UNIT- I
ELECTRO- PHYSIOLOGY AND BIO-POTENTIAL RECORDING

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

1.1 INTRODUCTION:

Biometrics is the branch of science that includes the measurement of physiological variable and parameters. Physiological parameters are blood pressure, velocity of blood flow, action potential of heat muscles, temperature, p^H value of blood etc. Physiology explains the physical and chemical factors that are responsible for the origin, development and progression of life. Human physiology is concerned with the specific characteristics and mechanisms of human body that make it a human being.

1.2 SOURCES OF BIOELECTRIC POTENTIAL

The body generate 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.

1.2.1 Resting and Action Potential

Nerve and Muscle cells are encased in a semi permeable membrane that permits some substances to pass through the membrane while other are kept out. The cells of the body are surrounded by body fluids. Fluid contains charged atoms known as ions. The principal ions are sodium (Na), potassium (K) and chloride. The cell membrane permits potassium and chloride ions and blocks sodium ions. The ions should seek a balance between the inside and outside of cell according to concentration and electric charge. The inability of sodium to penetrate the membrane results in two conditions.

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.

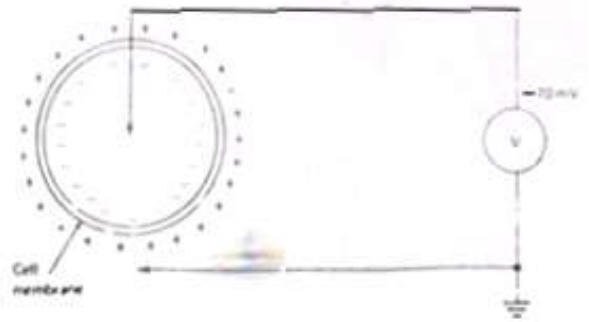


Figure: Polarized cell with its resting potential

This charge cannot be achieved. However an 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.

1.2.2 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

$$Vr = -\frac{KT}{q}\ln\left[\frac{Pk[K^+ i] + P_{Na}[Na^+ i] + P_{cl}[Cl^- o]}{P_k[K^+]_o + P_{Na}[Na^+]_o + P_{Cl}[Cl^-]_i}\right]$$

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

A cell in the resting state is to be polarized. When the cell membrane is excited by flow of ionic currents or by externally applied energy, the membrane allows sodium ions to enter. This movement of sodium ions into the cell constitutes an ionic current flow that reduces the barrier of membrane to sodium ions. The net result is an avalanche effect in which sodium ions rush into the cell to reach a balance with the ions outside.

Mean while, potassium ions try to leave the cell but are unable to move as rapidly as sodium ions. Therefore the cell has a slightly positive potential on inside due to the imbalance of potassium ions. This potential is known as action potential and is approximately + 20 mV. A cell that has been excited and that displays an action potential is said to be depolarized. The process of changing from the resting state to the action potential is called depolarization.

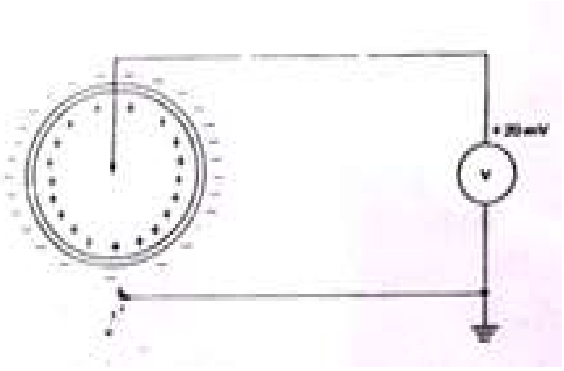


Fig : Depolarized cell with action potential

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.

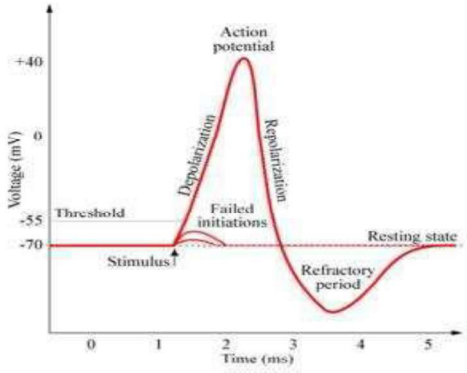


Fig : waveform of the action potential, (Time scale varies with type of cell)

In nerve and muscle cells, repolarisation occurs so rapidly following depolarization that the action potential appears as a spike of 1 ms total duration. But for heart, action potential is from 150 to 300 ms and so it repolarises much more slowly.

When a cell is excited, the action potential is always the same for any given cell. This is known as **all- or-nothing law**.

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. This period is called **absolute refractory period**.

Following this period, there occurs a **relative refractory period** during which another action potential can be triggered, but a stronger stimulation is required.

1.2.3 Propagation of action potentials:

The rate at which an action potential moves down a fiber or is propagated from cell to cell is called the propagation rate. In nerve fibers, the propagation rate is also called the nerve conduction rate or conduction velocity. In nerves, velocity ranges from 20 to 140 meter/ sec. But in heart muscle, it is very slower ranging from 0.2 to 0.4 m/s.

1.3 DESIGN OF MEDICAL INSTRUMENT

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

1. **Accuracy** : Accuracy 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

1.4 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.

Transducer acts as an impedance matching device between the biological system and signal processor. Signal processor amplifier amplifies & modifies the electrical output of transducer to run the recording or display devices. The signal processor is also called signal conditioning equipment.

