GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Engineering

Level: Diploma

Branch: Biomedical Engineering

Course / Subject Code: DI03003061

Course/Subject Name: Biomedical Circuit Design and Simulation

w. e. f. Academic Year:	2024-25
Semester:	3rd
Category of the Course:	PCC-07

Prerequisite:	Basic understanding of electronics, signals and systems, analog and digital circuits, mathematics, and introductory biomedical engineering concepts.
Rationale:	This practical-based course is designed to equip students with hands-on skills in designing, testing, and simulating circuits relevant to biomedical applications. Students will work with analog and digital circuits, sensors, bio-signal processing elements, and circuit simulation tools. The course promotes experiential learning, preparing students for roles in medical equipment design, diagnostic instrumentation, and embedded biomedical systems.

Course Outcome:

After Completion of the Course, Student will be able to:

No	Course Outcomes	RBT Level
CO-1	Simulate basic analog electronic circuits including amplifiers, filters, and power supplies using schematic design software tools.	R,A
CO-2	Design and analyze amplifier circuits for weak biomedical signals using appropriate simulation platforms.	U,A
CO-3	Develop and simulate signal conditioning circuits for biomedical sensor interfaces with focus on noise filtering and signal integrity.	A, A
CO-4	Create PCB layouts from schematic diagrams and generate fabrication files using PCB design tools.	C
CO-5	Develop simple project-based biomedical circuit solutions for healthcare applications, including PCB layout design using free or licensed tools.	E, C

**Revised Bloom's Taxonomy (RBT)*

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE (E)	PA(M)	PA(I)	ESE (V)	
0	0	6	3	00	00	20	30	50

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1	**Unit – I Introduction to Electronic Circuit Simulation and PCB Design Using Software Tools**	20	
	• State the features of different circuit simulation tools (Open source or licensed) used for electronic circuit simulation. • List different PCB layout design tools (Open source or License) used for PCB layout design.		
2	**Unit – II Design and Simulation of Bio-signal Amplifier Circuits Using Schematic Software Tools**	16	
	• Design Bio-signal amplifier for specific gain and application. • Define the general terms used in circuit simulation software. • Create new projects and save it. • Use 'Search', 'add' and 'create' commands of simulation software. • Assemble Amplifier circuit using circuit simulation software.		
3	**Unit – III Design and Simulation of Signal Conditioning Circuits Using Schematic Software Tool**	24	
	• Design signal processing circuits like filters, notch filter, clipper and clampers. • Simulate and test filter using circuit simulation software. • Simulate and test notch filter for noise removal • Simulation and testing of diode applications in signal shaping circuits • Simulate and test the analog or digital IC based electronic circuit using circuit simulation software.		
4	**Unit – IV PCB Layout Design and Basic Fabrication Process**	16	
	• Overview of PCB Design Workflow • Converting simulated circuits into PCB layout • Search, add and create footprint of different electronic		

	components used in PCB layout design software. • Place, route and generate the layout of given circuit using manual or auto routing using PCB layout design software.		
5	**Unit-V Mini Project**	8	
	• Power supply design for biomedical circuits (±5V/±12V) • Complete project simulation (e.g., ECG module, temperature monitor)		
	Total	**84**	**100 %**

Suggested Specification Table with Marks

Distribution of Theory Marks (in %)					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
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Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

1. "**Biomedical Instrumentation: Technology and Applications**" by Nandini Joshi, McGraw-Hill Education
2. **"Op-Amps and Linear Integrated Circuits"** by Ramakant A. Gayakwad, Pearson Education
3. **"Introduction to Biomedical Engineering"** by John Enderle, Joseph Bronzino, Academic Press
4. **"Electronic Circuit Design: From Concept to Implementation"** by Nihal Kularatna, CRC Press
5. **"Electronic Devices and Circuit Theory"** by Robert L. Boylestad, Louis Nashelsky, Pearson Education

(b) Open-source software and website:

1. **KiCad** : https://kicad.org/
2. **LTspice** : https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html
3. **Fritzing** : https://fritzing.org/

4. **EasyEDA** : https://easyeda.com/
5. **SimulIDE** : http://simulide.blogspot.com/
6. **All About Circuits** : https://www.allaboutcircuits.com/
7. **Electronics Hub** : https://www.electronicshub.org/
8. **CircuitLab** : https://www.circuitlab.com/
9. **Falstad Circuit Simulator** : https://www.falstad.com/circuit/
10. **MIT OpenCourseWare - Bioengineering** : https://ocw.mit.edu/courses/biological-engineering/

