Course Plan

Subject code: BM8502 **Branch/Year/Sem: B.E BME/III/V**
Subject Name: BIOMEDICAL INSTRUMENTATION **Batch:2020-2024**
Staff Name: Dr. Amit Kumar Singh **Academic year:2022-2023**

Course Objectives:

1. To Illustrate the origin of bio potentials and its propagations
2. To understand the different types of electrodes and its placement for various recordings
3. To design bio amplifier for various physiological recordings
4. To learn the different measurement techniques for non-physiological parameters.
5. To Summarize the different biochemical measurements.

TEXT BOOK:

T1. Leslie Cromwell, "Biomedical Instrumentation and measurement", 2nd edition, Prentice hall of India, New Delhi, 2015.

REFERENCES:

John G. Webster, "Medical Instrumentation Application and Design", 4th edition, Wiley India Pvt Ltd,New Delhi, 2015.

2. Joseph J. Carr and John M. Brown, "Introduction to Biomedical Equipment Technology", Pearson Education, 2004.

3. Myer Kutz, "Standard Handbook of Biomedical Engineering and Design", McGraw Hill Publisher, 2003.

4. Khandpur R.S, "Handbook of Biomedical Instrumentation", 3rd edition, Tata McGrawHill New Delhi, 2014

TEACHING METHODOLOGIES:

- BB - Black Board
- VIDEO - VIDEO TUTORIAL
- PPT - POWER POINT PRESENTATION

DEPARTMENT OF BIOMEDICAL ENGINEERING

BM8502 BIOMEDICAL INSTRUMENTATION

L T P C
3 0 0 3

UNIT I BIOPOTENTIAL ELECTRODES: **9**

Origin of bio potential and its propagation. Electrode-electrolyte interface, electrode–skin interface, half-cell potential, Contact impedance, polarization effects of electrode – non polarizable electrodes. Types of electrodes - surface, needle and micro electrodes and their equivalent circuits. Recording problems - motion artifacts, measurement with two electrodes.

UNIT II : BIOPOTENTIAL MEASUREMENTS: 9

Bio signals characteristics – frequency and amplitude ranges. ECG – Einthoven's triangle, standard 12 lead system, Principles of vector cardiography. EEG – 10-20 electrode system, unipolar, bipolar and average mode. EMG– unipolar and bipolar mode. Recording of ERG, EOG and EGG

UNIT III SIGNAL CONDITIONING CIRCUITS: 9

Need for bio-amplifier - single ended bio-amplifier, differential bio-amplifier, Impedance matching circuit, isolation amplifiers – transformer and optical isolation - isolated DC amplifier and AC carrier amplifier., Power line interference, Right leg driven ECG amplifier, Band pass filtering

UNIT IV MEASUREMENT OF NON-ELECTRICAL PARAMETERS: 9

Temperature, respiration rate and pulse rate measurements. Blood Pressure: indirect methods - Auscultatory method, oscillometric method, direct methods: electronic manometer, Pressure amplifiers, Systolic, diastolic, mean detector circuit. Blood flow and cardiac output measurement: Indicator dilution, thermal dilution and dye dilution method, Electromagnetic and ultrasound blood flow measurement.

UNIT V BIOCHEMICAL MEASUREMENT AND BIOSENSORS: 9

Biochemical sensors - pH, pO2 and pCO2, Ion selective Field effect Transistor (ISFET), Immunologically sensitive FET (IMFET), Blood glucose sensors, Blood gas analyzers - colorimeter, Sodium Potassium Analyser, spectrophotometer, blood cell counter, auto analyzer (simplified schematic description) – Bio Sensors – Principles – amperometric and voltometric techniques

Laboratory Manual

BM8511

Biomedical Instrumentation Laboratory

VSB Engineering College, Karur

List of Experiments

1. Design of pre amplifiers to acquire bio signals along with impedance matching circuit using suitable IC's
2. Design of ECG Amplifiers with appropriate filter to remove power line and other artifacts.
3. Design of EMG amplifier
4. Design a suitable circuit to detect QRS complex and measure heart rate
5. To design a band pass filter to obtain the alpha frequency band of an amplified EEG signal.
6. Design of EOG amplifier to detect eye blink
7. Design a right leg driven ECG amplifier.
8. Design and study the characteristics of optical Isolation amplifier 9. To demonstrate the use of IC 4051 as multiplexer or demultiplexer
10. Measurement of pulse-rate using Photo transducer.
11. Measurement of pH and conductivity.
12. Measurement of blood pressure using sphygmomanometer.
13. Measurement and recording of peripheral blood flow
14. Design a PCB layout for any bio amplifier using suitable software tool.

Extra Experiments

15. Monitoring of Electroencephalogram (EEG) signal for different lobes using VLAB.
16. Monitoring of electrocardiogram (ECG) for bipolar limb leads l1, l2 and l3 using VLAB.
17. Determination of pH using VLAB.
18. Design and study the characteristics of optical Isolation amplifier using Proteus simulation.

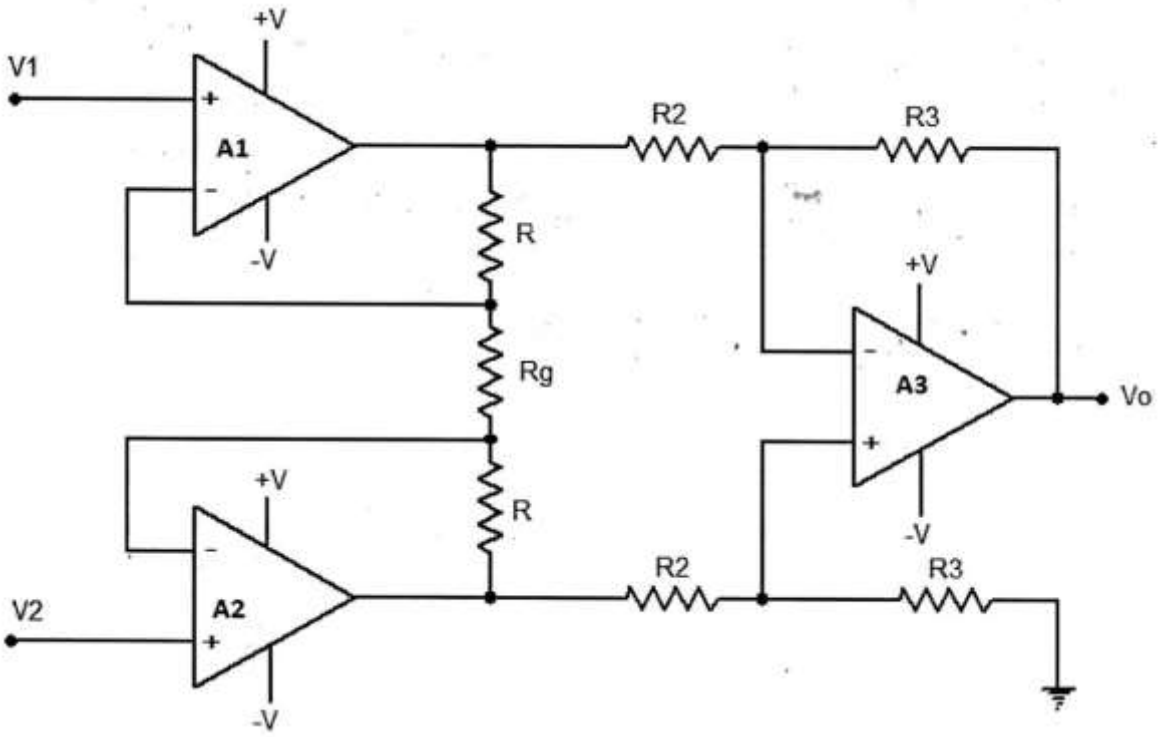
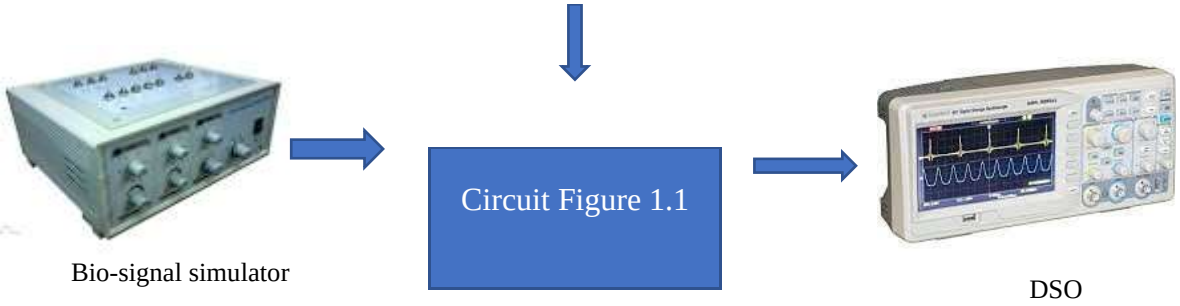


Figure1.1: Instrumentation amplifier circuit



Bio-signal simulator

DSO

Figure 1.2: Block diagram of the experiment

Experiment -1: To study the design of pre amplifiers

Objective: Design of pre amplifiers to acquire bio signals along with impedance matching circuit using suitable IC's

Apparatus and Components Used: Multiparameter (ECG, EMG, EEG) Simulator: 1 No. DSO, Regulated Power supplies, Bread boards – 1, IC AD 620, and resistors and connectors as per design.

Theory:

1.1 Need for Pre-amplifier:

Generally, biological/bioelectric signals have low amplitude and low frequency. Therefore, to increase the amplitude level of biosignals amplifiers are designed. The outputs from these amplifiers are used for further analysis and they appear as ECG, EMG, or any bioelectric waveforms. Such amplifiers are defined as Bio Amplifiers or Biomedical Amplifiers or preamplifiers.

1.2 Basic Requirements for Pre Amplifiers

1. The pre amplifier should have a high input impedance value. The range of value lies between 2 - 10 Mohm depending on the applications. Higher impedance value reduces distortion of the signal.
2. When electrodes pick up biopotentials from the human body, the input circuit should be protected. Every bio-amplifier should consist of isolation and protection circuits, to prevent the patients from electrical shocks.
3. Since the output of a bioelectric signal is in millivolts or microvolt range, the voltage gain value of the amplifier should be higher than 100dB.
4. Throughout the entire bandwidth range, a constant gain should be maintained.
5. A bio-amplifier should have a small output impedance.
6. A good bio-amplifier should be free from drift and noise.
7. Common Mode Rejection Ratio (CMRR) value of amplifier should be greater than 80dB to reduce the interference from common mode signal.
8. The gain of the bio-amplifier should be calibrated for each measurement.

1.3 Types of Pre Amplifiers

1. Differential Amplifier
2. Operational Amplifier
3. Instrumentation Amplifier
4. Chopper Amplifier
5. Isolation Amplifier **1.4 Impedance matching circuit:**

Instrumentation Amplifier:

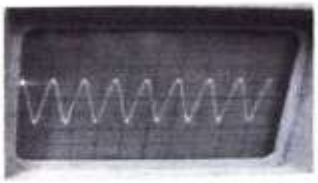
Instrumentation amplifier is a kind of differential amplifier with additional input buffer stages. The addition of input buffer stages makes it easy to match (impedance matching) the amplifier with the preceding stage. Instrumentation are commonly used in industrial test and

1. ECG & Pulse output Signal on DSO

1. ECG Simulator Voltage knob at Maximum position
2. DSO Voltage/ Div on 1V
3. DSO Time / Div 0.5S
4. DSO connection at RL & C

1. ECG Simulator Voltage knob at Maxi.position
2. DSO Voltage/ Div on 5V
3. DSO Time / Div 0.5S
4. DSO connection at Pulse + & Ground

2.EMG output Signal on DSO



1. EMG Simulator Voltage knob at Maximum position
2. DSO Voltage/ Div on 1V
3. DSO Time / Div 5mS
4. DSO connection at A & G

3.EEG output Signal on DSO

1. EEG Simulator Voltage knob at Maximum position
2. DSO Voltage/ Div on 0.5V
3. DSO Time / Div 50mS
4. DSO connection at A & G

Figure 1.3 Different waveform generated on the DSO by the circuit

measurement application. The instrumentation amplifier also has some useful features like low offset voltage, high CMRR (Common mode rejection ratio), high input resistance, high gain etc. The circuit diagram of a typical instrumentation amplifier using Op-amp is shown in Figure 1.1. Instrumentation amplifiers are generally used in situations where high sensitivity, accuracy and stability are required.

A circuit providing an output based on the difference between two inputs (times a scale factor) is given in the above figure. In the circuit diagram, Opamps labelled Al and A2 are the input buffers. Anyway the gains of these buffer stages are not unity because of the presence of R and Rg. Op amp labelled A3 is wired as a standard differential amplifier. R3 connected from the output of A3 to its non-inverting input is the feedback resistor. R2 is the input resistor. The voltage gain of the instrumentation amplifier can be expressed by using the equation below. $V_0 = R_3 / R_2 (1 + 2*R/ R_g) (V_2 - V_1)$

Procedure:

(1) Use the simulator kit to generate different biological signals (ECG, EMG, and EEG).
(2) Make the circuit mentioned in Figure 1.1 on the breadboard.
(3) Connect the output of the simulator as shown in Figure 1.2.
(4) The output of the circuit is connected to the DSO to check the output signal as mentioned in Figure 1.3.
(5) Change the value of gain by choosing different values of R_g to get the desired signal voltage level.
(6) Draw the output waveform as seen on the DSO also shown in Figure 1.3. Table 1: Preamplifier Input and output voltages

S. No	Input Voltage Level (mV)	Gain	Output Voltage Level (V)
1	1	100	0.1
2	1	200	0.2
3	1	400	0.4
4	1	800	0.8
5	1	1200	1.2

Results:

The circuit of the pre amplifier is verified as mentioned in Figure 1.3 for different biomedical signals by the readings of the table along with impedance matching.

Precautions:

(1) Handle the Bio-signal simulator properly as it is the sensitive device.
(2) Make the connections properly on the breadboard.
(3) Check all the connections before power on all the equipment's.
(4) Beware of using any liquid near the setup.

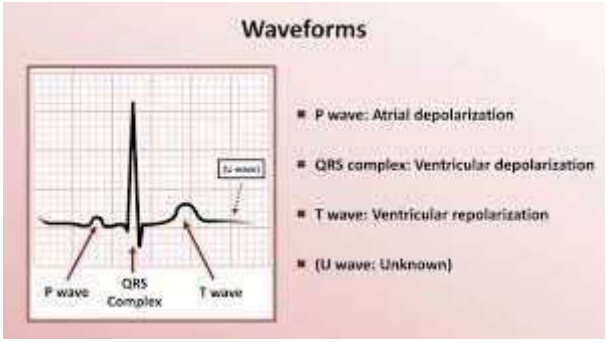


Figure 2.1 Normal ECG of the human

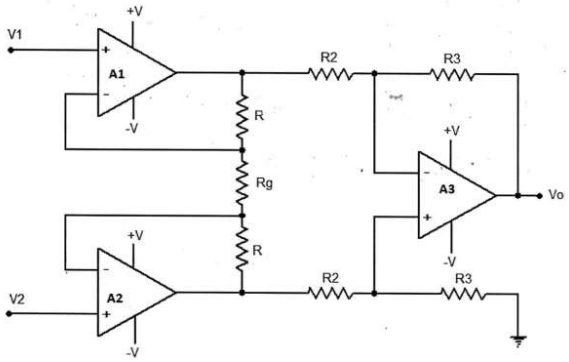


Figure 2.2 Instrumentation amplifier

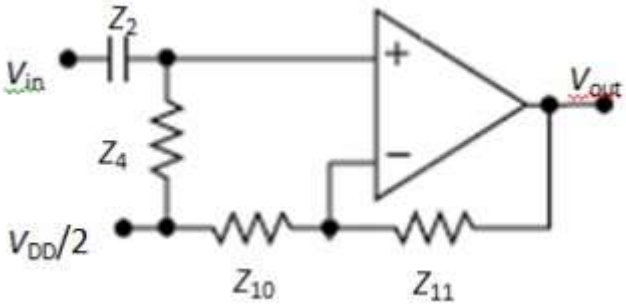


Figure 2.3 1st-order HPF

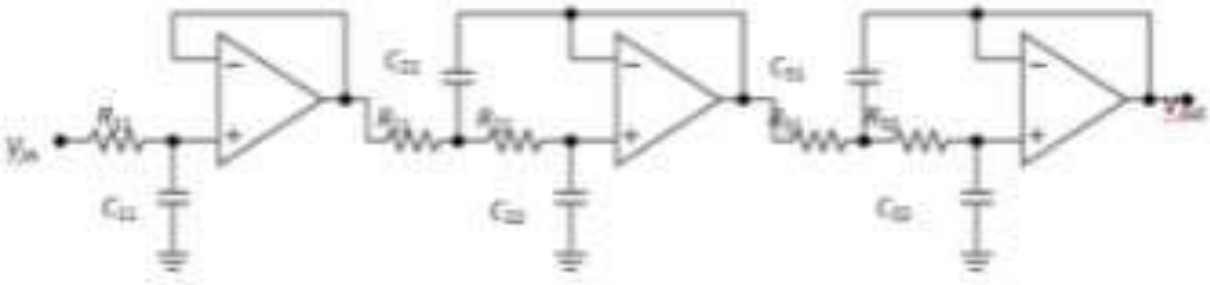


Figure 2.4 Circuit diagram of the 5th-order active Bessel LPF

Experiment -2 To study the design of removal of artifacts

Objective: Design of ECG Amplifiers with appropriate filter to remove power line and other artifacts.

Apparatus and Components Used: Multiparameter (ECG) Simulator: 1 No. DSO, Regulated Power supplies, Bread boards – 1, IC LM324, INA126, AD 620, and resistors and connectors as per design.

Theory:

2.1 ECG: Also known as an electrocardiogram or an EKG, an ECG is a test that detects and records the strength and timing of the electrical activity in your heart. This information is recorded on a graph as shown in Figure 2.1 that shows each phase of the electrical signal as it travels through your heart.

2.2 Signal conditioning circuit design and implementation

Other noise or higher frequencies within the biophysical bandwidth come from:

(1) Movement artifacts that change the skin-electrode interface
(2) Muscle contraction or electromyographic spikes
(3) Respiration
(4) Electromagnetic interferences
(5) Noise from other electronic devices that couple into the input

To effectively remove unwanted noise and preserve the useful components of ECG signals, the following bio-signal conditioning schemes and sequence were developed:

(1) Amplify the raw ECG signal with an instrumentation amplifier to raise the signal voltage level
(2) Use a high-pass filter to eliminate DC offset developed between electrodes.
(3) Apply a low-pass filter to remove high frequency noise.
(4) Filter out power line interference using a notch filter.