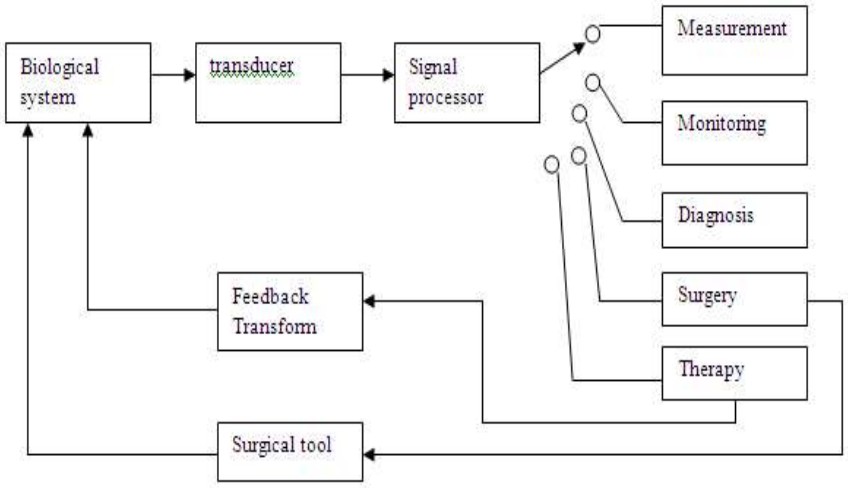


Fig1.4: Block diagram of a generalized bio-medical instrument system

In case of therapy, it must feedback the signal to biological system through the feedback transform. In case of surgery, a surgical tool and laser is in contact with the biological system.

1.5 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.
5. The biosignal should be transferred from the electrode to the amplifier without any leakage current.
6. The output impedance should be very small.
7. CMRR should be more than 80 dB to eliminate interference from the mains.

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

1.5.1 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. Q_1 and Q_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 Q_1 is connected to base of Q_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.

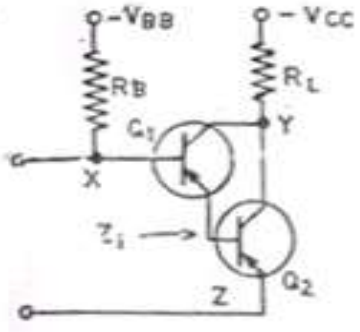


Fig 1.5.1(a) : Darlington pair

Bootstraping circuit: is also used as isolation amplifier to get very high input impedance. A feedback network is connected between the emitter of Q_2 and collector of Q_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 Q_2.

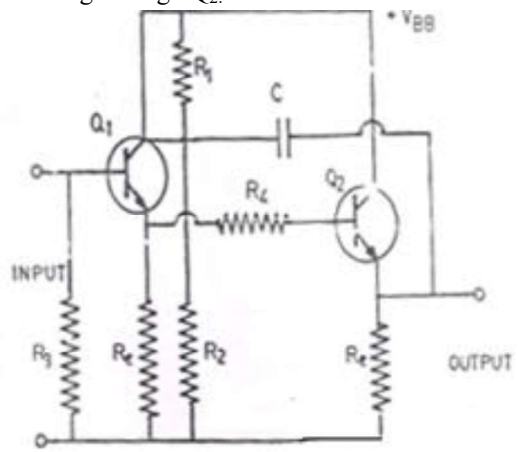


Fig 1.5.1 (b) : Bootstraping circuit

Fig (c)shows the high input impedance amplifier formed by connecting an isolation amplifier at each input and their outputs are acting as inputs to differential amplifier.

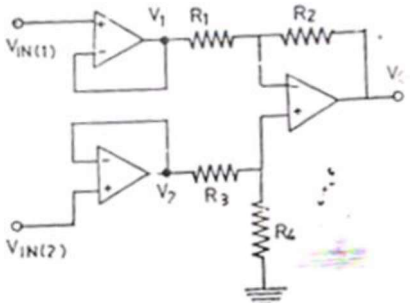


Fig 1.5.1(c): Isolation amplifier using operational amplifier

If $R_2/R_1=R_4/R_3$

$V_0 = R_2/R_1(V_2-V_1)$

Thus the loading effect is reduced to a minimum value and the amplifier works as a high performance biomedical preamplifier.

1.5.2 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.

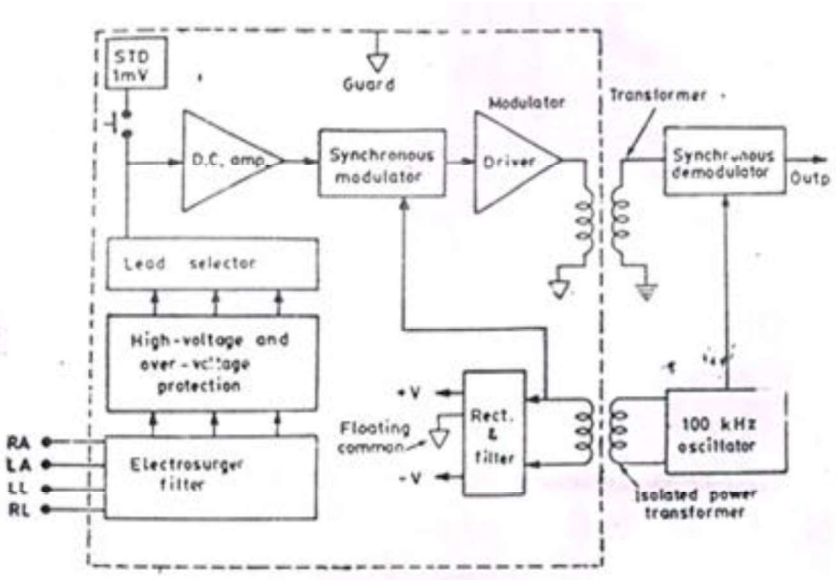


Fig ECG isolation amplifier circuit.

The d.c amplifier also receives a standard d. c voltage of 1mV through a push button. The primary of an isolated power transformer is connected to 100 KHz oscillator.The secondary of that transformer along with rectifier and filter circuits is used to obtain isolated power supply. The synchronous modulator modulates the ECG signal from the d.c amplifier. Another transformer is used to deliver the output from driver of modulator to synchronous demodulator. The demodulator output is used as the input f power amplifier. The perfect shielding of preamplifier circuit enables to achieve higher CMRR. The line frequency interference is eliminated by introducing a notch filter after power amplifier.

1.5.3 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.

