UNIT- I
ELECTRO- PHYSIOLOGY AND BIO-POTENTIAL RECORDING

The origin of Bio–potentials, Biopotential Electrodes, Biological Amplifiers, ECG, EEG, EMG, PCG, EOG, lead system, and Recording Methods, Typical Wave forms and signal characteristics.

SOURCES OF BIOELECTRIC POTENTIAL

The body generates their own monitoring signals which convey useful information about the function they represent. These signals are the bioelectric potential. Bioelectric potential are actually ionic voltage produced as a result of electrochemical activity of certain special type of cells.

Resting and Action Potential

1. The concentration of sodium ions inside the cell becomes much lower than outside. Since the sodium ions are positive, the outside of the cell is more positive than inside.

2. To balance the electric charge, potassium ions which are positive enters the cell causing a higher concentration of potassium on inside than on outside.

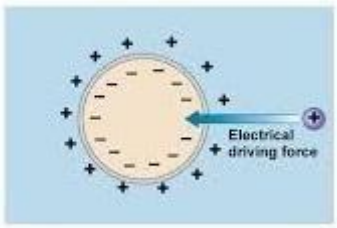


Fig 1.1: Polarized cell with its resting potential [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

This charge cannot be achieved. However Equilibrium is reached with a potential difference across the membrane, negative on inside and positive on outside. This membrane potential is called the resting potential of the cell.

Characteristics of Resulting Potential

The resting potential is maintained as a constant until some kind of disturbance upsets the equilibrium. It is strongly depending on temperature. It is given as negative and various from 60 to 100mA. The resting potential ‗V'of a cell can be written as

$$V_r = - \frac{kT}{q} \ln \left[\frac{P_K [K^+]_i + P_{Na}[Na^+]_i + P_{Cl}[Cl^-]_o}{P_K [K^+]_o + P_{Na} [Na^+]_o + P_{Cl} [Cl^-]_i} \right]$$

Where k – Boltzmann's constant

T- Absolute Temperature of cell q- Change of electron

Pk, P_{Na}, P_{Cl}- Permeability of K, Na, & Cl ions

$[K^+]$, $[Na+]$, $[Cl^-]$ –Concentration of K, Na & Cl ions

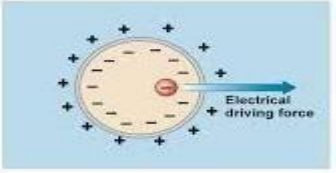


Fig 1.2: Depolarized cell with action potential [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

When the passage of sodium ions is stopped, there is no ionic current and hence the membrane reverts back to the original condition. By an active process called a sodium pump, sodium ions are quickly transported to the outside of cell and the cell is in its resting potential. This is called repolarization.

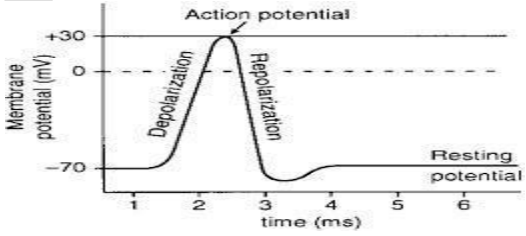


Fig 1.3: waveform of the action potential [Source: Leslie Cromwell - Biomedical instrumentation and measurement],

varies with type of cell)

The net height of action potential is defined as the difference between the potential of depolarized membrane at the peak of action potential and resting potential. Following the action potential, there is a brief period of time during which the cell cannot respond to any new stimulus.

DESIGN OF MEDICAL INSTRUMENT

To design any medical instrument, the factors to be considered are

1. **Accuracy:** ccuracy is the closeness with which an instrument reading approaches the true value of variable being measured.
2. **Frequency Response:** It is the response of the instrument for various frequency components present in a physiological signal.
3. **Hysteresis**: Hysteresis error occurs due to mechanical friction.
4. **Isolation:** Electrical isolation is made for electrical safety and to avoid any interference between different instruments.
5. **Linearity:** It is defined as the degree to which variations in the output of an instrument follow input variations
6. **Sensitivity:** It is the ability of an instrument to detect even a very small change that is taking place in the input.
7. **Signal to Noise (S/N) ratio:** It should be high to get reliable information about input.
8. **Simplicity:** It is an essential one to eliminate the human errors.
9. **Stability:** It is the ability of the instrument to produce constant output for a given input.
10. **Precision:** It is the measure of the reproducibility of the measurements.

COMPONENTS OF BIO- MEDICAL INSTRUMENT SYSTEM:

The clinical laboratory instrument is used to investigate the pH value and concentration of various radicals present in the body fluids and to count blood cells in the blood sample. Each switch position connects an instrument for measurement, for monitoring, diagnosis, therapy or surgery with signal processor.

Transducer transforms the physiological signal like temperature, pressure or bio-potential into an electrical form.

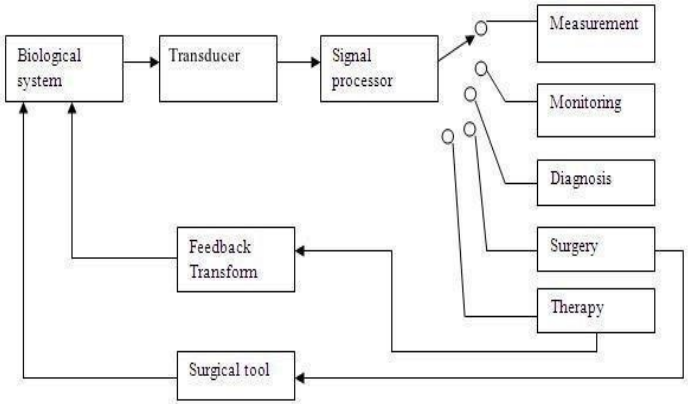


Fig 1.4: Block Diagram of a Generalized Bio-Medical Instrument System [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

PHYSIOLOGICAL SIGNAL AMPLIFIERS

The biomedical pre- amplifier should satisfy the following condition

1. The voltage gain should be more than 100 db to amplify the biosignal properly to drive the recorder.
2. It should have low frequency response.
3. The gain and frequency response should be uniform throughout the required bandwidth.
4. There is no drift in the amplifier.

The biosignal amplifiers are designed with operational amplifiers as the basic unit.

Isolation Amplifier

Isolation amplifiers are used to increase the input impedance of the monitoring system in order to isolate the patient from biomedical instrument. They are called pre- amplifier isolation circuits. High quality isolation amplifiers are required so that any electrical faults cannot result in electrical shock to the patient.

Darlington pair: It is an isolation amplifier which provides high input impedance with high current gain. θ_1 and θ_2 are connected in

common emitter mode. The input impedance is given by $Zi = \beta^2 Z_0$; β - Current amplification factor. The emitter of θ_1 is connected to base of θ_2 and both collectors share a common lead P_L. This results in high input impedance. R_B is chosen so that both stages operate in active region X, Y, and Z are the external terminals.

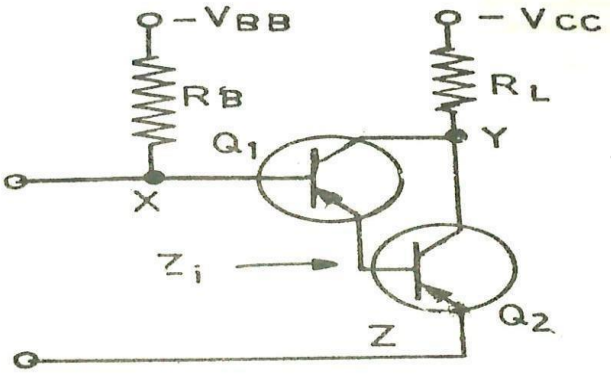


Fig 1.5: Darlington Pair [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Bootstrapping circuit: is also used as isolation amplifier to get very high input impedance. A feedback network is connected between the emitter of θ_2 and collector of θ_1. The feedback voltage increases the signal level at input which in turn increases the input impedance. R is used to limit the current flowing through θ_2.

ECG Isolation Amplifier Circuit

The signals from the different leads are given to LPF. This filtering reduces the interference caused by electron surgery and radio frequency emission. The filter circuit is following by high voltage and over voltage protection circuit so that amplifier can withstand large voltage. Now the signals are fed into lead selected switch and then the output is given to a d.c amplifier.