2.3 Instrumentation amplifier

An Analog Devices'AD620 instrumentation amplifier (IA) was used first to amplify the ECG signal obtained from the biopotential difference between the right and left arm electrodes (Lead I in Figure 2.2).

2.4 First-order active High-pass Filter (HPF)

After the amplification, the ECG signal passes through a non-inverting active high-pass filter (HPF) to eliminate DC offset (developed between the electrodes) and to be amplified further as shown in Figure 2.3

2.5 Fifth-order active bessel low-pass filter (LPF)

After the HPF, the ECG signal is sent to a low-pass filter (LPF) to remove its high frequency noise components. 160 Hz was chosen as the cutoff frequency based on the normal ECG frequency range for minimum ECG frequency bandwidth. The LPF is a cascaded 5th-order active Bessel filter which has excellent transient and linear phase response. The circuit diagram is shown in Figure 2.4.

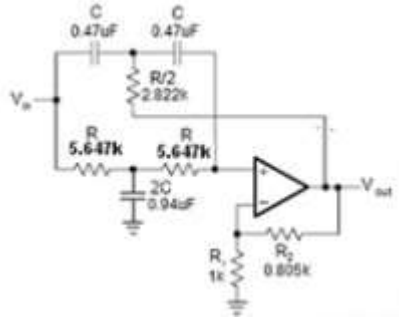


Figure 2.5 The Twin-T notch filter to remove 50 Hz powerline noise

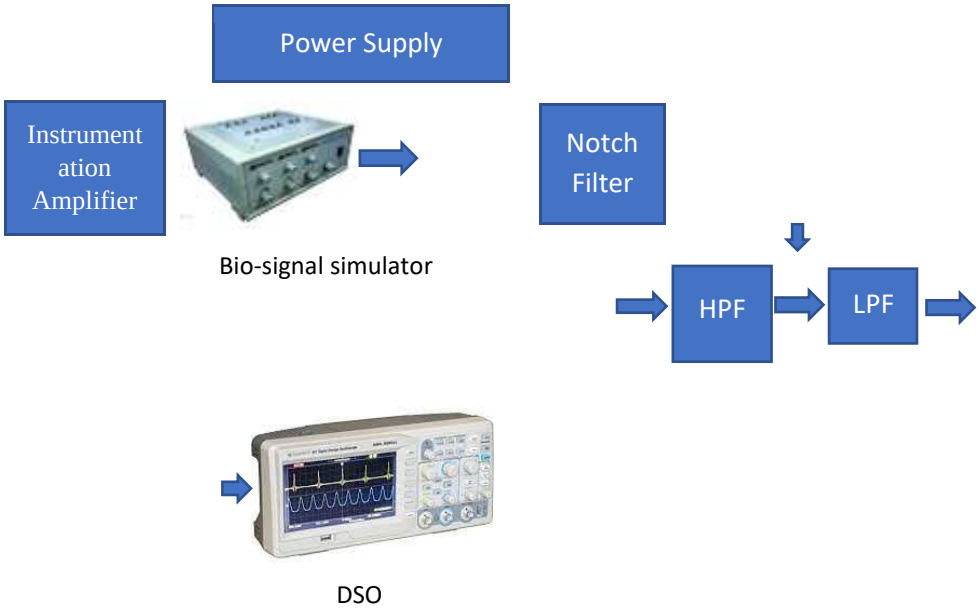


Figure 2.6 Overall block diagram of the ECG conditioning circuit experiment

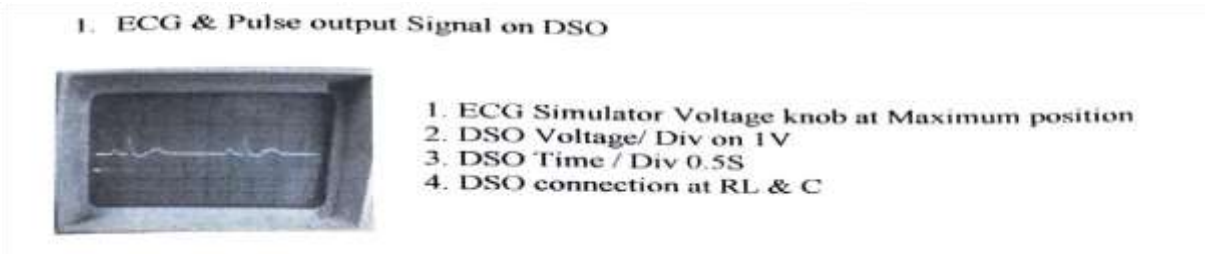


Figure 2.6 ECG waveform generated on the DSO by the circuit

2.6 Notch/Band-reject filter

A notch or band-reject filter is typically used in biomedical instrumentation to suppress the 50 Hz power field interference needs to be rejected. This requires a small transition bandwidth or high Q factor to achieve the steeper roll-off. A Twin-T notch filter is one of the few RC networks capable of providing an infinite deep notch at a particular frequency. Two "T" shape RC filters combined with a op-amp, as shown in Figure 2.5, form an active notch filter.

Procedure:

(1) Use the simulator kit to generate ECG signal.
(2) Make the circuit mentioned in Figure 2.2, 2.3, 2.4 and 2.5 on the breadboard.
(3) Connect the output of the simulator as shown in Figure 2.6.
(4) The output of the circuit is connected to the DSO to check the output signal as mentioned in Figure 2.6.
(5) Change the value of gain by choosing different values of R_g to get the desired signal voltage level.
(6) Draw the output waveform as seen on the DSO also shown in Figure 2.7.

Results:

The circuit of the ECG amplifier is verified as mentioned in Figure 2.7 for ECG signal generated on the DSO.

Precautions:

(1) Handle the Bio-signal simulator properly as it is the sensitive device.
(2) Make the connections properly on the breadboard.
(3) Check all the connections before power on all the equipment's.
(4) Beware of using any liquid near the setup.

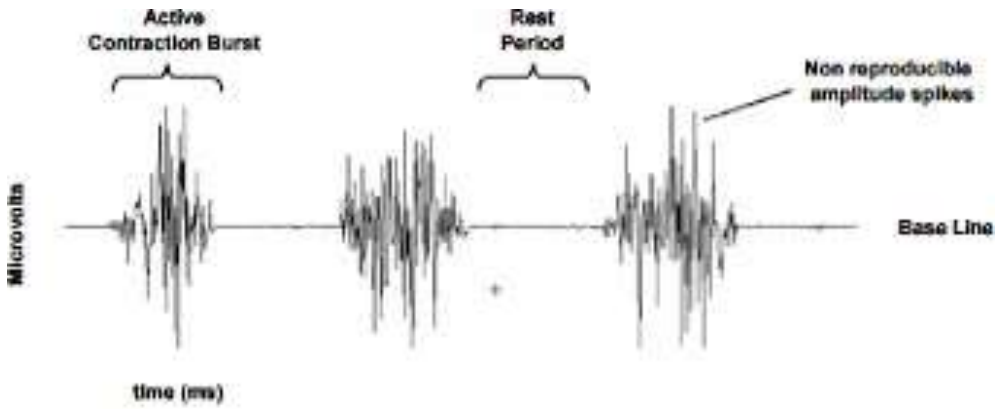


Figure 3.1 Raw EMG signal

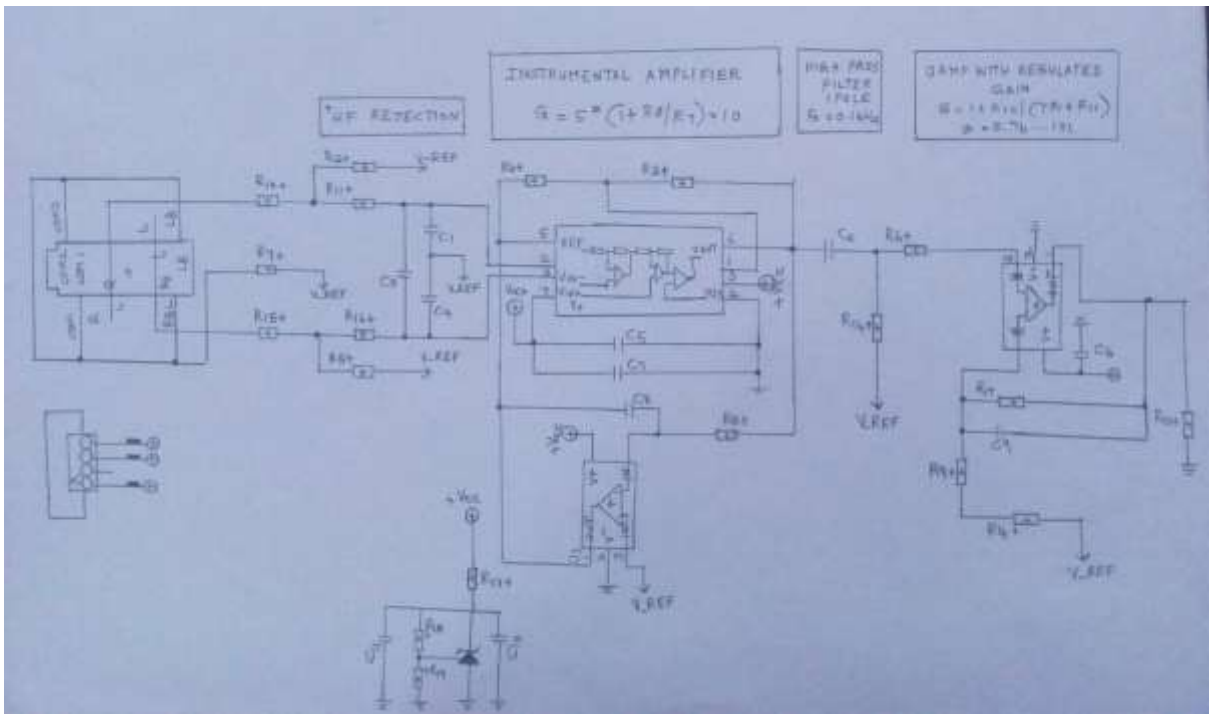


Figure 3.2 Circuit Diagram of the EMG amplifier

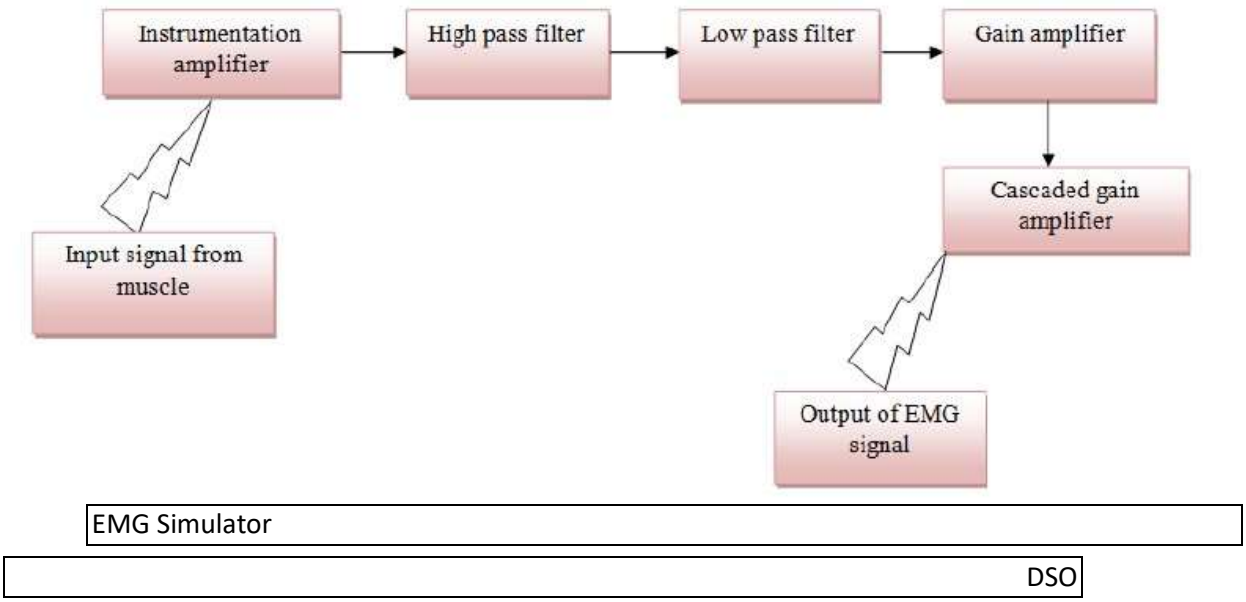


Figure 3.3: Block Diagram of ECG experiment Design

Experiment - 3: To study the design of EMG amplifier

Objective: Design of EMG Amplifier

Apparatus and Components Used: Multiparameter (EMG) Simulator: 1 No. DSO, Regulated Power supplies, Bread boards – 1, IC LM324, INA126, AD 620, and resistors and connectors as per design.

Theory:

3.1 Electromyography (EMG) is a diagnostic procedure that evaluates the health condition of muscles and the nerve cells that control them. These nerve cells are known as motor neurons. They transmit electrical signals that cause muscles to contract and relax. An EMG translates these signals into graphs or numbers, helping doctors to make a diagnosis.

A doctor will usually order an EMG when someone is showing symptoms of a muscle or nerve disorder. These symptoms may include tingling, numbness, or unexplained weakness in the limbs. EMG results can help the doctor diagnose muscle disorders, nerve disorders, and disorders affecting the connection between nerves and muscles.

The results of an EMG can help your doctor determine the underlying cause of these symptoms. Possible causes could include:

(1) Muscle disorders, such as muscular dystrophy
(2) Disorders that affect the ability of the motor neuron to send electrical signals to the muscle, such as myasthenia gravis radiculopathies
(3) Peripheral nerve disorders that affect the nerves outside the spinal cord, such as carpal tunnel syndrome
(4) Nerve disorders, such as amyotrophic lateral sclerosis (ALS)

A typical EMG waveform is shown in Figure 3.1. The circuit consists of instrumentation amplifier. It also consist of high pass filter ,resistors, capacitors, diodes, in which the gain of the circuit is designed by using the formula:

Gain= V_{out} /V_2-V_1= (1+2R_1/R_g) R_3/R_2.

The resistor has values of 10K and 5K.By using these resistor values in the above formula we obtain the gain to be 5V. The capacitor has the value of 0.1μF.High pass filter eliminates all the low frequencies and allows only high frequencies to pass through while the low pass filter allows only low frequencies and eliminates the high frequency signals. The frequency of the filters can be calculated using the formula: f= 1/2πRC

Procedure

(1) Draw the circuit on the Bread board as mentioned in Figure 3.2
(2) The muscle signal from the EMG simulator is given as input to the instrumentation amplifier as shown in Figure 3.3.
(3) The output of the instrumentation amplifier is given as input to the high pass filter (HPF) which eliminates the low frequency noise signal.
(4) Then LPF is there to filter which allows only low frequencies to pass through and eliminates all the frequency signals.

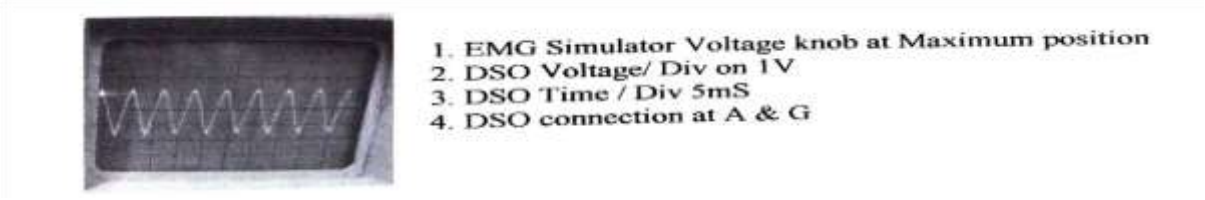


Figure 3.4 EMG waveform generated on the DSO by the circuit

(5) The noise free signal is given as input to the gain amplifier which helps to boost up the amplitude of the signal which lies in between 1-10mv. A typical EMG signal ranges from 0.1 to 0.5 mv.
(6) The final output of the EMG signal is recorded in DSO.
(7) Table 1 is plotted by varying the input voltage and verified on the DSO graph.

Table 1: Input voltage, Output voltage, and Gain for different States of Muscular Activity

S. No	State of muscular activity	Input Voltage (mV)	Output Voltage (V)	Gain
1	Relaxation			
2	Contraction			
3	Little Contraction			
4	High Contraction			
5	Eye blink			

Results:

Thus the EMG is designed for gain of 5V and the corresponding input voltage, output voltage and gain for different states of muscular activity i.e.) EMG signal waveform is obtained as shown in Figure 3.4.

Precautions:

(1) Handle the Bio-signal simulator properly as it is the sensitive device.
(2) Make the connections properly on the breadboard.
(3) Check all the connections before power on all the equipment's.
(4) Beware of using any liquid near the setup.

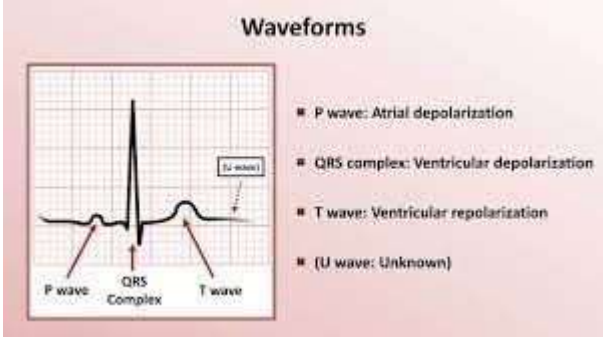


Figure 4.1 QRS complex waveform of ECG

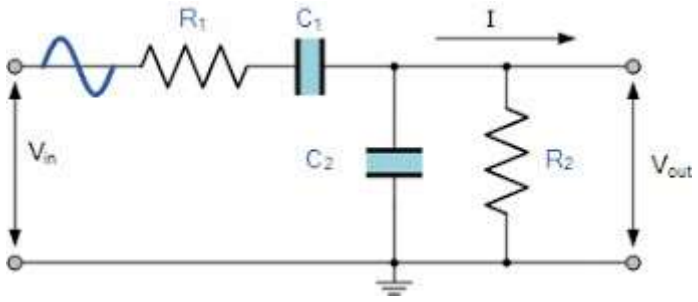


Figure 4.2 Circuit diagram of the band pass filter

Figure 4.3 Block diagram of the experiment

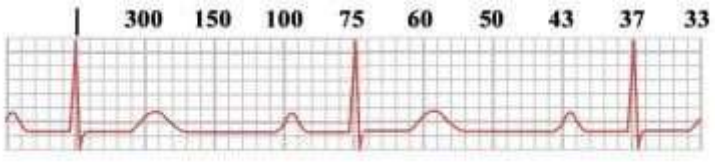


Figure 4.4 ECG graph of the subject

Experiment - 4: To study the design of filter for QRS complex

Objective: Design a suitable circuit to detect QRS complex and measure heart rate
Apparatus and Components Used: Multiparameter (ECG) Simulator: 1 No. DSO, Regulated Power supplies, Bread boards – 1, IC LM324, INA126, AD 620, and resistors and connectors as per design. **Theory:**

2.1 ECG: Also known as an electrocardiogram or an EKG, an ECG is a test that detects and records the strength and timing of the electrical activity in your heart. This information is recorded on a graph as shown in Figure 4.1 that shows each phase of the electrical signal as it travels through your heart.

