SCHEME : K

Name :
Roll No. : ______________ Year : 20___ 20___
Exam Seat No. :

LABORATORY MANUAL FOR
BIOSENSORS APPLICATIONS (313327)

ELECTRONICS ENGINEERING GROUP

MAHARASHTRA STATE BOARD OF
TECHNICAL EDUCATION, MUMBAI
(Autonomous) (ISO 9001: 2015) (ISO/IEC 27001:2013)

VISION

To ensure that the Diploma level Technical Education constantly matches the latest requirements of Technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

MISSION

To provide high quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the challenging technological & environmental challenges.

QUALITY POLICY

We, at MSBTE are committed to offer the best in class academic services to the students and institutes to enhance the delight of industry and society. This will be achieved through continual improvement in management practices adopted in the process of curriculum design, development, implementation, evaluation and monitoring system along with adequate faculty development programmes.

CORE VALUES

MSBTE believes in the following

- Skill development in line with industry requirements
- Industry readiness and improved employability of Diploma holders
- Synergistic relationship with industry
- Collective and Cooperative development of all stake holders
- Technological interventions in societal development
- Access to uniform quality technical education

A Laboratory Manual for

BIOSENSORS APPLICATIONS

(313327)

Semester – III

(MU)

Maharashtra State

Board of Technical Education, Mumbai

(Autonomous) (ISO 9001:2015) (ISO/IEC 27001:2013)

Maharashtra State Board of Technical Education , Mumbai
(Autonomous) (ISO 9001:2015) (ISO/IEC 27001:2013)
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(Printed on July, 2024)

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION MUMBAI

Certificate

This is to certify that Mr./Ms.…………………………………….........

Roll No.…………Of third Semester of Diploma in …..………………………………..................................of Institute ………………………………………………………………………… ……… (Code : ………) has completed the term work satisfactorily in course **BIOSENSORS APPLICATIONS (313327)** for the academic year 20…... .to 20…….. as prescribed in the curriculum.

Place: …………….. **Enrollment No. :……………….**

Date: ………………. **Exam Seat No.: ……………….**

Subject Teacher **Head of department** **Principal**

Seal of Institute

Preface

The primary focus of any engineering laboratory/field work in the technical education system is to develop the much needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'K' Scheme curricula for engineering diploma programmes with outcome-based education as the focus and accordingly, a relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work making each teacher, instructor and student realize that every minute of the laboratory time needs to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome- based curriculum, every practical course has been designed to serve as a ***'vehicle'*** to develop this industry identified competency in every student. The practical skills are difficult to develop through "chalk and duster" activity in the classroom situation. Accordingly, the "K' scheme laboratory manual development team designed the practical to focus on the outcomes, rather than the traditional age old practice of conducting practical to 'verify the theory" (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers and instructors to develop in the student the predetermined outcomes. It is expected. from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical. Every practical in this manual begins by identifying the competency, industry relevant skills, course outcomes and practical outcomes which serve as a key focal point for doing the practical. The students will then become aware about the skills they will achieve through the procedure shown there and necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student- centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

The course Biosensors Applications (313327) is intended to help student to learn the basics and application techniques of various biosensors and practical thereof. Biosensors are playing a vital role in the field of healthcare. From glucose monitoring in diabetes management to the detection of diseases, biosensors have revolutionized diagnostic procedures, offering rapid, accurate and minimally invasive solutions. The study of various biosensors in this course will be very useful for understanding the field of Medical Electronics. This course is developed in such a way that students will be able to apply the domain knowledge to solve various healthcare related problems.

Although best possible care has been taken to check for errors (if any) in this laboratory manual, perfection may elude us as this is the first edition of this manual. Any errors and suggestions for improvement are solicited and highly welcome.

Program Outcomes (PO's) to be achieved through Practicals of this Course

Following programme outcomes are expected to be achieved through the practical of the course.

- **PO1. Basic and Discipline specific knowledge**: Apply knowledge of basic mathematics, science and engineering fundamentals and engineering specialization to solve the broad based Electronic Engineering group program problems.

- **PO2. Problem analysis:** Identify and analyze well-defined Electronic Engineering group program problems using codified standard methods.

- **PO3. Design/ development of solutions:** Design solutions for well-defined technical problems and assist with the design of Electronic Engineering group program systems components or processes to meet specified needs.

- **PO4. Engineering Tools, Experimentation and Testing:** Apply modern Electronic Engineering group program tools and appropriate technique to conduct standard tests and measurements

- **PO5. Engineering practices for society, sustainability and environment:** Apply appropriate Electronic Engineering group program technology in context of society, sustainability, environment and ethical practices.

- **PO6. Project Management:** Use Electronic Engineering group program management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities.

- **PO7. Life-long learning:** Ability to analyze individual needs and engage in updating in the context of Electronic Engineering group program technological changes.

List of Industry Relevant Skills

The following industry relevant skills of the identified of competency "Use relevant transducers to measure bio-signals." are expected to be developed in the student by undertaking the laboratory work as given in laboratory manual.

1. Use the concept of RTD, Thermistor and Thermocouple in real life applications.
2. Identify various parts of a given electrode.
3. Apply safety measures and precaution before using any biosensor.
4. Build signal conditioning circuit to amplify and filter biosignals.

Practical-Course Outcome Matrix

COURSE LEVEL LEARNING OUTCOMES (COS)

CO1 - Identify different biosignals and sensors used for different medical applications.
CO2 - Use biopotential electrodes for medical applications.
CO3 - Measure temperature, pressure and displacement by using various transducers.
CO4 - Identify various transducers involved in measuring different chemical parameters.
CO5 - Build signal conditioning circuit for various applications.

Sr.No.	Title of the Practical	CO1	CO2	CO3	CO4	CO5
1	*Identification of various transducers	✓				
2	*Identification of various types of bio-potential electrodes		✓			
3	Pressure measurement using piezoelectric transducer			✓		
4	*Pressure measurement using bourdon tube			✓		
5	*Temperature and sensitivity measurement of thermistor			✓		
6	Sensitivity measurement of RTD and thermocouple.			✓		
7	*pH level measurement of solution				✓	
8	*Blood glucose level measurement using glucometer				✓	
9	*Blood flow measurement using ultrasonic flow transducer				✓	
10	Flow measurement using rotameter				✓	
11	Identification of various parts of pO_2 and pCO_2 electrodes				✓	
12	Gain measurement of an instrumentation amplifier					✓
13	*Performance of signal conditioning circuit for temperature measurement using thermistor					✓
14	Performance of signal conditioning circuit for temperature measurement using RTD					✓
15	Performance of signal conditioning circuit for temperature measurement using thermocouple					✓
16	Simulation of biopotential amplifier					✓

Guidelines to Teachers

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain prior concepts to the students before starting of each practical.
3. Involve students in the performance of each experiment.
4. Teacher should ensure that the respective skills and competencies are developed in the students after the completion of the practical exercise.
5. Teachers should give opportunities to students for hands-on experience after the demonstration.
6. Teacher is expected to share the skills and competencies to be developed in the students.
7. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected of the students by the industry.
8. Finally give practical assignments and assess the performance of students based on tasks assigned to check whether it is as per the instructions.
9. Teacher is expected to refer complete curriculum document and follow guidelines for implementation
10. At the beginning of the practical which is based on the simulation, teacher should make the students acquainted with any simulation software environment.

Instructions for Students

1. Listen carefully to the lecture given by the teacher about the subject, curriculum, learning structure, skills to be developed.
2. Organize the work in the group and record all programs.
3. Students shall develop maintenance skills as expected by industries.
4. Students shall attempt to develop related hand-on skills and gain confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. those included in scope of manual.
6. Students shall refer to technical magazines.
7. Students should develop the habit to submit the practicals on date and time.
8. Students should prepare well while submitting a write-up of exercise.
9. Attach/paste separate papers wherever necessary

Content Page

List of Practicals and Progressive Assessment Sheet

Sr. No.	Title of the Practical	Page no.	Date of Performance	Date of Submission	Assessment Marks (25)	Dated sign.of Teacher	Remark (If any)
1	*Identification of various transducers						
2	*Identification of various types of bio-potential electrodes						
3	Pressure measurement using piezoelectric transducer						
4	*Pressure measurement using bourdon tube						
5	*Temperature and sensitivity measurement of thermistor						
6	Sensitivity measurement of RTD and thermocouple.						
7	*pH level measurement of solution						
8	*Blood glucose level measurement using glucometer						
9	*Blood flow measurement using ultrasonic flow transducer						
10	Flow measurement using rotameter						
11	Identification of various parts of pO_2 and pCO_2 electrodes						
12	Gain measurement of an instrumentation amplifier						
13	*Performance of signal conditioning circuit for temperature measurement using thermistor						
14	Performance of signal conditioning circuit for temperature measurement using RTD						

15	Performance of signal conditioning circuit for temperature measurement using thermocouple							
16	Simulation of biopotential amplifier							
Total								

Note : Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

Practical No.1: Identification of various transducers

I. Practical Significance

In industries, different types of transducers are used for various processes such as automation, measurement and control systems. Hence students should know about various transducers and the transduction. Transduction is the process used by a transducer to convert the energy of one form to other. Some of the common examples of transducers include microphones, RTD, Rotameter etc.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences:

Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

- Identify different bio signals and sensors used for different medical applications.

IV. Laboratory Learning Outcome(s)

- Identify the type of given transducer.
- Compile the list of provided transducers along with their brief specification.

V. Relevant Affective Domain related outcome(s)

Identification of various types of transducers

VI. Relevant Theoretical Background

Many physical, chemical and optical properties and principles can be applied to construct transducers for applications in the medical field.

The transducers can be classified in many ways, such as:

(i) By the process used to convert the signal energy into an electrical signal. For this, transducers can be categorised as:

Active Transducers:

- Definition: Active transducers do not require an external power source (usually electrical) to operate and produce an output signal that is a function of the input quantity they are sensing.
- Operation: They actively generate an output signal in response to a physical phenomenon (such as pressure, temperature, or strain). This output signal typically requires amplification because it is relatively weak.
- Examples:
    - Thermocouples, Photovoltaic cells (Solar cells), Piezoelectric sensors

Passive Transducers:

- Definition: Passive transducers require an external power source to operate. They generate an output signal in response to the variation in some physical quantity they are measuring.
- Operation: They rely on the physical phenomenon directly affecting their electrical properties (such as resistance, capacitance, or inductance) to produce an output signal.

- Examples:
    - Resistance temperature detectors (RTDs), Strain gauges, LVDTs (Linear Variable Differential Transformers)

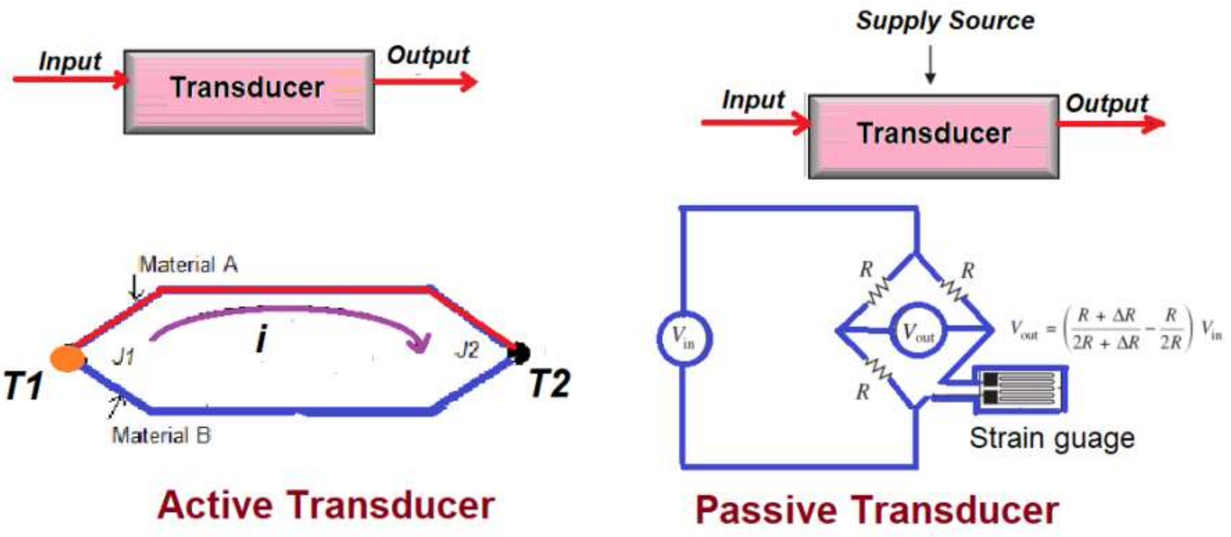

Fig. 1.1 Active & Passive Transducers

(ii) Based on the process used, transducers can be categorised as:

Primary Transducer:

1. Definition: The primary transducer is the initial component in a measuring system that directly converts the input quantity (such as pressure, temperature, or displacement) into a proportional electrical signal or mechanical response.
2. Examples:
    - Bellows, Bourdon tube

Secondary Transducer:

1. Definition: The secondary transducer is the component that receives the signal from the primary transducer and further processes, conditions, or converts it into a standardized electrical signal suitable for measurement or display.
2. Examples:
    - LVDT, strain gauge

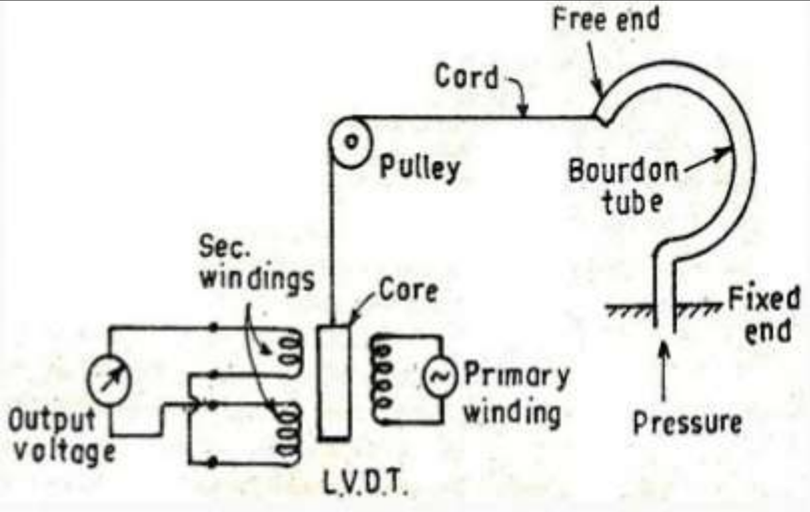

Fig. 1.2 Bourdon tube (acting as Primary transducer) and LVDT (acting as Secondary transducer)

(iii) Based on Physical Principles:

1. Mechanical Transducers:

○ Strain Gauges, LVDTs (Linear Variable Differential Transformers). Accelerometers, Tachometers, Flow meters

2. Electrical Transducers:

○ Thermocouples, Photovoltaic Cells (Solar Cells), Piezoelectric Sensors

3. Optical Transducers:

○ Photodiodes/Phototransistors, Fiber Optic Sensors, Laser Doppler Vibrometers

(iv) Based on Chemical Principles:

1. Electrochemical Transducers:

○ pH Electrodes, Gas Sensors

2. Biochemical Transducers:

Enzyme-Based Sensors, Immunoassay Sensors, Gas Sensors, Metal Oxide Sensors, Catalytic Bead Sensors

VII. Circuit diagram

Layout of Laboratory

(Draw various transducer available in the laboratory and label it.)

VIII. Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	RTD	PT 100	01
2	Thermister	NTC/PTC	01
3	Strain Gauge	BF350 High Precision Resistance Strain Gauge 350 Ohm Pressure Sensor	01
4	pH electrode	pH electrode with three different buffer solutions- 7, 4 and 9.2 pH	01

IX. Precautions to be followed

1) Ensure that the transducer is working within the specified range. Overloading can damage the transducer or lead to inaccurate readings.
2) Check the operating temperature range and environmental conditions (humidity, pressure, etc.) specified for the transducer. Exposing it to conditions outside these ranges could affect its performance.
3) Regularly calibrate the transducer according to the manufacturer's recommendations. This ensures accuracy and reliability of the measurements over time.
4) Keep the transducer clean and free from debris that could interfere with its operation.

X. Procedure

1) Identify the specific requirements of your application, including the type of energy conversion needed.
2) Based on the requirements, select a transducer that suits your application. Consider factors like range, sensitivity, accuracy, and environmental conditions.
3) Securely mount the transducer in the appropriate location. Ensure that it is positioned correctly to interact with the measured parameter (e.g., temperature, pressure, displacement).
4) Connect the transducer to the necessary electrical circuitry.
5) Perform an initial calibration to ensure the transducer provides accurate readings.
6) Turn on the transducer and associated systems.
7) Begin acquiring data from the transducer. Ensure that the data is being correctly recorded and monitored.

XI. Observations and Calculations (use blank sheet provided if space not sufficient)

Table 1.1

Name of the Transducer	Active/Passive	Primary/ Secondary

XII. Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XIII. Actual Procedure

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XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are a few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identifying CO.

1. Write the name and specification of the various transducers available in the laboratory.
2. Write the examples of transducers based on different classification criteria.
3. Define Transducer. List advantages of active transducers.
4. Show the location of Transducer in MIS.
5. Write general constraints in design of MIS.