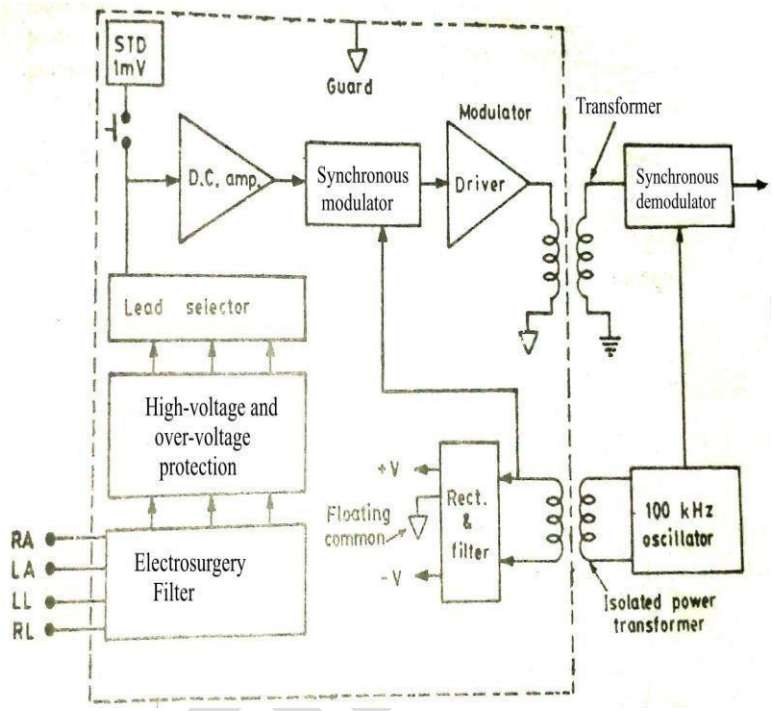


Fig1.6: Block Diagram of Transformer Coupled ECG Isolation Amplifier Circuit [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Medical Preamplifier Design. (Instrumentation Amplifier):

It has very high input impedance. It consists of op-amps. First two are working at non-inverting mode but their inverting terminals are not grounded. The third op-amp will act as a differential amplifier.

By this configuration we can get high stability high fidelity high CMRP and high input impedance. By virtual ground concept, inverting terminal of op-amp 1 is fed by a voltage V_2 through R_2 and inverting terminal of op-amp 2 is fed by a voltage V_1 through R_1. The common mode signal at input will lead to zero voltage drop

across variable resistor R_1. The common mode voltage gain is unity. Thus most of common mode signals will be rejected by third op-amp. V_o^{1} is the output of first op-amp and V_0^{11} is the output of second op-amp.

Gain calculation

$V_0^{1} = (1 + aR_1/R_1) V_1 – (aR_1 /R_1) V_2$

$V_0^{11} = (1+aR_1 / R_1) V_2 – (aR_1 / R_1) V$

$V_{out} = (V_0^{11} – V_0^{1}) bR_2 /R_2$

$V_{out} = (1+ 2a) (V_2 –V_1)$

b Net gain is (1+2a) b

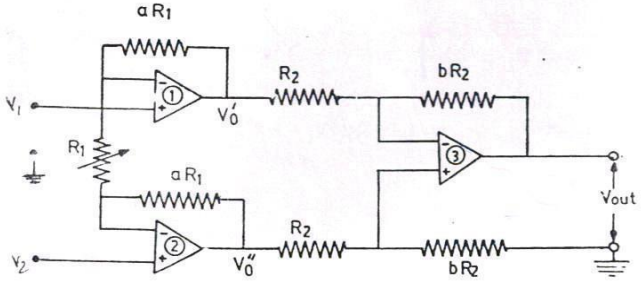


Fig1.7: Medical Preamplifier Bridge amplifiers:

[Source: Leslie Cromwell - Biomedical instrumentation and measurement]

They are used to measure the magnitude of biosignal parameters in terms of current or voltage. They are also measured in terms of frequency.

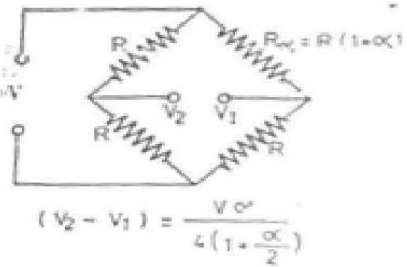


Fig 1.8: Bridge Amplifier for Voltage Readout

[Source: Leslie Cromwell - Biomedical instrumentation and measurement]

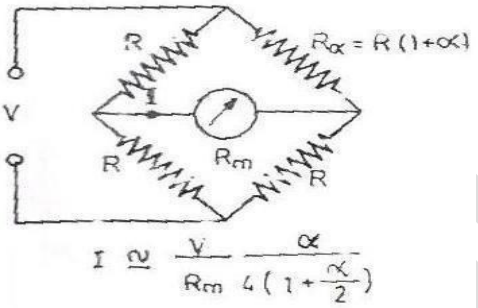


Fig1.9: Bridge Amplifier for Current Readout [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

In both bridge, the unbalance is measured by measuring the unbalance voltage or unbalance current. It is a measure of fractional change _α'in resistance of transducer Rα. Using op-amp, the unbalance voltage or current can be amplified.

Chopper Amplifier:

The chopper is used to convert low frequency signal into a high frequency signal. The modulated high frequency signal is amplified and finally the amplified signal is demodulated and filtered to get low frequency signal. Chopper amplifier has no drift. Chopper amplifiers are available in the form in the form of mechanical and non-mechanical chopper.

i) Mechanical Chopper Amplifier:

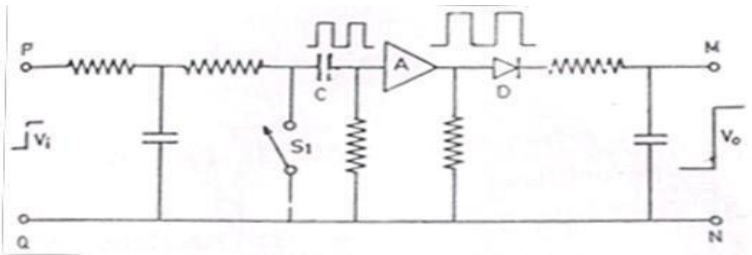


Fig 1.10: Chopper amplifier using a mechanical switch [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Chopper S_1 is an electromagnetically operated switch or relay. S_1 connect the input terminal of amplifier _A'to reference

terminal _Q'which is connected to ground. When the amplifier input terminal is connected with Q, it is short circuited and the input voltage is zero. When S_1 is open, the amplifier receives the signal voltage from P.

ii) Non mechanical Chopper Amplifier:

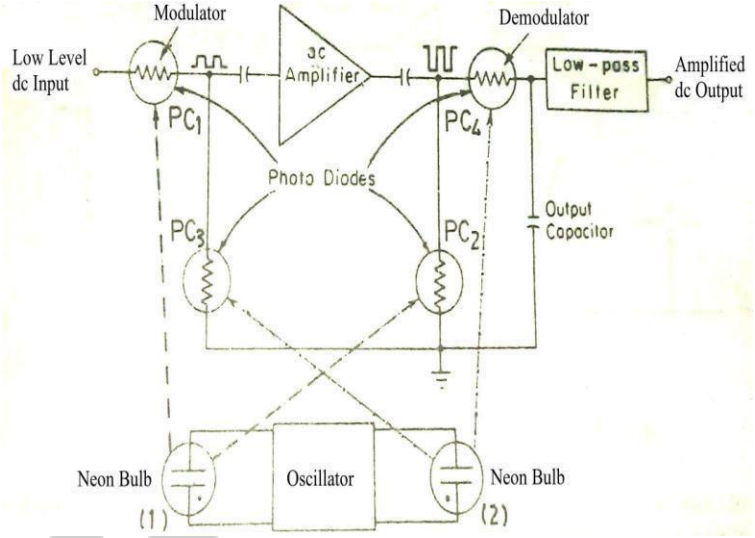


Fig 1.11: Non Mechanical Photoconductive Chopper Amplifier [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Photoconductors or photodiodes are used as non mechanical chopper for modulation and demodulation. When there is no incident light on photoconductor, its resistance is high and hence it is in RB and no current flows through it. When there is incident light on photoconductor, its resistance is very low and hence it is in FB and current flows through it. Thus it can act as a switch by means of incident light.

ELECTRODES

Electrodes are used to pick up the electrical signals of the body. They transfer the bioelectric event to the amplifier. The type

of electrode to be used depends upon the bioelectric generator.

Half Cell Potential (or) Electrode Potential:

The voltage development at an electrode – electrolyte interface is designated as the half cell potential. In metal solution interface, an electrode potential results from two processes.

1. The passage of ions from metal into solution
2. The combination of metallic ions in solution with electrons in metal to from atoms of metal.

The net result is the creation of charge gradient, the spatial arrangement of which is called the electrical double layer. Electrodes in which no net transfer of charge occurs across the metal electrolyte interface are called as perfectly polarized electrodes.