2.2 Heart Rate

Heart rate is the speed of the heartbeat measured by the number of contractions (beats) of the heart per minute (bpm). The heart rate can vary according to the body's physical needs, including the need to absorb oxygen and excrete carbon dioxide, but is also modulated by a myriad of factors including but not limited to genetics, physical fitness, stress or psychological status, diet, drugs, hormonal status, environment, and disease/illness as well as the interaction between and among these factors. It is usually equal or close to the pulse measured at any peripheral point.

Procedure:

(1) Use the simulator kit to generate ECG signal.

(2) Make the circuit mentioned in Figure 4.2 on the breadboard.
(3) Choose the component values of resistor and capacitor for the 8-50 Hz design.
(4) Connect the output of the simulator as shown in Figure 4.3.
(5) The output of the circuit is connected to the DSO to check the output signal as mentioned in Figure 4.3.
(6) Calculation for Heart rate=300/No of boxes between two consecutive QRS complex.
(7) Draw the output waveform as seen on the DSO also shown in Figure 4.4.

Results:

The filter circuit of the QRS complex is verified and the heart rate is calculated from the ECG pattern generated on the DSO and found normal for the healthy subject.

Precautions:

(1) Handle the Bio-signal simulator properly as it is the sensitive device.
(2) Make the connections properly on the breadboard.
(3) Check all the connections before power on all the equipment's.
(5) Beware of using any liquid near the setup.

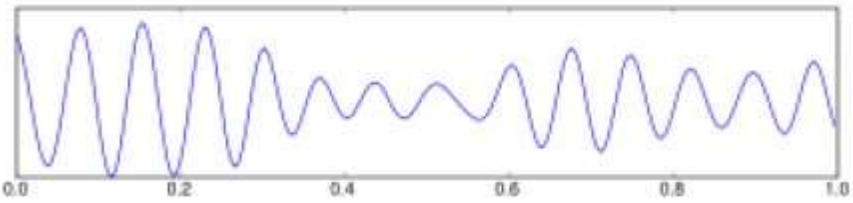


Figure 5.1 Alpha wave of the human

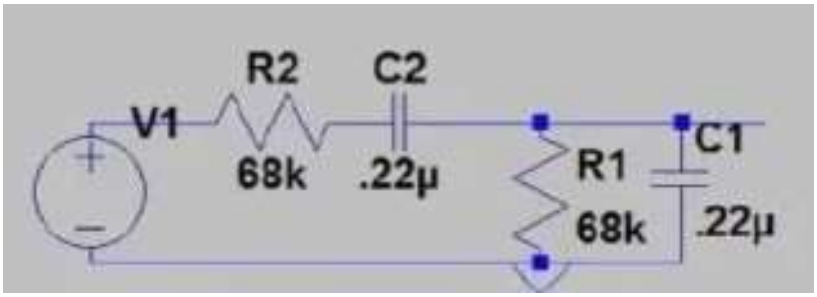


Figure 5.2 Circuit diagram of the band pass filter

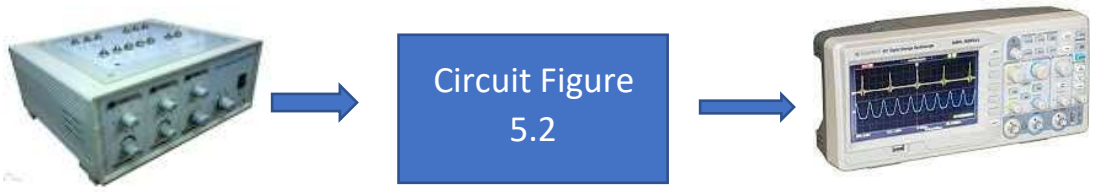


Figure 5.3 Block diagram of the experiment

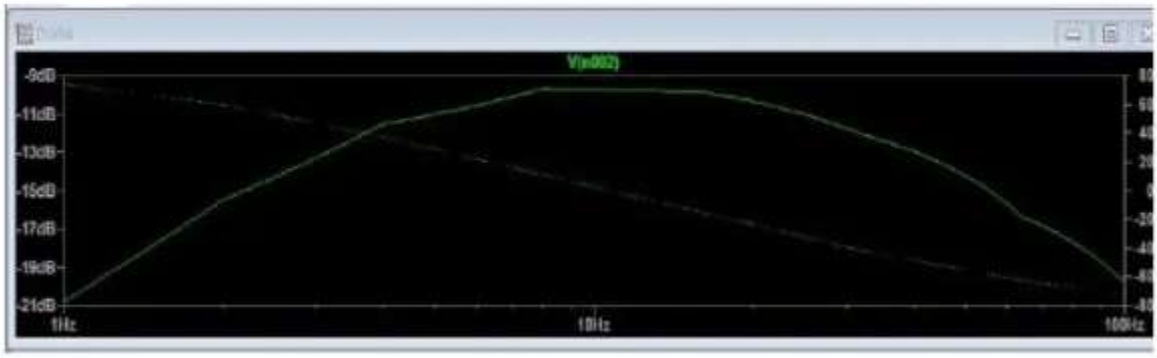


Figure 5.4 Filtered graph on DSO of alpha wave

Experiment – 5: To study the design of EEG signals with filter

Objective: To design a band pass filter to obtain the alpha frequency band of an amplified EEG signal.

Apparatus and Components Used: EEG simulator kit, DSO, EEG electrodes, Bread boards – 1, and resistors and connectors as per design.

Theory:

5.1 Electroencephalography (EEG): EEG is the recording of electrical activity along the scalp produced by the firing of neurons within the brain. In conventional scalp EEG, the recording is obtained by placing electrodes on the scalp with a conductive gel or paste. Electrode locations and names are specified by the International 10–20 system for most clinical and research applications. Each electrode is connected to one input of a differential amplifier (one amplifier per pair of electrodes); a common system reference electrode is connected to the other input of each differential amplifier. These amplifiers amplify the voltage between the active electrode and the reference. A typical adult human EEG signal is about 10µV to 100 µV in amplitude when measured from the scalp and is about 10–20 mV when measured from subdural electrodes.

5.2 Alpha waves: Alpha is the frequency range from 8 Hz to 12 Hz. Hans Berger named the first rhythmic EEG activity he saw, the "alpha wave. It emerges with closing of the eyes and

with relaxation, and attenuates with eye opening or mental exertion. The posterior basic rhythm is actually slower than 8 Hz in young children. The alpha wave is shown in figure 5.1.

5.3 Circuit Design: The circuit used in this design is a RC band pass filter, in such filters the cut-off frequencies can be accurately controlled by the resistors connected in series with a nonpolarized capacitor. Sometimes it is necessary to only pass a certain range off frequencies (in this case 8-13 Hz) that do not begin with 0 Hz, or end at some higher frequency point but are within a certain range or band of frequencies, either narrow or wide. By connecting or "cascading" together a single low pass circuit or high pass circuit, we can produce RC filter that passes selected range of frequencies or "band" of frequencies while attenuating all those outside this range. This type of filter is commonly known as band pass filter.

Procedure:

(1) Rig up the circuit as shown in the circuit diagram of figure 5.2 on the bread board.
(2) Make the connections as shown in figure 5.3.
(3) Apply the signal from the EEG simulator.
(4) Keeping the input signal of the amplitude constant, vary the frequency of the input signal.
(5) Vary the frequency from 1 to 20 Hz, in increments of 1 Hz.
(6) Note down the output voltage for various frequencies.
(7) Plot the frequency response.

Results:

The EEG of the subject is plotted and shown in figure 5.4. The design of the EEG amplifier for alpha wave is verified.

Precautions:

(1) Handle the kit properly.
(2) Make the connections properly on the breadboard.
(3) Check all the connections before power on the system.
(4) Beware of using any liquid near the setup.

Figure 6.1 Ag/AgCl electrodes

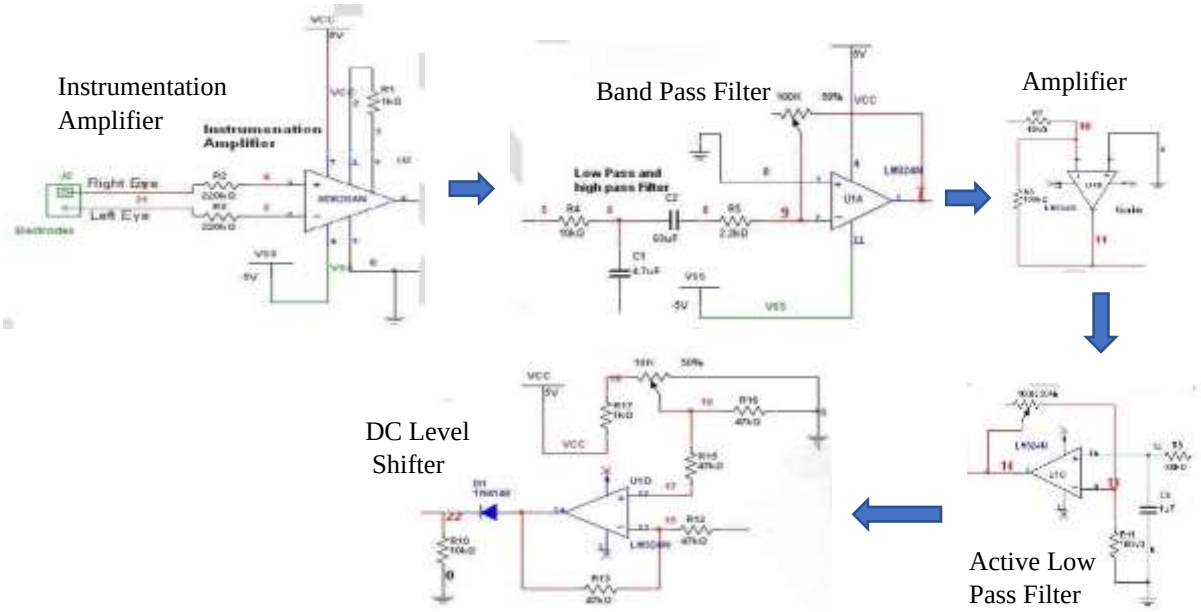


Figure 6.2: Circuit Diagram of EOG experiment

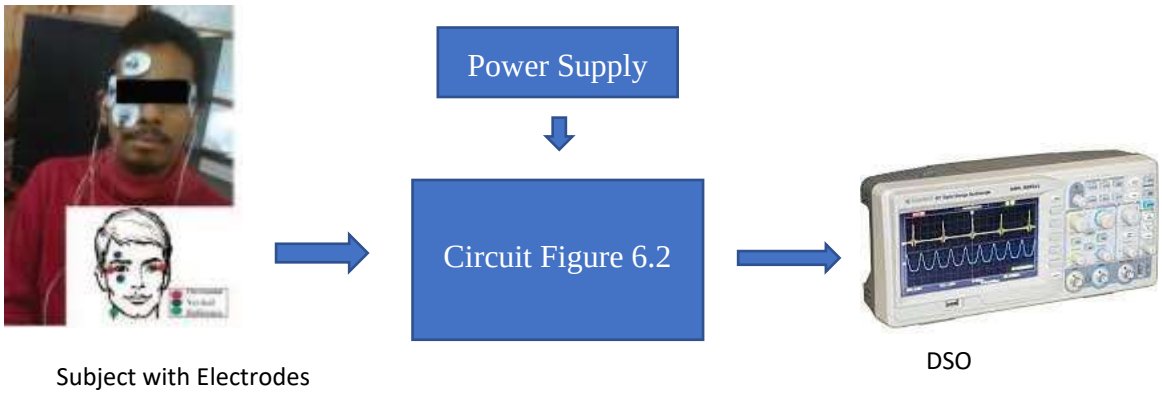


Figure 6.3 Block diagram of the experiment

Experiment – 6: To study the design of EOG amplifier

Objective: Design of EOG amplifier to detect eye blink.

Apparatus and Components Used: DSO, Ag/AgCl electrodes, Regulated Power supplies, Bread boards – 1, IC LM324, INA126, AD 620, and resistors and connectors as per design.

Theory:

6.1 Electrooculography (EOG)

EOG is a technique for measuring the corneo-retinal standing potential that exists between the front and the back of the human eye. The resulting signal is called the ELECTROOCULOGRAM. Measurement of eye movements is done by placing pairs of electrodes either above and below the eye or to the left and right of the eye. If the eye moves from center position toward one of the two electrodes, this electrode sees the positive side of the Retina and the opposite electrode sees the negative side of the retina. potential difference occurs between the electrodes. The recorded potential is a measure of the eye's position. Measurement of electric potential between electrodes placed at points close to eye used to investigate eye movements especially in psychology research. The EOG ranges from 0.05 to 3.5 mV in humans and is linearly proportional to eye displacement. The human eye is an electrical dipole with a negative pole at the Fundus and a positive pole at the Cornea.

6.2 Silver/Silver Chloride (Ag/AgCl) Electrodes

These are specialized bio potential electrodes which are mainly used for bio signal acquisition. The signal from the eye is of low magnitude and is acquired through low impedance electrodes which minimizes signal attenuation. Non-invasive surface ECG Ag/AgCl electrodes were used for picking up EOG signals in our experiment. These electrodes are attached to the patients' skin and can be easily removed. Placing the same set of electrodes above and below the user's eye, vertical movement and blink of eyes can be detected.

Procedure

(1) Draw the circuit on the Bread board as mentioned in Figure 6.2
(2) Place the five electrodes on the subject as mentioned in figure 6.3.
(3) Make the experiment ready as per block diagram mentioned in figure 6.3.
(4) EOG for eye movements over an interval of approximately 30 minutes (30×60=1800seconds) are recorded and processed for eye blink detection.
(5) The output of the circuit is plotted on the DSO (6) The subject is asked to blink his eye at proper rate.

Results:

The EOG of the subject is plotted and shown in figure 6.4 and figure 6.5. The design of the EOG amplifier is verified.

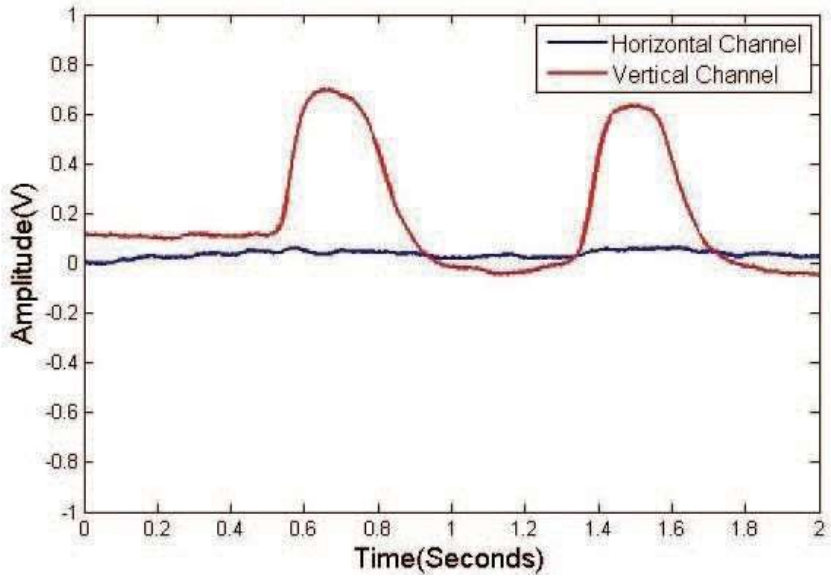


Figure 6.4 EMG waveform generated on the DSO by the circuit (For Blink Signal)

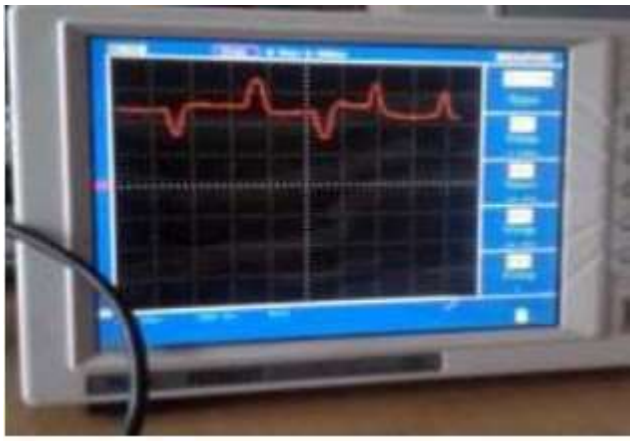


Figure 6.5 EOG signal displayed on the DSO

Precautions:

(1) Place the electrodes properly over the skin.
(2) Make the connections properly on the breadboard.
(3) Check all the connections before power on the supply.

(4) Beware of using any liquid near the setup.

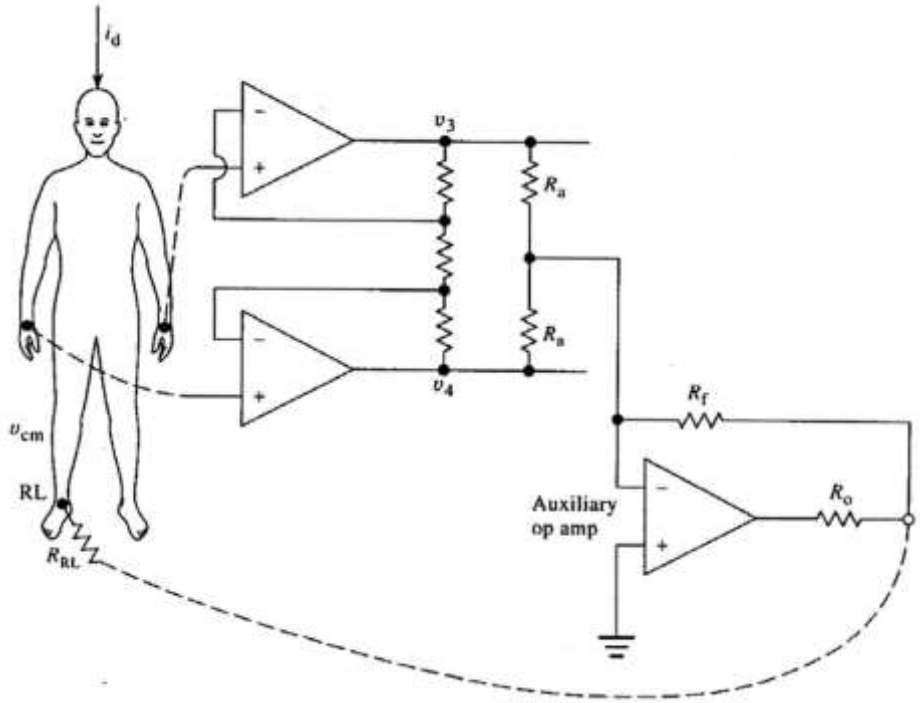


Figure 7.1 The circuit diagram of the right leg driven ECG amplifier

Table 1 : For finding the minimum value of Vcm

S. No.	R_f	R_a	V_{cm} (V)
1			
2			
3			
4			
5			

Experiment – 7: To study the design of right leg driven ECG amplifier

Objective: Design a right leg driven ECG amplifier.