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://gmw.com/transducers/
2. https://www.electrical4u.com/transducer-types-of-transducer/
3. https://www.electricaltechnology.org/2021/11/transducer.html

XIX. Assessment Scheme

	Performance Indicators	Weightage
	Process Related : 15 Marks	60 %
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.2: Identification of various types of bio-potential electrodes

I. Practical Significance

Biopotentials are electrical signals (voltages) that are generated by physiological processes occurring within the body. Hence to study various physiological parameters, biopotential electrodes are essential. Students must know various types of biopotential electrodes which are necessary for diagnosis of various diseases.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences:

Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

- Use biopotential electrodes for medical applications.

IV. Laboratory Learning Outcome(s)

- Identify different types of bio-potential electrodes.

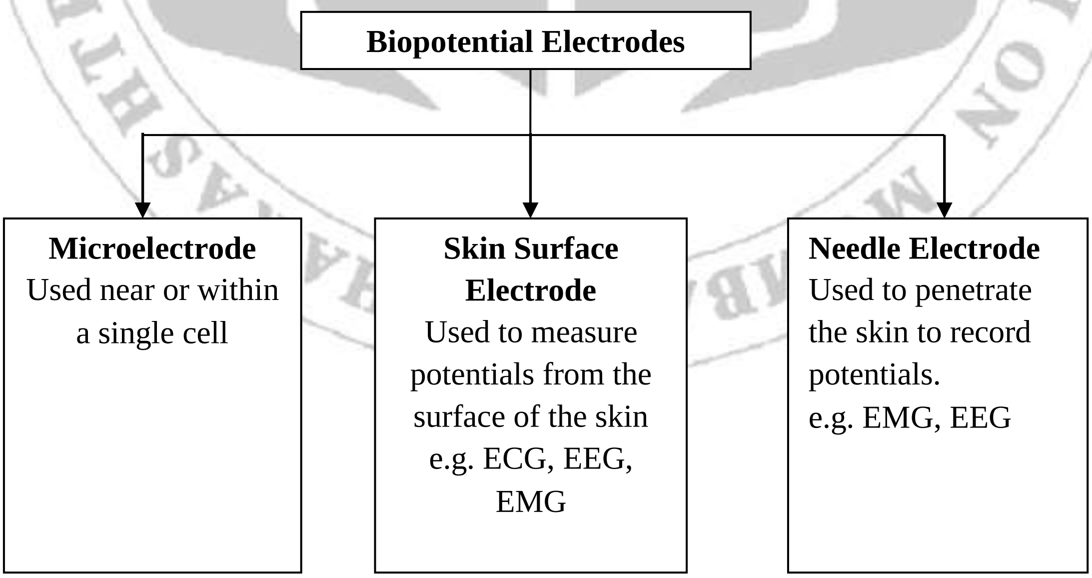
V. Relevant Affective Domain related outcome(s)

Identification of different types of bio-potential electrodes.

VI. Relevant Theoretical Background

Biopotentials are produced by the electrochemical activity of a type of cell, called an excitable cell such as cells of nervous, muscular and glandular systems in the body. A biopotential electrode is a transducer that senses physiological signal on the surface of tissue, and converts it into electron current.

A wide variety of electrodes can be used to measure bioelectric events can be classified as



Microelectrodes:

Tips of microelectrode are sufficiently small to penetrate a single cell in order to obtain readings from within the cell. Microelectrodes are of two types – metal and micropipette

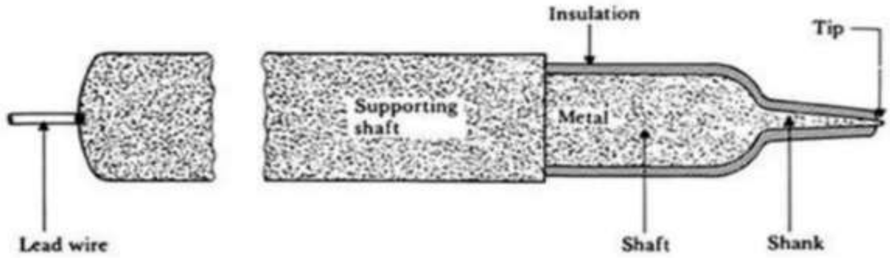


Fig 2.1 Metal Microelectrode

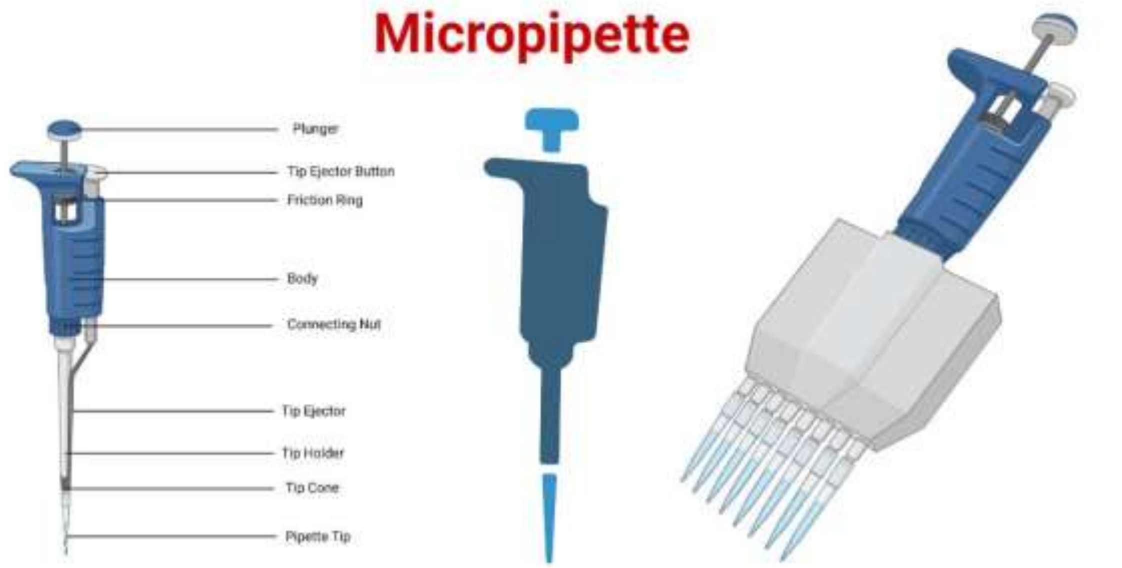
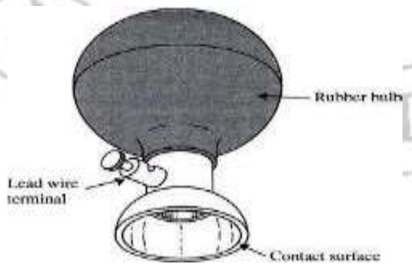
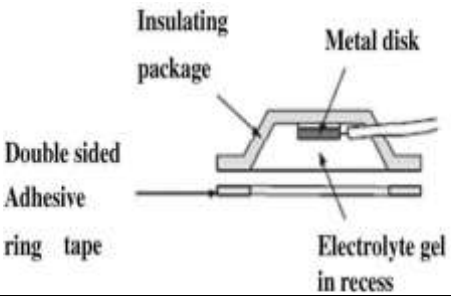
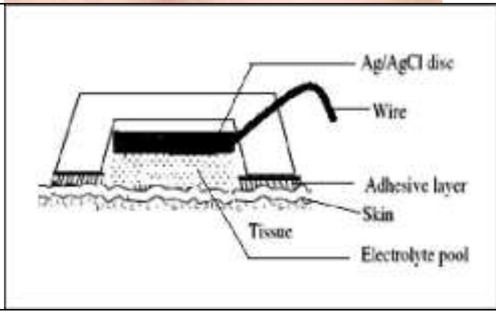


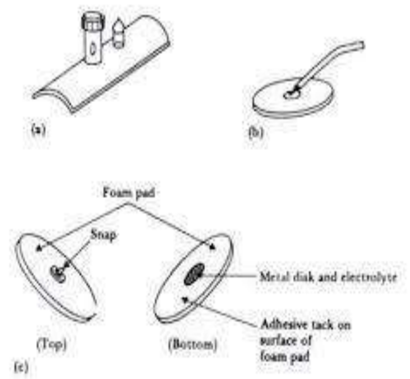
Fig 2.2 Micropipette

Body Surface Electrodes:

Electrodes used to obtain bioelectric potentials from the surface of the body are found in many sizes and forms. The larger electrodes are usually associated with ECG whereas smaller electrodes are used in EEG and EMG measurement.

Table 2.1

Name of Electrode	Diagram	Application
1.Suction Cup Electrode		
2. Floating Type electrode		

3. Disposable electrodes		

Needle electrodes: These electrodes are designed to penetrate the skin surface of the body to a certain depth in order to record EEG or EMG potentials in a specific area.

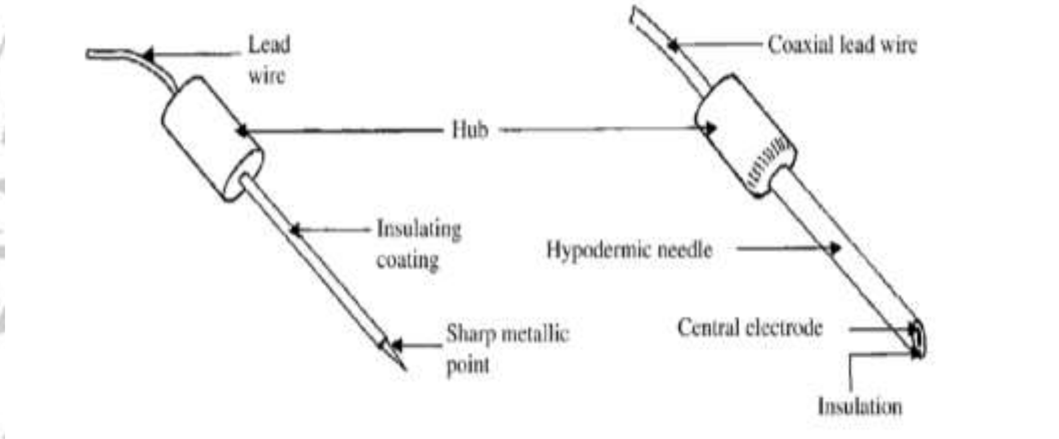


Fig 2.3 Needle Electrode.

VII. Circuit diagram

Layout of Laboratory

(Draw various biopotential electrodes available in the laboratory and label it.)

VIII. Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Electrodes	Suction Electrode Disposable Electrode Needle Electrode Metal surface electrodes Button Shaped Electrodes	01 each
2	Electrode Gel	ECG/ Sonography Electrode gel	01

IX. Precautions to be followed

1. Do not use the Electrode on injured areas of the skin.
2. Do not use the Self-adhesive Electrode if it loses its adhesion strength. The electric current may concentrate in a certain area, depending on conditions of contact with the skin, resulting in burns or inflammation.
3. Insert each pin of the electrode cable into the end of each cord firmly until you can no longer see the metal portion.
4. When removing the electrode from the storage plate or the skin, grasp a corner and slowly lift. Never pull the cord to remove it.

X. Procedure

Skin Preparation

- Thoroughly clean the skin of any oils, creams, dirt, dead skin etc.
- Use water to clean the area and ensure skin is fully dry before placing the electrodes on the skin.
- If hairy, use beard trimmers or scissors to clip the hair. Do not shave the area as this causes tiny micro abrasions which will make the stimulation uncomfortable.
- Ensure there are no wrinkles on the electrodes when placed on the skin

Electrode Size

- Any muscle lying under an electrode will be stimulated. Therefore, select the correct size to ensure only the muscles you want to target are stimulated.

Looking after your electrodes

- The key to longevity of electrodes is slowing down the drying out of them when not in use.
- When removed from the skin, slightly moisten the sticky side of the electrode (a damp fingertip works well).
- Place the clear backing back on the sticky side after moistening.
- Place the electrodes back in their bag for storing.
- Typically, standard electrodes will last about 30 applications. It may vary according to manufacturer.

XI. Observations and Calculations (use blank sheet provided if space not sufficient)

Table 2.2

Name of Biopotential electrode	Application of the given electrode

XII. Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1			
2			

XIII. Actual Procedure

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XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Write the application of Electrodes.
2. Observe various types of electrodes available in the laboratory and identify various parts of it.
3. Draw types of microelectrodes and label it.
4. Compare Metal microelectrode and glass micropipette.

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://uomus.edu.iq/img/lectures21/MUCLecture_2023_91025616.pdf
2. https://www.vsbec.com/wp-content/uploads/2022/03/QUESTION-BANK-III-ECE.pdf

XIX. Assessment Scheme

	Performance Indicators	**Weightage**
	Process Related : 15 Marks	60 %
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.3: Pressure measurement using piezoelectric transducer

I. Practical Significance

Recent years show progress in the applications of piezoelectric materials in biomedical devices due to their biocompatibility and biodegradability. Piezoelectric transducers employed in devices like phonocardiography to detect and record heart sounds by measuring and converting pressure into electrical signals.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences:

Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

Measure temperature, pressure and displacement by using various transducers.

IV. Laboratory Learning Outcome(s)

Test the performance of piezoelectric transducer.

V. Relevant Affective Domain related outcome(s)

a) Follow safety practices.

b) Maintain cleanliness of transducer setup.

VI. Relevant Theoretical Background

A piezoelectric sensor is a device that uses the piezoelectric effect to measure changes in pressure, acceleration, temperature, strain, or force by converting them to an electrical charge.

A piezoelectric transducer consists of quartz crystal which is made from silicon and oxygen ranged in crystalline structure (SiO2). Generally, the unit cell (basic repeating unit) of all crystals is symmetrical but in piezoelectric quartz crystal, it is not. Piezoelectric crystals are electrically neutral.

The materials are Barium Titanate, Lead zirconate titanate (PZT), Rochelle salt.

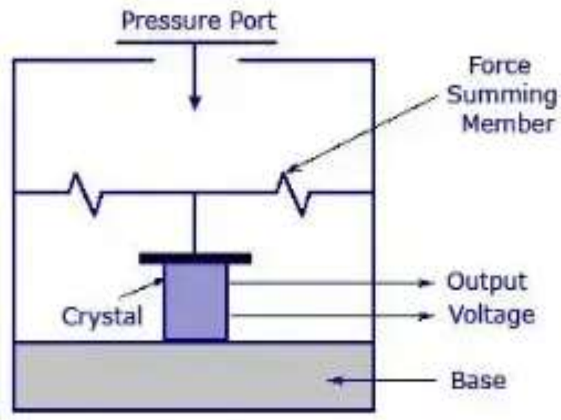

Fig. 3.1 Piezoelectric Transducer

The electric voltage produced by a piezoelectric transducer can be easily measured by the voltage measuring instruments. Since this voltage will be a function of the force or pressure applied to it, we can infer what the force/pressure was by the voltage reading. In this way, physical quantities like mechanical stress or force can be measured directly by using a piezoelectric transducer.

Medical Application of Piezoelectric Transducer

- Crystal microphone measures and records the heart sounds (phonocardiography). The microphone operates in the flat frequency range of 20 to 1000 Hz, which suppresses the breathing sounds and room noise. Sounds from heart chambers are measured with catheter-tip piezoelectric sensors.
- A piezoelectric crystal detects korotkoff sounds, crucial for measuring systolic and diastolic blood pressure, as illustrated in the figure.

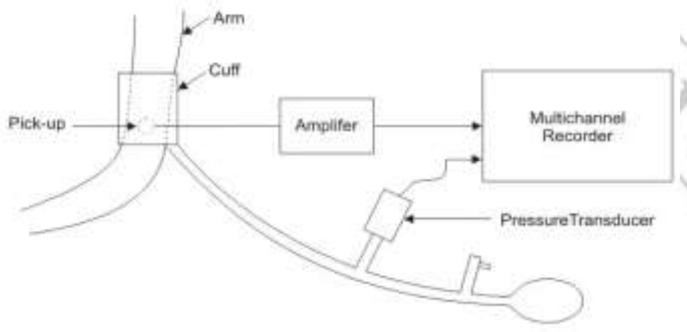

Fig. 3.2 Application of Piezoelectric transducer in Sphygmomanometer

- A piezoelectric sensor senses a radial pulse.
- In ultrasonic scanning devices, piezoelectric transducers are used. When an ultrasonic pulse transmits through the human body, it reflects an echo signal of different frequency. The received signal is displayed on a cathode ray oscilloscope.
- In hospitals, continuous medication delivery requires monitoring the dosage. This is achieved through drop-counting using a piezoelectric crystal, where a mesh attached to the transducer generates a pulse with each medicine drop.

VII. Actual Circuit diagram used in a laboratory with related equipment rating.

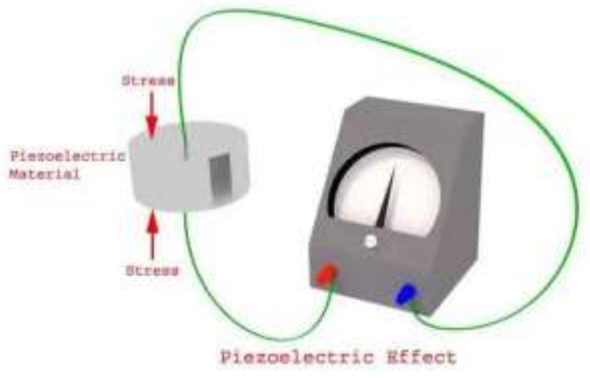

Fig 3.3 Pressure Measurement Setup

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Piezoelectric Transducer pressure measurement setup	Piezoelectric Transducer Trainer Kit: Power supply – 230V, 50Hz, piezo sensor- donut type 1000 pf piezo-crystal, display -3 1/2 digit to read +-1999 counts	1

IX. Precautions to be followed

1) Ensure that proper connections are made as per the setup.
2) Ensure proper setting of devices used.
3) Ensure the power switch is in off condition initially.

