GUJARAT TECHNOLOGICAL UNIVERSITY

BIO MEDICAL ENGINEERING (31)
MEDICAL INSTRUMENTATION & SYSTEMS
SUBJECT CODE: 2713108
SEMESTER: I

Type of course: Core Subject

Prerequisite:

1. Circuit analysis techniques with dependent sources, equivalence
2. Basic systems analysis concepts using Laplace techniques and Bode Plots
3. Transient and frequency response of 1^{st}-order circuits

Rationale: This course is offered to aid postgraduate biomedical engineering students by helping them to understand the analog electronic circuits used in signal conditioning in biomedical instrumentation. Because many bioelectric signals are in the microvolt range, noise from electrodes, amplifiers, and the environment is often significant compared to the signal level. This course illustrates how op amps can be used to build instrumentation amplifiers, isolation amplifiers, active filters, and many other systems and subsystems used in biomedical instrumentation.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
L	T	P	C	Theory Marks		Practical Marks				
				ESE (E)	PA (M)	PA (V)		PA (I)		
						ESE	OEP	PA	RP	
3	2#	2	5	70	30	20	10	10	10	150

Content:

Sr. No.	Topics	Teaching Hrs.	Module Weightage
1	**Operational Amplifier Fundamentals:** Circuits With Resistive Feedback, Static Op Amp Limitations, Dynamic Op-Amp Limitations	6	15
2	**Active filters:** The transfer function, first-order active filters, audio filter applications, standard second-order responses, KRC filters, multiple-feedback filters, filter approximations, cascade design, generalized impedance converters, direct design, the switched capacitor, the switched-capacitor filters	6	20
3	**Instrumentation and Medical Isolation Amplifiers:** Instrumentation Amps, Medical Isolation Amps, Safety Standards in Medical Electronic Amplifiers, Medical-Grade Power Supplies, Electrical safety issues in medical devices	6	15
4	**Noise and the Design of Low-Noise Amplifiers for Biomedical Applications:** Noise Properties, Noise Dynamics, Sources of Noise, Propagation of Noise through LTI Filters, Noise Factor and Figure of Amplifiers, Noise in Differential Amplifiers, Effect of Feedback on Noise, Examples of Noise-Limited Resolution of Certain Signal Conditioning Systems, Low-Noise Amplifiers, The Art of Low-Noise Signal Conditioning System Design	6	20
5	**Special Analog Circuits and Systems in Biomedical**	10	20

	Instrumentation: The Phase-Sensitive Rectifier, Phase Detectors, Voltage and Current-Controlled Oscillators, Phase-Locked Loops, IC Thermometers, Instrumentation Systems, Voltage Comparators, Sample-and-Hold Circuits, V-F and F-V Converters, Voltage References and Regulators		
6	**Digital Interfaces:** Aliasing and the Sampling Theorem, Digital-to-Analog Converters (DACs), Hold Circuits, Analog-to-Digital Converters (ADCs), Quantization Noise, Modulation and Demodulation of Biomedical Signals.	8	10

Reference Books:

1. Robert B. Northrop, Analysis and Application of Analog Electronic Circuits to Biomedical Instrumentation, CRC press, 2004.
2. Sergio Franco, Design with Operational Amplifiers and Analog ICs, 3 Ed., WCB/McGrawHill, 2002.
3. David Prutchi, Michael Norris, Design And Development of Medical Electronic Instrumentation, John Wiley & Sons, Inc. Publications, 2005

Course Outcome:

After learning the course the students should be able to:

1. To investigate a variety of resistive op amp circuits with emphasis on feedback principles.
2. To analyze and design active filters
3. To investigate the effect of op amp non-idealities upon the DC as well as the AC and transient responses of popular op amp circuits
4. To study the design of popular op amp and comparator applications in test, control, and instrumentation

Performance Criteria:

Objective 1:

1.1 Students will demonstrate the ability to analyze and design a variety of popular op amp circuits, including signal converters and instrumentation blocks.

1.2 Students will demonstrate an understanding of the curative properties of negative feedback.

1.3 Students will demonstrate an ability to identify negative-feedback topologies and estimate the loop gain of a circuit.

Objective 2:

2.1 Students will become conversant with systems poles, zeros, and Bode Plots as applied to op amp circuits.

2.2 Students will demonstrate an ability to analyze and design first-order op amp filters.

2.3 Students will demonstrate an ability to analyze and design second-order active filters and compare different topologies.

Objective 3:

3.1 Students will become conversant with the internal structure of a practical op amp and the origins of its non-idealities.

3.2 Students will demonstrate a skill in using data sheets to assess the limitations of practical analog ICs.

3.3 Students will demonstrate an ability to predict the effect of static op amp limitations upon DC circuit performance.

3.4 Students will demonstrate an ability to predict the effect of dynamic op amp limitations upon circuit performance in both the frequency and time domains.

Objective 4:

4.1 Students will become conversant with a variety of popular test, control, and instrumentation blocks (comparators, Schmitt triggers, precision rectifiers, SHAs, timers, function generators, VCOs, and *V-F* and *F-V* converters).

4.2 Students will be capable to assess the impact of component non-idealities upon circuit performance

Objective 5:

5.1 Students will demonstrate a skill in software simulation of the circuits investigated in the course.

Suggested List of Experiments:

- Testing of static and dynamic limitations of op-amp.
- Design and testing of first order and second orders filters.
- Design and testing of KRC filters.
- Design and testing of Cascade filters.
- Design and testing of multiple-feedback filters.
- Design and testing of Instrumentation Amplifiers.
- Design and testing of Medical Isolation Amplifiers.
- Design and testing of Low-Noise Amplifiers.
- Design and testing of Voltage and Current-Controlled Oscillators.
- Design and testing of V-F and F-V Converters.
- Design and testing of ADC and DAC

Suggested Open Ended Problems:

- Consideration of time complexity in medical design.
- Consideration of Kolmogorov complexity in medical design.
- Consideration of Connectivity complexity in medical design.
- Consideration of Functional complexity in medical design.
- Consideration of Isolation and safety in medical design.
- Consideration of noise in low level bio-signal acquisitions.

Major Equipments:

- Test and Measurement Lab Setup

List of Open Source Software/learning website:

1. Quite Universal Circuit Simulator
2. Logisim
3. Circuit Design Aids
4. TinyCAD
5. DesignSpark