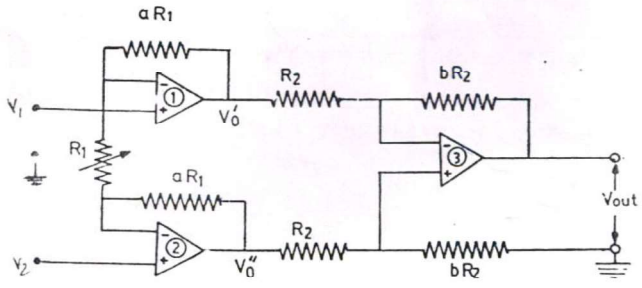


Fig:Medical Preamplifier

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

$V_0^1 = (1 + aR_1/R_1)\, V_1 - (aR_1/R_1)\, V_2$

$V_0^{II} = (1+aR_1/R_1)\, V_2 - (aR_1/R_1)\, V_1$

$V_{out} = (V_0^{II} - V_0^1)\, bR_2/R_2$

$V_{out} = (1+2a)(V_2 - V_1)\, b$

Net gain is (1+2a) b

1.5.4 Bridge amplifiers:

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

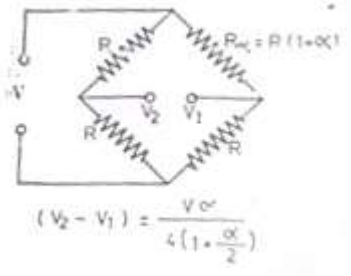


Fig : Bridge amplifier for voltage readout

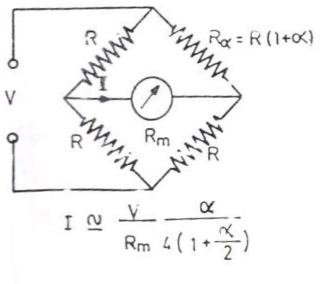


Fig: Bridge amplifier for current readout

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.

1.5.5 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 :

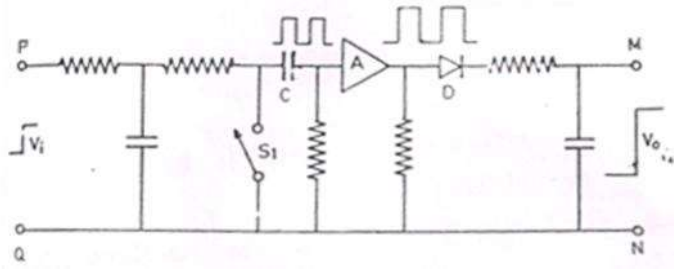


Fig : Chopper amplifier using a mechanical switch

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.

Thus the signal is chopped into a train of square wave pulses having a frequency equal to rate chopper. After amplification the chopped signal is rectified with a diode 'D'. The rectified signal is obtained at the output terminals M and N.

The response time of chopper amplifier is governed by chopping or sampling rate. Using mechanical chopper we cannot achieve high chopping rates due to their inertia.

ii) Non mechanical Chopper Amplifier:

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.

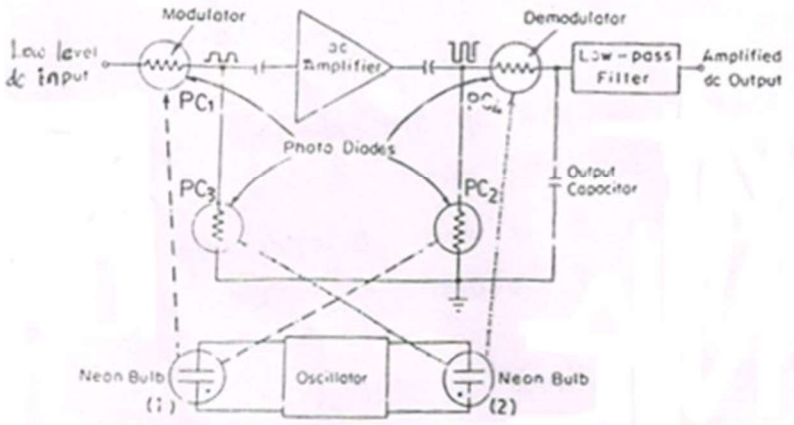


Fig :Non mechanical photoconductive chopper amplifier

An oscillator drives two neon bulbs into illumination on alternate half cycle of oscillation. Neon bulb (1) gives flash of light on photoconductors PC_1, and PC_2. Neon bulb (2) gives flash of light on PC_3 and PC_4.

When light flash on PC_1, its resistance decreases and i/p capacitor charges. When there is no light on PC_1 and light is on PC_3, input flow through PC_3. Thus by the alternate incident light on PC_3 & PC_1 we have a square wave across the capacitor.

The square wave is applied to ac amplifier and an amplified square wave voltage is obtained at the output. PC_2 and PC_4 are in the amplifier output circuit. They recover dc signal by demodulation and output capacitor charges to peak of output voltage. Then the dc output voltage is passed to a LPF to remove any ripples and finally amplified dc output is obtained.

1.6 ELECTRODES

Electrodes are used to pick up the electrical signals of the body. They transfers the bioelectric event to the amplifier. The type of electrode to be used depends upon the bioelectric generator.

1.6.1 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.

Electrodes in which unhindered exchange of charge is possible across the metal electrolyte interface are called perfectly non- polarisable electrode. The electrode potential is not a stable and its variations constitute a source of variable noise voltage called artifact.

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'.

Equivalent Circuit

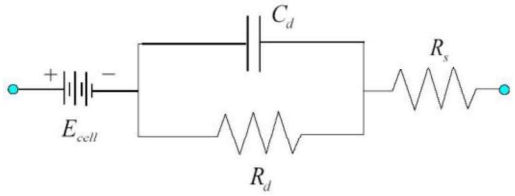


Fig: surface electrode equivalent circuit

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

$$Z = R_s + \frac{R_d}{1 + j2\pi f C_d R_d}$$

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

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

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. This area should be coated with an electrically conductive paste called electrode paste.

The electrode is then applied to prepared site and held in place with a rubber strap. The electrode paste decreases the impedance of contact and also reduces the artifacts resulting from movement of electrode.