X. Procedure

1. Switch ON the kit.
2. Apply pressure to piezoelectric transducer
3. Note the applied pressure (Input) and corresponding voltage (Output)
4. Repeat steps 3 and 4 for 5 times.
5. Plot the graph pressure versus voltage output.

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity
1			
2			
3			
4			

XII. Actual Procedure

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XIII. Observation Table

Table 3.1: Observations and Calculations

Sr. No.	Applied Pressure (Input)	Voltage on Digital Display (Output)
1		
2		
3		
4		
5		

XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Explain working of inverse transducer
2. List applications of piezoelectric transducer
3. Mention piezoelectric transducer is an active or passive. Justify your answer.
4. Draw the neat circuit diagram of pressure measurement setup using piezoelectric transducer available in your laboratory.

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://vssd-iitd.vlabs.ac.in/exp/piezoelectric-sensors/index.html
2. https://en.wikipedia.org/wiki/Piezoelectric_sensor
3. https://my.avnet.com/abacus/solutions/technologies/sensors/pressure-sensors/core-technologies/piezoelectric/

XIX. Assessment Scheme

	Performance Indicators	Weightage
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Scale -

X-Axis -

Y-Axis -

Practical No.4: Pressure measurement using bourdon tube

I. Practical Significance

The physical parameters such as temperature, pressure, flow etc. need to be monitored and controlled in the hospitals. The pressure measurement can be done directly or indirectly. The bourdon tube is a transducer used to measure pressure.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ empolyer expected outcome through various teaching learning experiences:

Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

Measure temperature, pressure and displacement by using various transducers.

IV. Laboratory Learning Outcome(s)

Measure the air pressure using bourdon tube.

V. Relevant Affective Domain related outcome(s)

a) Follow safety practices.

b) Maintain cleanliness of transducer setup.

VI. Relevant Theoretical Background

Bourdon Tube is known for its very high range of differential pressure measurement in the range of almost 100,000 psi (700 MPa). It is an elastic type pressure transducer. A C type bourdon tube consists of a long thin wall cylinder of non-circular cross section, sealed at one end and made up of material such as phosphorous bronze, steel, beryllium copper, and attached by light line mechanism which operates the pointer. The other end of the tube is fixed and is open for application of pressure which is to be measured. The tube is soldered to a socket at the base through which pressure connection is to be made.

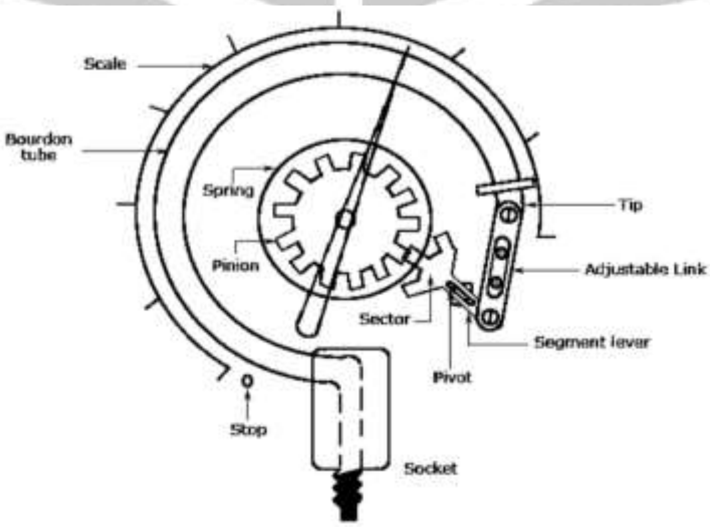

Fig 4.1 C shaped Bourdon Tube Pressure Gauge

Working

As the fluid pressure enters the bourdon tube, it tries to be reformed and because of a free tip available, this action causes the tip to travel in free space and the tube unwinds. The simultaneous actions of bending and tension due to the internal pressure make a non-linear movement of the free tip. This travel is suitably guided and amplified for the measurement of the internal pressure. But the main requirement of the device is that whenever the same pressure is applied, the movement of the tip should be the same and on withdrawal of the pressure the tip should return to the initial point.

Fig 4.2 Indicator front with pointer and dial

Fig 4.3 Mechanical side with Bourdon tube

VII. Actual Circuit diagram used in a laboratory with related equipment rating.

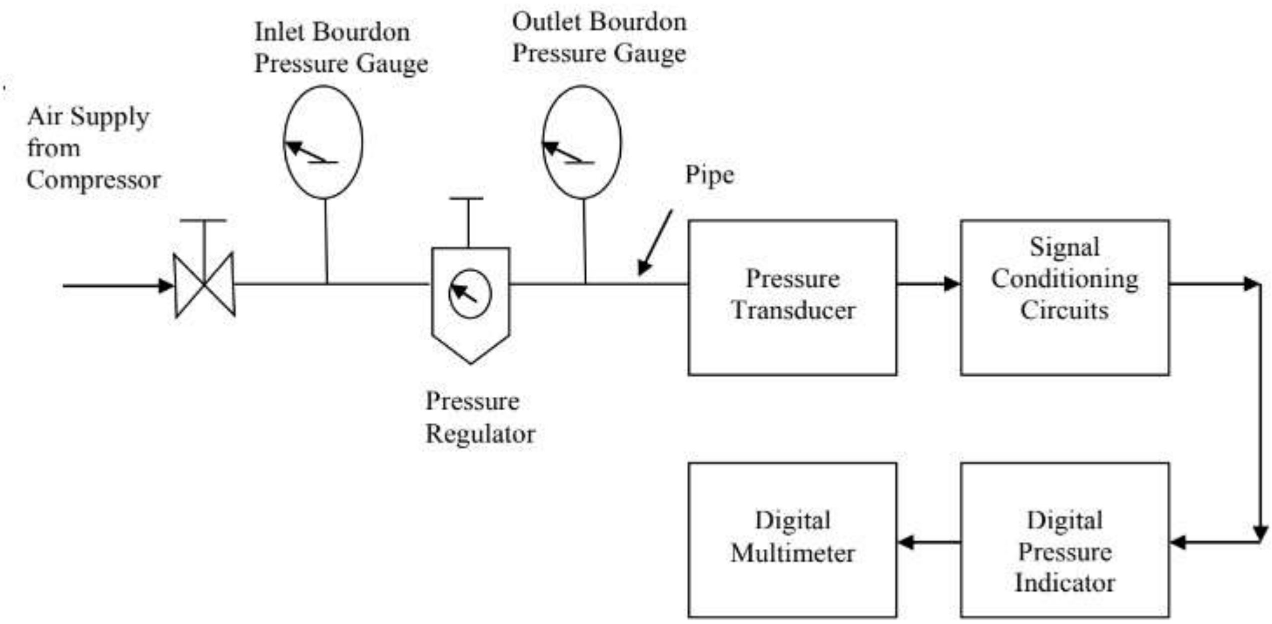

Fig. 4.4 Pressure Measurement Setup

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Bourdon tube pressure gauge measurement setup	Bourdon tube pressure measurement setup - Pressure store tank with attached bourdon tube, pressure gauge range- 0 - 150 PSI, 0 – 10 kg/cm^2	1

IX. Precautions to be followed

1) Ensure that proper connections are made as per the setup.
2) Ensure proper setting of devices used.
3) Ensure the power switch is in off condition initially.

X. Procedure

1. Identify the component of given setup diagram
2. Connect pressure measurement setup as in diagram.
3. Switch on the power supply
4. Provide pressure of 5 psi with a compressor.
5. Increase the pressure in steps of 5 PSI
6. Record the output pressure on dial gauge
7. Record the output pressure on digital display
8. Repeat the steps 4 to 7 for 5 times.

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity
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XII. Actual Procedure

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XIII. Observation Table

Table 4.1: Observations and Calculations

Sr. No.	Pressure on dial gauge	Pressure Indication on Digital Display
1		
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3		
4		
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XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. State the output pressure when no pressure is applied from the compressor.
2. State the maximum range of pressure measurement.
3. State the type of bourdon tube used in practice.
4. State the type of material used for the construction of in bourdon tube.

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://en.wikipedia.org/wiki/Pressure_measurement#Bourdon_tube
2. https://www.gteek.com/Bourdon-tube-pressure-gauges
3. https://tameson.com/pages/bourdon-tube-pressure-gauge

XIX. Assessment Scheme

	Performance Indicators	Weightage
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.5: Temperature and sensitivity measurement of thermistor

I. Practical Significance

The Temperature is one of the most important measurement parameters that is used for monitoring and control of processes in the medical field. It can be measured with the help of a variety of temperature sensing devices which reacts to a change in temperature. Thermistor is the cheapest temperature transducer which converts temperature into an equivalent resistance. As it is available in small size and various shapes, thermistors are widely used in the biomedical field.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences:

Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

Measure temperature, pressure and displacement by using various transducers.

IV. Laboratory Learning Outcome(s)

1. Measure the temperature using a thermistor.
2. Determine the sensitivity of the thermistor.

V. Relevant Affective Domain related outcome(s)

a) Follow safety practices.
b) Maintain cleanliness of transducer setup.

VI. Relevant Theoretical Background

Thermistor is a linear passive transducer used for the measurement of temperature.

The term is a combination of “thermal” and “resistor”. It is made of metallic oxides, pressed into a bead, disk, or cylindrical shape and then encapsulated with an impermeable material such as epoxy or glass.

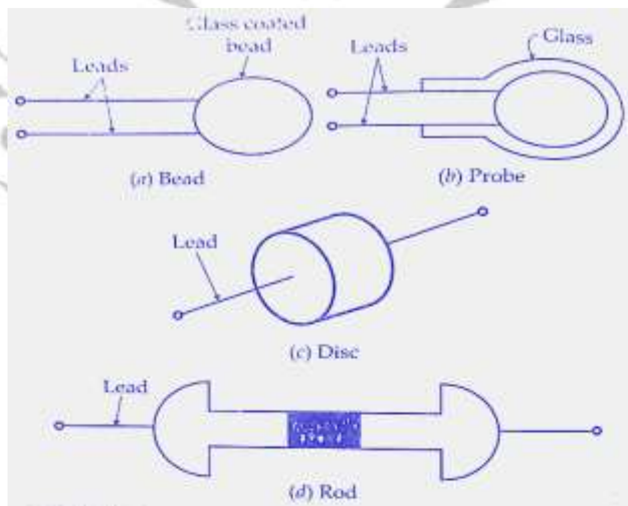

Fig 5.1 Types of thermistors

Thermistor is the temperature transducer which converts temperature into an equivalent resistance. The change in resistance can be measured using an ohmmeter or converted into a voltage using a bridge circuit.

$$V_{out} = V_1 - V_2 = \left[\left(\frac{R_a}{(R_a + R(t))} - \frac{R_c}{(R_c + R_b)} \right) \right] V_s$$

- V_1 and V_2 are the bridge voltages,
- R_a , R_b , and R_c are the bridge resistors
- V_s is the supply voltage

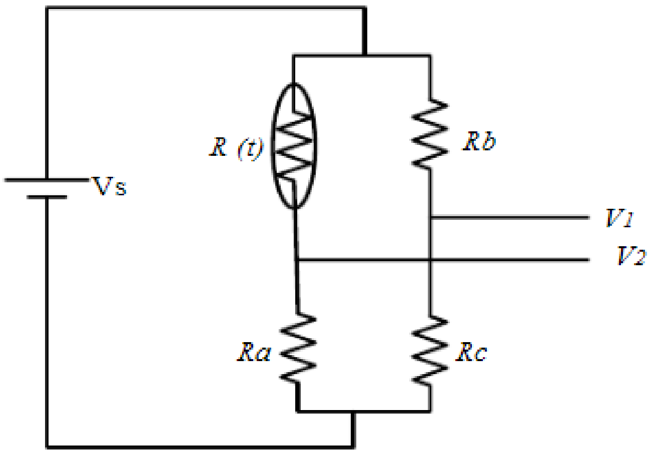

Fig 5.2 Bridge circuit with thermistor

Thermistors are classified into two types:

With *NTC* thermistors, resistance decreases as temperature rises; and With *PTC* thermistors, resistance increases as temperature rises.

The resistance follows an exponential variation with temperature which is given by the following relation:

$R=R_0\exp [\beta (1/ T - 1/ T_0)]$

Where T_0 = Initial Temperature

R_0= Resistance of the thermistor at T_0

β = An experimental constant that can have a value between 3500-4500° K.

Sensitivity: It is defined as the ratio of the changes in the output of a sensor to a change in the value of the quantity being measured. It denotes the smallest change in the measured variable to which the sensor responds.

VII. Actual Circuit diagram used in laboratory with related equipment rating.

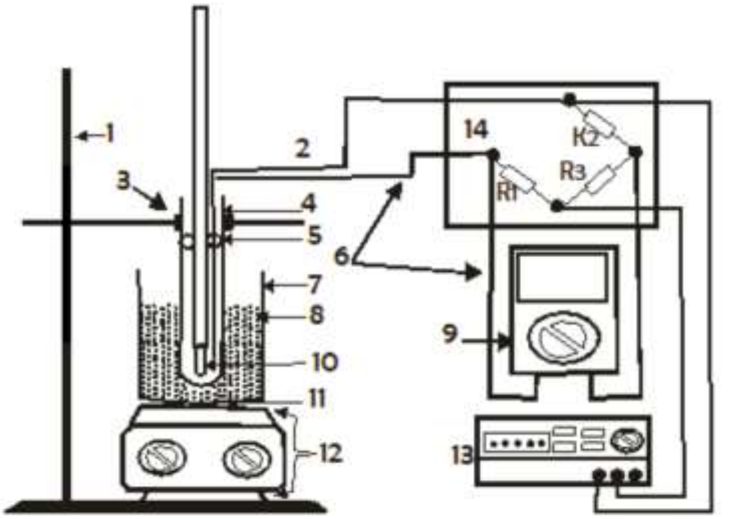

Diagram showing the experimental set-up to measure the performance of the built circuit. 1.Retort stand 2. Thermometer 3. Clamp 4. Test tube 5. Cotton 6. Isolation 7. Beaker 8. Water 9. Multimeter 10. Thermistor 11. Stirrer 12. Stove 13. DC supply voltage 14. Electrical board.

Fig. 5.3 Thermistor temperature measurement setup

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Thermistor temperature measurement setup	Trainer kit suitable to measure the temperature using a thermistor setup should be provided with heater which can go up to 200 °C with facility to vary heater power, constant current source with amplifier, 3 1⁄2 digit digital indicator of temperature, In built DC regulated power supply etc.	1

IX. Precautions to be followed

1) Ensure that proper connections are made as per the setup.
2) Ensure proper setting of devices used.
3) Ensure the power switch is in off condition initially.

X. Procedure

1. Connect set up for temperature measurement with thermocouple.
2. Place the thermistor, thermometer and immersion heater in a temperature bath.
3. Record the room temperature with a mercury thermometer.
4. Record the temperature displayed on the kit for room temperature.
5. Switch on the power supply of the heater.
6. Note down the temperature for every 10 degree temperature rise.
7. Record the temperature using mercury thermometer.

8. Record the output temperature displaying on the kit
9. Complete the observation table.
10. Repeat the steps 6 to 9 for 10 readings.
11. Plot the graph of thermometer temperature (Input) Vs temperature on kit (Output)
12. To calculate thermistor sensitivity, find the slope of the graph.

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure

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XIII. Observation Table

Table 5.1: Observations and Calculations

Sr. No.	Thermometer temperature (Input) °C	Temperature on kit (Output) °C
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XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. List applications of PTC thermistor.
2. Explain the importance of thermistor
3. List types of thermistors
4. Explain the working of thermistor.

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://htv-au.vlabs.ac.in/heat-thermodynamics/Characteristics_of_Thermistor/
2. https://vlab.amrita.edu/?sub=1&brch=282&sim=1511&cnt=1
3. https://en.wikipedia.org/wiki/Thermistor

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Scale -

X-Axis -

Y-Axis -

Practical No.6: Sensitivity measurement of RTD and thermocouple

I. Practical Significance

The Temperature is one of the most important measurement parameters that is used for monitoring and control of processes in the medical field. It can be measured with the help of a variety of temperature sensing devices which reacts to a change in temperature. One such device is a resistance temperature detector, commonly called RTD (Resistance Temperature Detector) which converts temperature into an equivalent resistance whereas Thermocouple converts temperature into equivalent voltage.

RTD (Resistance Temperature Detector) is the most linear passive temperature transducer. PT-100 is commonly used, economic RTD. It is made up of platinum and it have 100 Ω resistance at 0^o temperature, hence the name is PT-100 . RTD have higher accuracy and repeatability. Thermocouple is the most useful active temperature transducer. It works on Seebeck and Peltier effects. Since it is an active transducer, designing a signal conditioning unit is easy. This is commonly used to measure the temperature above 300^o C.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences:

Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

Measure temperature, pressure and displacement by using various transducers.