Fig shows the electrical equivalent circuit of a surface electrode when it is in contact with body surface. The electrode-electrolyte interface resemble a voltage source having half cell potential ‗E_{hc}‘which is developed due to charge gradient and a capacitor ‗C_d‘(i) parallel with a leakage resistance ‗R_d‘.

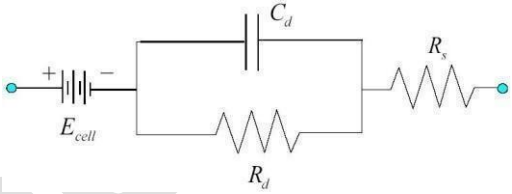


Fig 1.12: surface electrode equivalent circuit [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

E_{hc} - half – cell potential

C_d – electrode capacitance

R_d – leakage resistance

R_S – Series electrolyte and skin resistance

The series resistance ‗R_S‘represents the series electrolyte and skin resistance under equilibrium conditions. The impedance of the equivalent circuit can be written as

$$Z \quad R_S \quad = \quad \frac{R_d}{1 - j2\,fC_d\,R_d}$$

The value of voltage and impedance depend on the

electrode metal, its area, electrolyte, charge density and frequency of current. The electrode potential is measured with reference to hydrogen electrode placed in electrolyte near metallic electrode. The half cell potential development can be expressed by Nernst equation as

$$E_{hc} = \frac{RT}{nF} \ln \frac{C_1}{C_2} \cdot \frac{f_1}{f_2}$$

Where R – Gas Constant

T – Absolute Temperature

F – Faraday Constant

N – Valency of Ion

C_1, C_2 – Concentration of selected ion on two sides of membrane

f_1, f_2 – Activity coefficients of ion on two sides of membrane.

Purpose of Electrode paste:

The outer skin of the body is highly non- conductive and will not establish a good electrical contact with an electrode. The skin should be washed and rubbed to remove some of the outer cells. The electrode paste decreases the impedance of contact and also reduces the artifacts resulting from movement of electrode.

Electrode Material:

The electrode, electrode paste and body fluids can produce a battery like action causing ions to accumulate on the electrodes. This polarization of electrode can affect the signal transfer.

Types of Electrodes:

These are three types of electrodes

Micro electrodes (Intracellular Electrodes):

These are used to increase the bioelectric potential within a single. It is divided into metallic and non metallic. The microelectrodes should have smaller diameter and during insertion of electrode into the cell, there will not be any damage to the cells.

They are formed by electrolytically electing the tip of a fine tungsten or stainless steel wire to a fine point. This technique is known as electro pointing. The metal microelectrodes are coated almost to the micro tip with a material.

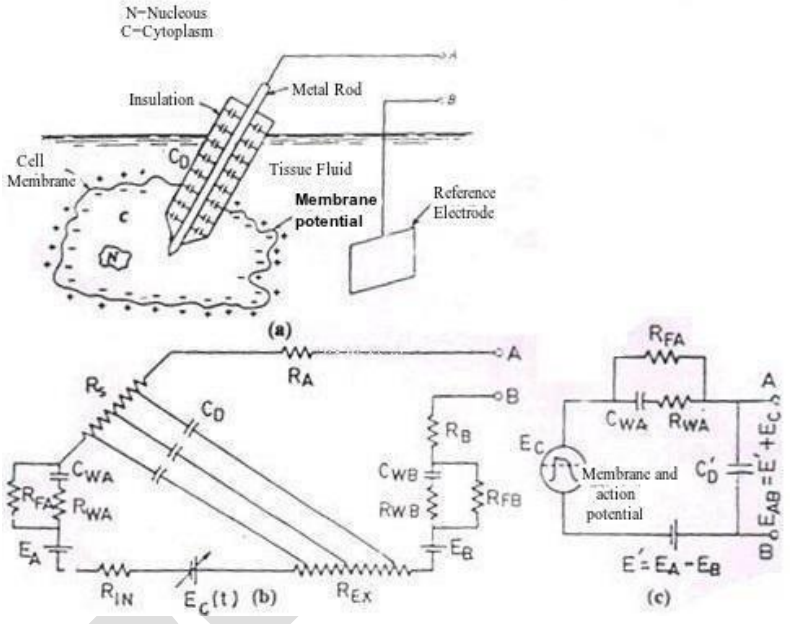


Fig 1.13: Metal Microelectrode [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

The impedance of microelectrode tip is inversely proportional to the area of the tip and frequency. When the electrode output is couple with an amplifier, the low frequency components of the bioelectric potentials will be attenuated if the input impedance of the amplifier is not high.

ii) Micropipet

It consists of a glass micropipet tips diameter is about1 micrometer. The micropipette is filled with an electrolyte usually 3M Kcl which is compatible with the cellular fluids.

E_A is the potential between metal wire and electrolyte filled in the micropipette

E_B is the potential between the reference electrode and the extracellular fluid.

E is variable membrane potential

E_D potential existing at the tip due to different electrolytes present in the pipet and the cell

$$E = E_A + E_B + E_D$$

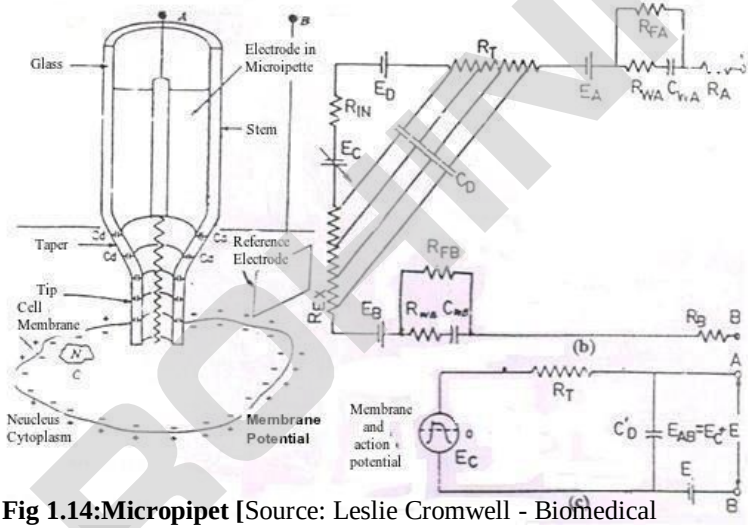


Fig 1.14:Micropipet [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Depth and Needle Electrodes

These are used to measure the bioelectric potentials of the highly localized extracellular regions in brain or bioelectric potentials from specific group of muscles.

i) Depth Electrode

These are used for study the electrical activity of the neutrons in superficial layers of the brain. Normally each electrode consists of a bundle of Teflon insulated platinum (90%) iridium (10%) alloy wires, bonded to a central supporting stainless steel wire which can act as indifferent electrode by an insulating varnish.

ii) Needle electrode

These are used to record the peripheral nerve‘s action potentials (Electro neurography). The needle electrode resembles a medium dropper or hypodermic needle.

Surface Electrode

Generally large area surface electrodes are used to sense ECG potentials and smaller area surface electrodes are used to sense EEG and EMG potentials.

i) Metal plate Electrodes

Rectangular and circular plates from German silver, nickel silver or nickel plated steel are used as surface electrodes in the case of ECG measurement.

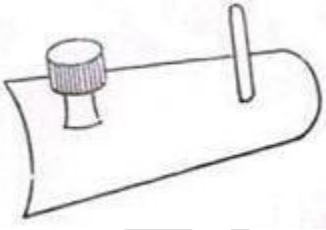


Fig 1.15: Metal plate Electrodes [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

ii)Suction Cup Electrode

It is more practical and is well suited for attachment to flat surfaces of the body and to regions where the underlying tissue is soft. Although physically larger this electrode has a small area because only the rim is in contact with the skin.

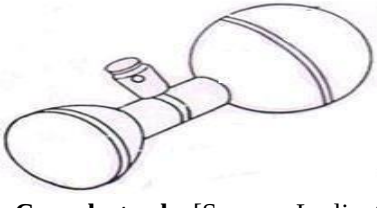


Fig 1.16: Suction Cup electrode [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

iii) Adhesive Tape Electrode

The pressure of the surface electrode against the skin may square the electrode pasted. To avoid this problem, adhesive tape electrode is used.

Fig 1.17: Adhesive tape electrode [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

iv) Multipoint Electrode

It is a very practical electrode for ECG measurements and it contains nearly 1000 fine active contact points. By this a low resistance contact is established with the subject.

v) Floating electrode

Here, the metal does not contact the subject directly. The contact is made via an electrolytic bridge. By means of this electrode, movement artifact is eliminated. This is also called as liquid junction electrode.

BOIPOTENTIAL RECORDERS

The bio – potential recorder plays an important role in the biomedical instrumentation. ach doctor is performing his diagnosis based on the output from recorder.