Apparatus and Components Used: ECG simulator kit, DSO, Ag/AgCl electrodes, Regulated Power supplies, Multi-meter, Bread boards – 1, IC LM324, INA126, AD 620, and resistors and connectors as per design.

Theory:

7.1 Driven Right Leg: A Driven Right Leg circuit or DRL circuit, also known as Right Leg Driving technique, is an electric circuit that is often added to biological signal amplifiers to reduce common-mode interference. Biological signal amplifiers such as ECG (electrocardiogram) EEG (electroencephalogram) or EMG circuits measure very small electrical signals emitted by the body, often as small as several micro-volts (millionths of a volt). Unfortunately, the patient's body can also act as an antenna which picks up electromagnetic interference, especially 50 Hz noise from electrical power lines. This interference can obscure the biological signals, making them very hard to measure. Right leg driver circuitry is used to eliminate interference noise by actively cancelling the interference. Objective of this circuit is to reduce interference in amplifier and improve patient safety approach. To perform the experiment

Procedure:

(1) Patient right leg tied to output of an auxiliary amp rather than ground as shown in figure 7.1.
(2) Make the circuit on the bread board as shown in figure 7.1.
(3) Common mode voltage on body sensed by averaging resisters, Ra's & R_F fed back to right leg.
(4) Provides negative feedback to reduce common mode voltage.
(5) If high voltage appears between patient and ground, auxiliary Op-amp effectively ungrounds the patient to stop current flow.
(6) Determine the common-mode voltage V_{cm} on the patient in the driven right- leg circuit of when a displacement current id flows to the patient from the power lines.
(7) Choose appropriate values for the resistances in the circuit so that the common-mode voltage is minimal and there is only a high-resistance path to ground when the auxiliary operational amplifier saturates.

$$v_{cm} = \frac{R_{RL}}{1 + 2\,R_f / R_a}\, i_d$$

Result:
Studied the right leg driven circuit and verified the output.

Precautions:

(1) Make the connections properly on the breadboard.
(2) Check all the connections before power on the supply.
(3) Beware of using any liquid near the setup.

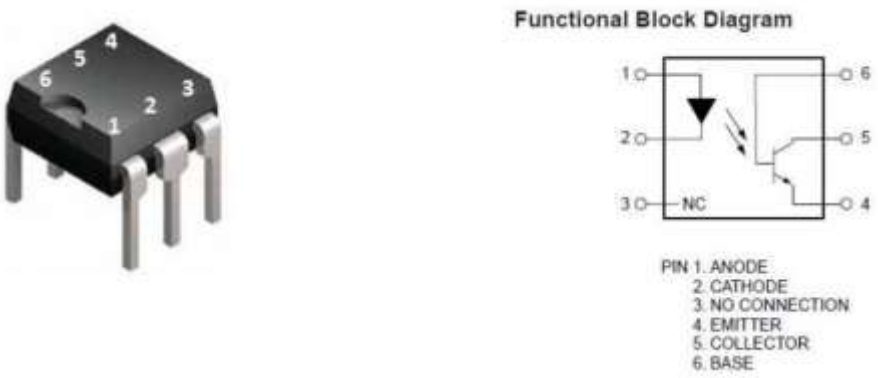


Figure 8.1: MCT2E pin diagram

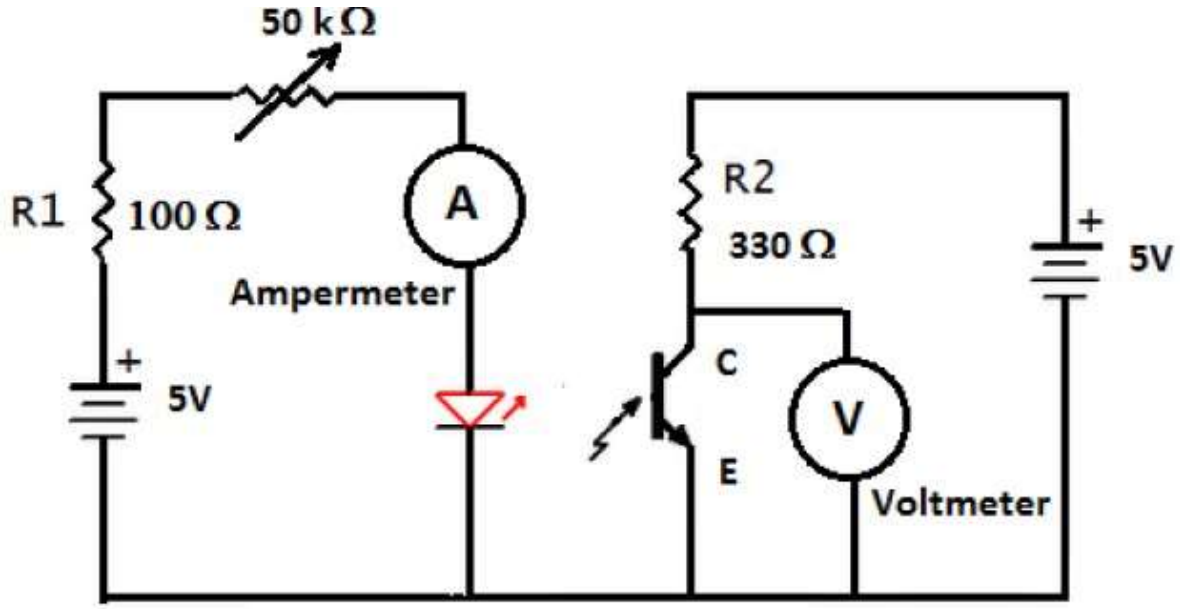


Figure 8.2: Circuit diagram of the experiment

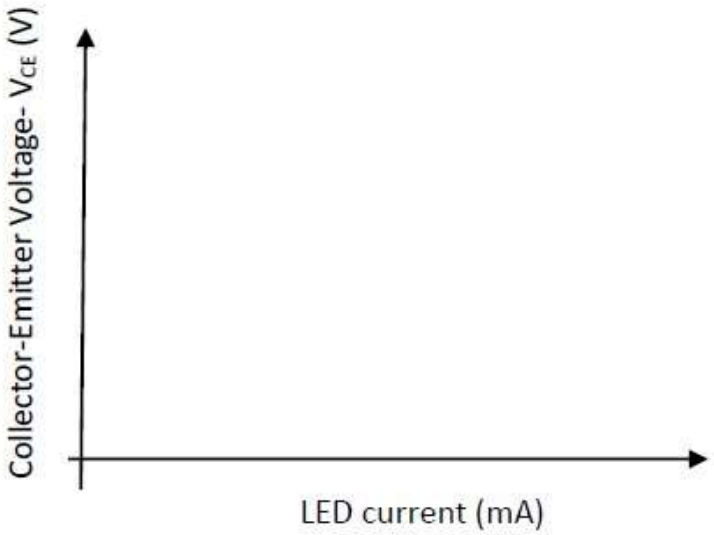


Figure 8.3: Transfer characteristic curve of the MCT2E IC

Experiment – 8: To study the use of optical amplifier

Objective: Design and study the characteristics of optical Isolation amplifier

Apparatus and Components Used: MCT2E, Multi-meter, Regulated Power supplies, Bread boards – 1, and resistors and connectors as per design.

Theory:

8.1 Need for Isolation amplifier

For safety, it is important to protect the user from the hazards of electrical shock. Electrical shock can always present a safety risk with electrical circuits and it is important to consider the problem seriously. It is worth highlighting that it is current, not voltage, which is the real hazard here. Current flow in tissue can cause excessive resistive heating, leading to burns, electrochemical heating, and electrical stimulation of neuromuscular systems. Isolation amplifiers can be used to break ground loops, eliminate source ground connections, and provide isolation protection to patient and electronic equipment. In a biopotential amplifier, the main purpose of the isolation amplifier is the protection of the patient by eliminating the hazard of electric shock.

8.2 Optical Isolation amplifier

Isolation could also be achieved by optical means in which the patient is electrically connected with neither the hospital line nor the ground line. A separate battery-operated circuit supplies power to the patient circuit and the signal of interest is converted into light by a light source (LED). This light falls on a phototransistor on the output side, which converts the light signal again into an electrical signal, having its original frequency, amplitude and linearity. No modulator/ demodulator is needed because the signal is transmitted optically all the way.

8.3 MCT2E

MCT2E is an opto isolator chip, which is often used to provide isolation and to avoid any electrical connection between the input and output stages. The prominent components in MCT2E are a phototransistor and an LED. The phototransistor is made of silicon material and is activated by the LED made of Germanium Arsenide. The output light of the LED is infrared and the intensity is directly proportional to the potential applied between its two leads. In circuits, where optical isolation is required between two stages, the output of the first stage is given to the LED of MCT2E and the photo transistor inside the chip transduces the emitted light in to a proportional collector current. This is given as the input to the second stage, thus providing electrical isolation. By means of providing optical isolation between input and output, interference due to leads and other such artifacts can be avoided. Opto-couplers usually finds applications in medical circuits, where patient safety is of much importance. The pin diagram of MCT2E is shown in figure 8.1.

Procedure:

(1) Make the circuit mentioned in Figure 8.2 on the breadboard.
(2) Set the LED current to values in the table by varying the variable resistor of 50 kΩ. Measure the voltage of V_{CE} for different LED currents.
(3) Complete the table by calculating the I_{RI} and V_{R2}.

(4) Calculate the current transfer ratio (CTR) in saturation case. For this process, set the LED current to minimum and increase slowly watching the voltmeter. LED current is increased until the V_{CE} is minimum value. This indicated that the transistor is conducting fully or it is saturated. The LED current of I_F that produces saturation and V_{CE} are noted.

(5) Draw the Transfer characteristics curve of the optocoupler by using the table1.

Table 1: For the characteristic of the opto-coupler (MCT2E)

S. No.	I_{LED} (mA)	V_{CE} (V)	I_{RI}(mA)	V_{R2} (V)
1	0			
2	2			
3	4			
4	6			
5	8			
6	10			
7	12			
8	14			
9	16			

Results:

The transfer characteristics of the opto-coupler IC MCT2E is plotted and found as per their data sheet.

Precautions:

(1) Make the connections properly on the breadboard.

(2) Check all the connections before power on the supply.

(3) Beware of using any liquid near the setup.

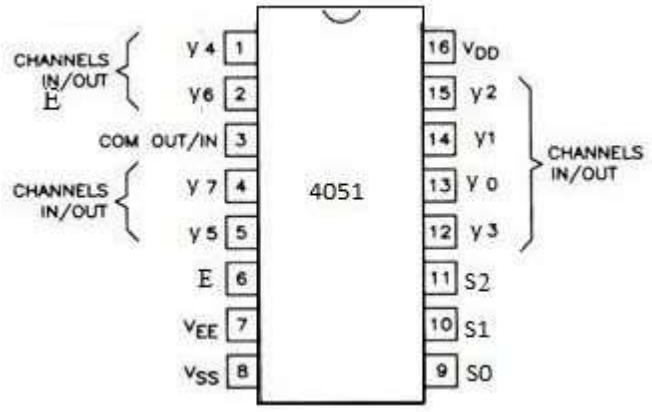


Figure 9.1 Pin diagram of the IC4051

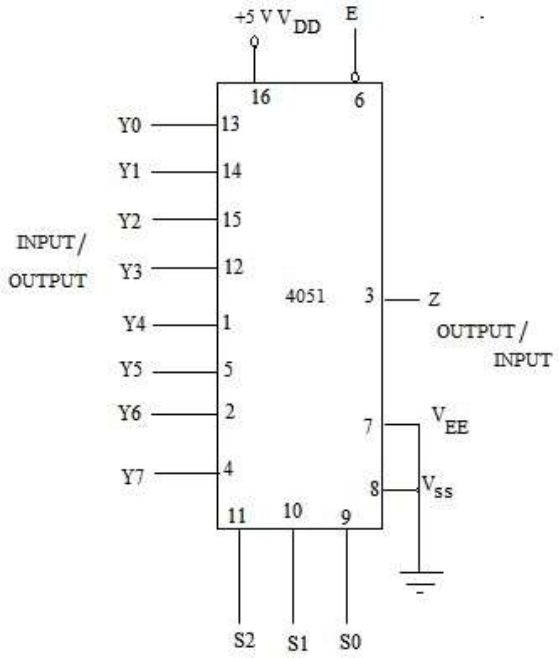


Figure 9.2: Circuit Diagram of the experiment

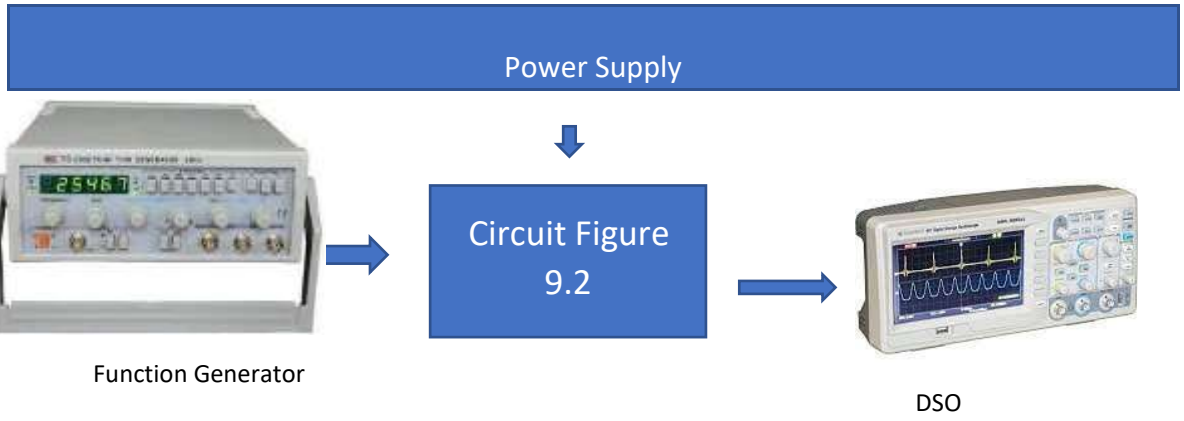


Figure 9.3 Block diagram of the experiment

Experiment – 9: To study the use of multiplexer and demultiplexer IC

Objective: To demonstrate the use of IC 4051 as multiplexer or demultiplexer.

Apparatus and Components Used: IC4051, Function Generator, DSO, Regulated Power supplies, Bread boards – 1, and resistors and connectors as per design.

Theory:

9.1 IC 4051: The IC 4051 is an 8-channel analog multiplexer/demultiplexer with three address inputs (S0 to S2), an active LOW enable input (E), eight independent inputs/outputs (Y0 to Y7) and a common input/output (Z). The device contains eight bidirectional analog switches, each with one side connected to an independent input/output (Y0 to Y7) and the other side connected to a common input/output (Z). With E LOW, one of the eight switches is selected by S0 to S2. With E HIGH, all switches are in the high-impedance OFF-state, independent of S0 to S2. If break before make is needed, then it is necessary to use the enable input. VDD and VSS are the supply voltage connections for the digital control inputs (S0 to S2, and E). The VDD to VSS range is 3 V to 15 V. The analog inputs/outputs (Y0 to Y7, and Z) can swing between VDD as a positive limit and VEE as a negative limit. VDD VEE may not exceed 15 V. Unused inputs must be connected to VDD, VSS, or another input. For operation as a digital multiplexer/demultiplexer, VEE is typically ground. VEE and VSS are the supply voltage connections for the switches. The IC 4051 cab be used for applications like analog and Digital Multiplexing and Demultiplexing, A/D and D/A Conversion , Signal Gating etc.

Procedure:

1. Set up the circuit on the bread board as shown in figure 9.2 to operate as multiplexer.
2. Make the connections as mentioned in figure 9.3.
3. Connect V_{DD} to +5 V supply and V_{SS} and V_{EE} to ground.
4. Feed the Y0 to Y7 pins with LOW(0V) or HIGH(5V) input combinations.
5. Connect the enable pin to ground.
6. Verify the output Z by selecting the appropriate input using select lines S0 to S2 and complete the Table 1.
7. By interchanging the input and output the circuit can be used as demultiplexer. Table 1:

   Truth table for the multiplexer and demultiplexer use of IC 4051

INPUTS				CHANNEL ON
$\bar{E}$	X_2	X_1	X_0	
L	L	L	L	Y_0–Z
L	L	L	H	Y_1–Z
L	L	H	L	Y_2–Z
L	L	H	H	Y_3–Z
L	H	L	L	Y_4–Z
L	H	L	H	Y_5–Z
L	H	H	L	Y_6–Z
L	H	H	H	Y_7–Z
H	X	X	X	none

H = HIGH state (the more positive voltage)
L = LOW state (the less positive voltage)
X = state is immaterial

Result:

Studied the IC 4051 and set up the multiplexer/ demultiplexer circuit and verified the output.

Precautions:

(1) Make the connections properly on the breadboard.
(2) Check all the connections before power on the supply.
(3) Beware of using any liquid near the setup.