Suggested Course Practical List:

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hours Required
1	Introduction to Simulation Tools (LTSpice, Multisim, Proteus or any others)	1	2
2	Simulation of Basic Op-Amp Circuits (Inverting & Non-Inverting Amplifiers)	1	4
3	Design and Simulation of a Power Supply Circuit (Rectifier + Filter + Regulator)	1	4
4	Simulation of Instrumentation Amplifier for Weak Bio-Signals	2	4
5	Design of Two-Stage Amplifier for Pulse Signal (Analog only)	2	4
6	Design and Simulation of Low-Pass Filter for Noise Removal	3	2
7	Design and Simulation of High-Pass Filter to Remove DC Offset	3	2
8	Simulation of Notch Filter for 50 Hz Interference Rejection	3	4
9	Complete Signal Conditioning Circuit for a Pulse Sensor	3	4
10	Schematic Entry and PCB Layout of a Signal Amplifier Circuit (e.g., for Pulse Sensor)	4	4
11	Generate Gerber Files and Simulate the PCB in 3D Viewer	4	4
12	Mini Project Work Session: Combine Learned Circuits into One Project	5	4

List of Laboratory/Learning Resources Required:

Hardware Components:

- Breadboards
- Power supply modules (dual rail ±12V, 5V)
- Function generator
- Digital oscilloscope or PC-based virtual oscilloscope
- Analog multimeter / Digital multimeter
- Biomedical signal simulators (ECG simulator or virtual signal generator)

- ECG electrodes and leads (for demo/testing only)
- Photodiodes / IR LEDs
- Thermistors / LM35 temperature sensor
- Operational amplifiers (e.g., LM324, TL072)
- Resistors, capacitors, diodes, Zener diodes, LEDs
- Logic ICs (7400 series): AND, OR, NOT, NAND, NOR, XOR gates, counters, multiplexers
- ADC / DAC ICs (e.g., ADC0804, DAC0808)
- Microcontroller development boards (optional, e.g., Arduino Uno for integration)

Software Tools (Free or Licensed):

- **Circuit Simulation:**
  - LTspice / Multisim / Proteus / TINA-TI / Falstad Circuit Simulator
- **PCB Design:**
  - KiCad (open-source)
  - Proteus
  - Autodesk Eagle (free for education)
  - EasyEDA (web-based, free tier available)
  - Fritzing (beginner-friendly)
- **Bio-signal Data Reference Tools (optional):**
  - MATLAB/Octave with BioSig Toolbox
  - OpenSignals (from PLUX) – demo version

Computing Infrastructure:

- Desktop PCs or Laptops (1 per 2 students)
- Internet access for online tools and reference data
- Printer (for printing PCB layouts if needed)

Suggested Project List:

The projects serve as practical learning experiences for students in the field of Biomedical Engineering. These projects integrate theoretical knowledge with hands-on application, fostering competency development across various Course Outcomes (COs). Below are guidelines for designing and executing projects:

- **Project Types:**
  - It can be industry-based, workshop-based, laboratory-based, or field-based.
  - Each project should align with specific COs and address real-world challenges.
- **CO Integration:**

- It should encompass two or more COs.
- Integration involves aligning Program Outcomes (PrOs), Unit Outcomes (UOs), and Assessment and Design Outcomes (ADOs).

- **Project Duration:**
  - Students are encouraged to maintain a dated work diary to document their individual contributions and sufficient engagement time for each project should be allocated by faculty during the course.
- **Project Demonstration:**
  - Before submission, students must give a project demonstration on their project.
  - The presentation should highlight the project's objectives, methodology, results, and relevance to industry-oriented COs.
- **Seminar Presentation:**
  - Before submission, students must give a seminar presentation on their project.
  - The presentation should highlight the project's objectives, methodology, results, and relevance to industry-oriented COs.

Following are suggestive projects, and additional ones can be tailored to specific course objectives. Encourage students to explore innovative solutions and apply their engineering skills effectively.