IV. Laboratory Learning Outcome(s)

1. Measure the temperature using RTD and thermocouple.

2 Determine the sensitivity of RTD and thermocouple.

V. Relevant Affective Domain related outcome(s)

a) Follow safety practices.

b) Maintain cleanliness of transducer setup.

VI. Relevant Theoretical Background

Part A.

RTD is a linear passive transducer used for the measurement of temperature. These are made up of metal wire or fiber material that responds to temperature change by changing resistance, Platinum, nickel, and tungsten are most commonly used that have high resistivity, good temperature coefficient of resistance, good tensile strength and chemical inertness with packaging and insulation materials. The change in resistance can be measured using an ohmmeter or converted into a voltage using a bridge circuit. RTDs are generally more accurate than thermocouples, but are less rugged and cannot be used at high temperatures The most commonly used RTD is PT100. For small ranges of temperatures the expression for resistance may be,

$R_2 = R_1 [1+\boldsymbol{\alpha} (t_2 - t_1)]$

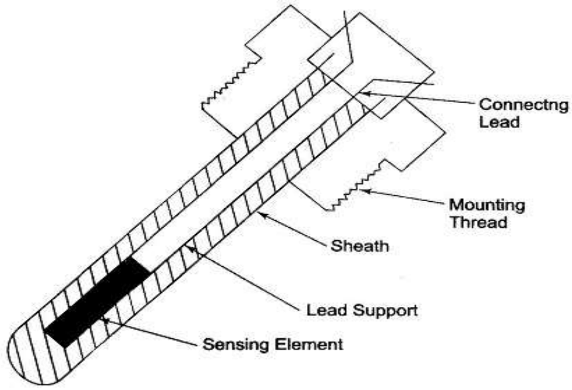


Fig 6.1 Resistance Temperature Detector

where t_1- initial temperature
t_2 - final temperature
R_1 -Initial resistance
R_2- final resistance
$\boldsymbol{\alpha}$ -Temperature coefficient of resistance at initial temperature

Part B.

Thermocouple: A thermocouple is a device made by two different wires joined at one end, called junction end or measuring end. The two wires are called thermo elements or legs of the thermocouple: the two thermo elements are distinguished as positive and negative ones. The other end of the thermocouple is called reference end. The junction end is immersed in the environment whose temperature T_2 has to be measured, which can be for instance the temperature of a furnace at about 500°C, while the reference end is held at a different temperature T_1, e.g. at ambient temperature.

Thermocouples will cause an electric current to flow in the attached circuit when subjected to changes in temperature. The amount of current that will be produced is dependent on the temperature difference between the measurement and reference junction; the characteristics of the two metals used; and the characteristics of the attached circuit.

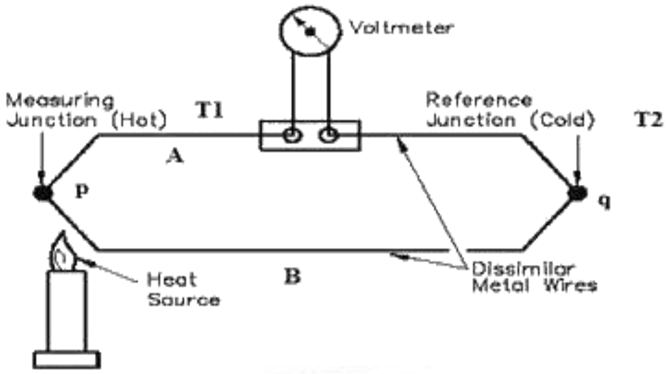


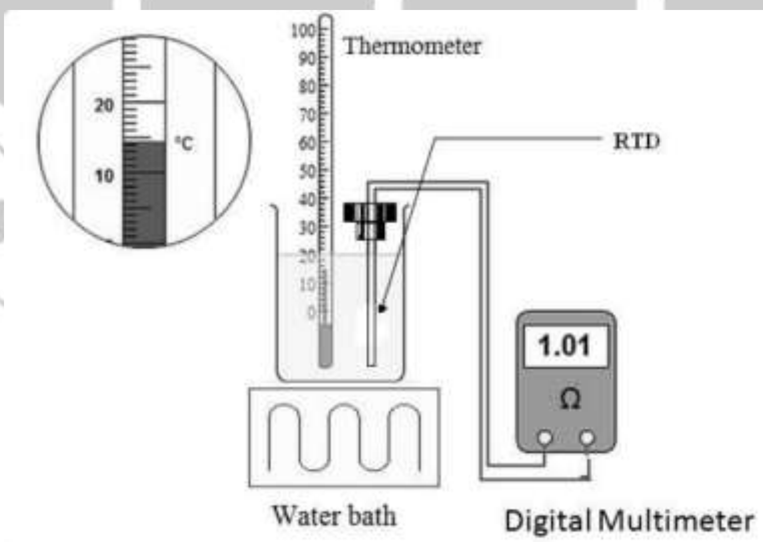
Fig. 6.2 Thermocouple

Heating the measuring as shown in above figure Simple Thermocouple Circuit junction on the thermocouple produces a voltage which is greater than the voltage across the reference junction. The difference between the two voltages is proportional to the Difference in temperature and can be measured on the voltmeter (in millivolts).

Sensitivity: It is defined as the ratio of the changes in the output of a sensor to a change in the value of the quantity being measured. It denotes the smallest change in the measured variable to which the sensor responds.

VII. Actual Circuit diagram used in laboratory with related equipment rating.

Part A:



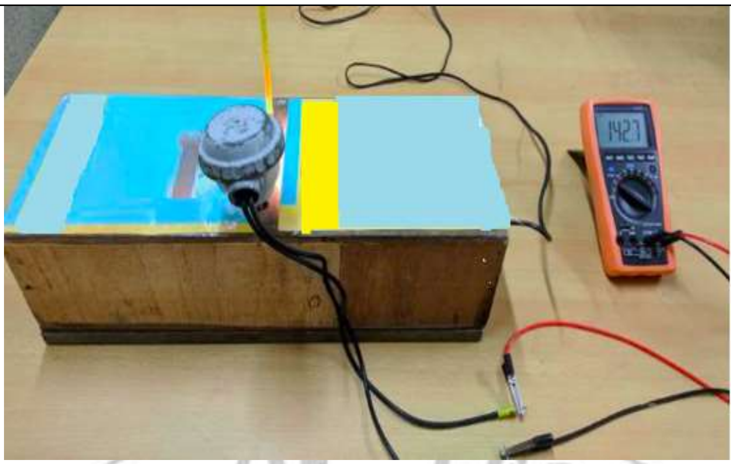
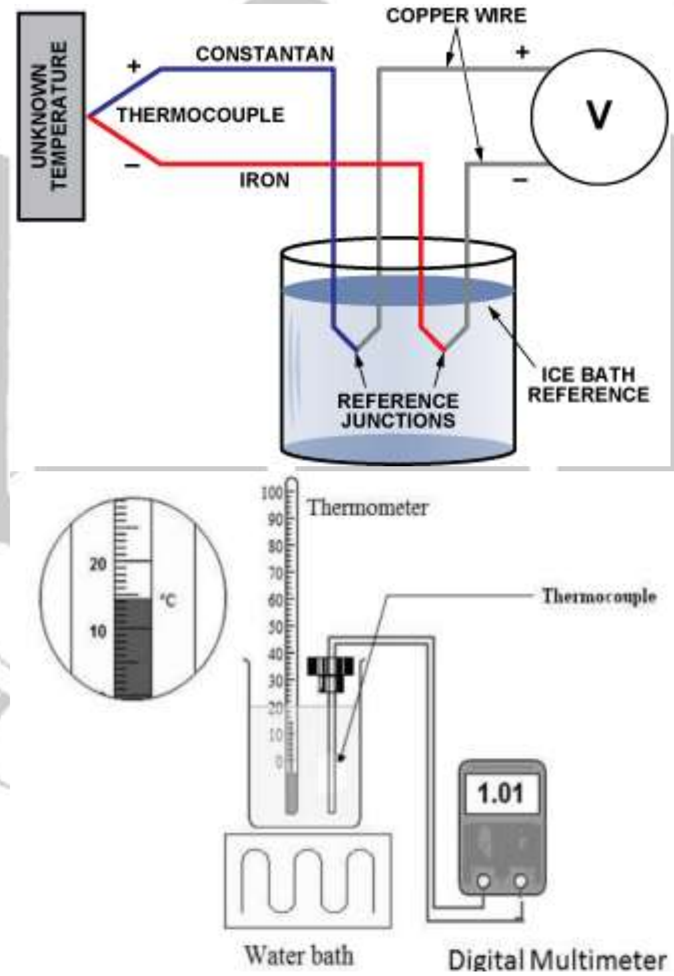


Fig. 6.3 RTD temperature measurement setup

Part B:



Courtesy :https://srmvalliammai.ac.in/

Fig. 6.4 Pressure Measurement Setup

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	RTD temperature measurement setup	Trainer kit suitable to measure the temperature using PT 100 type RTD, housed in S.S. type industrial housing, set up should be provided with heater which can go up to 200^{O} C with facility to vary heater power, constant current source with amplifier, 3 1⁄2 digit digital indicator of temperature, In built DC regulated power supply	1
2	Thermocouple temperature measurement setup	Temperature measurement set- up trainer kit suitable to measure the temperature using K type Cr-Al thermocouple housed in S.S. type industrial housing, heater which can go up to 200^{O} C with facility to vary heater power, 3 ½ digit digital indicator of temperature, in built DC regulated power supply etc.	1

IX. Precautions to be followed

1) Ensure that proper connections are made as per the setup.
2) Ensure proper setting of devices used.
3) Ensure the power switch is in off condition initially.

X. Procedure

Part A:

1. Arrange/connect the experimental set up as per the given diagram.
2. Place the thermometer upright inside the heater.
3. Note down readings of thermometer and temperature on kit at room temperature.
4. Switch on the heater.
5. Note down the temperature for every 10 degree temperature rise.
6. Now, switch off the heater.
7. Plot the graph of thermometer temperature (Input) Vs temperature on kit (Output)
8. To calculate RTD sensitivity, find the slope of the graph.

Part B:

1. Connect set up for temperature measurement with thermocouple.
2. Place the thermocouple, thermometer, and immersion heater in a temperature bath.
3. Record the room temp. with a mercury thermometer
4. Record the room temperature displayed on the kit
5. Switch on the power supply of the heater.
6. Note down the temperature for every 10 degree temperature rise.
7. Record the temperature using mercury thermometer.
8. Record the output Temperature displayed on the kit
9. Complete the observation table.
10. Repeat the steps 6 to 9 for 10 readings.
11. Plot the graph of thermometer temperature (Input) Vs temperature on kit (Output)
12. To calculate Thermocouple sensitivity, find the slope of the graph.

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure

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XIII. Observation Table

Table 6.1: Observations and Calculations Part A: RTD

Sr. No.	Thermometer temperature (Input)	Temperature on kit (Output)
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3		
4		

5		
6		
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8		
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10		

Table 6.2: Observations and Calculations Part B: Thermocouple

Sr. No.	**Thermometer temperature (Input)**	**Temperature on kit (Output)**
1		
2		
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XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. State the classification of RTDs along with materials used and temperature ranges.
2. Enlist any four temperature measuring devices.
3. State any two advantages and disadvantages of RTD.
4. State the materials used for J and K type thermocouple.
5. State the output voltage when two terminals are short of thermocouple.
6. State the output when one of the elements of thermocouple becomes open.
7. State the output voltage at room temperature. List the different types of thermocouples with their composition?
8. Enlist the limitations of thermocouple.

[Space for Answers]

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2. https://sl-coep.vlabs.ac.in/exp/temperature-sensor/
3. http://www.physicsclassroom.com/class/thermalP/Lesson-1/Temperature-and-Thermometers
4. http://hk-phy.org/contextual/heat/tep/tempe/
5. https://www.azom.com/article.aspx?ArticleID=5573
6. https://www.omega.com/Temperature/pdf/RTD_GEN_SPECS_REF.pdf
7. https://www.electrical4u.com/resistance-temperature-detector-or-rtd-construction-and-working-principle/

XIX. Assessment Scheme

	Performance Indicators	**Weightage**
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Scale -

X-Axis -

Y-Axis -

Scale -

X-Axis -

Y-Axis -

Practical No.7: pH level measurement of solution

I. Practical Significance

pH meter is one of important instruments used for pathology laboratory. The pH of a solution can be measured accurately with the help of a pH meter. Measurement of pH is employed to monitor the cause of acid-base titration.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences:

Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

Identify various transducers involved in measuring different chemical parameters.

IV. Laboratory Learning Outcome(s)

Measure pH level of given solution using pH electrode.

V. Relevant Affective Domain related outcome(s)

a) Follow safety practices.

b) Maintain cleanliness of the electrode

c) When electrode is not in use, Keep it wet

VI. Relevant Theoretical Background

pH of water is a measure of amount of hydrogen ions that is present in the water. It determines if the water is alkaline or acidic in nature. pH stands for potential of hydrogen. As per the World Health Organization (WHO), value of pH of drinking water should be within 6.5 to 8.5. pH can be calculated mathematically as

$$pH = -\log [H^+]$$

This scale was developed by the scientist Sorenson in the year 1909. The below reaction implies that the water shows that the number of H^+ and OH^- ions are equal in amount experimentally. It has also been proved that the product of both the concentration is equal to a constant 'K'. The value of this constant found to be between 10 and 14.

$$H_2O \rightarrow H^+ + OH^-$$

For acids, the pH value is between 1 to 7. Alkaline solutions will have pH value from 7 to 14.

VII. Actual Circuit diagram used in laboratory with related equipment rating.

Fig.7.1 Flow Measurement Setup

Table no. 7.1

pH range	Description	Colour
0-3	Strong acid	Red
3-6	Acid	Orange/Yellow
7	Neutral	Green
8-11	Base	Blue
11-14	Strong Base	Violet/Purple

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	pH level measurement setup	pH meter - pH electrode with three different buffer solutions- 7, 4 and 9.2 pH, combined electrode for pH measurement, display - 3 1⁄2 digit LED	1
2	Glass Beakers	Minimum 100 ml capacity, Borosil glass or equivalent glass	5

IX. Precautions to be followed

1. Ensure that proper connections are made as per the setup.
2. Ensure proper setting of devices used.
3. Ensure the power switch is in off condition initially.

X. Procedure

1. Dip the pH electrode in the beaker of buffer solution having pH value 4 and note down the pH.
2. In case, pH value obtained is different than 4 then adjust the calibration knob till meter gives pH value.
3. Clean the combined electrode with the distilled water and dry it using tissue paper.
4. Dip the pH electrode in the beaker of buffer solution having pH value 7 and note down the pH. In case, pH value obtained is different than7 then adjust the calibration knob till meter gives pH value 7.
5. Clean the combined electrode with the distilled water and dry it using tissue paper.
6. Dip the pH electrode in the beaker of buffer solution having pH value 7 and note down the pH. In case ,pH value obtained is different than7 then adjust the calibration knob till meter gives pH value 7 .
7. Clean the combined electrode with the distilled water and dry it using tissue paper.
8. Dip the pH electrode in the beaker of buffer solution having pH value 9.2 and note down the pH. In case, pH value obtained is different than 9.2 then adjust the calibration knob till meter gives pH value 9.2 .
9. Clean the combined electrode with the distilled water and dry it using tissue paper.
10. Dip the pH electrode in the beaker of sample 1 solution and note down the pH. Write the result as whether the solution is acidic, basic or neutral.
11. Also dip the pH paper & observe the colour Change & note down the nature of solution.
12. Repeat steps 8, 9, 10 for sample 2 solution, sample 3 solution and note down the readings.

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure

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XIII. Observation Table

Table 7.2: Observations and Calculations

Sr.No.	Solution	pH Paper	Change in colour	pH meter reading	Type of Solution
1	Solution 1	Neutral pH Paper			
2	Solution 2	Neutral pH Paper			
3	Solution 3	Neutral pH Paper			

XIV. Result(s)

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XV. Interpretation of results

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Conclusion and recommendation

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XVI. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Define term pH value.
2. What is the pH of water?
3. Which different methods are used for determination of pH?
4. Describe working of pH electrode.

[Space for Answers]

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XVII. References/Suggestions for further reading

1. https://ee1-nitk.vlabs.ac.in/exp/determination-of-ph/simulation.html
2. https://en.wikipedia.org/wiki/PH_meter

XVIII. Assessment Scheme

	Performance Indicators	Weightage
	Process Related: 15 Marks	**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.8: Blood Glucose Level Measurement using Glucometer

I. Practical Significance

Glucometer is commonly known as blood glucose meter. It is a simple, portable, and convenient blood sugar monitoring device. The hand-held device helps in checking our glucose levels accurately, anywhere, anytime, within a short time. Regular monitoring of blood sugar levels can help manage not only your diabetes but also reduce the risk of any long-term complications. Hence students must know the working of Glucometer which is largely used to solve relevant problems in the healthcare industry.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ empolyer expected outcome through various teaching learning experiences: Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

- Identify various transducers involved in measuring different chemical parameters.

IV. Laboratory Learning Outcome(s)

- Measure glucose level of the given blood sample.