The electrode contact impedance varies with fat content, blood supply and electrode contact pressure. Even after the application of electrode paste, contact impedance decreases with increase of frequency of signal.

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.

The polarization effect can be reduced by coating the electrodes with some electrolytes. By electrolytically coating a piece of pure silver with silver chloride, silver – silver chloride electrode is developed. Silver – silver chloride electrode has

- Half cell potential is 2.5 mV
- Reduces the noise voltage
- Increases the stability
- Stabillzes the half cell potential

- Reduces the low frequency electrode - electrolyte impedance. Hence these electrodes are used in biomedical instrumentation extensively.

1.6.2 Types of Electrodes:

These are three types of electrodes

1.6.2.1 Micro electrodes (Intracellular Electrodes):

These are used to increase the bioelectric potential with in a single cell

It is divided into metallic and non metallic. Non metallic micro electrode is called Micropipet.The microelectrodes should have smaller diameter and during insertion of electrode into the cell, there will not be any damage to the cells.

When the micro electrode is used to measure the potential of the cell, it is located with in the cell while the reference electrode is situated out side the cell. The size of the electrode is determined by the size of the cell. Since the size of the cell is about 50 microns, the diameter of the tip of the micro electrodes is ranging from 0.5 to 5 microns.

1) Metal microelectrode:

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

To reduce the impedance, some electrolytic processing like chloriding the tip and then developing by the photographic developer can be performed.

Since the measurement of bio electric potentials requires two electrodes, the voltage measured is really the difference between the instantaneous potentials of the microelectrode and the reference electrode

E_A – Metal electrode electrolyte potential at microelectrode tip.
E_B – Reference electrode-electrolyte potential
E_C – Variable cell membrane potential.
R_A denotes the resistance of the connecting wire which is negligible.
R_S denotes the resistance of the shaft of the microelectrode which is also negligible.
R_{FA}, R_{WA} and C_{WA} constitute the impedance of the microelectrode tip intracellular fluid interface.
R_{IN} is the resistance of the intracellular fluid.

Similarly R_B is the resistance of wire connected to the reference electrode which is negligible. R_{FB}, R_{WB} and C_{WB} constitute the impedance of the reference electrode – extracellular fluid interface and R_{EX} is the resistance of the extracellular fluid.

C_D is the distributed capacitance between the insulated shaft of the micro electrode and the extracellular fluid.

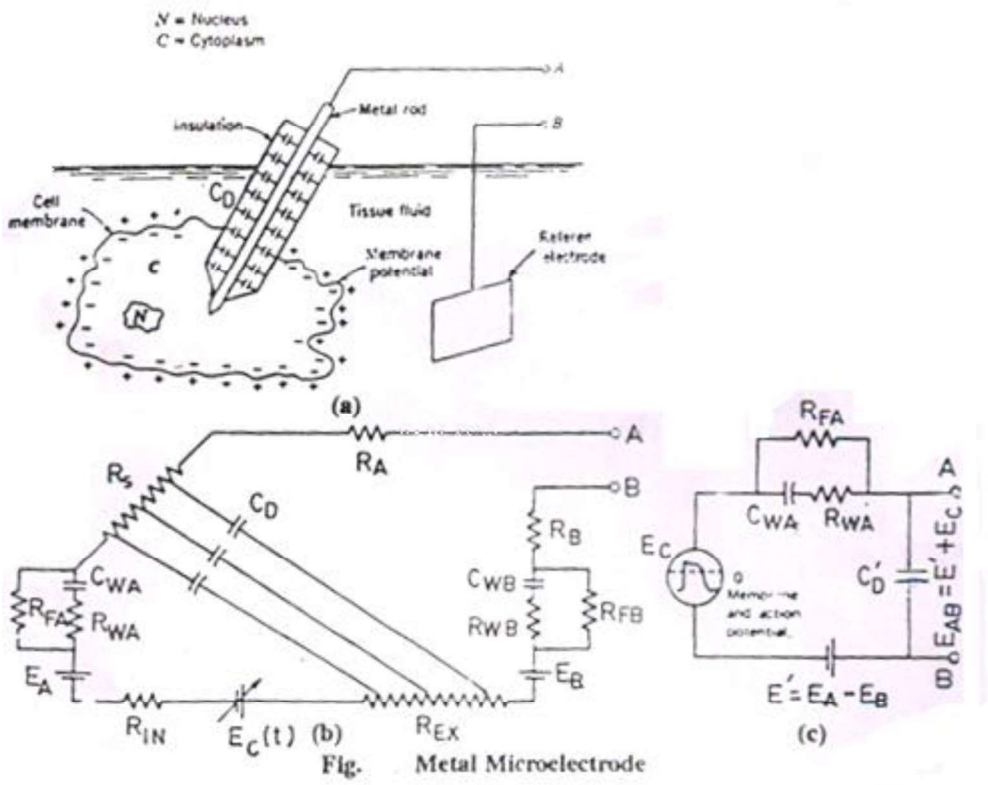


Fig. Metal Microelectrode

The capacitance between the top of the microelectrode and the intracellular fluid is negligible because the potential difference across it does not change. Since the area of the reference electrode is many times greater than the metal electrodes tip whose area of cross section is very small, its impedance is very small. 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. Thus if the input impedance of the amplifier is not high enough it behaves as a high pass filter.