Characteristics of Recording System:

i) **Sensitivity:** The sensitivity is the magnitude of input voltage required to produce a standard deflection in the recorded trace.

ii) **Linear:** a recorder is said to be linear if the pen deflection is proportional to the amplitude of input signal.

iii) **Frequency Response:** A recorder is said to have good frequency response when the sensitivity is constant for all the frequencies present in the signal.

ELECTRO CARDIO GRAPHY (ECG)

ECG deals with the study of electrical activity of heart muscles. Electrocardiogram is the recorded ECG wave. ECG is also called EKG is derived from the German Electro Kardio Gam.

i) Origin of Cardiac action potential:

Heart is divided into four chambers. The top two champers are atria and lower two champers are ventricles.

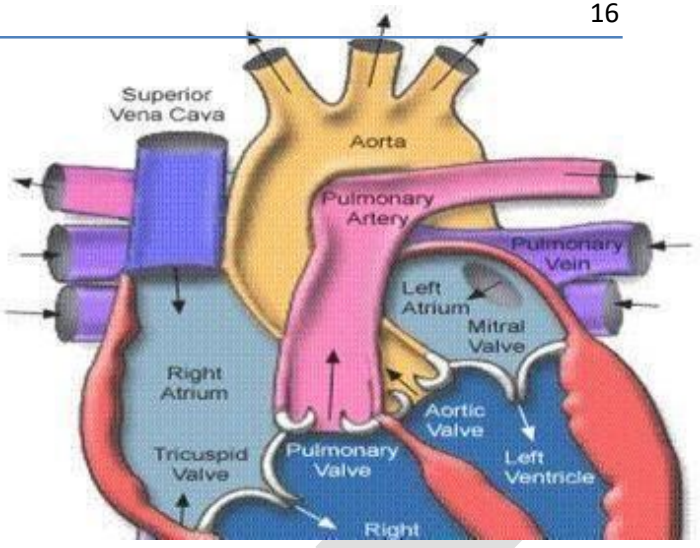


Fig 1.18: Cross Section of the Interior of the Heart

Table 1.1Physiological Nature of ECG Waveform

[Source: Leslie Cromwell - Biomedical instrumentation and measurement]

	Origin	Amplitude mV	Duration sec
P Wave	Atrial depolarization or contraction		0.12 to o.22 (P-R interval)
R wave	Repolarisation of the atrial and the depolarization of theventricles	1.60	0.07 to 0.1
	Ventricular repolarisation (Relaxation of myocardium)	0.1 to 0.5	0.05 to 0.15 (S-T interval)
S-T interval	Ventricular contraction		
U wave	Slow repolarisation of the intraventricular (Purkinje fibers) system	< 0.1	0.2 (T-U interval)

The complete waveform is called electrocardiogram indicating important diagnostic features. If PR interval is more than 0.22 sec, AV (first heart attack) occurs. When QRS duration is more than 0.1 sec, the bundle block (severe heart attack) occurs.

(ii) Lead configuration

The electrode systems are

1) Bipolar limp leads (or) standard leads.
2) Augment unipolar limp leads.
3) Chest leads (or) precordial leads.
4) Frank lead system (or) corrected orthogonal leads.

1) Bipolar Limb leads – Standard leads I, II, and II

In standard leads, the potential are tapped from four locations of our body. They are i) right arm ii) Left arm iii) Right Leg and iv) Left leg.

Right leg electrode is acting as ground reference electrode. Fig.1.20 shows the standard bipolar limp lead positions and the corresponding wave patterns.

Lead I position – give voltage V_I, the voltage drop from left arm(LA) to right arm (RA)

Lead II position- gives voltage V_{II}, voltage drop from left leg (LL) to right arm (RA)

Lead III position – gives voltage V_{III}, voltage drop from left leg (LL)to left arm (LA)

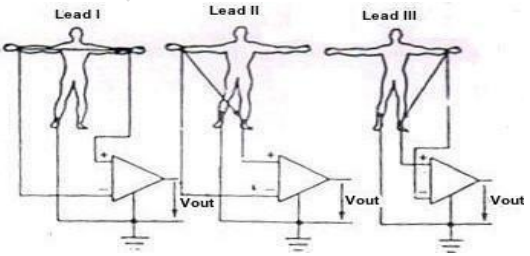


Fig 1.20: Standard Bipolar Limb Leads and the Corresponding ECG [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

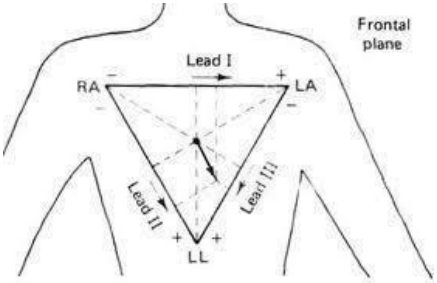


Fig 1.21: Einthoven Triangle
[Source: Leslie Cromwell - Biomedical instrumentation and measurement]18

The closed path RA to LA to LL and back to RA is called the **Einthoven triangle**. Along the sides of this triangle, three projections of ECG vector are measured.

2) Augmented unipolar Limb leads

In this, the electrocardiogram is recorded between a exploratory electrode and the central terminal.

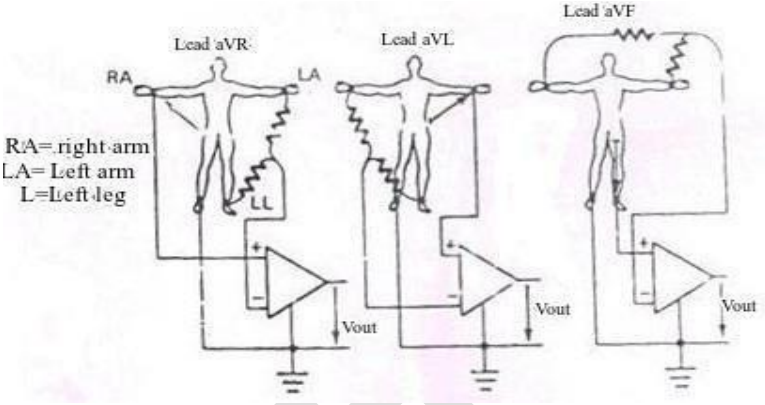


Fig.1.22: Augmented Unipolar Limb Leads [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

3) Unipolar Chest Leads

In this, exploratory electrode is obtained from one of the chest electrodes. The chest electrodes are placed on six different points on chest closed to the heart. By connecting three equal large resistances to LA, RA and LL a reference electrode or central terminal is obtained. This lead system is known as Wilson system. Electrocardiogram recorded from these 12 lead selections such that 3 standard bipolar leads, 3 augmented unipolar leads and 6 chest leads.

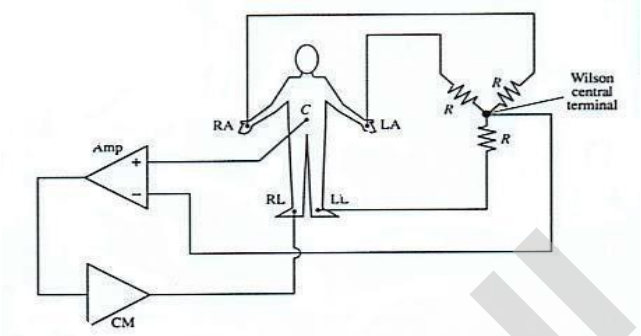


Fig.1.23: Unipolar Chest Leads [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

The ECG potentials are measured with colour coded leads for easy reference.

4) Frank lead system:

The corrected orthogonal lead system (or) Frank lead system is used in vector cardiography. Here one can get the information from 12 leads. The state of the heart is studied three dimensionally.

iii) ECG Recording setup:

i) Patient cable and Defibrillator Protection Circuit

The patient cable connects the different leads from the limbs and chest to the defibrillator protection circuit. It consists of buffer amplifiers and over voltage protection circuit. Each patient lead is connected to one buffer amplifier.

ii) Lead selector switch

It is used to feed the input voltage from appropriate electrode to the preamplifier.

iii) Calibrator

A push button allows a standardization voltage of 1 mV to the preamplifier. This enables to observe the output on display unit. From lead selector switch, ECG signal goes to bio-amplifier.