V. Relevant Affective Domain related outcome(s)

Identification of various types of transducers

VI. Relevant Theoretical Background

A Glucometer is a portable device used to measure blood sugar levels. It is essential for individuals with diabetes to monitor their glucose levels at home. The glucometer provides immediate feedback, allowing informed decisions on diet, medication, and health. By pricking the skin and placing blood on a test strip, the device measures blood sugar levels digitally. Understanding and using a glucometer helps individuals manage diabetes and improve their quality of life.

Parts of a Glucometer

Understanding the different components of a glucometer and their functions is essential for accurate blood sugar readings.

- **Test Strips:** These strips are where a small drop of blood is placed for testing. The strip contains chemicals that react with glucose in the blood.
- **Meter:** The meter reads the reaction on the test strip and displays the blood glucose level. It usually has a screen to show the results.
- **Lancet & Lancet Device:** The lancet is a small needle that pricks the finger to obtain a blood sample. The lancet device holds the lancet and controls the depth of the prick.
- **Control Solution:** This solution is used to ensure the glucometer is providing accurate results by testing it with a known glucose level.
- **Battery:** The battery powers the glucometer for operation. It is essential to ensure the device functions correctly.

Understanding these components and their roles in the device is key to utilizing a glucometer effectively for monitoring blood glucose levels accurately.

VII. Circuit diagram

Layout of Laboratory

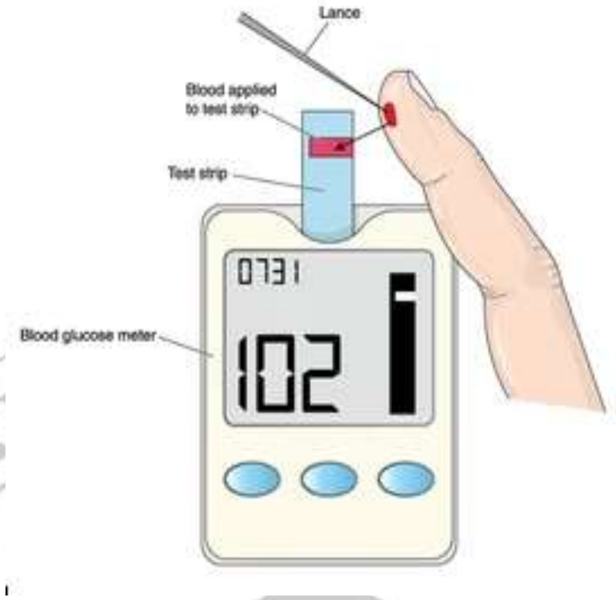

Fig. 8.1 Glucometer

VIII. Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Glucometer	Blood glucose monitor: Range: 20–600 mg/dL, calibration: plasma-equivalent, sample: fresh capillary whole blood, sample volume: 0.4 µL, test time: 5 seconds, expected meter battery life: 6 to 8 weeks in between charges, unit of measure: mg/dL, memory: 750 test results	01
2	Test strips	Glucometer kit includes test strips	10

IX. Precautions to be followed

1) Store your meter, test strips in a cool, dry place below 86°F but Do Not refrigerate.
2) Keep all items away from direct sunlight and heat.
3) Testing must be done within the operating temperature range (43–111°F).
4) Wash your hands thoroughly before blood sampling.

X. Procedure

1. Begin by gathering all the necessary supplies - a test strip, lancet, and the glucometer machine itself.
2. Insert a test strip into the glucometer according to the instructions provided by the manufacturer.
3. Use the lancet to prick your finger, allowing a small drop of blood to form
4. Carefully touch the blood drop to the designated area on the test strip.

5. The test strip draws the blood sample in and initiates the measurement process using its technology. Within seconds, the glucometer displays your blood sugar level on its screen.
6. Take note of the reading.

XI. Observations and Calculations (use blank sheet provided if space not sufficient)

Table 8.1

Subject's Name	Blood Glucose Level		Remark
	Fasting	2-3 hours after eating	

Standard chart for reference:

Blood Glucose Chart

Mg/DL	Fasting	After Eating	2-3 Hours After Eating
Normal	80-100	170-200	120-140
Impaired Glucose	101-125	190-230	140-160
Diabetic	126+	220-300	200+

XII. Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity

XIII. Actual Procedure

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XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Write the model specification of the Glucometer used in the laboratory
2. Write the name, specification, cost and manufacturer of the Glucometers.

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://www.medicalnewstoday.com/articles/a1c-chart-diabetes-numbers#a-1-c-chart
2. https://diabesmart.in/blogs/diabetes-mangement-1/how-does-a-glucometer-work

XIX. Assessment Scheme

	Performance Indicators	Weightage
	Process Related : 15 Marks	60 %
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.9: Blood flow measurement using ultrasonic flow transducer

I. Practical Significance

An adequate blood supply is necessary for all organs of the body, an impaired supply of blood is the cause of various diseases. The rate of flow of a liquid or a gas in a pipe is expressed as the volume of the substance that passes through the pipe in a given unit of time. Flow rates are therefore usually expressed in litres per minute or millimetres per minute (cm3 /min). The commonly used blood flow meter in clinical and research applications is ultrasonic flow transducer.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences:

Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

Identify various transducers involved in measuring different chemical parameters.

IV. Laboratory Learning Outcome(s)

Measure the blood flow using ultrasonic flow transducer.

V. Relevant Affective Domain related outcome(s)

a) Follow safety practices.
b) Maintain cleanliness of transducer setup.

VI. Relevant Theoretical Background

In an ultrasonic blood flow meter, a beam of ultrasonic energy is used to measure the velocity of flowing blood. There are two different ways of ultrasonic blood flow meter, they are transit time and doppler type.

Transit time: In transit time ultrasonic blood flow meter, a pulsed beam is directed through a blood vessel at a shallow angle and its transmit time is then measured. When the blood flows in the direction of the energy transmission, the transit time is shortened, if it flows in the opposite direction, the transit time is lengthened.

Doppler type: The block diagram of ultrasonic blood flow meter, Doppler type is given below.

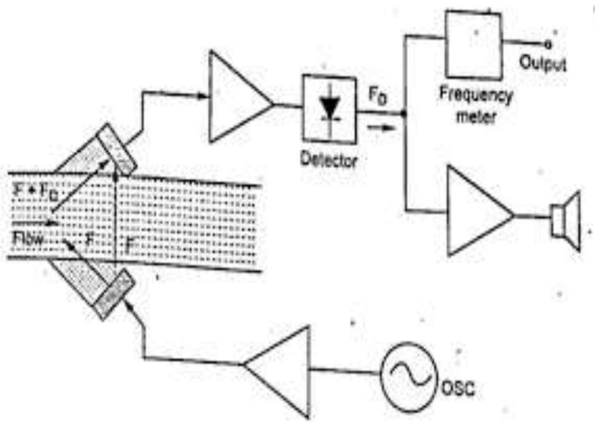

Fig No. 9.1 Ultrasonic Blood Flow Meter

An oscillator, opening at a frequency of several megahertz (MHz), excites a piezoelectric transducer. The piezoelectric transducer is coupled to the wall of an exposed blood vessel and sends an ultrasonic beam with a frequency F into the following blood. A small part of the transmitted energy is scattered back and is received by a second transducer arranged opposite the first transducer. Because the scattering occurs mainly as a result of the moving blood cells, the reflected signal has a different frequency due to the doppler effect. The transmitted frequency is either $F+F_D$ or $F-F_D$, depending on the direction of the blood flow. When the blood flow is in same direction to the beam, then the frequency is $F+F_D$, if the blood is in opposite direction to the beam, then the frequency is $F-F_D$. The doppler component F_D is directly proportional to the velocity of the flowing blood. A fraction of the transmitted ultrasonic energy, with the frequency being unchanged. The measure of blood flow can be obtained with the help of frequency meter. The doppler signal of the pulsating blood flow can also be heard with the help of loudspeaker.

VII. Actual Circuit diagram used in laboratory with related equipment rating.

Fig.9.2 Flow Measurement Setup

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Ultrasonic blood flow measurement setup	Ultrasonic blood flow measurement kit: Power supply- 230V/50Hz, real time measurement system, operating frequency 8 MHz, transducer piezoelectric Doppler type, audio and visual indication, output audio head phone and speaker	1

IX. Precautions to be followed

1) Ensure that proper connections are made as per the setup.
2) Ensure proper setting of devices used.
3) Ensure the power switch is in off condition initially.

X. Procedure

1. Arrange set up as shown in diagram
2. Apply ultrasound gel as a coupling medium in all ultrasound procedures between the transducer and the subject's skin
3. Carefully place ultrasonic electrode on the subject's limb
4. Note down the reading (audible/visual form).

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity
1			

XII. Actual Procedure

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XIII. Observation Table

Table 9.2: Observations and Calculations

Sr. No.	Input Flow rate	Displayed flow rate on indicator

XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Give reason to use gel for ultrasonic transducers.
2. List different methods of blood flow measurements
3. Compare Doppler and transmit type blood flow meter.

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. A book by Medical instrumentation application and design
2. A book by A.K. Sawhney-A course in Electrical and Electronic Measurements and Instrumentation
3. A book by S K Singh -Industrial Instrumentation and Control

XIX. Assessment Scheme

	Performance Indicators	**Weightage**
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.10: Flow measurement using rotameter

I. Practical Significance

Rotameter is one of the important instruments used by many medical equipment such as Hemodialysis, Heart lung machine. The Rotameter has been used for fluid flow measurement. It belongs to a class of variable area flow meters. This variable area principle consists of three basic elements: A uniformly tapered flow tube, a float, and a measurement scale. Therefore, this practical will help you to measure the flow using Rotameter.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ empolyer expected outcome through various teaching learning experiences:

Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

Identify various transducers involved in measuring different chemical parameters.

IV. Laboratory Learning Outcome(s)

Measure flow rate by using rotameter.

V. Relevant Affective Domain related outcome(s)

a) Follow safety practices.

b) Maintain cleanliness of transducer setup.

VI. Relevant Theoretical Background

Rotameter: It is a variable area flow meter used for flow measurement. It consists of a vertical tapered tube with a float which is free to move up and down within the tube. The free area between the float and inside wall of the tube forms an annular orifice. The tube is mounted vertically with the small end at the bottom. The fluid to be measured enters the tube from the bottom and passes upwards around the float and exits at the top.

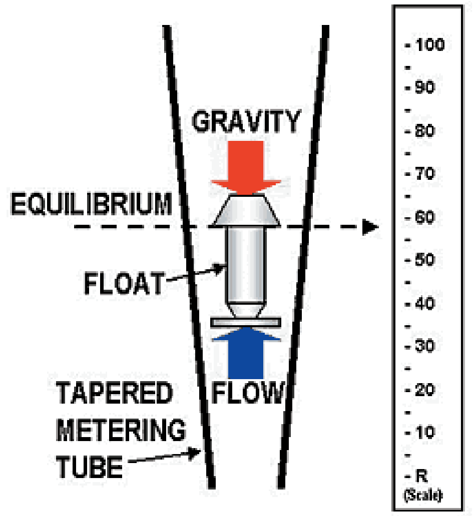

Fig no. 10.1 Rotameter

Operating Principle

Its operating principle is based on a float of given density establishing an equilibrium position where, with a given flow rate, the upward force of the flowing fluid equals the downward force of gravity.

Rotameters are the most widely used type of variable-area (VA) flow meter. In these devices, the falling and rising action of a float in a tapered tube provides a measure of flow rate as shown in Figure. Rotameter are known as gravity-type flow meters because they are based on the opposition between the downward force of gravity and the upward force of the flowing fluid. When the flow is constant, the float stays in one position that can be related to the volumetric flow rate. That position is indicated on a graduated scale. It can be used to measure the flow rates of most liquids, gases, and steam. The materials of construction include stainless steel, glass, metal, and plastic. The tapered tube's gradually increasing diameter provides a related increase in the annular area around the float, and is designed in accordance with the basic equation **f**or volumetric flow rate:

$$Q = kA\sqrt{(gh)}$$

where:

Q = volumetric flow rate, e.g. gallons per minute

k = a constant

A = annular area between the float and the tube wall

g = force of gravity

h = pressure drop (head) across the float

With h being constant in a Variable Area meter, we have A as a direct function of flow rate Q.

VII. Actual Circuit diagram used in laboratory with related equipment rating.

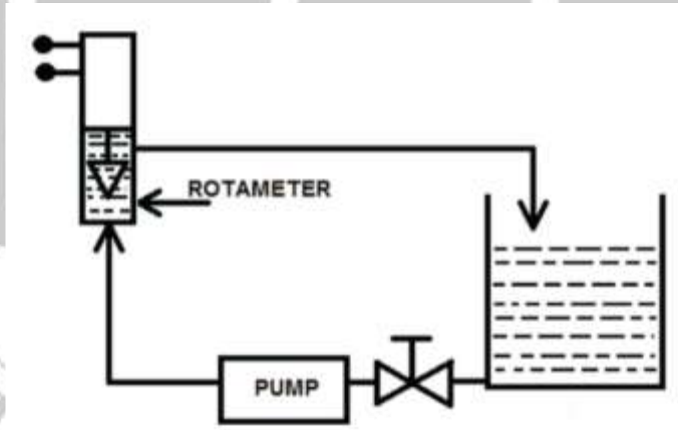

Fig.10.2 Flow Measurement Setup

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Rotameter flow measurement setup	Flow measurement by using rotameter kit: sump tank capacity -20 liters, material- MS / plastic, water circulation pump -20 (litre per minute) hand valve, rotameter - 35 (litre per minute), water manometer: U tube type	1

IX. Precautions to be followed

1) Ensure that proper connections are made as per the setup.
2) Ensure proper setting of devices used.
3) Ensure the power switch is in off condition initially.

X. Procedure

1. Identify the component of given setup diagram
2. Connect Rotameter measurement setup as in diagram.
3. Fill the sump tank with water.
4. Switch on the power supply.
5. Start the pump and ensure flow rate through pipe line
6. Measure flow rate indication on the Rotameter.
7. Change valve position for increasing flow rate in pipe line.
8. Record flow rate in observation table.
9. Repeat the steps 6 to 8 for 5 to 6 readings.

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity
1		-	1

XII. Actual Procedure

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XIII. Observation Table

Table 10.1: Observations and Calculations

Sr. No.	Flow rate on indicator (litre per minute)	Calculated flow rate (litre per minute)

XIV. Result(s)

XV. Interpretation of results

XVI. Conclusion and recommendation

XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. State mounting position of Rotameter device used for flow measurement.
2. State the maximum range of flow rate measurement.
3. State the type of flow measurement used in practical.
4. State the type of material used in Rotameter in practical setup.

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://en.wikipedia.org/wiki/Rotameter
2. A book by A.K. Sawhney-A course in Electrical and Electronic Measurements and Instrumentation
3. A book by S K Singh -Industrial Instrumentation and Control

XIX. Assessment Scheme

	Performance Indicators	**Weightage**
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Scale -

X-Axis -

Y-Axis -

Practical No.11: Identification of various parts of pO2 and pCO2 electrodes

I. Practical Significance

The partial pressure of oxygen (pO2) and carbon dioxide (pCO2) electrodes are essential tools in various medical, environmental, and industrial applications. They are widely used for Blood Gas Analysis, Monitoring Oxygen Therapy, Critical Care and Surgery, Water Quality Testing, Environmental Control Systems and many more applications. Hence as a medical electronics engineer, students must know the basics of these biochemical sensors.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences: -

Identify various transducers involved in measuring different chemical parameters.

III. Course Level Learning Outcome(s)

- Use biochemical electrodes for medical application

IV. Laboratory Learning Outcome(s)

- Use pO2 electrode for measurement of partial pressure of oxygen.
- Use pCO2 electrode for measuring partial pressure of carbon dioxide

V. Relevant Affective Domain related outcome(s)

Identification of different types of bio-potential electrodes.

VI. Relevant Theoretical Background

pO_2 MEASUREMENT

The term pO2 is defined as the partial pressure of oxygen. The determination of pO2 is one the most important physiological chemical measurement. The effective functioning of both respiratory and cardiovascular system can be by pO2 measurement. The partial pressure of a gas is proportional to the quantity of that gas present in the blood.