ii) Micropipet

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

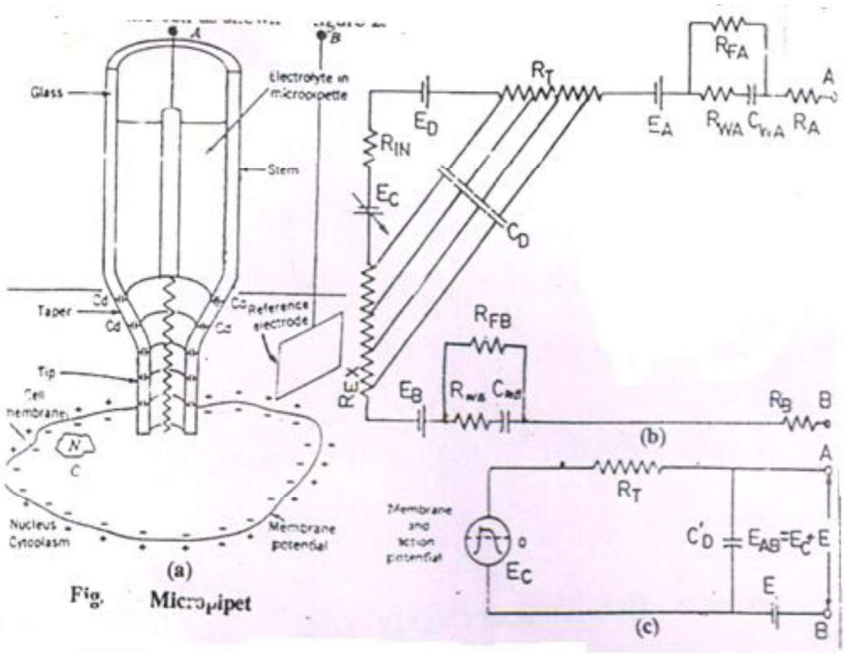
A thin flexible metal wire from chloride silver, stainless steel or tungsten is inserted into the stem of the micropipet. The fraction between the wire and the stem of the micropipette and the fluid surface tension hold the micropipette on the wire.

The other end of the metal wire is mounted to a rigid support and the other free end of it is resting on the cell.

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_C is variable membrane potential
E_D potential existing at the tip due to different electrolytes present in the pipet and the cell

$$E = E_A+E_B+E_D$$

R_A denotes the resistance of the connecting wire, R_{FA}, R_{WA} and R_{CA} constitute the impedance of the electrode- electrolyte interface in the stem of the micropipette, and R_T is the resistance of the electrolyte filling the of the micropipette which is very large.



R_{IN} and R_{EX} are the resistance of the electrolyte inside the cell and the electrolyte outside the cell respectively R_{FB} R_{WB} and C_{WB} constitute reference electrode – electrolyte interface impedance and R_B is the resistance of the wire connect with reference electrode. C_D is the distributed capacitance existing between the fluid in the pipet and the extracellular fluid. C is the equivalent of distributed capacitances.

When the micropipette is coupled with the amplifier terminals A and B, Then the membrane potential E_C is coupled with it Via a high series resistance R_T and a capacitance C_D along with electrode potentials. The impedance of the electrode pause limit on the response time of circuit such that it behaves as a LPF when the input impedance of the amplifier is not enough high.

1.6.2 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. When it is desired to bring an electrode close to a bioelectric generator, it is often practical to penetrate the

skin and advance the electrode through the penetration. So the electrode should be sharp for penetration and to obtain highly localized extracellular recording of bioelectric events, these are used.

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.

The end of supporting wire is rounded for ease of insertion into the brain. The electrode is resting on the sub cortical nerve cells. The ends of the individual wire the bundle constitute individual electrode.

The active area of depth electrode is about $0.5mm^2$. Therefore the depth electrode impedance is smaller than the micro electrode impedance. In some depth electrodes, the supporting steel wire is in the form of a capillary tube which is used to inject medicines into the brain or to pass a microelectrode. It is also used to nearsury oxygen function.

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. A short length of the fine insulated metal wire is bent at it's one end and the bent portion is inserted through the lumen of the needed and is advanced into the muscle.

The needle is withdrawn and the bent wire is resting inside the muscle. When the reference electrode is placed on the skin, then the needle electrode is called polar. When we insert two insulated wires into the lumen of the needle, then the two wires constitute bipolar electrode such that wire is reference electrode.

1.6.2.3 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. When these electrodes are applied on the skin with electrode paste, typical d.c resistance values are in the range from 2 to 10 kΩ, the high frequency impedance amounts to a few hundred

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.

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. If consists of a light weight metallic screen back by a pad for electrode paste. The adhesive packing holds the electrode in place and retards the evaporation of the electrode present in the electrode paste.

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. If the subject has hairs on the regions of interest, then one can use the multipoint electrode without removing the hair. It can be used under any environmental conditions.

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.

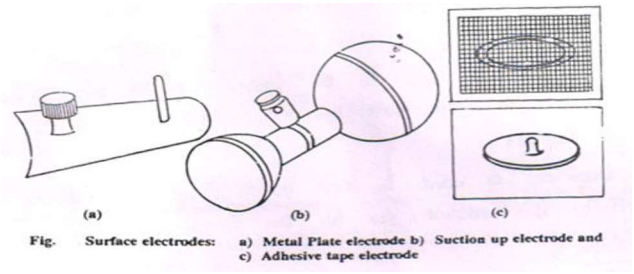


Fig. Surface electrodes: a) Metal Plate electrode b) Suction up electrode and c) Adhesive tape electrode

1.7 BIOPOTENTIAL RECORDERS

The bio – potential recorder plays an important role in the biomedical instrumentation. Each 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.

iv) **phase response:** Phase response is measured by the time delay between the input and output.

1.7.1 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 chambers are ventricles. The right atrium receives blood from the Superior vena cava and pumps it into right ventricle. The right ventricle pumps the blood into the lungs where it is purified and oxygenated. The oxygen enriched blood enters the left atrium & then it is pumped into left ventricle. Then the left ventricle pumps the blood into arteries through Aortic valve for circulation throughout the body. For circulation, blood requires proper pressure. Sufficient pressure is delivered by the ventricular muscle's contraction achieved through cardiac potential.The action potential contracts the atrial muscle and the impulse spreads through the atrial wall of about 0.04 sec to the atrio – ventricular (AV) node. AV node is located in the lower wall between two atria. AV node acts as a " delay line" to provide timing between the atria and ventricles.