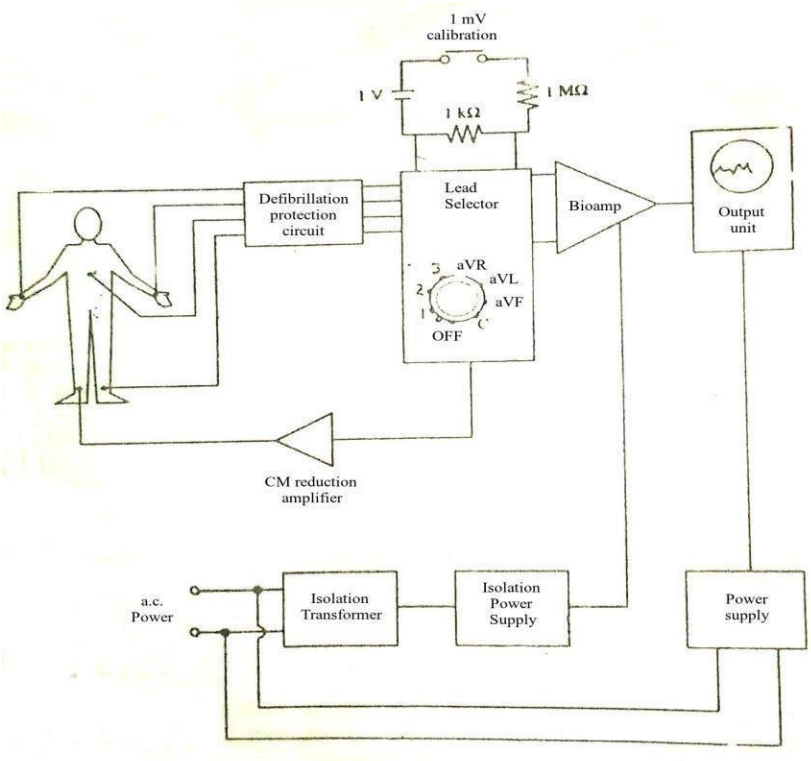


Fig1.24: ECG Recording [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Setup iv) Bio-Amplifier

The bio-amplifier consists of a preamplifier and power amplifier. The preamplifier should have high gain and high CMRR.

It consists of two power transistor such that their emitters are joined together and connected with R_L. When V_B is positive, Q_1 is FB and conducts while Q_2 is RB and remains off.

Output power pout = V_{out}^2 / R_L

Amplifier efficiency η = Pout / (pout +P_{loss})

To avoid the cross over distortion, an ideal non – inverting amplifier is inserted at the output. Since R_f is so large, it raise the gain and output voltage and thereby crossover distortion is eliminated. The effect control is provided by R_2 and gain adjustment

is provided by R_S.

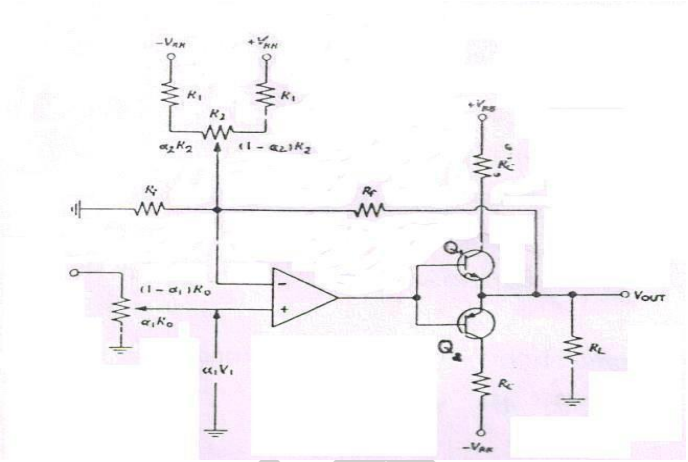


Fig.1.25: Push-Pull Power Amplifier with Crossover Compensation and Offset Control [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

v) Auxiliary Amplifier

The common mode signals can be reduced to a minimum level by adding an auxiliary amplifier between right leg lead and ECG unit.

vi) Isolation Tower Supply

It is used given power to the bio amplifier and hence the electrical safety for the patient is increased.

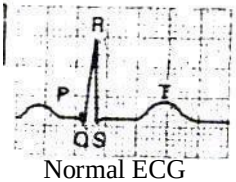
vii) Output Unit

In paper chart recorder, the power amplifier or pen amplifier supplies the required power to drive pen motor. Pen motor records the ECG trace on the wax coated heat paper. A position control is used to position the pen at the center on the recording paper.

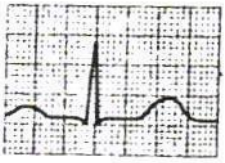
viii) Power switch

The power switch of the recorder has three positions. In ON position the power to the amplifier is turned on. But the paper drive is not running. In RUN position, the switch makes the paper drive to run. In OFF position, ECG unit is in switched off condition. **Analysis of Recorded ECG Signals**

Fig. shows the analysis of different ECG signals.

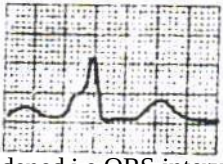


Normal ECG



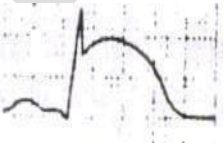
Here the PQ segment has prolonged conduction time i.e greater than 0.22second

Result: First degree AV block



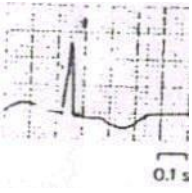
Here QRS complex is widened i.e QRS interval is greater than 0.1 second

Result: Bundle block

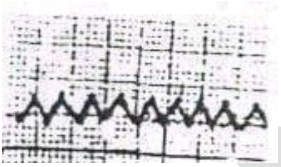


Here ST segment is elevated

Result: Myocardial infraction



Here ST segment is depressed and negative T wave is present Result: Coronary insufficiency



Here the train of pulses instead of PQRST waves

Result: Ventricular fibrillation which may lead to death if it is not properly corrected by defibrillator.

If the normal conduction system is disturbed, then the beat rate will be slower than the normal rate. This state s called heart block.

Vector cardiography

In electrocardiography, only the voltage generated by the electrical activity of the heart is recorded. In vector cardiography, the cardiac vector is displayed with its magnitude and spatial orientation.

Echocardiography

Echocardiography is a useful technique for diagnosis of heart diseases.. By changing the position of transducer, we can get reflections from the desired areas on the heart. An aqueous get is used to couple the transducer to the skin and the beam from the transducer. The time compensated signal amplifier is used to collect the low amplitude signals with same signal to noise ratio. Then these amplified signals are given to the cathode ray tube display unit.

A – Mode display

In amplitude mode or A - mode display, the echoes produce vertical displacements of a horizontal trace on the screen. The amount of vertical displacement is proportional to the strength of echo and the distance along horizontal trace represents the time taken by ultrasound to travel through tissue. Since the heart is moving,

echoes dance up and down during cardiac cycle.

B – Mode display

In brightness mode or B – mode display, the echoes are rotated through 90^0 towards the observer and so the echoes are presented as dots of light. The distance between dots represents the tissue depth. When echoes are from moving structure, dot's of light move back and forth.

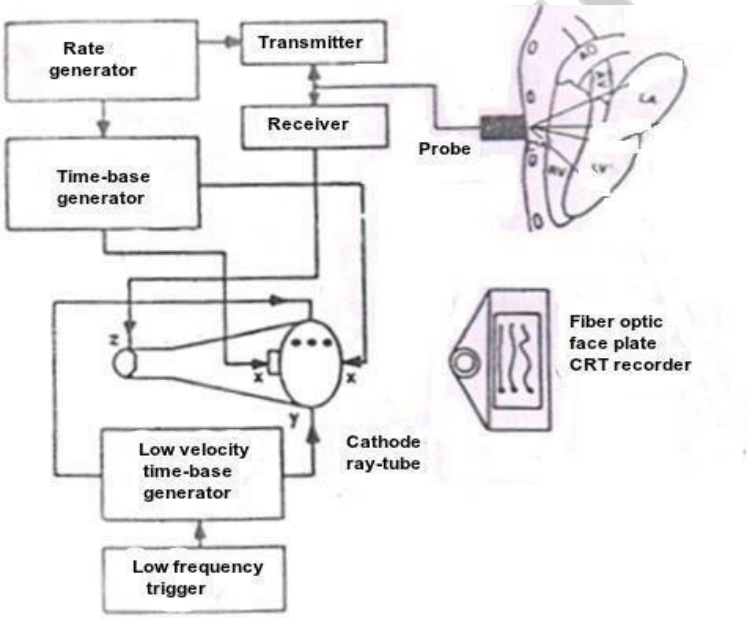


Fig.1.26: Block diagram of Echocardiograph and the typical Echocardiograms M – Mode display
[Source: Leslie Cromwell - Biomedical instrumentation and measurement]

In time – motion mode or m – mode Display, B – mode echo signal is recorded either by sweeping the oscilloscope screen or photographing the oscilloscope face on moving paper. In the conventional m – mode display time is on the x – axis distance on y – axis and intensity of echo is on z – axis

In echocardiogram the hill and valley regions indicate the working heart. A rapid b – mode scan of heart is known as real time

scan which is also called cross sectional or 2- D echocardiography.