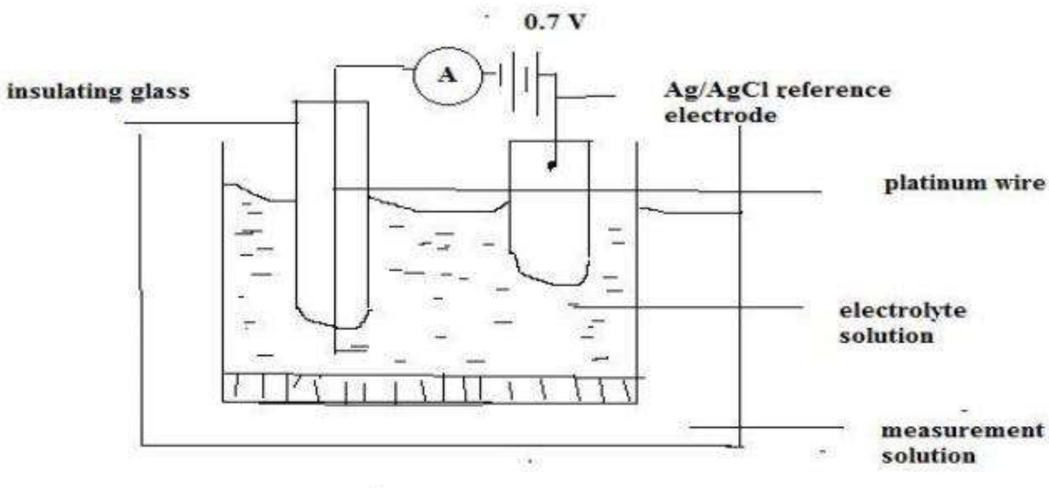


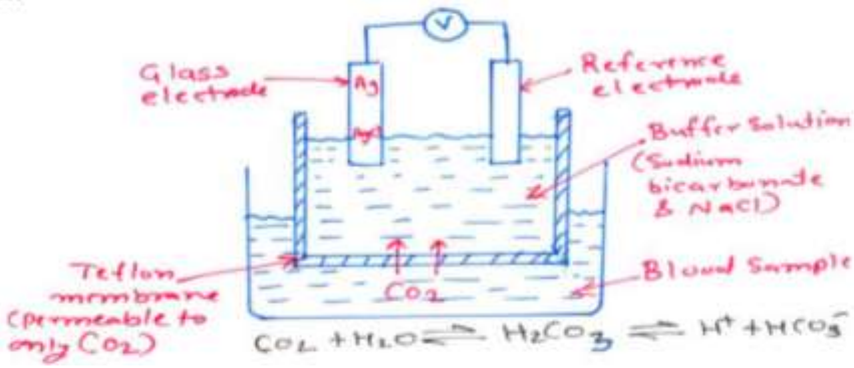
Fig no. 11.1 pO_2 electrode

The platinum wire, which is an active electrode, is embedded in glass for insulation and only its tip is exposed. It is kept in the electrolyte solution in which the oxygen is allowed to diffuse. The reference electrode is made up of silver-silver chloride (Ag/AgCl). A voltage of 0.7 is applied between the platinum wire and the reference electrode. The negative terminal is connected to the active electrode through a micro ammeter and the positive terminal is given to the reference electrode.

Due to the negative terminal, the oxygen reduction takes place at the platinum cathode. Finally the oxidation reduction current proportional to the partial pressure of oxygen diffused into the electrolyte can be measured in the micro ammeter. The electrolyte is generally scaled in the electrode chamber by means of a membrane through which the oxygen can diffuse from the blood or sample solution.

pCO_2 MEASUREMENT

The term pco2 is defined as the partial pressure of carbon dioxide. The determination of pCO_2 is one the most important physiological chemical measurement.



The pH electrode is used as a component of a pCO_2 electrode to measure the partial pressure of CO2 by the arrangement as shown in the figure. Sample chamber with one side made of silicon rubber membrane or Teflon membrane is in contact with another chamber containing sodium bicarbonate solution into which is dipped a pH electrode. Blood or other fluid for which pCO_2 is to be measured enters a sample chamber. It comes in contact with Teflon or Silicon rubber membrane. This membrane separates the fluid from sodium solution but it is permeable to pCO_2 into the solution. CO_2 combines with H_2O so as to produce free hydrogen ions.

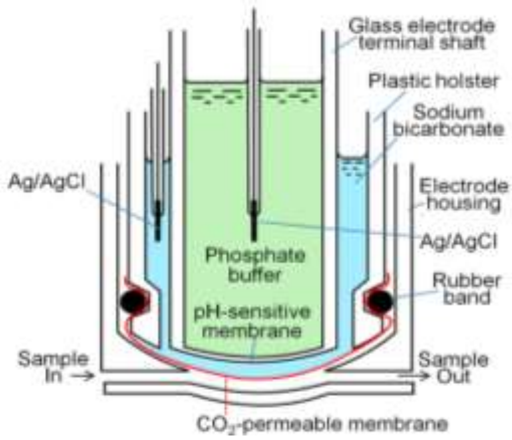


Fig no. 11.2 pCO_2 Electrode

VII. Circuit Diagram.

Fig no. 11.3 Blood Gas Analyzer for measurement pO_2 and pCO_2 electrode

VIII. Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	pO_2 electrode	pO2 & pCO_2 electrode: Digital pH/mV meter for monitoring pO2 and pCO_2 level, end fittings on pO_2 & pCO_2 probes attach directly to standard micro silastic tubing, electrodes are available with all standard pH meter connectors including BNC, output voltage from 0 to 2 volts allows connection of both pO_2 and pCO_2 flow through electrodes to any standard chart recorder for continuous monitoring of pO_2 and pCO_2 levels, microchamber with variable volume from 200 to 1000 microliters, micro stir bar for stirring sample (when needed), miniature magnetic stirrer, sealed septum sample injection system using syringe	01
2.	Samples	Pure water, contaminated water, any other liquid sample	01 each

IX. Precautions to be followed

1. Regularly calibrate the electrode using appropriate calibration gases or solutions to ensure accurate readings.
2. Keep the electrode clean and free of contaminants. Use proper cleaning solutions recommended by the manufacturer.
3. Handle the electrode with care to avoid damaging the sensitive membrane.
4. Avoid exposing the electrode to extreme temperatures or rapid temperature changes, which can affect its performance.
5. Ensure that the sample being measured is free from air bubbles, which can affect the accuracy of pO2 measurements.
6. Avoid contamination of the sample with oils, greases, or other substances that can interfere with the electrode's function.

X. Procedure

1. Check the pO2/ pCO2 electrode for any visible damage or contamination.
2. Obtain the sample to be tested, ensuring it is free from air bubbles and contaminants.
3. Allow the sample to equilibrate to the operating temperature of the electrode.
4. Submerge the pO2/ pCO2 electrode in the sample, ensuring the membrane is fully covered.
5. Allow the reading to stabilize, which may take a few minutes depending on the sample and electrode.
6. Once stable, record the output.
7. Rinse the electrode with distilled water or a suitable cleaning solution to remove any residues.
8. Place the electrode in the recommended storage solution or condition as specified by the manufacturer.

XI. Observations and Calculations (use blank sheet provided if space not sufficient)

Table no. 11.1

Name of the sample	pO_2 in mm Hg	pCO_2 in mm Hg

XII. Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1			
2			

XIII. Actual Procedure

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XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Write the applications of pO_2Electrode.
2. Write the applications of pCO_2Electrode.
3. Write the steps to measure pO_2 of water.
4. Write the name, specification, cost and manufacturer of the pO2and pCO2 electrode

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://www.brainkart.com/article/pO2-Measurement_11857/
2. https://conductscience.com/clark-oxygen-electrode/

XIX. Assessment Scheme

	Performance Indicators	**Weightage**
	Process Related : 15 Marks	60 %
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.12: Gain measurement of an instrumentation amplifier

I. Practical Significance

The output of the biosensor is generally a low level signal which is insufficient to drive the display indicators for displaying physical quantities like temperature, pressure, so the Instrumentation amplifier is connected to the output of biosensor through the bridge circuitry to amplify the low level signals in any of the measuring instruments. In this practical student will assemble IC LM324 as instrumentation amplifier and observe the amplification of low level signals with designed gain.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences:

Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

Build signal conditioning circuit for various applications.

IV. Laboratory Learning Outcome(s)

- Measure the gain of an instrumentation amplifier.

V. Relevant Affective Domain related outcome(s)

a) Follow safe practices.

b) Follow ethical practices

c) Demonstrate working as a leader/a team member Follow safety practices.

VI. Relevant Theoretical Background

Instrumentation amplifiers are configured for high input impedance, high CMRR and have single ended output. Instrumentation amplifiers are used for precise, low level signal amplification where low noise, low thermal and temperature drifts, high input impedance and accurate closed loop gain is required.

Instrumentation amplifiers can be used as a biopotential amplifier.The essential function of a biopotential amplifier is to take a weak electric signal of biological origin and increase its amplitude so that it can be further processed, recorded, or displayed. Usually such amplifiers are in the form of voltage amplifiers, because they are capable of increasing the voltage level of a signal.

Biopotential signals usually have amplitudes of the order of a few millivolts or less. Such signals must be amplified to levels compatible with recording and display devices. This means that most biopotential amplifiers must have high gains-of the order of 1000 or greater.

Instrumentation amplifier is having adjustable gain

Output voltage is given by

$$V_{out} = \left[\left(1 + \frac{2R_1}{R_{gain}}\right)\frac{R_3}{R_2}\right](V_2 - V_1)$$

Gain can be changed varying R_{gain} as shown in the Fig. no. 12.3

IC LM324 is quad Op-Amp.

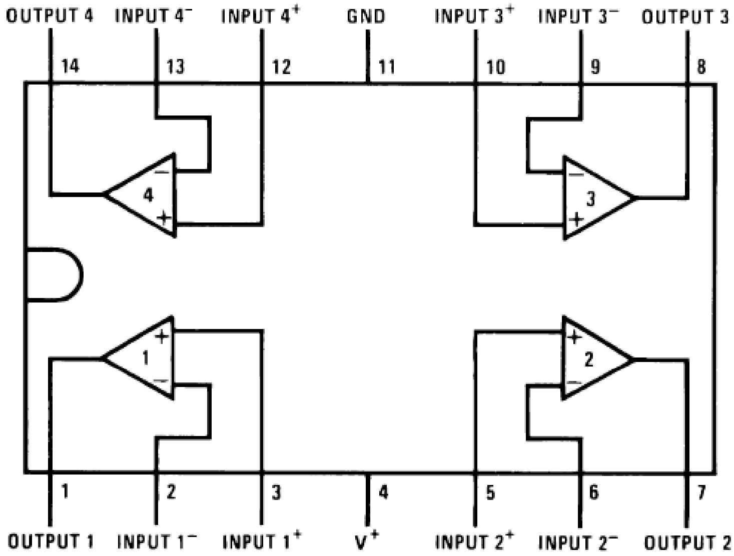


Fig. no. 12.1 Pin connection diagram of IC LM324

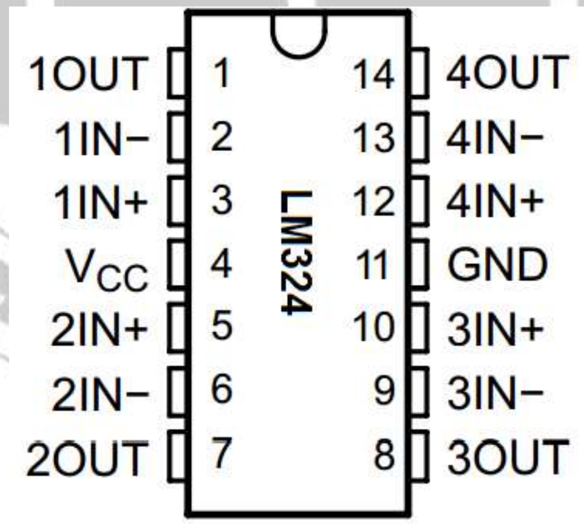
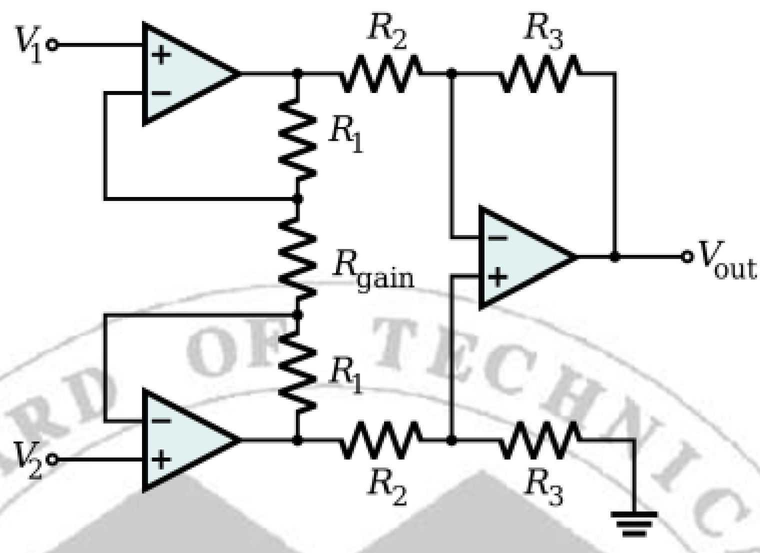


Fig. no. 12.2 Pin diagram of IC LM324

VII. Actual Circuit diagram used in laboratory with related equipment rating.



Note: Use "Rgain" as Variable resistor

Fig no. 12. 3 Circuit diagram of Instrumentation amplifier

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Variable DC power supply	0- 30V, 2A Dual tracking power supply	1
2	IC-LM324	14 pin DIP	1
3	Resistors	10KΩ	4
4	Potentiometer	1 KΩ,10KΩ	1
5	Analog IC tester	Suitable to test analog ICs	1
6	DMM	DC VOLTAGE Ranges : 200mV, 2V, 20V, 200V	1
7	Breadboard	5.5 cm X 17 cm	1
8	Connecting wires	Single strand Teflon coating (0.6 mm diameter)	As per requirement

IX. Precautions to be followed

1) Ensure proper connections are made as per the given setup.
2) Ensure the power switch is in 'off' condition initially.
3) Ensure the use of proper settings of input DC voltage.

X. Procedure

1. Test IC LM324 using IC tester and mount it on breadboard.
2. Make the connections as shown in Fig. 12.3.
3. Apply voltage V_{CC} = +15V and V_{EE} = -15V using DC power supply to pin no 4 and pin no 11 respectively, V_1 and V_2 in the range from 100 mV to 500 mV.

4. Measure the output voltage , Vout for the given corresponding input voltage, using DMM.
5. Calculate theoretical and practical gain.
6. Repeat steps from 3 to 5 for different values of V_1 and V_2 DC input voltage.
7. After the completion of practical switch off the supply, remove the connections and submit wires and equipments.

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity
1			
2			
3			
4			
5			
6			
7			
8			

XII. Actual Procedure

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XIII. Observation Table

Table 1: Observation Table for gain of instrumentation amplifier.

Sr. No.	DC Input Voltage		Input Difference	Output Voltage		Gain	
	V_1 in mV	V_2 in mV	$V_d = V_1 - V_2$	Practical	Theoretical	Practical	Theoretical
1							
2							
3							
4							

XIV. Result(s)

1. Measured output voltage =.......................
2. Theoretical Gain =................................
3. Practical Gain = ...

XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Draw an internal diagram of LM 324 IC.
2. Repeat the above experiment procedure for **V_1 =100 mV and V_2 =0 V**

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://www.youtube.com/watch?v=5yiJTp29AVY
2. K.R.Botkar, Integrated Circuits, Khanna publication,10th edition,2005, ISBN NO :81-7409-208-0
3. http://www.ti.com/sitesearch/docs/universalsearch.tsp?searchTerm=LM324#linkId=1&src=top

XIX. Assessment Scheme

	Performance Indicators	**Weightage**
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.13: Performance of signal conditioning circuit for temperature measurement using thermistor

I. Practical Significance

The Temperature is one of the most important measurement parameters that is used for monitoring and control of processes in the medical field. It can be measured with the help of a variety of temperature sensing devices which reacts to a change in temperature .Thermistor is the cheapest temperature transducer which converts temperature into an equivalent resistance. As it is available in small size and various shapes, thermistors are widely used in the biomedical field.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences:
Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

- Build signal conditioning circuit for various applications.

IV. Laboratory Learning Outcome(s)

1. Design signal conditioning circuit for thermistor
2. Test the performance of the designed signal conditioning circuit.

V. Relevant Affective Domain related outcome(s)

a) Follow safety practices.
b) Maintain cleanliness of transducer setup.

VI. Relevant Theoretical Background

Thermistor is a linear passive transducer used for the measurement of temperature.
The term is a combination of “thermal” and “resistor”. It is made of metallic oxides, pressed into a bead, disk, or cylindrical shape and then encapsulated with an impermeable material such as epoxy or glass.

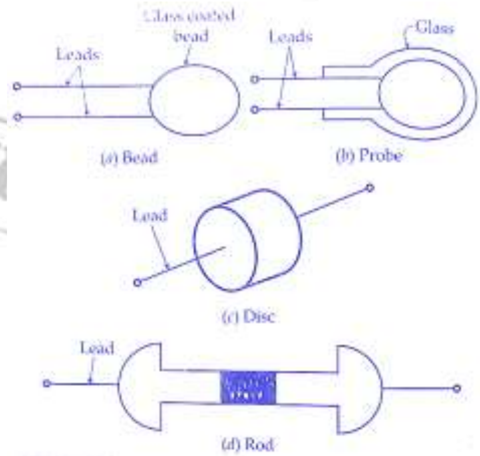

Fig.no.13.1 Thermistor shapes

Thermistor is the temperature transducer which converts temperature into an equivalent resistance. The change in resistance can be measured using an ohmmeter or converted into a voltage using a bridge circuit.

$$V_{out} = V_1 - V_2 = \left[\left(\frac{R_a}{(R_a + R(t))} - \frac{R_c}{(R_c + R_b)}\right)\right] V_s$$

- V_1 and V_2 are the bridge voltages,
- R_a , R_b , and R_c are the bridge resistors
- V_s is the supply voltage

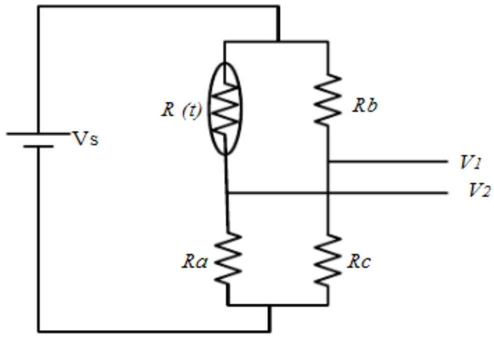

Fig.no.13.2 Bridge circuit with thermistor

thermistors are classified into two types:
With NTC thermistors, resistance decreases as temperature rises;and With PTC thermistors, resistance increases as temperature rises.
The resistance follows an exponential variation with temperature which is given by the following relation:

R=R0exp [β (1/ T - 1/ T_0)]
Where T_0 = Initial Temperature
R_0= Resistance of the thermistor at T_0
β = An experimental constant that can have a value between 3500-4500° K.

