



GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Engineering

Level: Diploma

Branch: Biomedical Engineering

Course / Subject Code: DI03003021

Course/Subject Name: Medical Electronics

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

| | |
|----------------------|--|
| Prerequisite: | Fundamentals of Analog Electronics, Elementary knowledge of Semiconductor Devices |
| Rationale: | Operational Amplifiers (Op-Amps) are the foundation of analog signal processing especially in medical electronics circuits like ECG, EEG, blood pressure monitoring, and other devices. Mastery over Op-Amp principles empowers biomedical students to design and troubleshoot analog systems essential for healthcare technology. |

Course Outcome:

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

| No | Course Outcomes | RBT Level |
|------|---|------------|
| CO-1 | Understand basic structure, parameters, and ideal characteristics of Op-Amps. | Understand |
| CO-2 | Apply the concepts of feedback to design basic Op-Amp amplifier configurations. | Apply |
| CO-3 | Design linear circuits using operational amplifiers for signal processing applications. | Apply |
| CO-4 | Analyze the operation of ADCs, DACs, comparators, 555 timer ICs, and oscillators. | Analyze |
| CO-5 | Apply Op-Amps in specialized biomedical signal acquisition and processing circuits. | Apply |

**Revised Bloom's Taxonomy (RBT)*



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Teaching and Examination Scheme:

| Teaching Scheme (in Hours) | | | Total Credits L+T+ (PR/2) | Assessment Pattern and Marks | | | | Total Marks |
|-------------------------------|---|----|---------------------------------|------------------------------|--------|-------|----------------------|-------------|
| L | T | PR | | C | Theory | | Tutorial / Practical | |
| | | | ESE (E) | | PA(M) | PA(I) | ESE (V) | |
| 3 | 0 | 2 | 4 | 70 | 30 | 20 | 30 | 150 |

Course Content:

| Unit No. | Content | No. of Hours | % of Weightage |
|----------|--|--------------|----------------|
| 1 | Introduction to Operational Amplifiers | 08 | |
| | 1. Basics of Operational Amplifier <ul style="list-style-type: none"> ● Definition ● Symbol ● Block Diagram of an Op-Amp ● Equivalent Circuit of an Op-Amp ● Pin diagram of IC741 Op-Amp & its description 2. Parameters of an Op-Amp <ul style="list-style-type: none"> ● Input Offset Voltage, Input Offset Current, Input Bias Current, Differential Input Resistance, Differential Input Capacitance, Input Voltage Range, Offset Voltage Adjustment Range, Common Mode Rejection Ratio (CMRR), Supply Voltage Rejection Ratio (SVRR), Slew Rate, Output Voltage Swing, Gain Bandwidth Product, Output Short Circuit Current, Transient Response Parameters: Rise Time, Delay Time, Peak Time, Maximum Overshoot and settling time 3. Characteristics of an Ideal Op-Amp | | 20% |
| 2 | Feedback Concepts and Op-Amp Configurations | 10 | |
| | 1. Concept of Feedback <ul style="list-style-type: none"> ● Positive Feedback ● Negative Feedback | | 25% |



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| | <ol style="list-style-type: none"> 2. Op-Amp Configurations <ul style="list-style-type: none"> ● Open Loop Configurations: Inverting, Non-Inverting & Differential ● Closed Loop Configurations: Inverting, Non-Inverting & Differential 3. Voltage Follower Circuit 4. Subtractor Circuit 5. Summing, Scaling and Averaging amplifier (Inverting Configuration) | | |
| 3 | General Linear Applications of an Op-Amp | 10 | |
| | <ol style="list-style-type: none"> 1. Instrumentation Amplifier (3 Opamp Constant Gain) and applications 2. Integrator 3. Differentiator 4. Filters <ul style="list-style-type: none"> ● Introduction to Filters & its Classification ● Advantages of active filters over passive filters ● Types of active filters: First Order Low Pass Butterworth Filter, First Order High Pass Butterworth Filter Wide Band Pass, Notch Filter | | 25% |
| 4 | Applications of Op-Amp as Converters, Comparators, Timers, and Oscillators | 09 | |
| | <ol style="list-style-type: none"> 1. Analog to Digital Converter <ul style="list-style-type: none"> ● Enlist Types of ADC ● Successive Approximation Register (SAR) type ADC 2. Digital to Analog Converter <ul style="list-style-type: none"> ● Enlist types of DAC ● Binary weighted resistor type DAC 3. Basic Comparator <ul style="list-style-type: none"> ● Inverting Configuration ● Non-Inverting Configuration ● Application of comparator in Biomedical field 4. 555 Timer IC <ul style="list-style-type: none"> ● Internal Structure ● Astable Mode ● Monostable Mode 5. Oscillator <ul style="list-style-type: none"> ● Working Principle of Oscillators ● Types of Oscillators | | 15% |



