mit.edu
- www.khanacademy.org
- https://nptel.ac.in/courses/117102060
- https://nptel.ac.in/courses/108105055

15. PO-COMPETENCY-CO MAPPING:

Semester I	**Biomedical Digital Signal Processing (Course code: 4350303)**						
	POs						
Competency & Course Outcomes	**PO 1** Basic & Discipline Specific knowledge	**PO 2** Problem Analysis	**PO 3** Design/ Develo-pment of Solution	**PO4** Engineering Tools, Experimen-tation & Testing	**PO 5** Engineering Practices for society, Sustainability & Environment	**PO 6** Project Manage-ment	**PO 7** Life-long learning
Competency	Analyze the biomedical signals using basic digital signal processing techniques and represent them mathematically.						
Classify signals and analyze signals in time domain and perform basic manipulations of signals.	2	2	-	-	-	-	2
Classify systems and describe LTI systems and also compute convolution sum.	2	1	-	-	-	-	2
Represent the signals in frequency domain using fourier series and fourier transform.	2	2	-	-	-	-	1
Convert analog signals to digital form while minimizing distortion and information loss.	2	1	1	-	-	-	2
Understand the block diagram of a digital signal processing system, recognize the advantages of digital signal processing over analog systems, and apply digital signal processing techniques to solve biomedical engineering problems.	-	3	2	-	-	-	2

*Legend: '**3**' for high, '**2**' for medium, '**1**' for low and '**-**' for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE:

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
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