Signal conditioning circuits are used to convert the output from the transducer into an electrical value. The instrument system sends this quantity to the display or recording system. Generally, signal conditioning process includes amplification, filtering, analogue to digital and Digital to analogue conversions. Signal conditioning improves the sensitivity of instruments.

Mostly thermisters use Wheatstone bridge circuit for measurement purpose. Bridge contains thermister at one arm and other remaining three arms connected with standard resistances. Bridge is generally a resistance measuring device which converts the resistance of thermister into electrical signal.
Here the as mention above the equation (1) may be written as

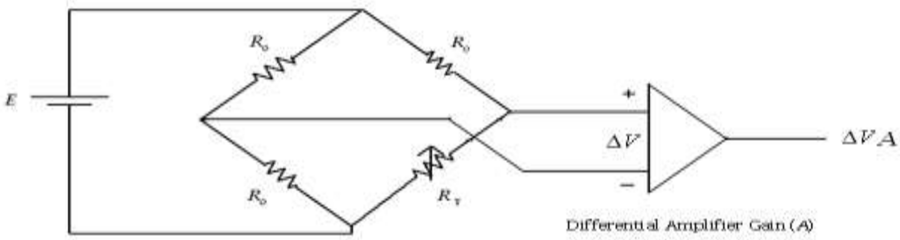

Fig.no.13.3 Bridge circuit with amplifier

$$R_T - R_0 = \alpha R_0 \, \Delta T$$

$$\Delta R = R_0 \, \Delta T$$

For given values of **α** and R_0,ΔR and ΔT, and hence measuring the ΔR (With the help of Wheatstone bridge circuit) change in temperature can be found out.

To measure the out-put voltage of signal conditioning circuit for thermister,

BRIDGE OUTPUT ΔV $= \left(\frac{R_T}{R_T+R_0} - \frac{1}{2}\right)E$

Differential amplifier output

$$V_{out} = \Delta V A,$$

where A is the voltage gain of the amplifier

VII. Actual Circuit diagram used in laboratory with related equipment rating.

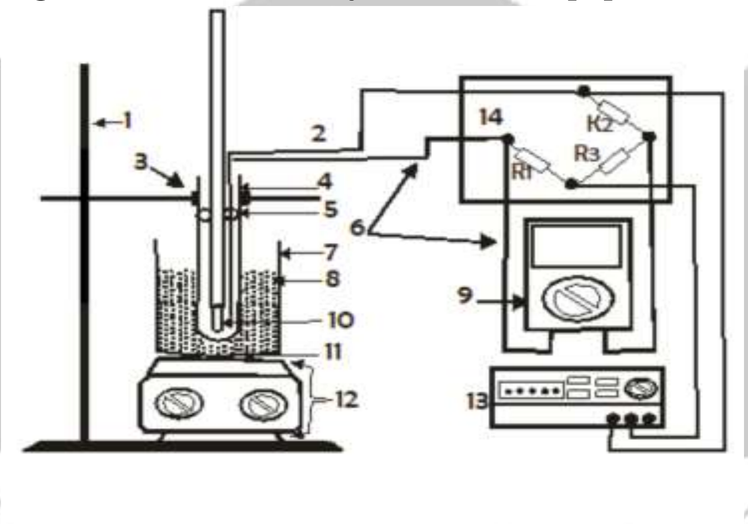

Diagram showing the experimental set-up to measure the performance of the built circuit. 1.Retort stand 2. Thermometer 3. Clamp 4. Test tube 5. Cotton 6. Isolation 7. Beaker 8. Water 9. Multimeter 10. Thermistor 11. Stirrer 12. Stove 13. DC supply voltage 14. Electrical board.

Fig. 13.1 Thermistor temperature measurement setup

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Thermistor temperature measurement setup	Trainer kit suitable to measure the temperature using a thermistor setup should be provided with heater which can go up to 200 °C with facility to vary heater power, constant current source with amplifier, 3 1⁄2 digit digital indicator of temperature, In built DC regulated power supply etc.	1

IX. Precautions to be followed

1) Ensure that proper connections are made as per the setup.
2) Ensure proper setting of devices used.
3) Ensure the power switch is in off condition initially.

X. Procedure

1. Connect set up for temperature measurement with thermistor.
2. Place the thermistor, thermometer and immersion heater in a temperature bath.
3. Record the room temperature with a mercury thermometer.
4. Record the temperature displayed on the kit for room temperature.
5. Switch on the power supply of the heater.
6. Note down the temperature for every 10 degree temperature rise.
7. Record the temperature using mercury thermometer.
8. Record the change in resistance across thermistor leads
9. Record the change in voltage at bridge output.
10. Complete the observation table.
11. Repeat the steps 6 to 9 for 10 readings.
12. Plot the graph of thermometer temperature (Input) Vs bridge output voltage on kit (Output)

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure

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XIII. Observation Table

Table 1: Observations and Calculations

Sr. No.	Thermometer temperature (Input) °C	Change in resistance °Ω	Voltage at bridge output. Volts
1			
2			
3			
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XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. List applications of NTC thermistor .
2. Explain the importance of thermistor
3. List types of thermistors
4. Explain the working of thermistor

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://htv-au.vlabs.ac.in/heat-thermodynamics/Characteristics_of_Thermistor/
2. https://vlab.amrita.edu/?sub=1&brch=282&sim=1511&cnt=1
3. https://en.wikipedia.org/wiki/Thermistor
4. Ramon Pallas-Areny, John G. Webster. "Sensors and signal conditioning" - 2nd ed. A Wiley-Interscience Publication .
5. H S Kalsi, "Electronic Instrumentation" / Tata McGraw-Hill, 2009

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Scale -

X-Axis -

Y-Axis -

Practical No.14: Performance of signal conditioning circuit for temperature measurement using RTD

I. Practical Significance

The Temperature is one of the most important measurement parameters that is used for monitoring and control of processes in the medical field. It can be measured with the help of a variety of temperature sensing devices which reacts to a change in temperature .One such device is a resistance temperature detector, commonly called RTD (Resistance Temperature Detector) which converts temperature into an equivalent resistance.

RTD (Resistance Temperature Detector) is the most linear passive temperature transducer. PT-100 is commonly used ,economic RTD. It is made up of platinum and it have 100 Ω resistance at 0^{o} temperature, hence the name is PT-100 . RTD have higher accuracy and repeatability.

RTD being a passive transducer it can not convert sensed change in temperature into electrical quantity directly. For that it needs a signal conditioning circuit which converts sensed change in resistance into equivalent electrical signal.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences:

Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

- Build signal conditioning circuit for various applications.

IV. Laboratory Learning Outcome(s)

1. Design signal conditioning circuit for RTD.
2. Test the performance of the designed signal conditioning circuit.

V. Relevant Affective Domain related outcome(s)

a) Follow safety practices.
b) Maintain cleanliness of transducer setup.

VI. Relevant Theoretical Background

RTD is a linear passive transducer used for the measurement of temperature. These are made up of metal wire or fiber material that responds to temperature change by changing resistance, Platinum, nickel, and tungsten are most commonly used that have high resistivity, good temperature coefficient of resistance, good tensile strength and chemical inertness with packaging and insulation materials. The change in resistance can be measured using an ohmmeter or converted into a voltage using a bridge circuit. RTDs are generally more accurate than thermocouples, but are less rugged and cannot be used at high temperatures The most commonly used RTD is PT100. For small ranges of temperatures the expression for resistance may be,

$$R_2 = R_1 \, [1+\boldsymbol{\alpha}(t_2 - t_1)]$$

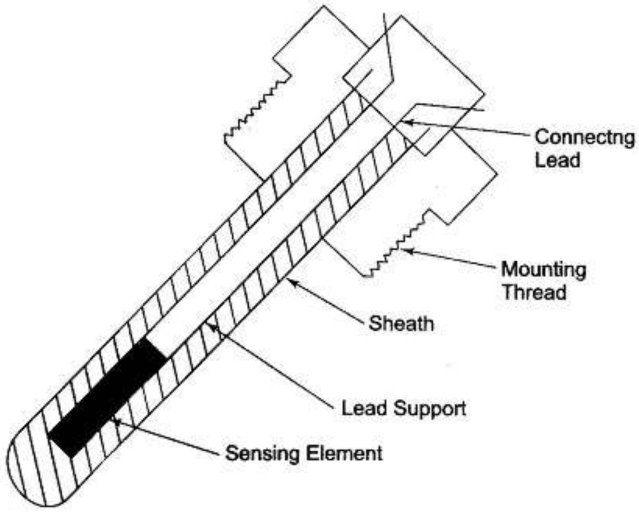

Fig.no.14.1 Resistance Temperature Detector

where t_1- initial temperatures
t_2 - final temperatures
R_1 -Initial resistances
R_2- final resistances
α -Temperature coefficient of resistance at initial temperature

Mostly RTD instruments used Wheatstone bridge circuit for measurement purpose. Bridge contains RTD at one arm and other remaining three arms connected with standard resistances. Bridge is generally a resistance measuring device which converts the resistance of RTD into electrical signal.
Here the as mention above the equation (1) may be written as

$$R_T - R_0 = \alpha R_0 \Delta T$$

$$\Delta R \quad = R_0 \Delta T$$

For given values of **α** and R0,ΔR and ΔT, and hence measuring the ΔR (With the help of Wheatstone bridge circuit) change in temperature can be found out.

As shown in the fig. below

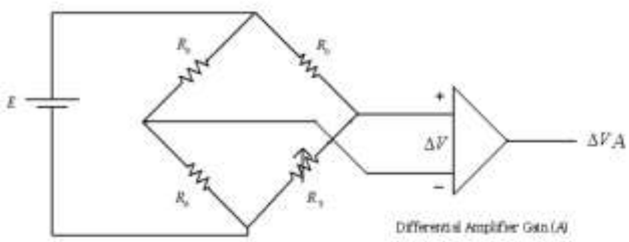

Fig.no.14.2 RTD with bridge circuit and amplifier

To measure the out-put voltage of signal conditioning circuit for RTD, following equations are required-

1. $R_T = R_0\,(1 + aT)$

RT is the resistance of platinum,R0 is the resistance at 0ºC,□ is the temperature coefficient of platinum wire and T is the temperature.

To measure the out-put voltage of signal conditioning circuit for thermister,

2. BRIDGE OUTPUT ΔV $= \left(\frac{R_T}{R_T + R_0} - \frac{1}{2}\right)E$

3.Differential amplifier output $V_{out} = \Delta V A$,
where A is the voltage gain of the amplifier

VII. Actual Circuit diagram used in a laboratory with related equipment rating.

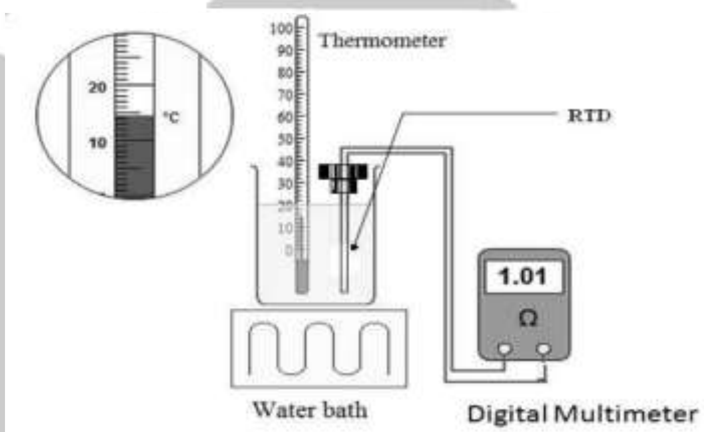

Fig. 14.3 RTD temperature measurement setup

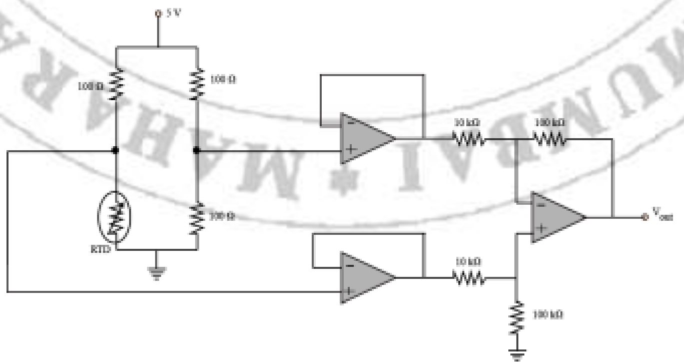

Fig. 14.4 RTD connected in a bridge and signal conditioning circuit

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	RTD temperature measurement setup	Trainer kit suitable to measure the temperature using PT 100 type RTD, housed in S.S. type industrial housing, set up should be provided with heater which can go up to 200^{O} C with facility to vary heater power, constant current source with amplifier, 3 1⁄2 digit digital indicator of temperature, In built DC regulated power supply	1

IX. Precautions to be followed

1) Ensure that proper connections are made as per the setup.
2) Ensure proper setting of devices used.
3) Ensure the power switch is in off condition initially.

X. Procedure

1. Connect set up for temperature measurement with RTD.
2. Place the RTD, thermometer and immersion heater in a temperature bath.
3. Record the room temperature with a mercury thermometer.
4. Record the temperature displayed on the kit for room temperature.
5. Switch on the power supply of the heater.
6. Note down the temperature for every 10 degree temperature rise.
7. Record the temperature using mercury thermometer.
8. Record the change in resistance across RTD leads
9. Record the change in voltage at bridge output.
10. Record the change in voltage at amplifier output.
11. Complete the observation table.
12. Repeat the steps 6 to 10 for 10 readings.
13. Plot the graph of thermometer temperature Vs amplifier output voltage

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure

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XIII. Observation Table

Table 1: Observations and Calculations

Sr. No.	Thermometer temperature (Input)	Change in resistance °Ω	Voltage at bridge output. Volts	Output Voltage Volts
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. State the classification of RTDs along with materials used and temperature ranges.
2. Enlist any four temperature measuring devices.
3. State any two advantages and disadvantages of RTD.

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://sl-coep.vlabs.ac.in/exp/characterize-temperature-sensor/edure.html
2. https://sl-coep.vlabs.ac.in/exp/temperature-sensor/
3. http://www.physicsclassroom.com/class/thermalP/Lesson-1/Temperature-and-Thermometers
4. http://hk-phy.org/contextual/heat/tep/tempe/
5. https://www.azom.com/article.aspx?ArticleID=5573
6. https://www.omega.com/Temperature/pdf/RTD_GEN_SPECS_REF.pdf
7. https://www.electrical4u.com/resistance-temperature-detector-or-rtd-construction-and-working-principle/

XIX. Assessment Scheme

	Performance Indicators	Weightage
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Scale -

X-Axis -

Y-Axis -

Scale -

X-Axis -

Y-Axis -

Practical No.15: Performance of signal conditioning circuit for temperature measurement using thermocouple

I. Practical Significance

The Temperature is one of the most important measurement parameters that is used for monitoring and control of processes in the medical field. It can be measured with the help of a variety of temperature sensing devices which reacts to a change in temperature .One such device is a Thermocouple which converts temperature into equivalent voltage. Thermocouple is the most useful active temperature transducer. It is not easy to transform the voltage generated by a thermocouple into an accurate temperature reading because the voltage signal is small, the temperature-voltage relationship is nonlinear, reference junction compensation is required, and thermocouples may pose grounding problems. Hence a signal conditioning circuit is needed.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences:
Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

- Build signal conditioning circuit for various applications.

IV. Laboratory Learning Outcome(s)

Test the performance of designed signal conditioning circuit for thermocouple.

V. Relevant Affective Domain related outcome(s)

a) Follow safety practices.
b) Maintain cleanliness of transducer setup.

VI. Relevant Theoretical Background

Thermocouple: A thermocouple is a device made by two different wires joined at one end, called junction end or measuring end. The two wires are called thermo elements or legs of the thermocouple: the two thermo elements are distinguished as positive and negative ones. The other end of the thermocouple is called reference end The junction end is immersed in the environment whose temperature T2 has to be measured, which can be for instance the temperature of a furnace at about 500°C, while the reference end is held at a different temperature T1, e.g. at ambient temperature.

Thermocouples will cause an electric current to flow in the attached circuit when subjected to changes in temperature. The amount of current that will be produced is dependent on the temperature difference between the measurement and reference junction; the characteristics of the two metals used; and the characteristics of the attached circuit.