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|---|--|----------------|--------------|
| | ● Wein Bridge Oscillator | | |
| 5 | Specialized Biomedical Applications | 08 | |
| | 1. Design Instrumentation Amplifier (3 Opamp Variable Gain) 2. ECG, EEG & EMG Signal Conditioning Circuit | | 15% |
| | Total | 45 Hrs. | 100 % |

Suggested Specification Table with Marks (Theory):

| Distribution of Theory Marks (in %) | | | | | |
|-------------------------------------|---------|---------|---------|---------|---------|
| R Level | U Level | A Level | N Level | E Level | C Level |
| 30 % | 40 % | 30 % | -- | -- | -- |

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. "Op-Amps and Linear Integrated Circuits" by Ramakant A. Gayakwad, Pearson
2. "Linear Integrated Circuits" by D. Roy Choudhury and Shail B. Jain, New Age International Publishers
3. "Operational Amplifiers and Linear Integrated Circuits" by Robert F. Coughlin and Frederick F. Driscoll, Pearson
4. "Design with Operational Amplifiers and Analog Integrated Circuits" by Sergio Franco, McGraw Hill Education (India) Private Limited
5. "Handbook of Biomedical Instrumentation" by Dr. R S Khandpur, McGraw Hill Education (India) Private Limited
6. "Introduction to Biomedical Equipment Technology" By Joseph J Carr, John M Brown

(b) Open-source software and website:

1. <http://ngspice.sourceforge.net>
2. <https://www.tinkercad.com/circuits>
3. <https://www.falstad.com/circuit/>
4. <https://www.allaboutcircuits.com/>
5. <https://ltspice.analog.com>
6. <https://www.multisim.com/>
7. <https://www.kicad.org/>
8. <https://circuitverse.org/>



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9. <https://everycircuit.com/>
10. <https://nptel.ac.in/courses/108105053>
11. https://youtube.com/playlist?list=PLwJK_ikyK4LLDBB1E9MFbxGCEnmMMOAXOH&si=c-IJ55hDi7c3gWkc
12. https://youtube.com/playlist?list=PLPD7Ds2_I0ggKZeS7jsx8N7k1DovnjTg&si=jcyyyyC-KKyW_Mxe

Suggested Course Practical List: If any

| Sr. No. | Practical Outcomes (PrOs) | Unit No. | Approx. hours required. |
|---------|--|----------|-------------------------|
| 1 | Describe the basics of Op-amp 741 IC | I | 02 |
| 2 | Demonstrate open loop inverting and non-inverting amplifier. | II | 02 |
| 3 | Demonstrate open loop differential amplifier. | II | 02 |
| 4 | Test closed loop inverting amplifier. | II | 02 |
| 5 | Test closed loop non-inverting amplifier. | II | 02 |
| 6 | Build differential amplifier using one op-amp. | II | 02 |
| 7 | Test voltage follower using op-amp. | II | 02 |
| 8 | Build Subtractor using op-amp. | II | 02 |
| 9 | Test summing amplifier, Scaling and Averaging Amplifier using inverting configuration. | II | 02 |
| 10 | Build Integrator circuit. | III | 02 |
| 11 | Build Differentiator circuit. | III | 02 |
| 12 | Test comparator circuit. | IV | 02 |
| 13 | Test first order Low Pass Filter | III | 02 |
| 14 | Test first order High Pass Filter | III | 02 |
| 15 | Test Wein bridge oscillator circuit. | IV | 02 |
| 16 | Test Analog to Digital Converter Circuit | IV | 02 |
| 17 | Test Digital to Analog Converter Circuit | IV | 02 |
| 18 | Implement 555 Timer IC in Astable mode | IV | 02 |
| 19 | Build Instrumentation Amplifier | V | 02 |

List of Laboratory/Learning Resources Required:

The major equipment/instruments and software required to develop PrOs are given below, with broad specifications to facilitate their procurement by the administrators/management of the institutes. This will ensure the conduction of practical skills in all institutions across the state properly so that the desired skills are developed in students.