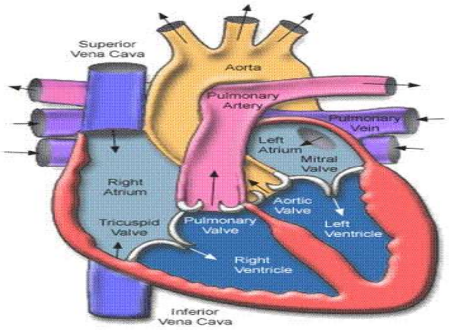


Fig. shows the cross section of the interior of the heart.

ECG wave consists of P wave, QRS complex and Twave

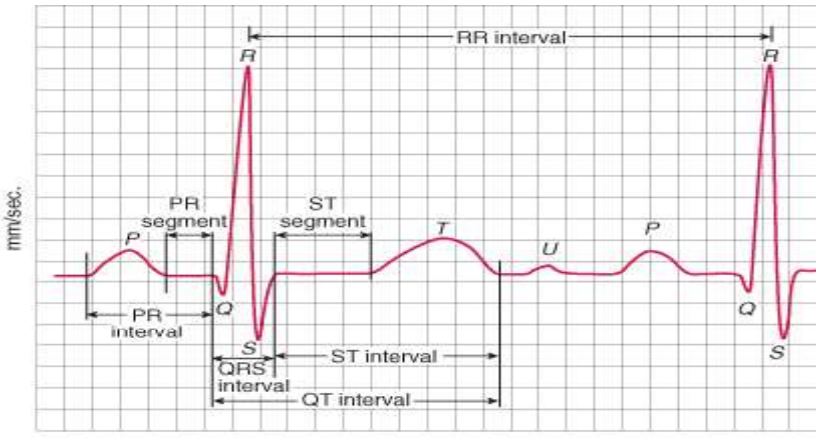


Table Physiological Nature of ECG Waveform

	Origin	Amplitude mV	Duration sec
P Wave	Atrial depolarization or contraction	0.25	0.12 to o.22 (P-R interval)
R wave (QRS complex)	Repolarisation of the atrial and the depolarization of the ventricles	1.60	0.07 to 0.1
T wave	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 system are

1) Bipolar limb leads (or) standard leads.
2) augment Unipolar limb leads.
3) Chest leads (or) precordial leads.
4) Frank lead system (or) corrected orthogonal leads.

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

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. 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)

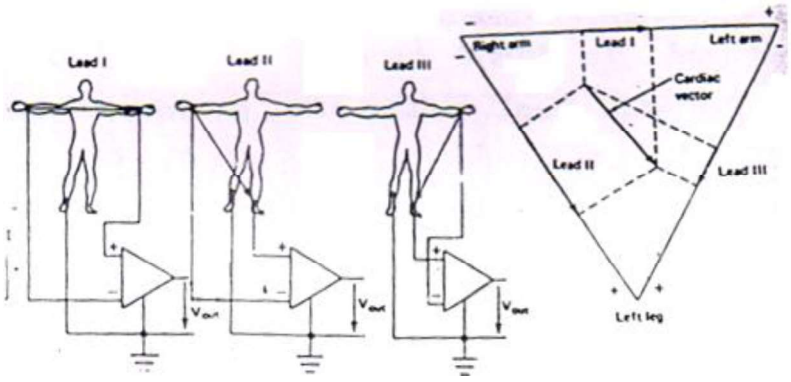


Fig : Standard bipolar limb leads and the corresponding ECG

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. The vector sum of the projections on all the three sides is equal to zero. By Kirchoff's law, the R wave amplitude of lead II is equal to the sum of R wave amplitudes of lead I and III. (ie) $V_{II} - V_I + V_{III.}$

2) Augmented unipolar Limb leads

In this, the electrocardiogram is recorded between a exploratory electrode and the central terminal. Two equal and large resistors are connected to a pair of limb electrodes and the center of this acts as central terminals.

The remaining limb electrode acts as exploratory electrode. Hence a small increase in ECG voltage can be realized. The augmented lead connections are augmented voltage right arms (aVR), augmented voltage left arm (aVL) and augmented voltage foot (aVF). By kirchoff's law, the augmented voltage can be written in term of standard leads voltages .aVR = $- V_1 - V_{III}/2$, aVL = $V_I - V_{II}/2$, aVF = $V_{II} - V_I/2$

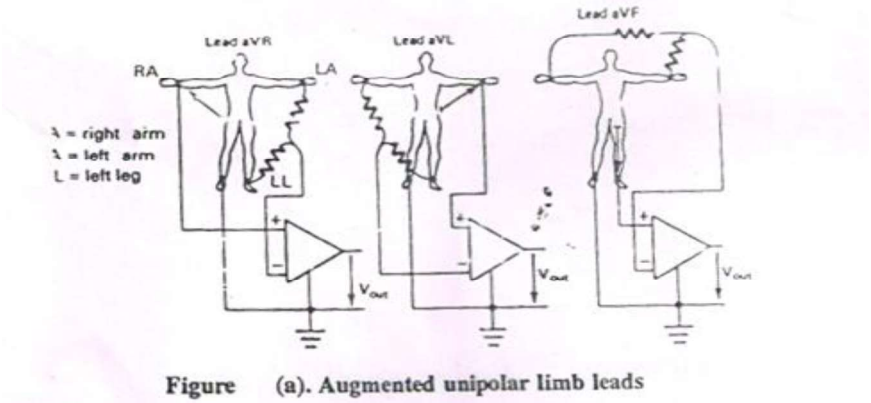


Figure (a). Augmented unipolar limb leads

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.

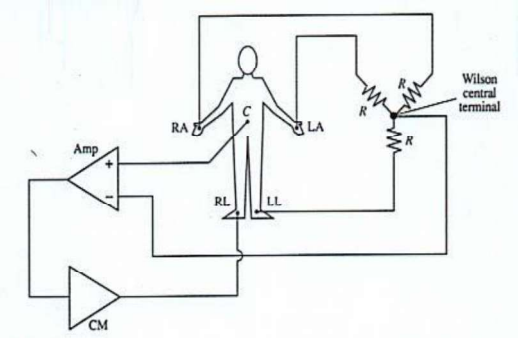


Fig : Unipolar chest leads

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

White – RA
Black – LA
Green – RL
Red _ LL
Brown – Chest

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. By this the input impedance is increased and the variations in electrode impedance are reduced.