PHONOCARDIOGRAPHY (PCG):

The graphic record of the heart sounds is called —Phonogram. Since the sound is from the heart, it is called phonocardiogram. The instrument used to measure the heart sounds is called phonocardiograph.

1) Heart sounds
2) Murmurs

Heart sounds have a transient character and are of short duration. Heart murmurs have a noisy characteristic and last for a longer time. Heart sounds are due to the closing and opening of valves whereas murmurs are due to turbulent flow of blood in the heart and large vessels.

Heart sounds

Heart sounds are classified into four groups based on their origin. They are

1) Valve closure sounds
2) Ventricular Filling sounds
3) Valve opening Sounds
4) Extra cardiac sounds

1) Valve Closure Sounds

The sounds occur at the beginning of systole (First heart sound) and the beginning of diastole (Second heart sound). The first heart sound is due to the closure of mitral and tricuspid valves. The second heart sound is due to the closure of aortic and pulmonary valves.

2) Ventricular filling sounds.

These sounds occur either at the period of rapid filling of the ventricles (Third heart sounds) or during the terminal phase of ventricular filling (ie) atrial contraction. These sounds are normally in audible.

3) Valve opening sounds

They occur at the time of opening of atrio – ventricular valves and semilunar valves.

4) Extra cardiac sounds

They occur in mid (or) late systole (or) early diastole. They are caused by thickened pericardium which limites ventricular distensibility.

Physical characteristics of sound

Heart sounds and murmurs are characterized by three physical properties. They are

1) Frequency

2) Amplitude

3) Quality

1) Frequency: All heart sounds and murmurs are made up of frequencies between 10 and 1000 Hz. They are divided into low, medium and high- pitch frequencies

i) Low range: 10 – 60 Hz. It is represented by the third and fourth heart sounds.

ii) Medium range: 60 – 150 Hz. It is represented by the first and second heart sounds.

iii) High range: 150 – 1000 Hz. It is represented by snaps, clicks and diastolic murmurs of aortic and pulmonary insufficiency.

1) Amplitude: Low frequency heart sounds have the biggest amplitude while the high frequency murmurs have small amplitudes.

2) Quality: quality depends upon the overtones (or) harmonics accompanying the fundamental frequency and applies to tones.

Origin of the heart sounds.

There are four separate heart sounds that occur during the sequence of one complete cardiac cycle.

1) First heart sound: It is produced by a sudden closure of mitral and tricuspid valves associated with myocardial contraction.

a) Timing: The low frequency vibrations occur approximately 0.05 sec after the onset of QRS complex of ECG.

b) Duration: It lasts for 0.1 to 0.12 sec.

c) Frequency : The first heart sound range from 30 – 50 Hz

d) Asculatory area: The first heart sound is best heard at the apex of the mid pericardium.

2) Second heart sound: It is due to the closure of semi lunar valves

(ie) the closure of aortic and pulmonary valves

a) Timing: The second heart sound start approximately 0.03 – 0.05 sec after the end of _T'wave of ECG.
b) Duration : 0.08 – 0.14 sec
c) Frequency : 250 Hz
d) Asculatory Area: It is best heard in the aortic and pulmonary areas.

3) Third heart sound: It arises as the ventricles relax and the internal pressure drops well below the pressure in atrium.

a) Timing: It starts at 0.12 – 0.18 sec after onset of second heart sound.
b) Duration : 0.04 – 0.08 sec
c) Frequency : 10 – 100 Hz
d) Asculatory Area: It is best heard at the apex and left lateral position after lifting the legs.

4) Fourth heart sound: Also called as atrial sound. It is caused by an accelerated flow of blood into the ventricles or due to atrial contraction. It occurs immediately before the first heart sound.

a) Timing : it starts at 0.12-0.18 sec after the onset of p-wave
b) Duration :0.03-0.06 sec
c) Frequency :10-50 Hz
d) Ausculatory Area: Because of its low frequency, it is inaudible

Heart murmurs

Murmurs are sounds related to non – laminar flow of blood in the heart and the great vessels.

They are distinguished from heart sounds such that

1) They have noisy character.
2) They have longer duration
3) They are high frequency components upto 1000 Hz.

Typical conditions in cardiovascular system which cause turbulence in blood flow.

1) Local obstructions to blood flow
2) Abrupt change in blood stream diameter.
3) Pathologic communication in cardiovascular system

4) Ruptured cardiac structures.

5) Valve insufficiency.

Transduction of heart sound

The sounds and murmurs originate from the heart which can be picked up from the chest using a stethoscope or by transduction of sound into electrical signals. The heart sounds are conducted from the heart to the cheat.

Recording setup:

The heart sounds are converted into electrical signals by means of a heart microphone. The electrical signals from microphone are amplified by a phonocardiographic preamplifier followed by suitable filters and recorder.

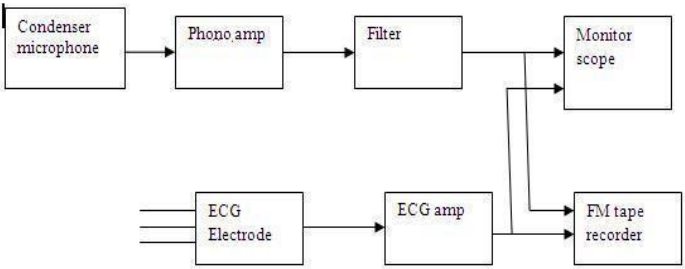


Fig.1.27: Block diagram of recording setup [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

The electrodes are placed on the limbs to pickup the electrical activity of heart and these signals are amplified and recorded. This recorded ECG is used as a reference for PCG.

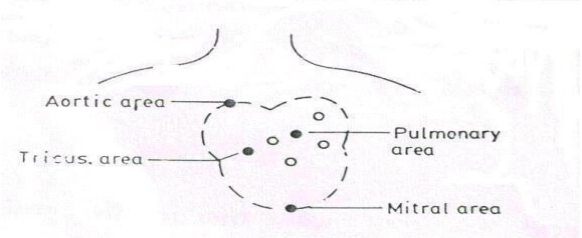


Fig1.28: Placement of Microphone on Different Areas of the chest for Recording PCG Heart Sound Microphone [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

The conversion of heart sounds into electrical signals can be done using transducers. Via condenser microphone, moving coil microphone etc. The two main categories of microphones used in P G are

1) The air coupled microphone
2) The contact microphone.

In the first case, the movement of chest is transferred via on air cushion and presents low mechanical impedance to chest.

$$C = Q/V$$

The vibrations produced by chest wall change the position of diaphragm which results in the change in voltage across electrode. The developed dc voltage is in the order of few mV. Relationship between heart and function of cardiovascular system

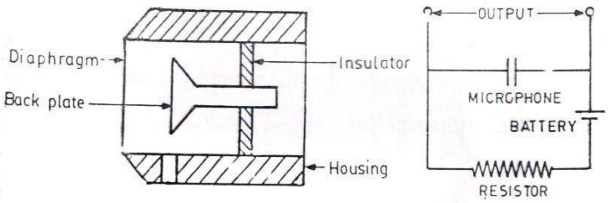


Fig 1.29: Condenser Microphone along with its Circuit [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

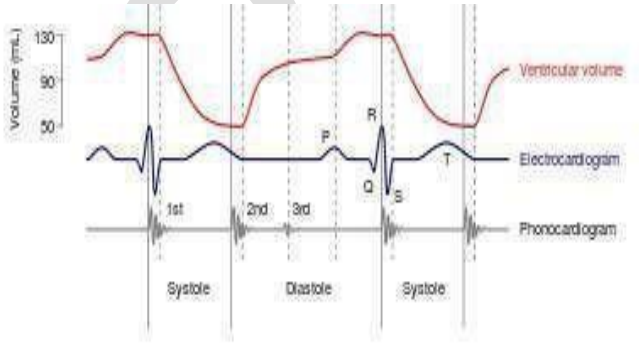


Fig 1.30: ECG waveform vs PCG [Source: Leslie Cromwell - Biomedical instrumentation and measurement] waveform Medical Applications

Rheumatic Valvular Lesions

Valvular lesions results from rheumatic fever. Rheumatic

fever is an allergic disease in which heart valves are damaged. This can be detected by phonocardiograph.