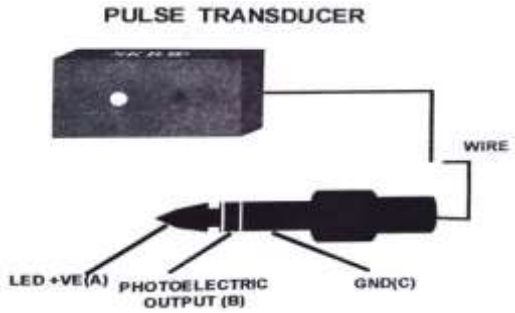


Figure 10.1 Optical Transducer

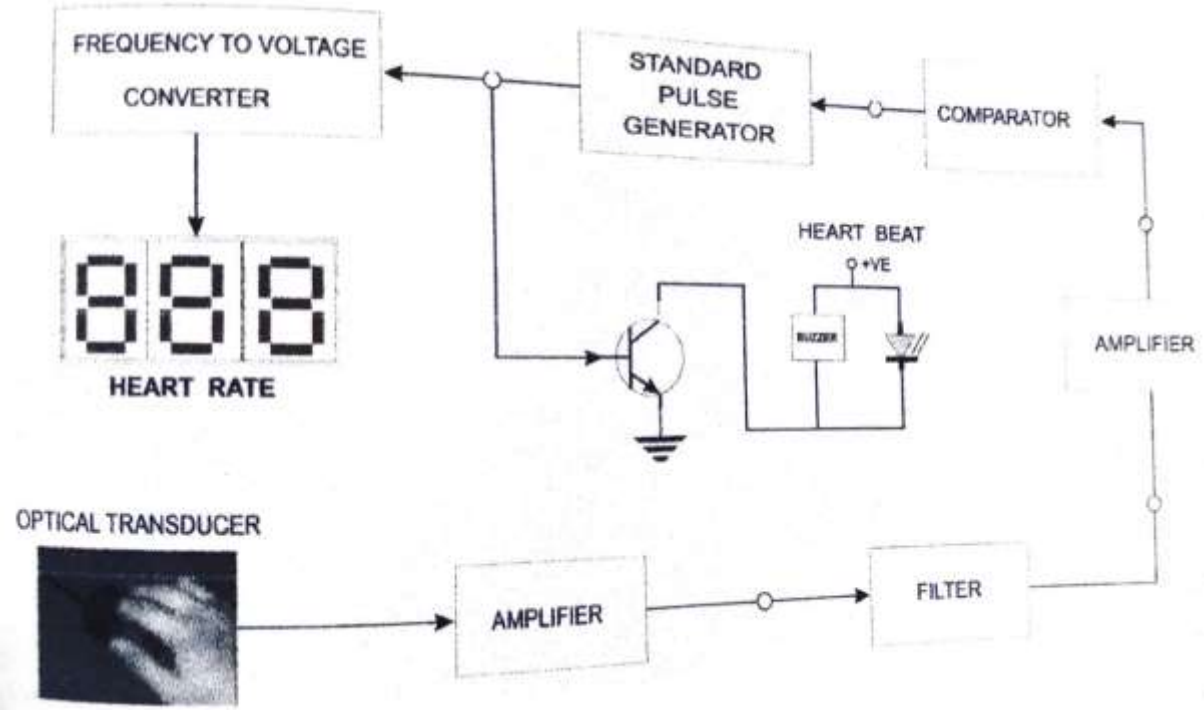


Figure 10.2 Block diagram of the pulse rate kit

Transducer with subject finger

Pulse rate monitor

DSO

Figure 10.3 Block diagram of the Experiment

Experiment -10: To study the measurement of pulse rate

Objective: Measurement of pulse-rate using Photo transducer.

Apparatus and Components Used: Pulse rate indicator kit, optical transducer, DSO, and connectors.

Theory:

10.1 Pulse Rate

The pulse rate is a measurement of the heart rate, or the number of times the heart beats per minute. As the heart pushes blood through the arteries, the arteries expand and contract with the flow of the blood. Taking a pulse not only measures the heart rate, but also can indicate the heart rhythm and the strength of the pulse.

The normal pulse for healthy adults ranges from 60 to 100 beats per minute. The pulse rate may fluctuate and increase with exercise, illness, injury, and emotions. Females ages 12 and older, in general, tend to have faster heart rates than do males. Athletes, such as runners, who do a lot of cardiovascular conditioning, may have heart rates near 40 beats per minute and experience no problems.

10.2 Optical Transducer

The common method uses to measure pulse is by the photoelectric method. In photoelectric method a transmitter (LED) and optical receiver are mounted in an enclosure and fitted on the finger of the subject. Light is transmitted through the finger tip and there is the change in the photo resistance. This change is detected and the there is a count of pulse. The transducer is shown in Figure 10.1.

10.3 Pulse rate indicator kit

The block diagram of the kit circuit is shown in Figure 10.2. The kit contains the following parts:

1. Amplifier: This is very high gain non inverting amplifier. Amplifier amplifies the change in resistance output in the form of voltage approximately 0.5V. This amplifier output to the filter section.
2. Filter: Output of the amplifier is further processed by a 2^{nd} order low pass filter. This filter passes only low frequency with unity gain amplifier.
3. Amplifier: This amplifier amplifies the output of filter.
4. Comparator: Amplifier increases gain and output to comparator. Input of amplifier is compared with threshold level, for detecting the pulse. This pulse is sent to standard pulse generator.
5. Standard pulse generator: Standard pulse generator convert pulse in standard pulse width for frequency to voltage convertor.

6. Frequency to voltage convertor: Frequency to voltage convertor, convert standard pulse output into DC voltage.
7. Display: This contains ADC, Analogue DC voltage into digital for seven segment LED indication for pulse rate.

1. Amplifier output

Volt/Div of DSO	Voltage Div	Total Voltage	Time/ Div of DSO
1V	2	≈ 2V	1S or 0. 5S

2. Filter & Amplifier Output

Volt/Div of DSO	Voltage Div	Total Voltage	Time/ Div of DSO
1V	2	≈ 2V	1S or 0. 5S

3. Comparator Output

Volt/Div of DSO	Voltage Div	Total Voltage	Time/ Div of DSO
1V	6	≈ 6V	1S or 0.5S

4. Standard Pulse Output

Volt/Div of DSO	Voltage Div	Total Voltage	Time/ Div of DSO
1V	5	≈5V	1S or 0.5S

5. +VE, Positive Voltage

Volt/Div of DSO	Voltage Div	Total Voltage	Time/ Div of DSO
5V	1	≈5 V	1S.

6. GND = 0V

7. –VE, Voltage

Volt/Div of DSO	Voltage Div	Total Voltage	Time/ Div of DSO
5V	1	≈ -5 V	1S.

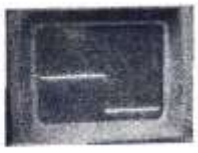


Figure 10.4 Pulse rate generated on the DSO by the circuit at different locations

Procedure

(1) To measure the pulse rate first make the experimental setup as shown in Figure 10.3.
(2) Place the transducer on the subject finger.
(3) On the mains supply of pulse rate indicator kit.
(4) Connect the DSO to monitor the pulse.
(5) Take the readings on the DSO at different locations of the kit. The output is shown in Figure 10.4.
(6) Take the readings of different students of the class and note it down in Table 1. Table 1 Pulse rate of different subjects

S. No	Subject Name	Reading on Instrument	Manual count reading	Calculated reading from DSO
1	A	70	72	T(1.16)*60=70
2	B	72	73	T(1.2)*60=72
3	C	68	69	T(1.13)*60=68
4	D	74	72	T(1.23)*60=74
5	E	66	68	T(1.1)*60=66

Results:

The pulse rate of different students is mentioned in Table 1 and found normal, thus indicating good cardiac cycle.

Precautions:

(1) Handle the kit properly.
(2) Keep the equipment free from vibration and shock.
(3) Check all the connections before power on all the equipment's.
(4) Beware of using any liquid near the setup.
(5) Place the transducer on the fingers properly.

Figure 11.1 Conductivity electrode

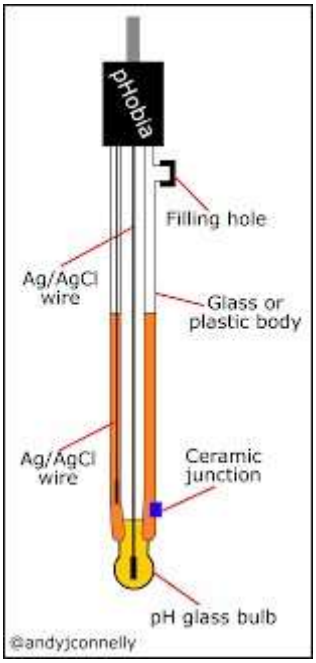
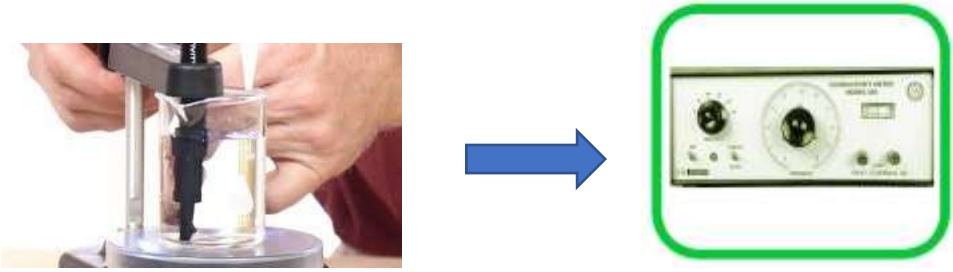


Figure 11.2 pH electrode (Ag/AgCl)



Conductivity electrode with solution

Conductivity meter

Figure 11.3 Block diagram of the conductivity Experiment

Experiment -11: To study the use of pH and conductivity meter

Objective: Measurement of pH and conductivity.

Apparatus and Components Used: pH probe, conductivity electrodes, pH meter, conductivity meter, stands for electrodes and standard solutions for calibrating the sensors.

Theory:

11.1 Conductivity: The conductivity indicates the ability of the solution to conduct electricity when a voltage is applied across two electrodes kept immersed in the solution. It also indicates the availability of metallic ions and dissolved solids in the solution. Conductivity measurement can also be used for making the estimate about the total dissolved solids in the solution. Unit is milli-siemens or micro-siemens. The resistance of the pair electrode is measured and the reciprocal of resistance indicates the conductance value.

11.2 Conductivity Electrodes: The simplest kind of conductivity electrode used consists of two similar poles. An alternating voltage applied to one of the conductivity electrode's poles causes the ions in the solution to migrate towards the pole. The more ions in the solution, the greater the current which flows between the conductivity electrode's poles. The electrode is shown in Figure 11.1. The materials used for making the conductivity electrodes are stainless steel, graphite and platinum.

11.3 pH: pH is a unit of measure which describes the degree of acidity or alkalinity (basic) of a solution. It is measured on a scale of 0 to 14. Low pH values correspond to high concentrations of H+ and high pH values correspond to low concentrations of H+. The pH value of a substance is directly related to the ratio of the hydrogen ion and hydroxyl ion concentrations. If the H+ concentration is higher than OH- the material is acidic. If the OH- concentration is higher than H+ the material is basic. 7 is neutral, < is acidic, >7 is basic. The pH scale is logarithmic and inversely indicates the concentration of hydrogen ions in the solution. This is because the formula used to calculate pH approximates the negative of the base 10 logarithm of the molar concentration of hydrogen ions in the solution. More precisely, pH is the negative of the base 10 logarithm of the activity of the H+ ion.

11.4 pH Electrode: The glass pH probe contains two electrodes, a sensor electrode and a reference electrode. These electrodes are in the form of glass tubes one contains pH 7 buffer and other contains saturated potassium chloride solution. The sensor electrode bulb is made up of porous glass or permeable glass membrane coated with silica and metal salts. A silver wire coated with silver chloride is immersed in pH 7 buffer in the bulb. Another silver wire coated with silver chloride is immersed in the saturated potassium chloride solution in reference electrode as shown in the figure 11.2. When the probe is placed in a solution to measure the pH, hydrogen ions accumulate around the bulb and replace the metal ions from the bulb. This exchange of ions generates some electric flow that is captured by the silver wire. The voltage of this electric flow is measured by the pH meter by converting it into pH value by comparing the generated voltage with the reference electrode.

pH probe with solution pH meter

Figure 11.4 Block diagram of the pH Experiment

Procedure for conductivity measurements

(1) To measure the conductivity first make the experimental setup as shown in Figure 11.3.
(2) Then calibrate the conductivity meter using standard solutions provided with the kit.
(3) Place the electrode in the solutions of different concentrations.
(4) On the mains supply of conductivity meter kit.
(5) Take the readings of different solutions mentioned in Table 1 and write their conductivity.

Procedure for pH measurements

(1) To measure the pH first make the experimental setup as shown in Figure 11.4.
(2) Then calibrate the pH meter with the standard buffer solutions of 4,7 and 10 pH.
(3) Place the electrode in the solutions of different hydrogen ion concentrations.
(4) On the mains supply of pH meter kit.
(5) Take the readings of different acidic and basic solutions mentioned in Table 1 and write their pH value in Table 2.

Table 1 : Conductivity readings of different solutions

S. No	Solution name	Conductivity of the standard solution at 25ºC(µSi/cm)	Conductivity reading of the solution at 25ºC(µSi/cm) from the kit
1	Water	0.05501	0.0549
2	Thumps up	1565	1560
3	Coca cola	1513	1500
4	Fruity	1630	1635
5	Sprite	1616	1620

Table 2 : pH readings of different drinks

S. No	Drink name	pH of the standard drink solution	pH reading from the pH instrument of drink
1	Coca cola	2.7	2.68
2	Lima	3.49	3.44
3	Pepsi cola	2.53	2.5
4	Thumps up	3.16	3.01
5	Bisleri	7.27	7.30

Results:

The conductivity of different drinks are tested and compared the results with their standard values and find that the instrument readings are within the 1% of their standard values. The pH

of different drinks are measured with our pH meter and the readings are within 5% of the standard values as compared to their standard pH values.

Precautions:

(1) Handle the kits properly.
(2) Keep the equipment free from vibration and shock.
(3) Check all the connections before power on all the equipment's.
(4) Don't put the pH electrode in dry conditions even when not in use.
(5) Never remove the conductivity electrodes from the process medium when the instrument is in use.

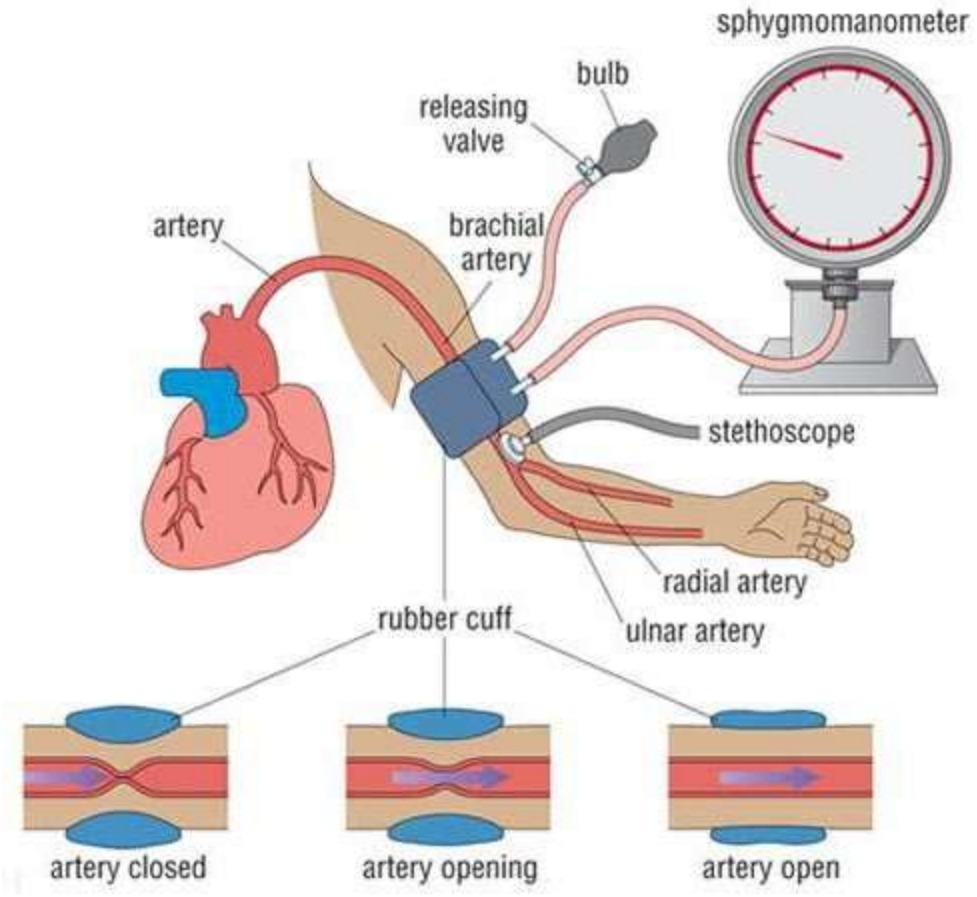


Figure 12.1 Experimental setup of the blood pressure measurement using sphygmomanometer

Experiment -12 To study the measurement of BP using sphygmomanometer

Objective: Measurement of blood pressure using sphygmomanometer.

Apparatus and Components Used: Sphygmomanometer, Blood pressure cuffs, Stethoscope, Chair, Table or other surface to support arm, and alcohol wipe

Theory:

12.1 Blood pressure is the force exerted by blood against the walls of arteries and veins. It is created by the pumping action of the heart. Blood pressure is measured in milli-meters of mercury (mm Hg) and is expressed by two numbers—120/80, for example. The higher number is systolic blood pressure, the maximum pressure that occurs when the heart contracts. The lower number is diastolic blood pressure, the pressure when the heart is relaxed between contractions. Range of the blood pressure is shown in Table 1 for different medical conditions.

Table 1: Blood pressure of different medical conditions.

S. No.	Category	Systolic (mm Hg)	Diastolic (mm Hg)
1	Normal	Below 120	Below 80
2	Prehypertension	120-139	80-89
3	Hypertension (Stage 1)	140-159	90-99
4	Hypertension (Stage 2)	160 and above	100 and above
5	Hypertensive crisis (Consult your doctor immediately)	180 and above	120 and above

12.2 Sphygmomanometer: A sphygmomanometer consists of an inflatable cuff, a measuring unit (the mercury manometer, or aneroid gauge), and a mechanism for inflation which may be a manually operated bulb and valve or a pump operated electrically.

Procedure

(1) First ask the subject to be at rest for some time before the measurements are to be taken.
(2) Then make the experimental setup as shown in figure 12.1.
(3) Then puts the cuff around subject arm and pumps it up, what it does is cutting off the blood flow with the pressure exerted by the cuff.
(4) As the pressure in the cuff is released, blood starts flowing again and the mentor can hear the flow in the stethoscope.
(5) The number at which blood starts flowing (120) is the measure of the maximum output pressure of the heart (systolic reading).
(6) The mentor continues releasing the pressure on the cuff and listens until there is no sound.
(7) That number (80) indicates the pressure in the system when the heart is relaxed (diastolic reading).

Table 2: Blood pressure reading of different subjects taken from sphygmomanometer

S. No	Subject Name	Systolic pressure from the Instrument (mm Hg)	Diastolic pressure from the Instrument (mm Hg)	Medical Condition of the subject
1	A	115	75	Normal
2	B	110	70	Normal
3	C	116	78	Normal
4	D	112	72	Normal
5	E	118	79	Normal

Results:

The blood pressure recording is helpful in diagnosing hypertension, hypotension and various diseases associated with changes in blood pressure. Monitoring of blood pressure provides an important clue on the overall condition of the body.