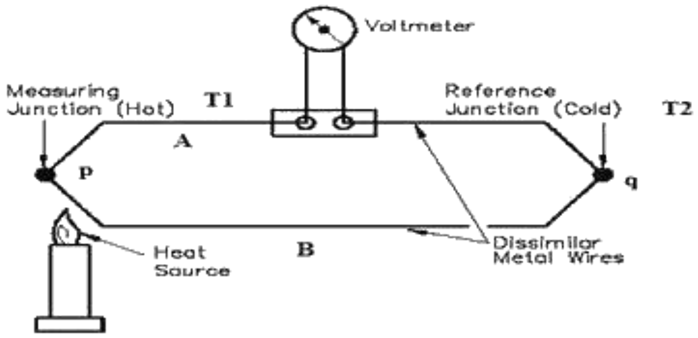
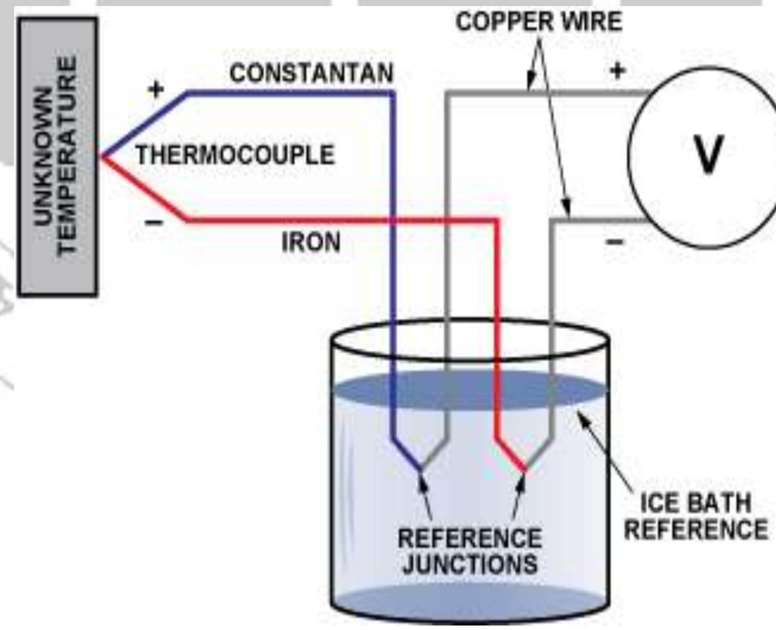


Fig. no.15.1 Thermocouple

Heating the measuring as shown in above figure Simple Thermocouple Circuit junction on the thermocouple produces a voltage which is greater than the voltage across the reference junction. The difference between the two voltages is proportional to the Difference in temperature and can be measured on the voltmeter (in milli volts).

Figure 15.2 shows a block diagram of the AD8495 thermocouple amplifier. Amplifiers A1, A2, and A3 and the resistors shown form an instrumentation amplifier that amplifies the K-type thermocouple's output with a gain appropriate to produce an output voltage of 5 mV/°C. Inside the box labeled "Ref junction compensation" is an ambient temperature sensor. With the measurement junction temperature held constant, the differential voltage from the thermocouple will decrease if the reference junction temperature rises for any reason. If the tiny AD8495 is in close thermal proximity to the reference junction, the reference-junction compensation circuitry injects additional voltage into the amplifier, so that the output voltage stays constant, thus compensating for the reference temperature change.

VII. Actual Circuit diagram used in laboratory with related equipment rating.



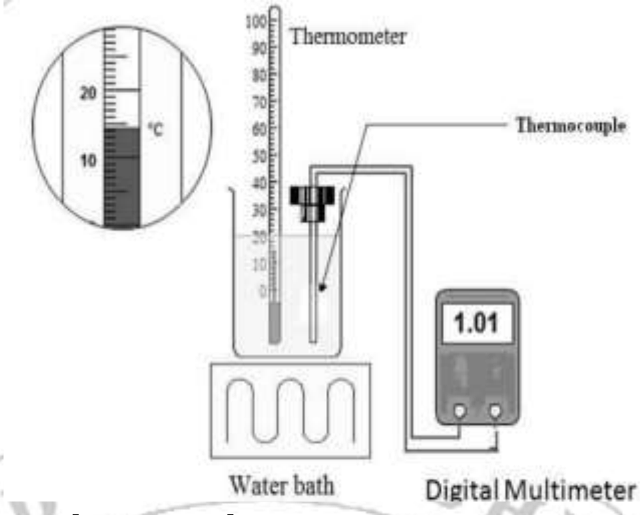


Fig 15.2 Thermocouple Temperature measurement setup

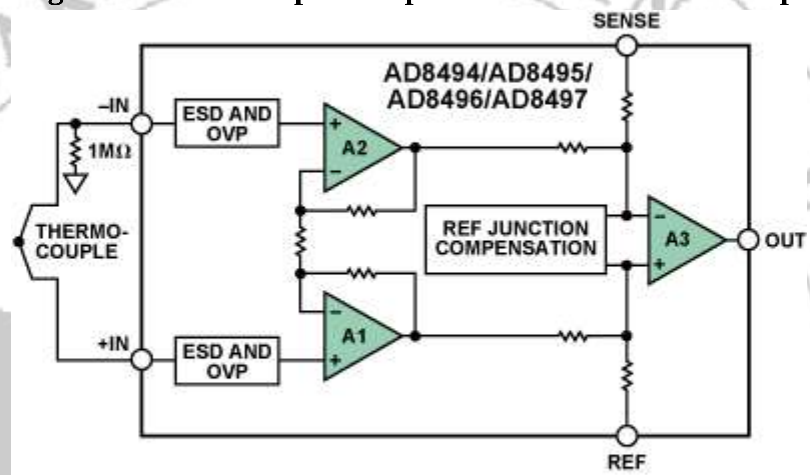


Fig. 15.3 Signal conditioning setup

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Thermocouple temperature measurement setup	Temperature measurement set- up trainer kit suitable to measure the temperature using K type Cr-Al thermocouple housed in S.S. type industrial housing, heater which can go up to 200^{O} C with facility to vary heater power, 3 ½ digit digital indicator of temperature, in built DC regulated power supply etc. IC AD8495	1

IX. Precautions to be followed

1) Ensure that proper connections are made as per the setup.
2) Ensure proper setting of devices used.
3) Ensure the power switch is in off condition initially.

X. Procedure

1. Connect set up for temperature measurement with thermocouple and IC AD8495 as shown in fig.15.3
2. Place the thermocouple, thermometer, and immersion heater in a temperature bath.
3. Record the room temp. with a mercury thermometer
4. Record the room temperature displayed on the kit
5. Switch on the power supply of the heater.
6. Note down the temperature for every 10 degree temperature rise.
7. Record the temperature using mercury thermometer.
8. Record the output voltage using a multimeter at output pin of IC.
9. Complete the observation table.
10. Repeat the steps 6 to 9 for 10 readings.
11. Plot the graph of thermometer temperature Vs amplified voltage.

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity

XII. Actual Procedure

XIII. Observation Table

Table15. 1: Observations and Calculations

Sr. No.	Thermometer temperature ^{o}C	Amplified Output Voltage V
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. State the materials used for S and E type thermocouple.
2. State the output voltage when two terminals are short of thermocouple.
3. State the output when one of the elements of thermocouple becomes open.
4. State the output voltage at room temperature. List the different types of thermocouples with their composition?
5. Enlist the limitations of thermocouple.

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://sl-coep.vlabs.ac.in/exp/temperature-sensor/
2. http://www.physicsclassroom.com/class/thermalP/Lesson-1/Temperature-and-Thermometers
3. http://hk-phy.org/contextual/heat/tep/tempe/
4. https://www.azom.com/article.aspx?ArticleID=5573
5. https://www.analog.com/en/resources/analog-dialogue/articles/measuring-temp-using-thermocouples.html

XIX. Assessment Scheme

	Performance Indicators	**Weightage**
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Scale -

X-Axis -

Y-Axis -

Practical No.16: Simulation of bio-potential amplifier

I. Practical Significance

Amplifiers are an important part of modern instrumentation systems for measuring biopotentials. Such measurements involve voltages that often are at low levels, have high source impedances, or both. Amplifiers are required to increase signal strength while maintaining high fidelity. Amplifiers that have been designed specifically for this type of processing of biopotentials are known as biopotential amplifiers.

II. Industry/Employer Expected Outcome(s)

The aim of this course is to help students to attain the following industry/ employer expected outcome through various teaching learning experiences:
Use relevant transducers to measure bio-signals.

III. Course Level Learning Outcome(s)

Build signal conditioning circuit for various applications.

IV. Laboratory Learning Outcome(s)

- Simulate biopotential amplifier.

V. Relevant Affective Domain related outcome(s)

a) Follow safe practices.
b) Follow ethical practices

VI. Relevant Theoretical Background

The essential function of a biopotential amplifier is to take a weak electric signal of biological origin and increase its amplitude so that it can be further processed, recorded, or displayed. Usually such amplifiers are in the form of voltage amplifiers, because they are capable of increasing the voltage level of a signal. Nonetheless, voltage amplifiers also serve to increase power levels, so they can be considered power amplifiers as well. In some cases, biopotential amplifiers are used to isolate the load from the source. In this situation, the amplifiers provide only current gain, leaving the voltage levels essentially unchanged.
Figure below show the basic Biopotential amplifier circuit diagram.

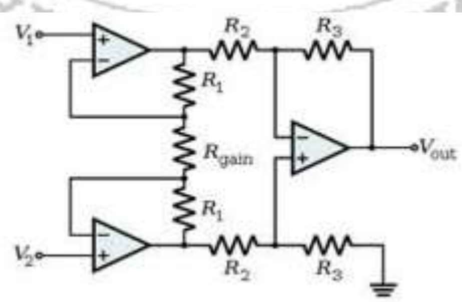


Fig no. 16.1 Instrumentation amplifier

The gain of the circuit is

$$\frac{V_{out}}{V_2 - V_1} = \left(1 + \frac{2R_1}{R_{gain}}\right)\frac{R_3}{R_2}$$

The rightmost amplifier, along with the resistors labeled R_2 and R_3 is just the standard differential amplifier circuit, with gain $=R_3 / R_2$ and differential input resistance = $2 \cdot R_2$. The two amplifiers on the left are the buffers. With Rgain removed (open circuited), they are simple unity gain buffers; the circuit will work in that state, with gain simply equal toR_3 / R_2 and high input impedance because of the buffers.

The buffer gain could be increased by putting resistors between the buffer inverting inputs and ground to shunt away some of the negative feedback; however, the single resistor Rgain between the two inverting inputs is a much more elegant method: it increases the differential-mode gain of the buffer pair while leaving the common-mode gain equal to 1. This increases the common-mode rejection ratio (CMRR) of the circuit and also enables the buffers to handle much larger common-mode signals without clipping than would be the case if they were separate and had the same gain. Another benefit of the method is that it boosts the gain using a single resistor rather than a pair, thus avoiding a resistor-matching problem (although the two R1s need to be matched), and very conveniently allowing the gain of the circuit to be changed by changing the value of a single resistor. A set of switch-selectable resistors or even a potentiometer can be used for Rgain, providing easy changes to the gain of the circuit, without the complexity of having to switch matched pairs of resistors.

To be useful biologically, all biopotential amplifiers must meet certain basic requirements. They must have high input impedance, so that they provide minimal loading of the signal being measured. The characteristics of biopotential electrodes can be affected by the electric load they see, which, combined with excessive loading, can result in distortion of the signal. Loading effects are minimized by making the amplifier input impedance as high as possible, thereby reducing this distortion. Modern biopotential amplifiers have input impedances of at least 10 mega ohm.

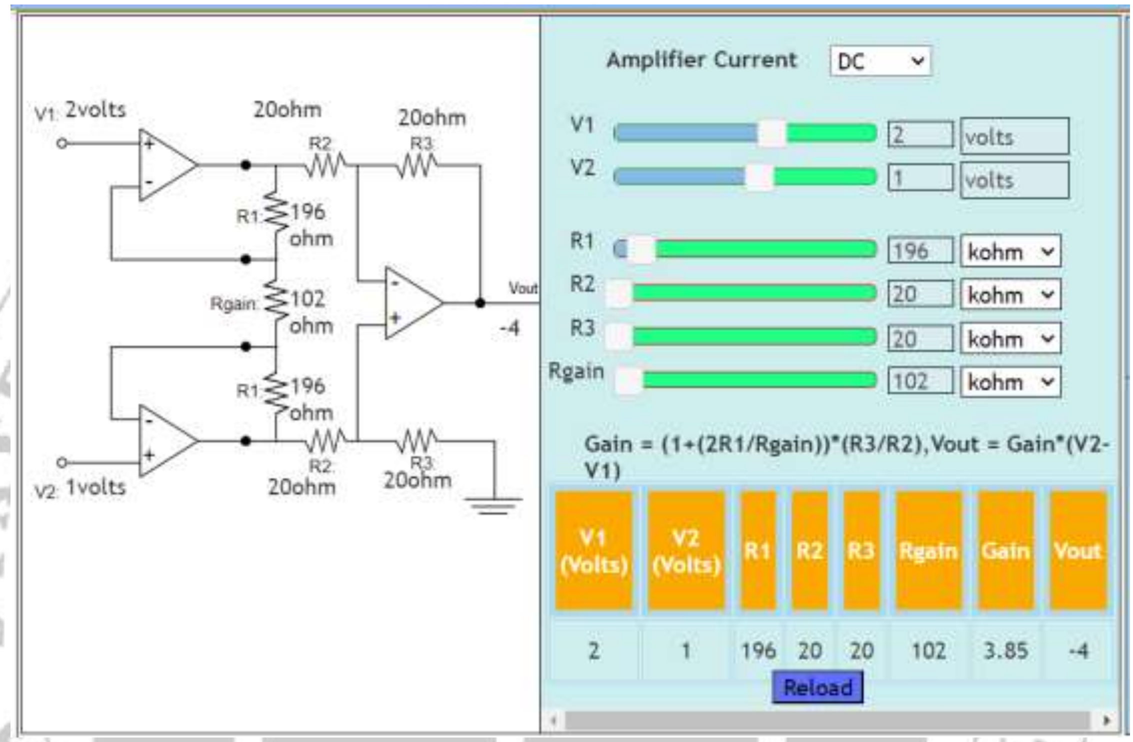
The input circuit of a biopotential amplifier must also provide protection to the organism being studied. Any current or potential appearing across the amplifier input terminals that is produced by the amplifier is capable of affecting the biological potential being measured. In clinical systems, electric currents from the input terminals of a biopotential amplifier can result in microshocks or macroshocks in the patient being studied-a situation that can have grave consequences. To avoid these problems, the amplifier should have isolation and protection circuitry, so that the current through the electrode circuit can be kept at safe levels and any artifact generated by such current can be minimized.

The output circuit of a biopotential amplifier does not present so many critical problems as the input circuit. Its principal function is to drive the amplifier load, usually an indicating or recording device, in such a way as to maintain maximal fidelity and range in this readout. Therefore, the output impedance of the amplifier must be low with respect to the load impedance, and the

amplifier must be capable of supplying the power required by the load.

Biopotential amplifiers must operate in that portion of the frequency spectrum in which the biopotentials that they amplify exist. Because of the low level of such signals, it is important to limit the bandwidth of the amplifier so that it is just great enough to process the signal adequately. In this way, we can obtain optimal signal-to-noise ratios (SNRs). Biopotential signals usually have amplitudes of the order of a few millivolts or less. Such signals must be amplified to levels compatible with recording and display devices. This means that most biopotential amplifiers must have high gains-of the order of 1000 or greater.

VII. Actual Circuit diagram used in laboratory with related equipment rating.



Note: Use "Rgain" as Variable resistor

Fig. 16.2 Simulation of biopotential amplifier

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Computer/ Laptop	https://bmsp-coep.vlabs.ac.in/exp/biopotential-amplifier/simulation.html	1

IX. Precautions to be followed

1) Ensure proper connections are made as per the given setup.
2) Ensure the power switch is in 'off' condition initially.
3) Ensure the use of proper settings of input DC voltage.

X. Procedure

1. Refer to the given link and go to the simulator tab for performing the simulation.
2. Apply input signal from various sources to the biosignal amplifier and observe the output of the biosignal amplifier.
3. To change the gain of the amplifier change values of resistor Rgain and observe the change in output signal.
4. Record the output of a biosignal amplifier with different gains and different inputs.
5. Plot the characteristics of a biosignal amplifier.
6. Calculate theoretical gain using a given formula and compare the output of a simulated biosignal amplifier with the theoretical value.

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity
1			
2			
3			
4			

XII. Actual procedure:

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XIII. Observation Table

Table no.16.1: Observation Table for gain of instrumentation amplifier.

Sr. No.	DC Input Voltage		Input Difference	Output Voltage		Gain	
	V_1 in mV	V_2 in mV	$V_d = V_1 - V_2$	Practical	Theoretical	Practical	Theoretical
1							
2							
3							
4							

XIV. Result(s)

1. Measured output voltage =.......................
2. Theoretical Gain =................................
3. Practical Gain = ...

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more such questions so as to ensure the achievement of identifies CO.

1. Repeat the above experiment procedure for **V_1 =0 mV and V_2 =50 V**
2. **https://bmsp-coep.vlabs.ac.in/exp/biopotential-amplifier/pretest.html**
3. **https://bmsp-coep.vlabs.ac.in/exp/biopotential-amplifier/posttest.html**

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. https://en.wikipedia.org/wiki/Bioamplifier
2. A book by John Webster Medical Instrumentation: Application and Design

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60 %**
1	Handling of the components	10%
2	Identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	