Fig (a) shows the normal heart sounds

The valvular lesions cause the abnormal heart sounds as given below

1) The murmur of aortic steonosis
2) The murmur of aortic regurgitation
3) The murmur of mitral regurgitation
4) The murmur of mitral stenosis

Special applications of phonocardiogram

1) Fetal phonocardiogram
2) Esophageal phonocardiogram
3) Tracheal phonocardiogram

ELECTRO ENCEPHALO GRAPHY (EEG)

EEG deals with the recording and study of electrical activity of brain. The brain waves can be picked up and recorded by means of electrode attached to the skill of a patient. Brain waves are the summation of neural depolarization in the brain due to stimuli from five sense and thought process.

1) Anatomy of brain

The brain consists of three major parts such as cerebrum, cerebellum and the brain stem.

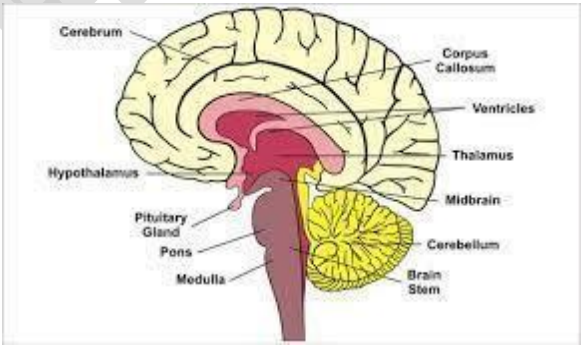


Fig 1.31: Internal structure of Human brain [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Cerebrum consists of two hemispheres and the hemispheres are divided into frontal lobe, parietal lobe, occipital lobe and temporal lobe.

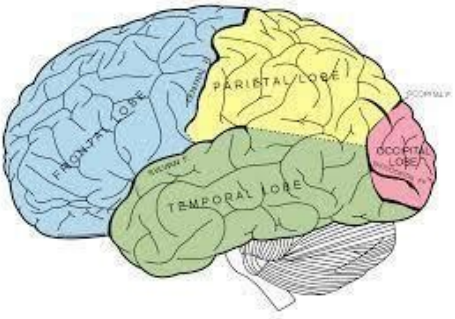


Fig 1.32: Human Brain [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

2) Action Potentials of Brain:

When the propagated action potential reaches the cell, the cell fires and thus a spike wave is produced. This firing spreads throughout the dendritic branches and causes the release of transmitter substances.

Inhibitory Post Synaptic Potential (PSP)

If the transmitter substance is inhibitory, membrane potential of receptor neuron increases in a negative direction. It is less likely to discharge; this induced potential charge is called an IPSP.

Excitatory Post Synaptic Potential (EPSP)

If the transmitter substance is excitatory, receptor membrane potential increases in a positive direction.

Evoked potentials

Evoked potential are the potentials developed in the brain as the responses to external stimuli like sound, light etc..

3) Brain waves

Brain waves are the recorded electrical potentials on the surface of brain. The intensity and patterns of electrical activity are determined by the overall level of excitation of brain.

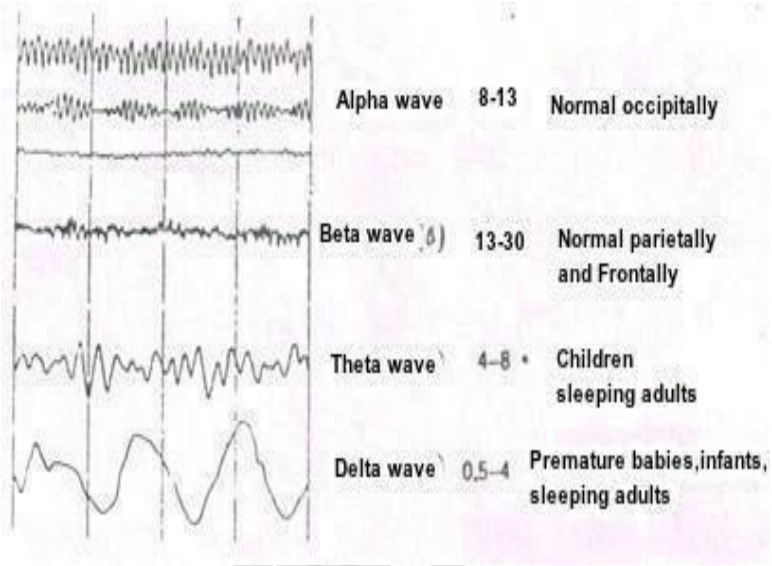


Fig 1.33: Brain Waves [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Alpha waves

Frequency: 8 – 13 Hz

Occurrence: They found in normal persons when they are awake in a quiet, state. They occur normally in occipital region. During step, these disappear

Beta waves

Frequency: 13 – 30 Hz

Occurrence: These are recorded from parietal and frontal regions of scalp two types: - Beta I – Inhibited by cerebral activity

Beta II – Excited by mental activity (tension)

Theta waves

Frequency: 4 – 8 Hz

Occurrence: These are recorded from parietal and temporal regions of scalp of children.

Delta waves

Frequency: 0.5-4Hz

Occurrence: These occur only in every 2 or 3 sec. These occur in deep

sleep in premature babies and in very serious brain disease.

4) Placement of electrode

In EEG, electrodes are placed in standard positions on skill in an arrangement called 10 – 20 system. The electrodes are arranged as follows.

1) Draw a line on the skull from the nasion, the root of nose, to the inion, ossification center on occipital lobe.

2) Draw a similar line from the left preauricular (ear) point to the right preauricular point.

3) Mark the intersection of two lines as Cz which is the midpoint of distance nasion and inion.

4) Mark points Fpz, Fz, Cz, Pz and Oz at 10, 20, 20, 20, and 10% of total nasion – inion distance.

5) Mark points T_3, C_3, Cz, C_4, and T_4 at 10, 20, 20, 20 and 10% of total distance between preauricular points.

6) Measure the distance between Fpz and Oz along the circle passing through T_3, and mark points as Fp_1, F_7, T_3, T_5, and O_1 at 10, 20, 20, 20 and 10% of this distance.

7) Repeat this procedure on right side and mark the positions as Fp_2, F_8, T_4, T_6, and O_2.

8) Measure the distance between Fp_1, and O_1 along the circle passing through C_3 and mark point as F_3, C_3, and P_3 at 25% intervals.

9) Repeat this procedure on right side and mark as F_4, C_4 and P_4.

10) Check that F_7, F_3, Fz,F_4 and F_8 are equidistant along transverse circle passing through F_7, Fz, and F_8 check that T_5, P_3, Pz,P_4, and T_6, are equidistant along transverse circle passing through T_5, P_z, & T_6

Pg_1 AND Pg_2 are nasopharyngeal electrodes and A_1 and A_2 are ear electrodes.

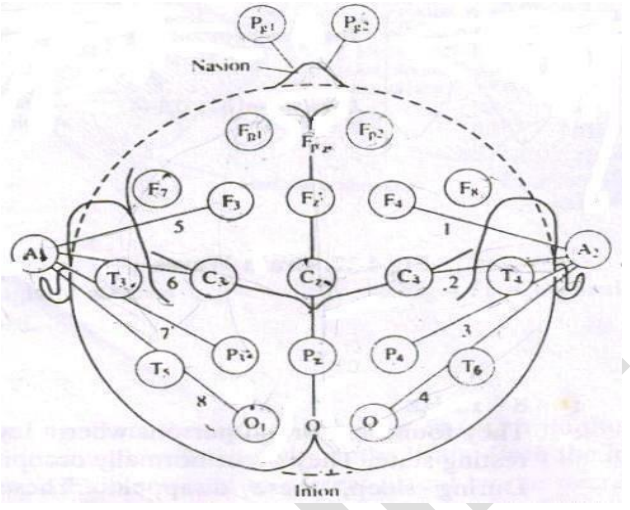


Fig 1.34: Placement of lectrodes on the Scalp for the EEG Recording
[Source: Leslie Cromwell - Biomedical instrumentation and measurement]

Pg_1 AND Pg_2 are nasopharyngeal electrodes and A_1 and A_2 are ear electrodes. The electrode systems are used to facilitate the location of foci, (ie) cortical areas from which abnormal waves spread.

5) Recording Setup

In EEG recording setup, there are and drive amplifier whose gain can be increased by cascading several stages. The patient cable consists of 21 electrodes and is connected to the eight channel selector. The electrodes are attached to the channel selector in groups of eight called a montage of electrodes. The interference is reduced by employing differential amplifiers as preamplifiers.