Precautions:

(1) Handle the apparatus properly.
(2) Keep the equipment free from vibration and shock.
(3) Don’t apply to much pressure on the cuffs.
(4) Patient seated and relaxed, not talking, legs uncrossed.
(5) Tight arm clothing of the subject should be avoided.
(6) Correct cuff size is also important.
(7) Arm supported with cuff horizontal with heart should be the ideal position.
(8) Locate brachial or radial pulse before taking measurements.

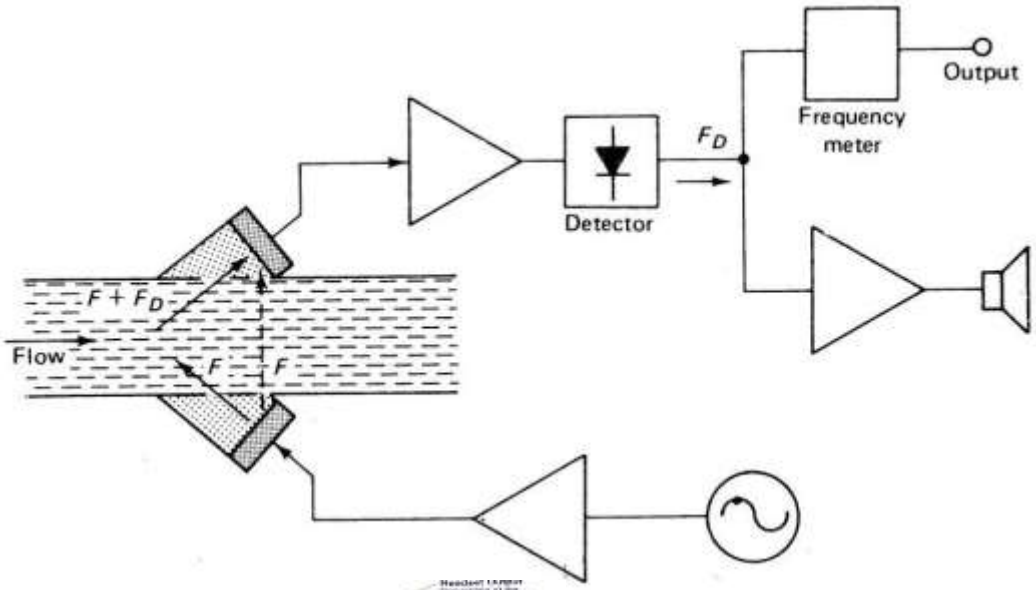


Figure 13.1 ultrasonic blood

Doppler Ultrasonic Transducer

Blood flow monitor and recorder

DSO

Figure 13.2 Experimental setup of the Doppler type ultrasonic flow measurement

Figure 13.3 Waveform of the blood flow recorded on the DSO

Experiment -13: To study the blood flow measurement technoique

Objective: Measurement and recording of peripheral blood flow.

Apparatus and Components Used: Blood flow measurement kit, Doppler type ultrasonic transducer, DSO, and connectors.

Theory:

13.1 Blood flow measurement: Adequate amount of blood supply to all the organs in the body is of paramount importance. Various diseases result in reduced amount of supply to the organs. The measurement of blood flow will therefore help in early diagnosis of diseases, arterial thickening etc. Therefore the purpose of measuring blood flow is to determine the amount of blood delivered to a given region per unit time (milliliters per minute) and it is desirable to achieve this goal by non-invasive methodologies.

13.2 Doppler type Ultrasonic Flow Meter: It is based on the Doppler principle. A transducer sends an ultrasonic beam with a frequency F into the flowing blood as shown in figure 13.1. A small part of the transmitted energy is scattered back and is received by a second transducer arranged opposite the first one. The reflected signal has a different frequency: $F + F_D$ or $F – F_D$ due to Doppler effect. Doppler Frequency equation":

$F_D = (2* f_0* u*\cos\Theta)/c$

Where, F_D = Doppler frequency shift, f_0 = source frequency, u = target velocity and c = velocity of sound

The Doppler component F_D is directly proportional to the velocity of the flowing blood. A fraction of the transmitted ultrasonic energy reaches the second transducer directly with the frequency being unchanged. After amplification of the composite signal, the Doppler frequency can be obtained at the output of the detector as the difference between the direct and the scattered signal components. For normal blood velocities, the Doppler signal is typically in the low audio frequency range.

Procedure:

(1) Make the experimental setup as mentioned in figure 13.2.
(2) On the blood flow measurement kit.
(3) Place the transducer at the specified location of the subject.
(4) Use a liberal amount of coupling gel and tilt the transducer at about 45º to the body.

Result:
High pitched pulsatile sounds are given by arteries whilst the veins give sounds like rearing wind. The recorded waveform is shown in figure 13.3 on the DSO.

Precautions:

(1) Handle the apparatus properly.
(2) Patient should be lied down and relaxed.
(3) Venous flow can be augmented by squeezing the surrounding muscles.

(4) If veins are difficult to locate, first find adjacent artery and then tilt the transducer to side.
(5) The Doppler unit and Transducer must be cleaned only with a soft cloth dampened in a mild detergent or with Iso Propyl Alcohol.

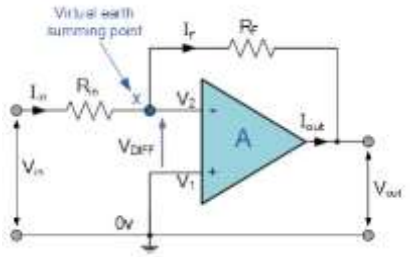


Figure 14.1 Non-Inverting amplifier circuit

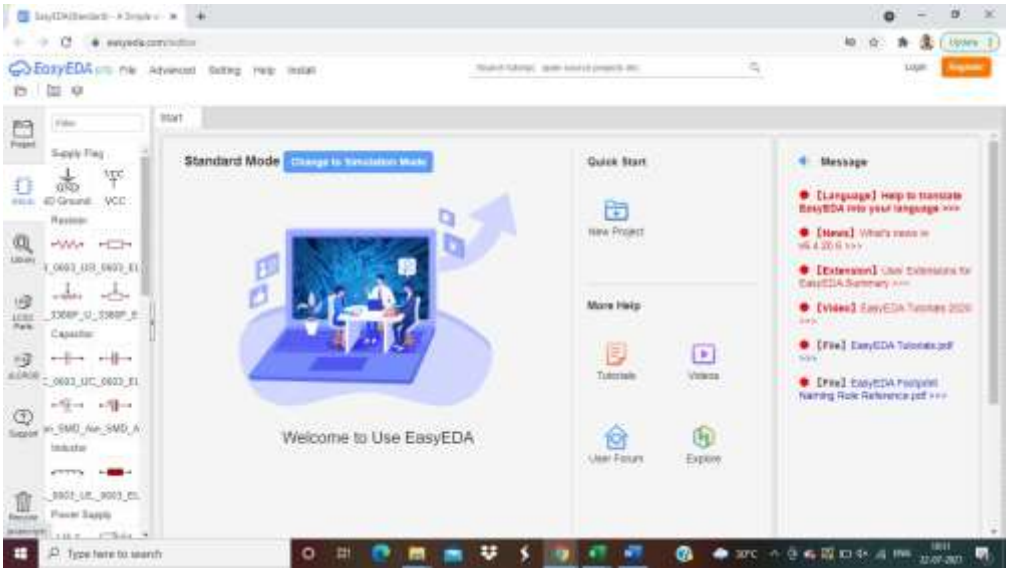


Figure 14.2 Web page of EasyEDA software tool

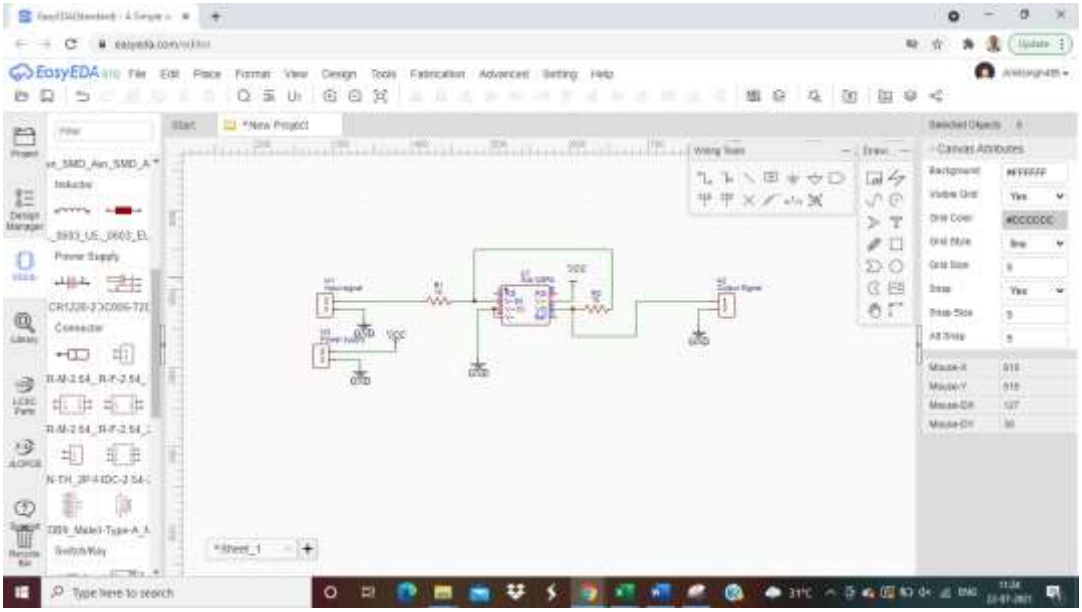


Figure 2.3 Circuit in the EasyEDA software

Experiment -14: To study the use of PCB design software using EDA tool

Objective: Design a PCB layout for any bio amplifier using suitable software tool

Apparatus and Components Used: Easy EDA online PCB design software tool.

Theory:

14.1 Printed circuit board (PCB)

A PCB mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a nonconductive substrate. PCB's can be single sided (one copper layer), double sided (two copper layers) or multi-layer. A PCB populated with electronic components is called a printed circuit assembly (PCA), printed circuit board assembly or PCB assembly (PCBA).

14.2 PCB Materials

A basic PCB starts with a copper-clad fiberglass material or thin copper sheets attached to either side of the board. It consist of :-
- Copper Foil
- Copper Plating
- Solder Flow
- Solder Mask
- Trace
- Slots and Cut-outs

14.3 Fabrication

Following are the basic steps of PCB design.
- Set-Up
- Imaging
- Etching
- Drilling
- Masking
- Silk Screening
- Route
- Electrical Test

14.4 PCB characteristics

- **Through-hole technology**

The first PCBs used through-hole technology, mounting electronic components by leads inserted through holes on one side of the board and soldered onto copper traces on the other side. Boards may be single-sided, with an un plated component side, or more compact doublesided boards, with components soldered on both sides.

- **Surface-mount technology**

Surface-mount technology emerged in the 1960s, gained momentum in the early 1980s and became widely used by the mid-1990s. Components were mechanically redesigned to have small metal tabs or end caps that could be soldered directly onto the PCB surface, instead of wire leads to pass through holes.

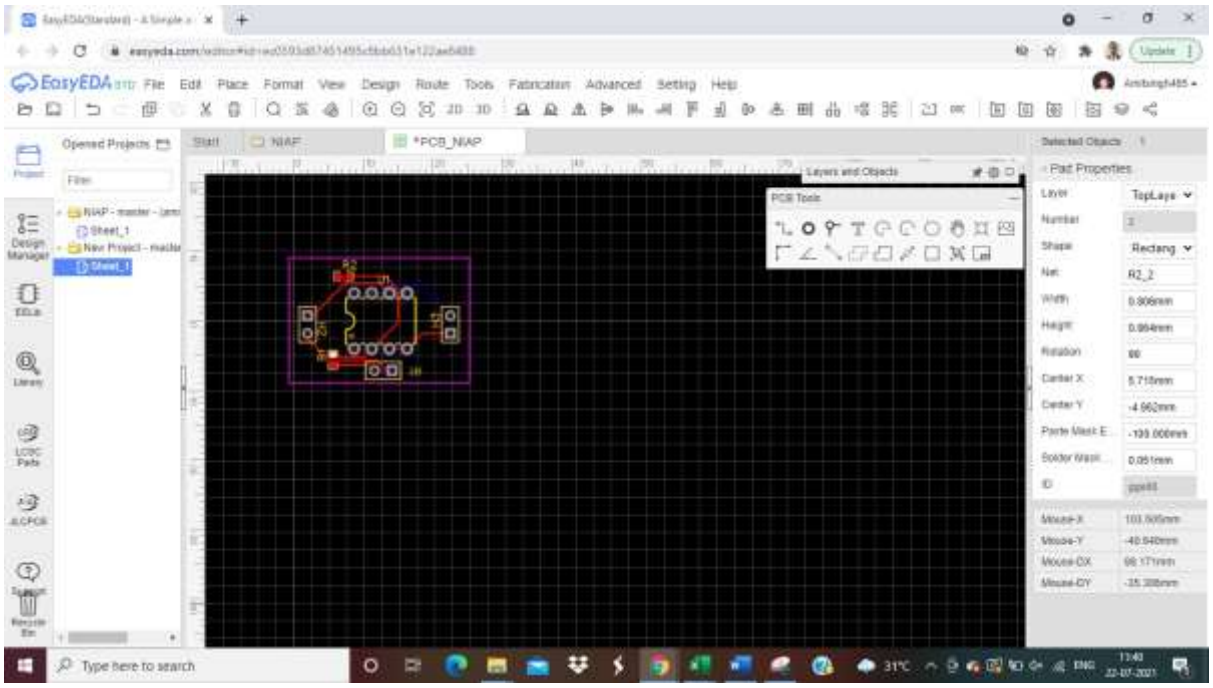


Figure 14.4 The PCB design of the non-inverting amplifier circuit

14.6 Routing

- **Manual Route**

Route the following types of nets first:

  - Most difficult
  - Most complex
  - Tight fitting nets first
  - Very high current (primarily external)
  - Very high voltage (primarily internal)

- **Auto Route**
  - Manually route those items shown in "manual routing " first, if necessary.
  - Manually clean up paths.
  - Mitre right angle corners.
  - Run DRC /design rules to ensure clearances are met.
  - Check annular ring.

Procedure:

(1) First open the website: https://easyeda.com/editor and make the online account on the website to use the software.

(2) Then after login for online PCB design making as shown in figure 14.2 start the new project.

(3) Make and save the schematic the circuit mentioned in Figure 14.1 on the website software as shown in figure 14.3.

(4) Go to design tab and convert schematic to PCB button.

(5) The PCB design page will open as shown in figure 14.4.

(6) Now select route tab then auto root and then again auto route tab for completing the PCB design as shown in figure 14.4.

(7) Now go for fabrication tab and select PCB fabrication (gerber) to generate the files that can be sent to the PCB manufacturer for the PCB making.

(8) Save the designs and log out from the website after the design is created.

Results:

The PCB for the non -inverting amplifier circuit has been drawn

Precautions:

(1) Take the precautions for making the circuit properly and checking for all the nets to be connected.

(2) Check for the mechanical placing and routing of all the components.

(3) Check for the gerber file generated in the last step of the procedure for and discrepancies in the PCB design required.

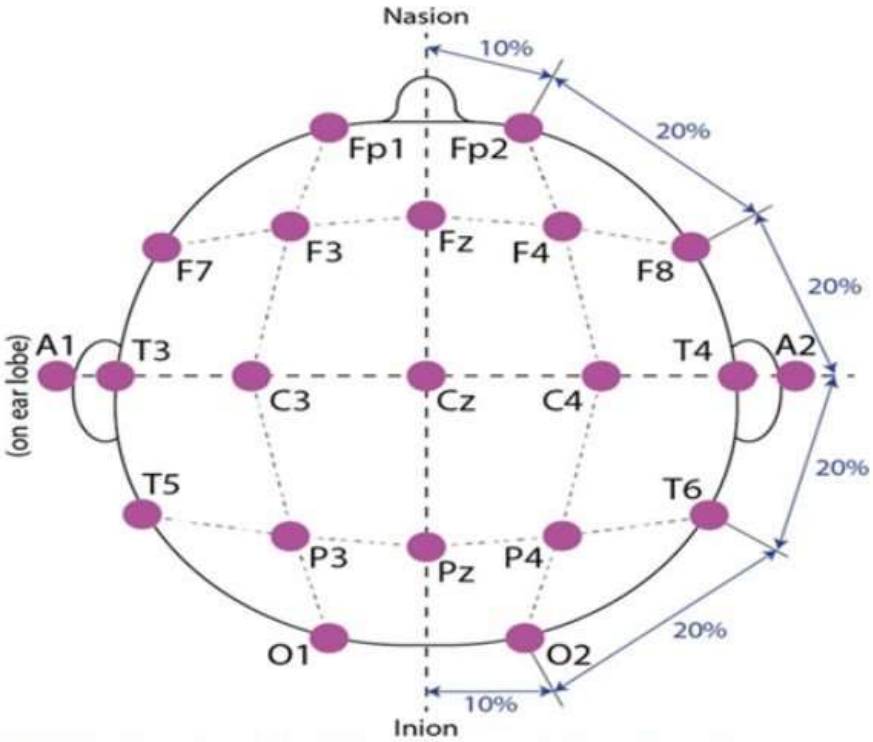


Figure-8: Front View of standard 10–20 electrode system for electrode placement and names.