The over voltage protection circuit is used to avoid any change to the bio amplifiers in the recorder.

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 enable to observe the output on display unit. From lead selector switch, ECG signal goes to bio-amplifier.

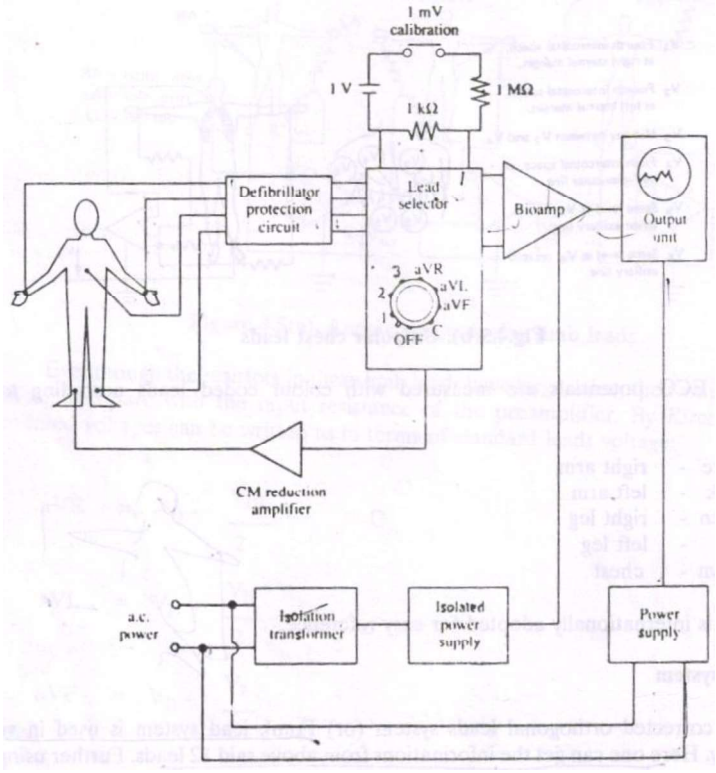


Fig : ECG Recording setup

iv) Bio-amplifier

The bio-amplifier consists of a preamplifier and power amplifier. The preamplifier should have high gain and high CMRR. The power amplifier is used to drive the recorder. It should have high power gain to activate the recording or display.

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^2_{out} / 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.

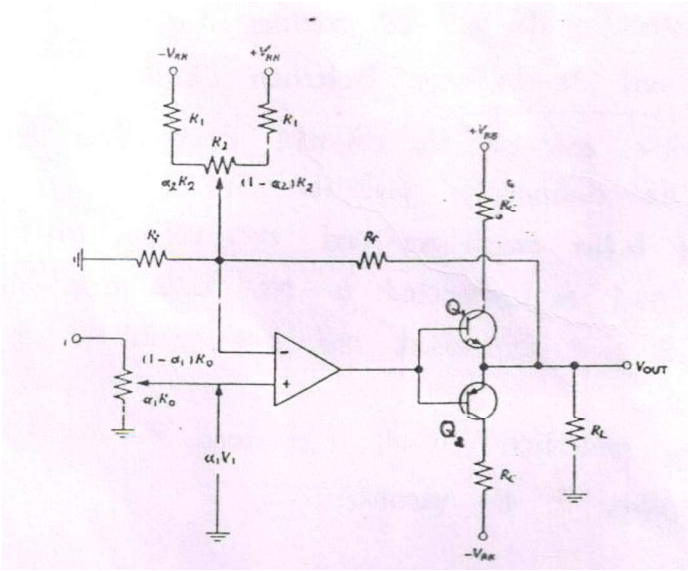


Fig:Push-pull power amplifier with crossover compensation and offset control

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. Thus common mode rejection ratio is increased and the current flow in the right leg electrode is reduced.

vi)Isolation power Supply

It is used give 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.

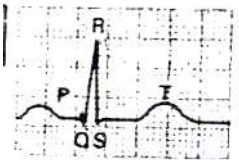
The stylus pen is heated and the temperature can be adjusted with a stylus heat control. A marker stylus is actuated by a push button and it marks a coded indication of the lead being recorded. The paper speed is made fast to allow better resolution of QRS complex at very high heart rates.

viii) Power switch

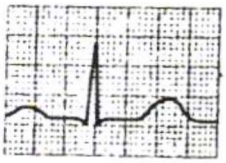
The power switch of the recorder has three positions. In ON position the power to the amplifier is turned on. But the paper drive is not running. In RUN position, the switch makes the paper drive to run. In OFF position, ECG unit is in switched off condition.

Analysis of Recorded ECG Signals

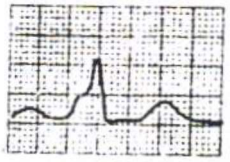
Fig. shows the analysis of different ECG signals.



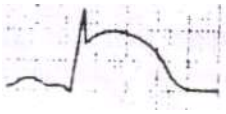
Normal ECG wave



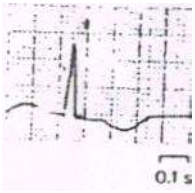
Here the PQ segment has prolonged conduction time
i.e greater than 0.22second
Result : First degree AV block



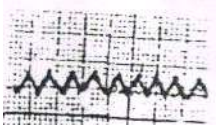
Here QRS complex is widened i.e QRS interval is greater than 0.1 second
Result: Bundle block



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.

There are different types of heart block

1 st degree AV block : Due to prolonged conduction time

2 nd degree AV block : due to conduction of few pulses instead of all from atrium

3 rd degree AV block : Due to asynchronous action of atrium and ventricle.

Adams – stokes attack : Due to sudden attack of total block

Bundle block : Due to improper conduction of stimulus to the ventricle.

Atrial fibrillation : Due to fast beating rate (300 – 500 beats/ min) of atrium. Here ventricles beat very slowly.