1. Variable DC power supply: 0-30V, 2A, Over Voltage and Current protection, display for voltage and current.



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2. Cathode Ray Oscilloscope: Dual Trace 20Mhz,1 Mega Ω Input Impedance
3. Digital Storage Oscilloscope: Dual or four Channel, 50 MHz or Higher Bandwidth
4. Function Generator: 0-2 MHz with Sine, square and triangular output with variable frequency and amplitude.
5. Digital Multimeter:3 1/2 digit display, 9999 count digital multimeter measures: Vac and Vdc (1000Vmax), Adc and Aac(10 amp max), Resistance (0 - 100M Ω), Capacitance and Temperature measurement
6. Electronic Workbench: 0-30V, 2 Amp Variable DC power supply, Function Generator-2MHz, CRO 0-30MHz or DSO 50MHz minimum Dual channel at least, Digital Multimeter, Soldering and Desoldering station
7. Bread Board 840-1000 contact points: Positive and Negative power rails on opposite sides of the board
8. Linear Trainer Kit: Fixed and variable DC power supply, Onboard Opamp 741 IC (4 Nos), 555 Timer IC(1 Nos), Resistor Bank 10 Ohm to 1M Ω (30 Nos), Capacitor Bank ranging from 100 pF to 3300 pF, Transistor BC547 and BC548, Voltage Regulator (7805, 7905, LM317), Diode 1N4007 (4 Nos), 12V SPDT Relay, Zener Diode (12V, 5.1V, 3.2V), Potentiometers (1K Ω , 10K Ω , 100K Ω), 2 mm LED (3 Color),Function Generator (Sine, Square, Triangular) 0-200KHZ in five steps, Dual Power supply (+/-5V, +/-12V), Variable DC Power Supply (0 to 15V, 0 to -15V), Breadboard for circuit assembly Seven-segment display and LED indicators, Digital Multimeter

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:**



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- 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.

Using various fundamental knowledge of medical electronics engineering students may develop mini/micro projects based on team/individual basis which concrete their fundamentals of medical electronics hardware and can work as prototypic models in various societal applications. Following are the suggested list of projects:

1. ECG Signal Pre-Amplifier

Design a low-noise amplifier for acquiring weak ECG signals.

2. Heartbeat Counter using Op-Amp Comparator

Count heartbeat pulses using a photodiode and Op-Amp comparator.

3. Temperature-Controlled Fan System

Automatically control fan speed using a temperature sensor and Op-Amp.

4. Design Instrumentation Amplifier for Biological Signal Acquisition ECG, EMG, EEG etc.

5. Design Analog Filters for Noise Reduction in Bio signals

Build active low-pass/high-pass filters to clean biomedical signals.

6. Design Smoke detector using op-amp

7. Design light intensity measurement using LDR

8. Design Closed loop Non inverting amplifier

9. Design Closed loop inverting amplifier

10. Design Closed loop inverting amplifier

11. Design closed loop differential amplifier

12. Design adder circuit to add two signals.

13. Galvanic Skin Response (GSR) Monitor



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- 14. Analog Stethoscope to listen heart sound**
- 15. Wearable Temperature Sensor with Alarm**
- 16. Hearing Aid Amplifier Circuit**
- 17. Electronic Weighing Scale with Patient Monitoring**
- 18. Respiration Rate monitor using Thermistor**
- 19. Heart rate monitoring using ECG**
- 20. Chart Preparations**
- 21. Model Making**

Suggested Activities for Students: If any

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.

Hands-on Circuit Design

- Activity: Design and build basic Op-Amp configurations (inverting, non-inverting amplifiers) on breadboards.
- Objective: Strengthen understanding of Op-Amp input-output characteristics.

Simulation-Based Analysis

- Activity: Use simulation tools (like LTspice, Tinkercad, Kicad Proteus, or Multisim) to simulate Op-Amp circuits.
- Objective: Verify theoretical results and observe the impact of parameter variations.

Signal Conditioning Challenge

- Activity: Design a signal amplifier for a low-amplitude biomedical signal (e.g., ECG preamplifier).
- Objective: Apply feedback and amplification principles in real-world biomedical scenarios.

Troubleshooting Practice

- Activity: Provide students with faulty Op-Amp circuits to diagnose and correct.
- Objective: Develop circuit analysis, fault finding, and logical reasoning skills.



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Mini-Project Group Activity

- Activity: In small teams, students develop a working prototype (e.g., precision rectifier, active filter, amplifier or instrumentation amplifier mentioned in above suggested list).
- Objective: Foster collaboration, circuit design, and presentation skills.

Data Sheet Interpretation

- Activity: Analyze the datasheet of a popular Op-Amp (e.g., LM741, TL081, OP07, LM 324, LM358 and INA122).
- Objective: Learn to extract technical information and specifications for practical use.

Expert Lecture or Industry Visit

- Activity: Organize a guest talk or visit to a biomedical device company.
- Objective: Relate classroom learning to industry applications.

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