Figure 15.1

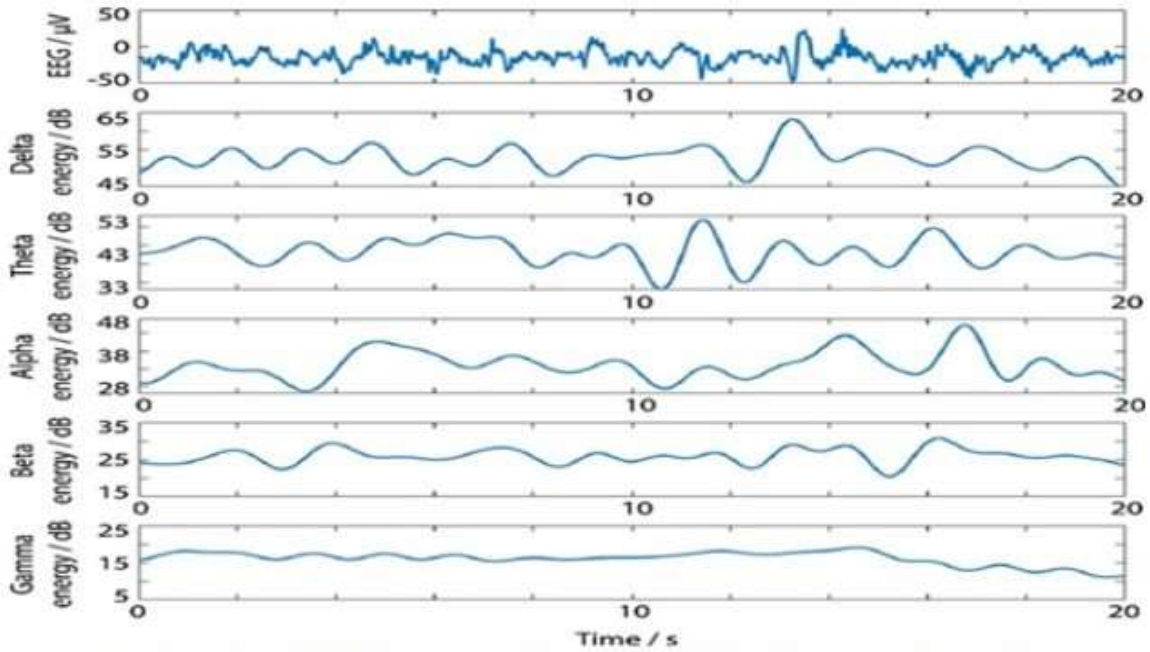


Figure-8: EEG Channel broken down into frequency bands.

Figure 15.2

Experiment -15: Monitoring of Electroencephalogram (EEG) signal for different lobes using online applications.

Objective: Monitor the EEG signals using VLAB platforms.

Apparatus and Components Used: EEG leads, Internet, PC/Laptop, VLAB application.

Theory:

15.1 HUMAN BRAIN

The human brain is an amazing three-pound organ that controls all functions of the body, interprets information from the outside world, and embodies the essence of the mind and soul. Intelligence, creativity, emotion, and memory are a few of the many things governed by the brain. Protected within the skull, the brain is composed of the cerebrum, cerebellum, and brainstem. The brain receives information through our five senses: sight, smell, touch, taste, and hearing - often many at one time. It assembles the messages in a way that has meaning for us, and can store that information in our memory. The brain controls our thoughts, memory and speech, movement of the arms and legs, and the function of many organs within our body. **15.2 EEG SIGNALS**

The EEG signal that arises on the scalp is measured as a voltage in the time domain, with a wide number of potential signal morphologies present. Fig.8 shows some example waveforms. In general, the EEG is not a nice looking signal. To the untrained eye, it often looks only like noise, and it takes significant experience for a human to be able to interpret anything beyond the coarse features that are present. These features can be classified in multiple ways, with different methods being common depending on the field of application. Very common is to divide the EEG into free-running, evoked and hybrid components.

Free-running EEG is the brain activity that is present due to the normal operation of the brain. It is there, all of the time, as the brain is operating. This EEG is characterized by diving it into frequency bands, each given the name of a Greek letter:

- Delta: Activity at less than 4 Hz
- Theta: Activity between 4 and 8 Hz
- Alpha: Activity between 8 and 13 Hz
- Beta: Activity between 13 and 30 Hz
- Gamma: Activity over 30 Hz

15.3 ELECTRICAL ACTIVITY OF THE BRAIN

- During the electrical activity neuronal signal generated in the brain. These signals are classified as:-

EEG (Electroencephalogram) – Continuous record of brains spontaneous electrical activity.
ERP or EP (Event Related Potential or Evoked Potential) – Electrical response of the brain due to specific stimulus.

- Electrical potentials of the brain are recorded by scalp electrode (Disk type surface electrode).

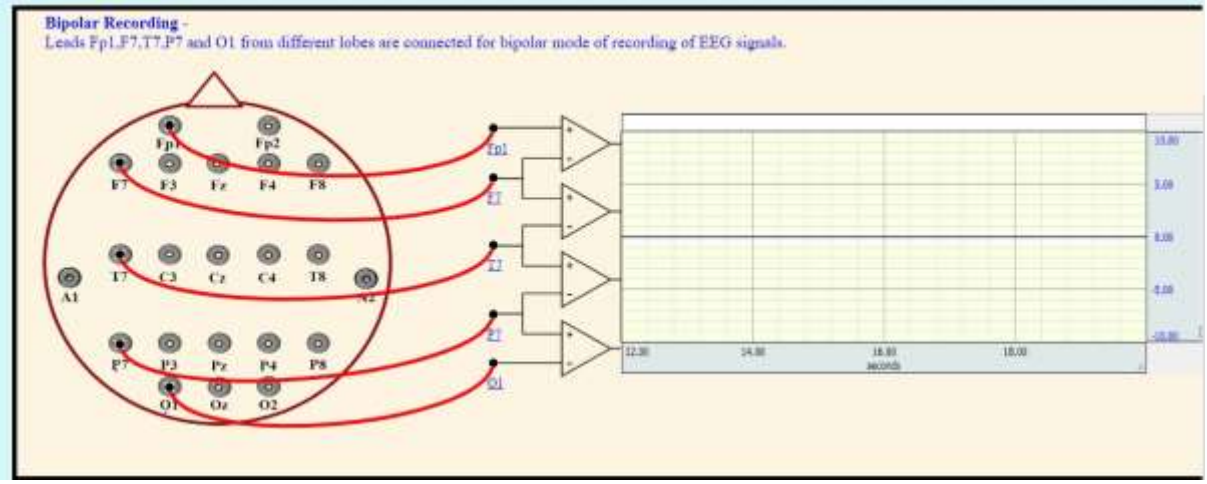


Figure. 15.3. The connections of the EEG leads with the circuit

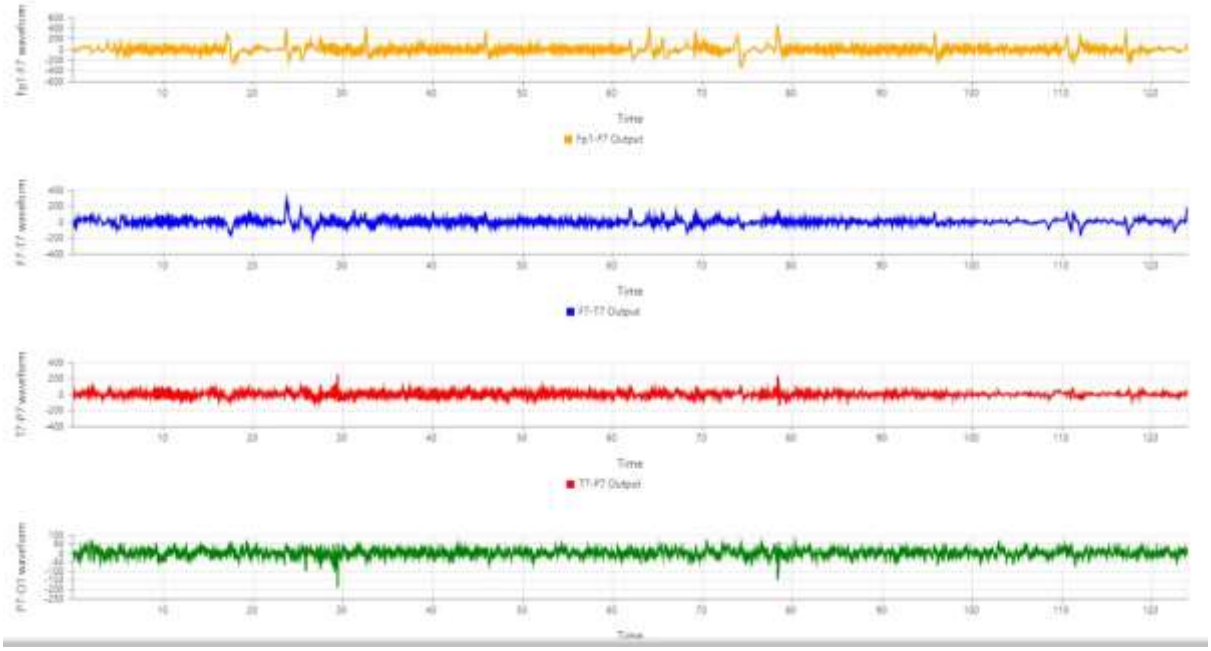


Figure. 15.4. The four graphs of the different waves of the EEG signals

- Cerebral cortex is the region where the neuronal signals in response to stimulus can be observed.
- Receives sensory information from skin, eyes, ears and other receptors.
- Superior part of temporal lobe contains primary auditory cortex which receives auditory receptors in the inner ear.
- The occipital lobe at the back of head is primary visual cortex. Light flashed into the eye evokes large electrical potentials from electrodes placed over this area of the cortex.
- Precentral gyrus functions as primary motor cortex. From this gyrus, nerve signals run down through the brain stem to the spinal cord for control of skeletal muscles via neural control of motor neurons in spinal cord.
- Premotor cortex is associated with motor movements related to speech or hearing.
- The frontal lobe is involved in control of emotional behaviour.
- Primary somatosensory cortex (Post central gyrus) receives impulses from general sense receptors from skin (e.g. pressure, touch and pain receptors).
- Each little area along this gyrus is related to a particular part of body. Area depends upon number of sensory nerves.

Procedure:

(1) Use the website address to open the application in the computer.
Link: https://bmi-iitr.vlabs.ac.in/exp/eeg-signal-different-lobes/theory.html

1. For Fp1-F7-T7-P7-O1

STEP 1 : Make all the Correct Connections as shown in figure 15.3.

1. Connect Fp1 lead point of human brain to the positive terminal (Fp1) of first op-amp circuit.
2. Connect F7 lead point of human brain to the terminal (F7) of op-amp circuit.
3. Connect T7 lead point of human brain to the terminal (T7) of op-amp circuit.
4. Connect P7 lead point of human brain to the terminal (P7) of op-amp circuit.
5. Connect O1 lead point of human brain to the negative terminal (O1) of op-amp circuit. STEP 2 : Click on check button to check for Correct Connections.

STEP 3 : If Connections are not correct click on reset button for reset connections.
STEP 4 : If Connections are correct click on play/pause button to see recorded EEG signals for Fp1-F7-T7-P7-O1.
STEP 5 : Click on waveform tab for data observation and measurement. STEP 6 : Click on print button to save the observations.

Results:

The four graphs are plotted and shown in figure 15.4. Also we have learn the use of the virtual lab.

Precautions:

(1) Make the proper connection's from the sensor to the circuit.
(2) Off the PC/laptop after use.
(3) The internet connect speed should be good for properly using the vlab applications.

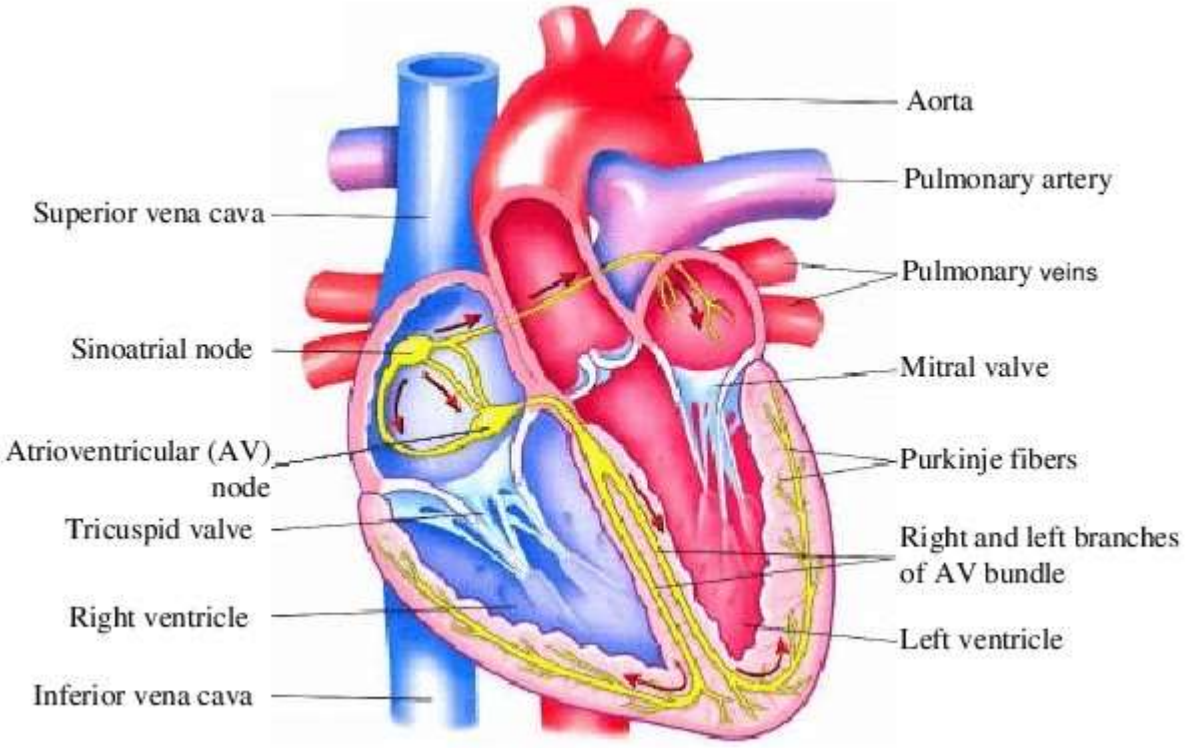


Figure 16.1. Anatomy of the human heart

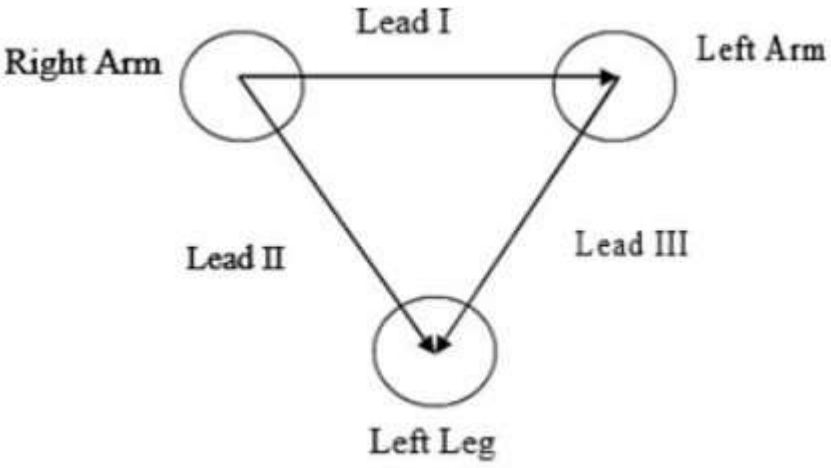


Figure-16.2: Einthoven's Triangle

Experiment -16: Monitoring of electrocardiogram (ECG) for bipolar limb leads l1, l2 and l3.

Objective: Monitor the ECG signals using VLAB platforms.

Apparatus and Components Used: ECG leads, Internet, PC/Laptop, VLAB application.

Theory:

ECG:

An ECG is a series of waves and deflections recording the heart's electrical activity from a certain view. Each part of wave corresponds to particular action in heart as shown. Many views, each called a lead, monitor voltage changes between electrodes placed in different position on the body.

The interior of the cell membrane is considered to be negative with respect to outside during resting conditions. When an electric impulse is generated in the heart, the interior part becomes positive with respect to the exterior. This change of polarity is called depolarization. After depolarization the cell comes back to its original state. This phenomenon is called repolarization. The ECG records the electrical signal of the heart as the muscle depolarize (contract) and repolarize.

A total of 12 Leads are derived from these 10 electrodes. These 12 leads are classified as 3 limb leads, 3 augmented limb leads and 6 precordial leads. Out of this 12 leads, limb leads are bipolar while all other leads are unipolar leads. The definition for all 12 leads is as follows:-

- Lead I – is the signal between negative RA and positive LA electrodes.
- Lead II – is the signal between negative RA and positive LL electrodes.
- Lead III – is the signal between negative LA and positive LL electrodes.

Procedure:

(1) Use the website address to open the application in the computer. Link: https://bmi-iitr.vlabs.ac.in/exp/bipolar-limb-leads/theory.html

1. For Lead 1

STEP 1 : Make all the Correct Connections as shown in figure 16.3.

1. Connect Left Arm Electrode (LA) of human to the positive terminal (LA) of op-amp circuit.
2. Connect Right Arm Electrode (RA) of human to the negative terminal (RA) of op-amp circuit.
3. Connect Right Leg Electrode (RL) of human to the ground terminal (RL) of op-amp circuit.

STEP 2 : Click on check button to check for Correct Connections.

STEP 3 : If Connections are not correct click on reset button for reset connections.

STEP 4 : If Connections are correct click on play/pause button to see waveform for lead 1.

STEP 5 : Click on waveform tab for data calculations and BPM measurement .

STEP 6 : Click on print button to save the observations.