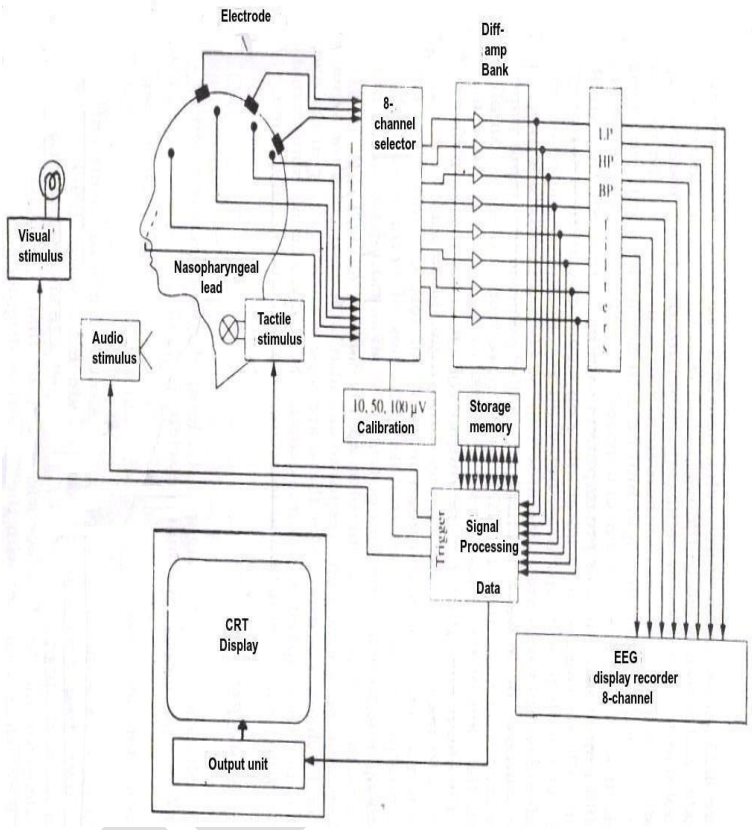


Fig 1.35: Fig: Modern EEG Unit [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

EEG unit is covered with ferrous metal screen to reduce a,c interference.

The filter bank consists of appropriate filters to select different types of brain waves. Visual stimulus, Audio stimulus and tactile (touch) stimulus are used to record evoked potentials from sensory parts of brain. The time delay between stimulus and response can be measured in the signal processing unit.

6) Analysis of EEG

EEG helps physicians to diagnose the level of

consciousness, sleep disorders, brain death, brain tumors, epilepsy etc.

i) Level of consciousness

EEG changes with the level of consciousness. Diminished mental activity results in a lower frequency and large amplitude EEG wave.

REM means Rapid Eye Movement. REM sleep coincides with the periods of dreaming. EEG displays the characteristic features during the application of anaesthesia.

If the tumor displays the cortex and if it is large enough, the electrical activity will be absent since no electric potentials originate in the tumor. Thus a damped EEG over the cortex can be a sign of a tumor.

iii) Epilepsy

Epilepsy is a symptom for brain damage. It may due to defects in birth delivery or head injury during accident or boxing. It may also be due to brain tumor. Epilepsy is divided into two types.

1) Grandmal

2) Peritmal

1) Grandmal

Before grandmal attack, the patient recognizes a set of symptoms such that he sees a flash of light if grandmal arises from visual center .He hears a noise if it arises from acoustic center. It extends from few sec to several min

2) Peritmal

In peritmal attack, spike type waves are produced with a frequency 3 Hz. It lasts for 1– 20 sec.

Application

(i) Epilepsy – EEG is very helpful to find acuteness of epilepsy.

(ii) Anesthetic level – It is helpful to find the depth of intensity of anesthesia

(iii) Brain injury – If there is a scar on the cerebral cortex, it creates irrigative effect on the nearby healthy cortex. It is identified by EEG waveform.

(iv) Monitor during surgery – Doctor to find patient's conditions.

(v) Effect of Yoga – Identified by EEG for a normal person initially EEG in recorded.

The person has to do yoga for some time. After some period, once again EEG recorded for same person. Then it is compared with previous wave form different gives the effect of yoga.

ELECTRO MYO GRAPHY (EMG)

Electromyography is the science of recording and interpreting the electrical activity of muscle's action potential. The recording of peripheral nerve's action potentials is called electroneurography.

Recording Setup

The surface electrodes or needle electrodes pickup the potentials produced by the contracting muscle fibers. The surface of the skin cleaned and electrode paste is applied.

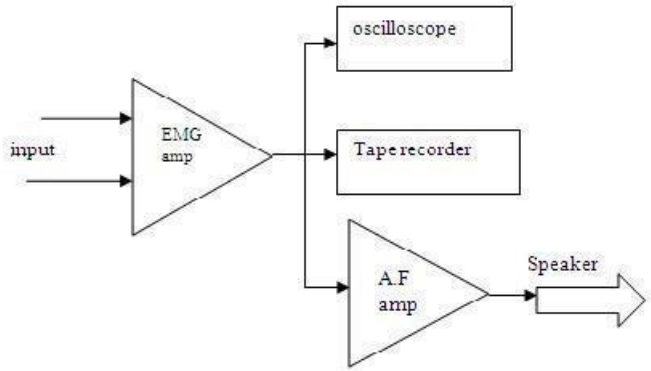


Fig 1.36: Block Diagram for EMG Recording Setup [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

The needle electrode picks up the action potentials from selected nerves or muscle. Further to record the action potentials from a signal nerve, microelectrodes are used.

The amplitude of EMG signals depends upon the type and placement of electrodes used. Surface electrode picks up many overlapping spikes and produces an average voltage from various muscles.

The amplifier should have uniform frequency response, high CMRR and high input impedance. The signal is also recorded in the tape recorder for further reference.

Determination of conduction velocities in motor nerves.

The measurement of conduction velocity is used to indicate the location and type of nerve lesion.

The EMG electrode and stimulating electrode are placed at two points on the skin, separated by a known distance l_1. An electrical pulse is applied through the stimulating electrode. The latency is now measured as _ t 2'seconds. The conduction velocity is

$$U = l_1 - l_2 / t_1 - t_2$$

The conduction velocity in peripheral nerves is normally 50 m/s. when it is below 40 m/s, there is some disorder in nerve conduction.

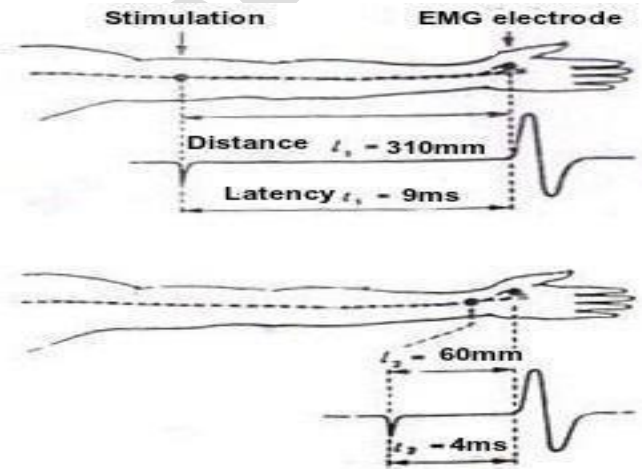


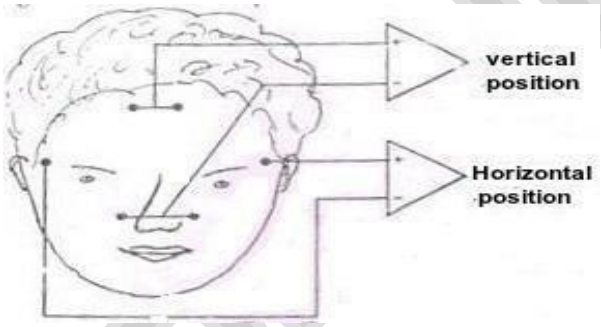
Fig 1.37: Determination of Conduction Velocity in a Motor Nerve [Source: Leslie Cromwell - Biomedical instrumentation and measurement]

ELECTRO OCULO GRAPHY (EOG)

A recorder of corneal – retinal potentials associated with eye movements is called electrooculogram. It is simpler to recorder then electroretinogram.

The electrodes are placed as shown in Fig one pair of skin electrodes on either side of eye for recording of horizontal movement of eyes and another pair of electrodes on for head and checks for recording for vertical movement of eyes. This electrodes position methods reduces the cross coupling between the vertical and horizontal pair of electrodes.

Fig 1.38: EOG measurement [Source: Leslie Cromwell - Biomedical instrumentation and measurement]



A commonly observed artifact in EOG recording of vertical eye movements has being attributed to the motions of upper eyelid. Some diseases which affect the steady potential the eye can be studied using EOG.

i) The effect of certain drugs on the eye movement system can determined.

ii) The state of the semicircular canals is analysis by EOG.

iii) Diagnosis of the neurological disorders

iv) The level of anesthesia can be indicated by the eye movements.