- **List of Suggested Projects:**

  - **Pulse Rate Monitor Using Photodiode & Analog Amplifier**
    Detects and amplifies pulse signal using basic analog components.
  - **Temperature Sensing and LED Bar Display Using Thermistor**
    Converts temperature changes into a visual LED output.
  - **Analog ECG Front-End Simulation Project**
    Simulates basic ECG signal amplification and filtering circuits.
  - **Portable Biomedical Amplifier Circuit**
    Designs a compact analog amplifier circuit for low bio-signals.
  - **Bio-Signal Conditioning Circuit on PCB**
    Combines amplifier and filter stages for a bio-sensor and designs its PCB.
  - **Analog Temperature Alarm Circuit**
    Activates an alert when temperature crosses a preset limit using analog components.
  - **Hand Tremor Detection Circuit**
    Detects and amplifies small vibrations caused by hand tremors.
  - **Sweat Sensor with Output Indicator**

Senses skin conductivity changes and triggers a visual or sound output.

- **Muscle Signal (EMG) Pre-Amplifier Circuit (Simulation)**
  Simulates amplification of weak electrical signals from muscles.
- **Respiration Monitoring Circuit Using Thermistor**
  Monitors breath cycles using temperature changes detected by a thermistor.
- **Analog Sleep Apnea Detection Circuit (Conceptual)**
  Detects pauses in breathing using analog timing and threshold circuits.
- **Notch Filter Design for 50 Hz Interference in ECG Signals**
  Simulates a filter to remove power line noise from ECG signals.

Suggested Activities for Students:

In addition to classroom and laboratory learning, students are encouraged to engage in co-curricular activities that enhance their understanding and practical skills. These activities can be conducted in groups on breadboard or PCB should be used and it should be documented in 5-page reports. Collecting physical evidence of their work will also contribute to their portfolio, which can be valuable during placement interviews.

List of Suggested Activities with brief description specifying the activity details and objective of the activity:

1. **Design and Build a Biomedical Sensor Interface on Breadboard**
   - **Activity Details:** In small groups, students will design and build a signal conditioning circuit (e.g., for pulse or temperature sensor) using Op-Amps and passive components.
   - **Objective:** To reinforce theoretical understanding by practical implementation of signal conditioning concepts.
2. **Compare Bio-Signal Amplifier Designs Using Simulation Tools**
   - **Activity Details:** Students simulate two or more amplifier configurations (e.g., inverting, non-inverting, instrumentation) and compare their gain, noise immunity, and bandwidth.
   - **Objective:** To evaluate different circuit topologies and understand their suitability for bio-signal amplification.
3. **Design and Fabricate a Simple Analog Bio-Signal Circuit PCB**
   - **Activity Details:** Students design a basic PCB (e.g., pulse rate amplifier circuit) using EasyEDA/KiCad and fabricate it if possible.
   - **Objective:** To bridge circuit simulation with real-world PCB design and learn documentation standards.
4. **Breadboard Implementation of a 2-Stage Amplifier with Filters**
   - **Activity Details:** Construct and test a two-stage amplifier with high-pass and low-pass filters for processing weak analog signals (like pulse or EMG).

- **Objective:** To gain experience in step-by-step circuit building and understanding filter responses.

5. **Noise Analysis in Biomedical Circuits Using Simulated and Real Setups**
   - **Activity Details:** Students observe and document the noise in amplifier circuits with and without filters, both in simulation and on breadboard.
   - **Objective:** To understand the importance of noise filtering in bio-signal acquisition circuits.
6. **Prepare a Circuit Testing and Troubleshooting Report**
   - **Activity Details:** After building a basic analog circuit (e.g., temperature alarm), students identify errors and document how they debugged the circuit.
   - **Objective:** To develop troubleshooting skills and documentation habits essential in industry practice.
7. **Create a Visual Comparison Between Simulated and Breadboard Signals**
   - **Activity Details:** Use simulation software and oscilloscope (or mobile apps) to compare signal shapes and amplitudes from both sources.
   - **Objective:** To help students correlate simulation outputs with real-world analog signals.
8. **Build and Document a Low-Cost Biomedical Signal Module**
   - **Activity Details:** Develop a working prototype of a pulse/temperature-based circuit module that can be reused or shown in a mini-exhibition.
   - **Objective:** To promote innovation and confidence in building functioning biomedical subsystems.
9. **Group Presentation on Common Biomedical Sensors and Their Signal Characteristics**
   - **Activity Details:** Students research and present key parameters and applications of common sensors (ECG, pulse, temperature, etc.).
   - **Objective:** To increase familiarity with real-world biomedical sensors and their signal requirements.
10. **Create a Personal Portfolio with Circuit Snapshots and Gerber Files**
    - **Activity Details:** Each student compiles a brief portfolio that includes snapshots of their simulations, breadboard setups, PCB designs, and output waveforms.
    - **Objective:** To encourage professionalism and provide a ready showcase for job or internship interviews.

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