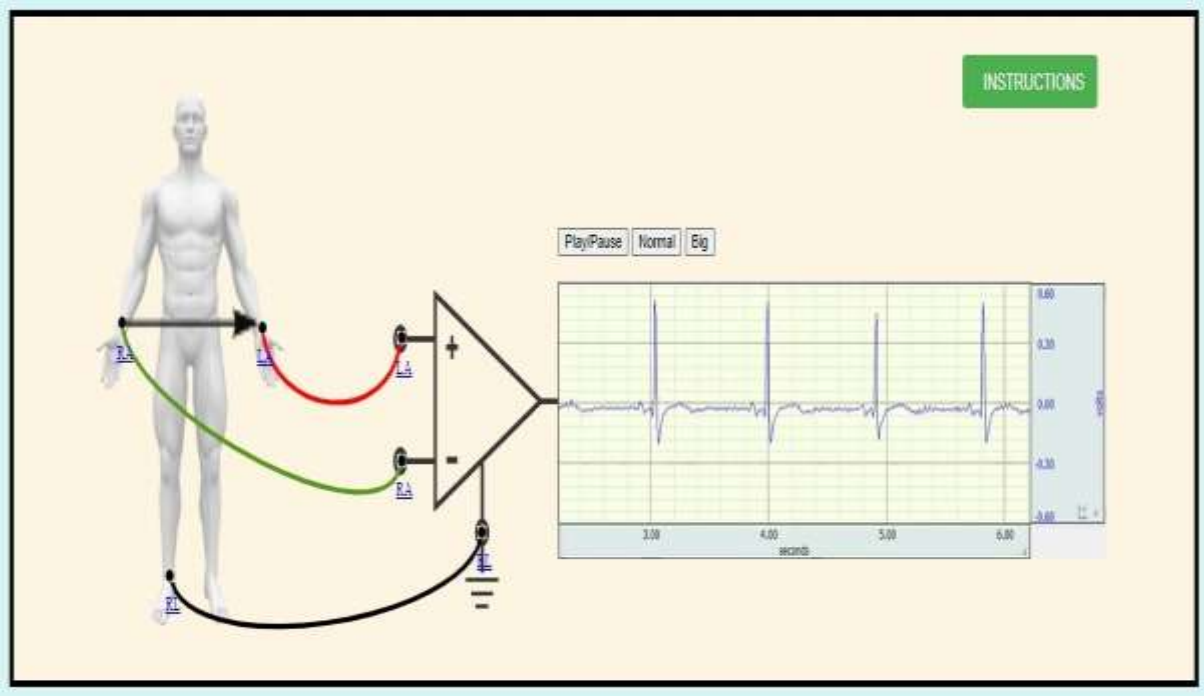


Figure 16.3. Connections of the leads with the circuit and the ECG

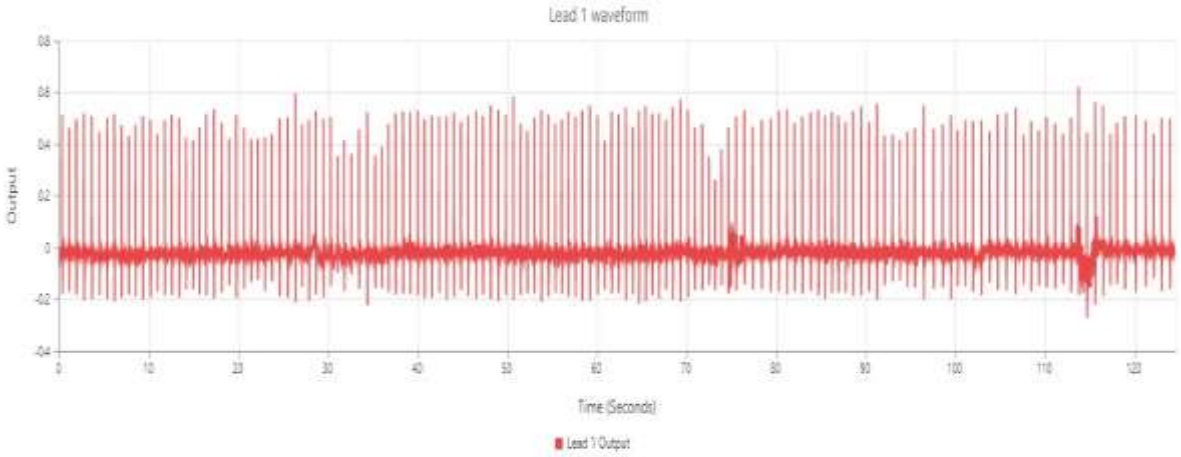


Figure 16.4. The ECG shown for L1 lead connections.

Results:

The L1 graph for L1 leads is shown in figure 16.4. Also we have learn the use of the virtual lab.

Precautions:

(1) Make the proper connection's from the sensor to the circuit.

(2) Off the PC/laptop after use.

(3) The internet connect speed should be good for properly using the vlab applications.

Apparatus used:

pH meter, Electrodes

Description

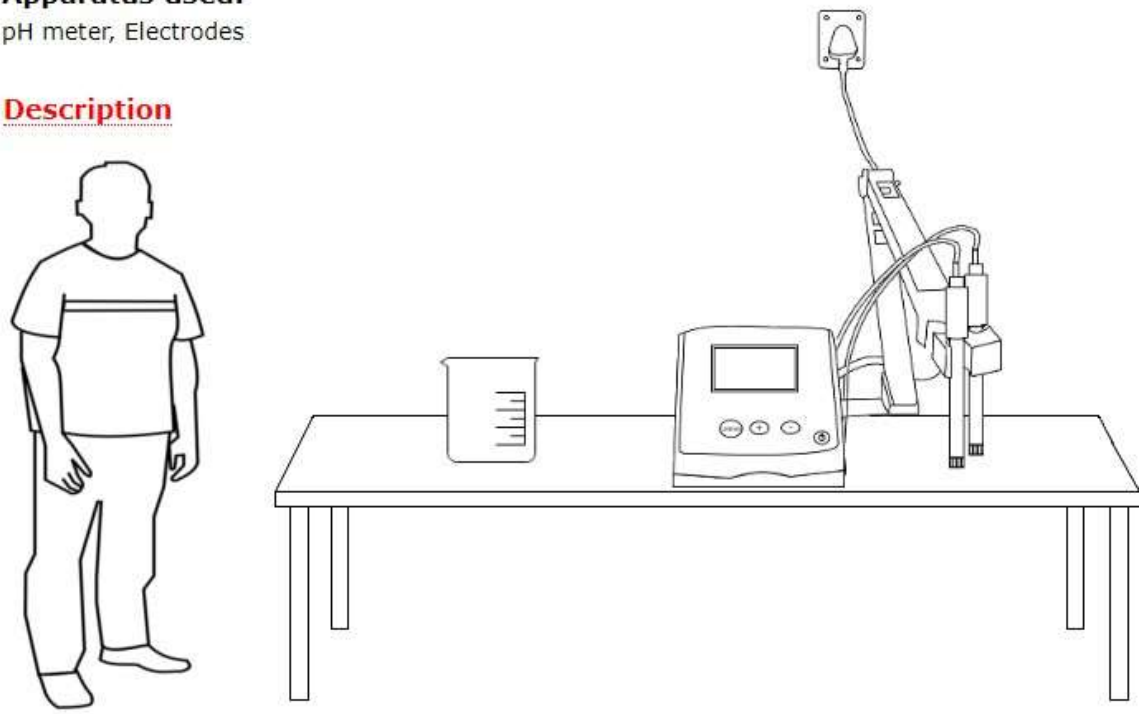


Figure 17.1. The pH electrode

Table 1. pH of different liquids taken from the pH meter.

S. No	Drink name	pH reading from the pH instrument of drink
1	Lime water	12.4
2	Sea water	8.1
3	Sewage water	6.8
4	Carbonated drink	3.05

Experiment -17: Determination of pH using VLAB

Objective: To determine the pH value of given solutions using pH meter using VLAB platforms.

Apparatus and Components Used: pH meter, Electrodes, Internet, PC/Laptop, VLAB application.

Theory:

INTRODUCTION

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.

H2O –> H+ + OH-

For acids, the pH value is between 1 to 7. Alkaline solutions will have pH value from 7 to 14. There are two methods involved in the determination of pH value of water. They are

1. Colorimetric Method

2. Electrometric Method

Determination of pH is one of the important objectives in biological treatment of the wastewater. In anaerobic treatment, if the pH goes below 5 due to excess accumulation of acids, the process is severely affected. Shifting of pH beyond 5 to 10 upsets the aerobic treatment of the wastewater. In these circumstances, the pH is generally adjusted by addition of suitable acid or alkali to optimize the treatment of the wastewater. pH value or range is of immense importance for any chemical reaction. A chemical shall be highly effective at a particular pH. Chemical coagulation, disinfection, water softening and corrosion control are governed by pH adjustment. Lower value of pH below 4 will produce sour taste and higher value above 8.5 a bitter taste. Higher values of pH hasten the scale formation in water heating apparatus and also reduce the germicidal potential of chlorine.

Procedure:

(1) Use the website address to open the application in the computer.
http://vlabs.iitb.ac.in/vlabsdev/labs/nitk_labs/Environmental_Engineering_1/experiments/determination-of-phnitk/simulation.html

(2) Select the sample to measure the pH

(3) Clean the electrodes with the distilled water and dry with tissue paper.
(4) Calibrate the electrodes by placing in the known buffer solutions of 4 pH.
(5) Again clean the electrodes with the distilled water and dry with tissue paper.
(6) Calibrate the electrodes by placing in the known buffer solutions of 9.2 pH.
(7) Again clean the electrodes with the distilled water and dry with tissue paper.
(8) Now put the electrode in the unknown solution whose pH is to be measured.
(9) The display on the pH meter will show the pH of the unknown solution.

Results:

The pH values of different solutions are shown in Table. 1. Also we have learn the use of the virtual lab.

Precautions:

(1) Always clean the pH electrode before and after the use.
(2) Also dry the electrode using tissue paper.
(3) Always use distilled water to clean the pH electrode.
(4) Off the PC/laptop after use.
(5) The internet connect speed should be good for properly using the vlab applications.

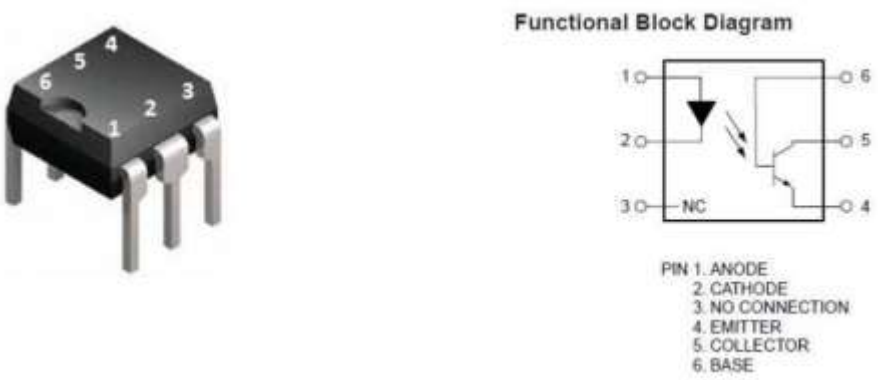


Figure 18.1: MCT2E pin diagram

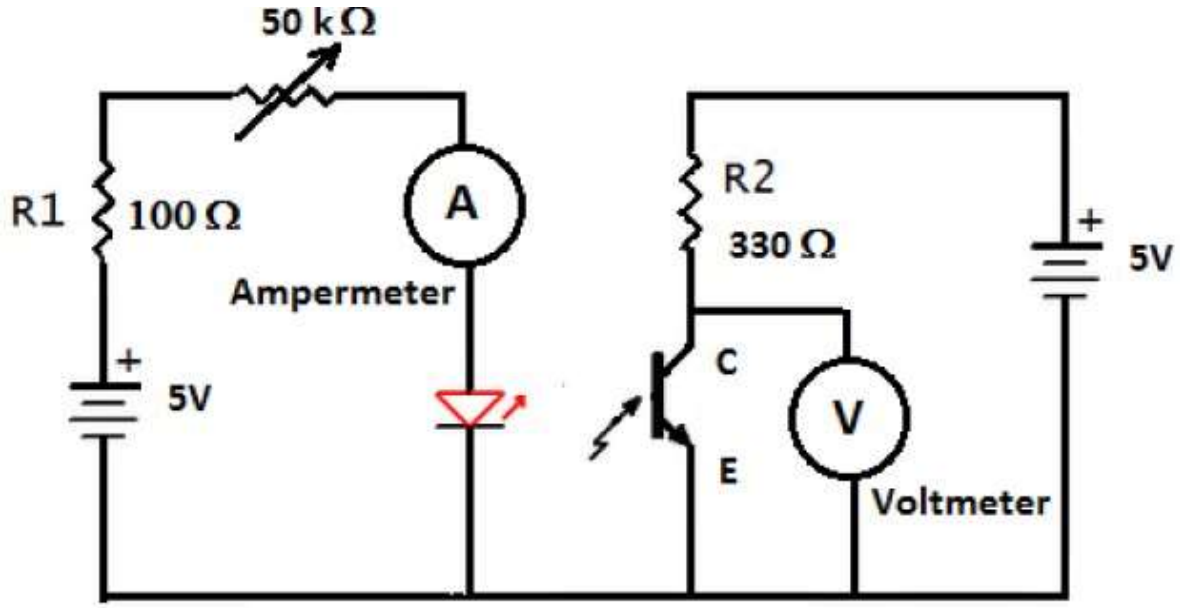


Figure 18.2: Circuit diagram of the experiment

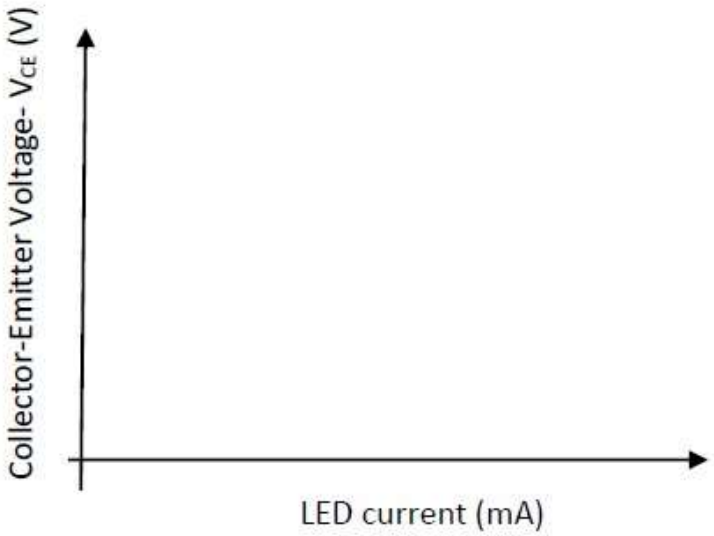


Figure 18.3: Transfer characteristic curve of the MCT2E IC

Experiment – 18: To study the use of optical amplifier using Proteus simulator

Objective: Design and study the characteristics of optical Isolation amplifier using proteus simulator.

Apparatus and Components Used: Computer, Proteus simulator.

Theory:

18.1 Optical Isolation amplifier

Isolation could also be achieved by optical means in which the patient is electrically connected with neither the hospital line nor the ground line. A separate battery-operated circuit supplies power to the patient circuit and the signal of interest is converted into light by a light source (LED). This light falls on a phototransistor on the output side, which converts the light signal again into an electrical signal, having its original frequency, amplitude and linearity. No modulator/ demodulator is needed because the signal is transmitted optically all the way.

18.2 MCT2E

MCT2E is an opto isolator chip, which is often used to provide isolation and to avoid any electrical connection between the input and output stages. The prominent components in MCT2E are a phototransistor and an LED. The phototransistor is made of silicon material and is activated by the LED made of Germanium Arsenide. The output light of the LED is infrared and the intensity is directly proportional to the potential applied between its two leads. In circuits, where optical isolation is required between two stages, the output of the first stage is given to the LED of MCT2E and the photo transistor inside the chip transduces the emitted light in to a proportional collector current. This is given as the input to the second stage, thus providing electrical isolation. By means of providing optical isolation between input and output, interference due to leads and other such artifacts can be avoided. Opto-couplers usually finds applications in medical circuits, where patient safety is of much importance. The pin diagram of MCT2E is shown in figure 8.1.

18.3 Proteus Simulator:

The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The software is used mainly by electronic design engineers and technicians to create schematics and electronic prints for manufacturing printed circuit boards.

It was developed in Yorkshire, England by Labcenter Electronics Ltd and is available in English, French, Spanish and Chinese languages.

Procedure:

(1) Install the proteus simulator in the computer.
(2) Make the circuit mentioned in Figure 18.2 in the proteus simulator.
(3) Set the LED current to values in the table by varying the variable resistor of 50 kΩ. Measure the voltage of V_{CE} for different LED currents.
(4) Complete the table by calculating the I_{RI} and V_{R2}.

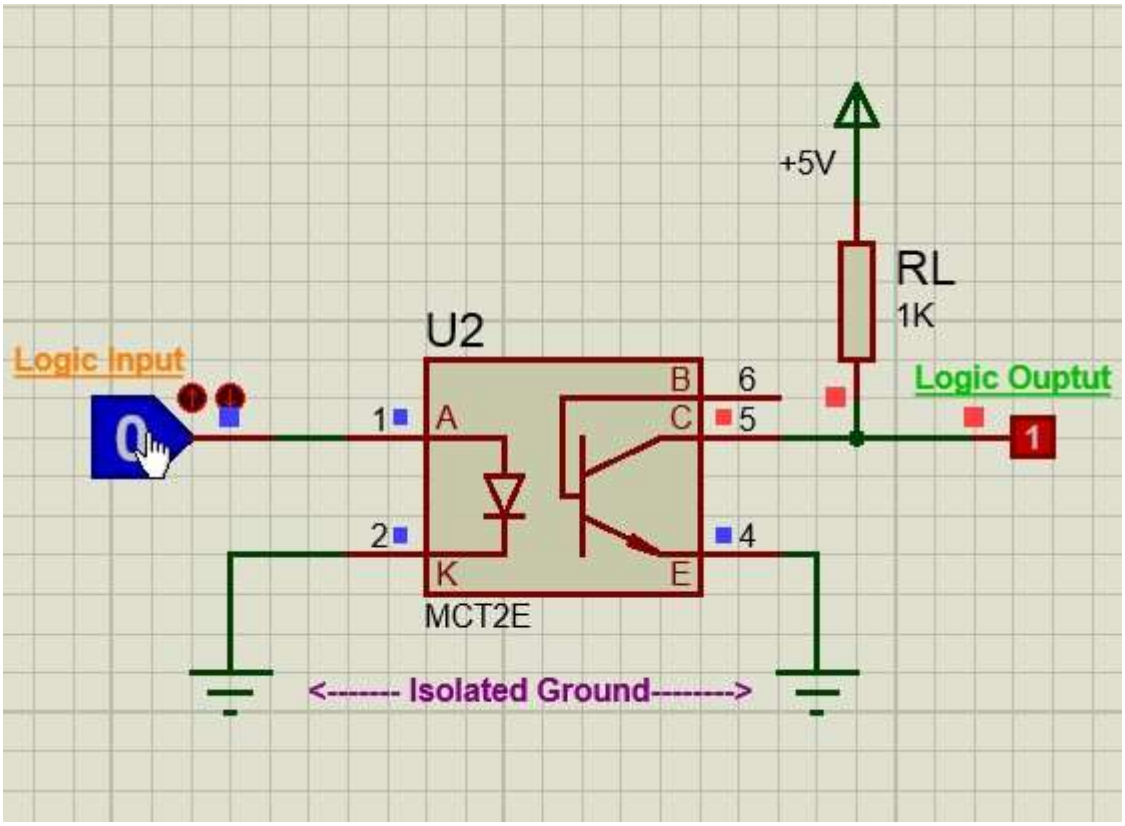


Figure 18.4 The sample of the simulation showing proteus simulator for MCT2E

(5) Draw the Transfer characteristics curve of the optocoupler by using the table1.

Table 1: For the characteristic of the opto-coupler (MCT2E)

S. No.	I_{LED} (mA)	V_{CE} (V)	I_{RI} (mA)	V_{R2} (V)
1	0			
2	2			
3	4			
4	6			
5	8			
6	10			
7	12			
8	14			
9	16			

Results:

The transfer characteristics of the opto-coupler IC MCT2E is plotted and found as per their data sheet. We also learned the use proteus solution

Precautions:

(1) Make the connections properly in the proteus simulator.
(2) Check all the connections before power on the run button.
(3) Switch off the system after completing the simulation.