Ventricular fibrillation : Due to fast beating rate of ventricles. No pumping of blood to different parts of body.

Thus electrocardiography can diagnose any form of arrhythmia or disturbance in heart rhythm.

Vectorcardiography

In electrocardiography, only the voltage generated by the electrical activity of the heart is recorded. In vectorcardiography, the cardiac vector is displayed with its magnitude and spatial orientation. The spatial relations are displayed on a cathode ray oscilloscope. The signal is resolved into three images corresponding to the frontal, sagittal and transverse planes. There are three loops corresponding to P, QRS and T waves. The QRS loop is a dominating one. A Polaroid camera photographs the oscilloscope screen to provide a permanent record. In case of diseased heart like myocardial infarction,

Echocardiography

Echocardiography is an useful technique for diagnosis of heart diseases. Echocardiogram displays the time versus motion information about the intra– cardiac structures on slow speeds. Echocardiography is used for the detection of mitral stenosis and for preliminary screening test related to heart diseases. The piezoelectric transducer is placed between the third an d fourth rids on the outer chest wall. From this transducer, an ultrasonic beam is directed towards the heart and the reflected signals called echves are collected by the same transducer. Thus a single transducer acts as a transmitter and recelver alternatively. 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.

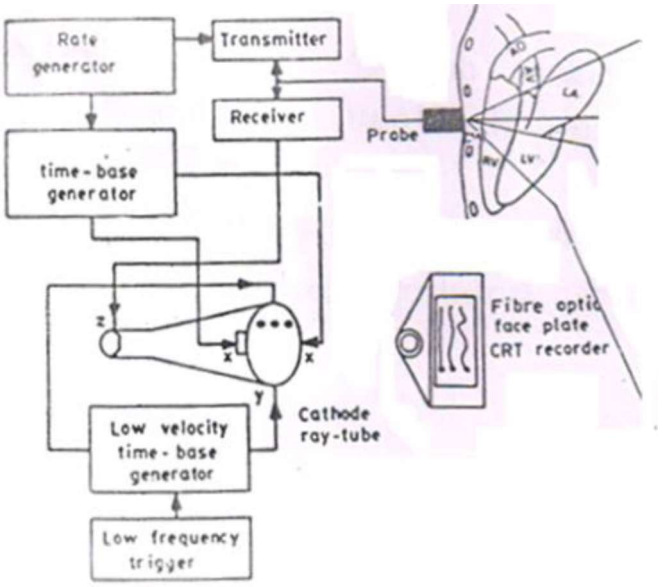


Fig : Block diagram of Echocardiograph and the typical Echocardiograms

M – Mode display

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.

1.7.3 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. The basic aim of phonocardiograph is to pick up the different heart sounds, filter out and to display them (or) record them. Heart sounds are acoustic phenomena resulting from the vibrations of cardiac structures. Acoustic events of the heart can be divided into two categories

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.

2) Amplitude: Low frequency heart sounds have the biggest amplitude while the high frequency murmurs have small amplitudes.
3) 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 semilunar 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) Pathalogic 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 sound are conducted from the heart to the of 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.

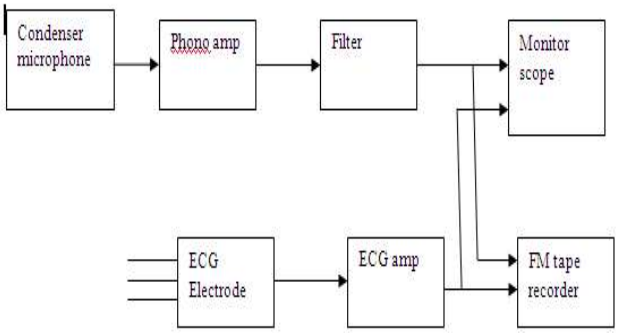


Fig: Block diagram of recording setup

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.

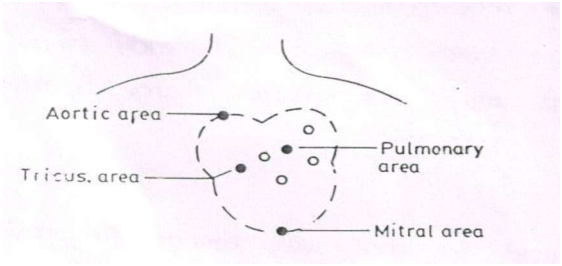


Fig : Placement of microphone on different areas of the chest for recording PCG

Heart sound microphone:

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 PCG 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 a low mechanical impedance to chest. In the second case, it is directly coupled to the chest wall and presents a higher impedance, high sensitivity, low noise and light weight.

The condenser microphone consists of a diaphragm which acts as the 'rotor' and the back plate as 'stator' of a variable capacitor. The two electrodes are spaced very close to each other. When a dc voltage is applied, a constant charge is maintained by electrodes.

$$C = Q/V$$

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.

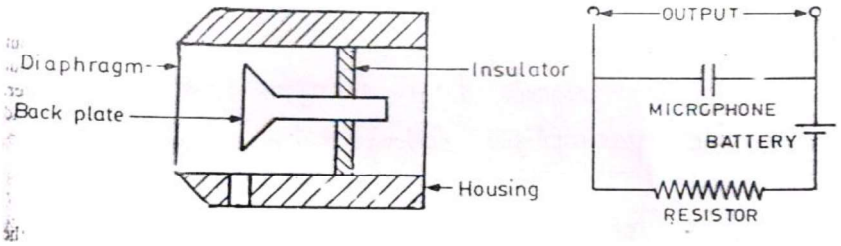
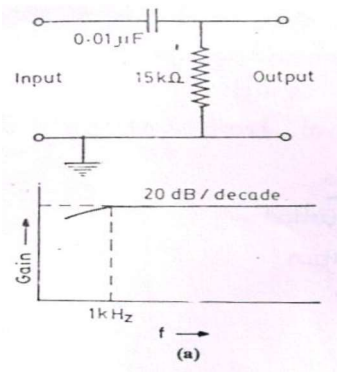


Fig : Condenser microphone along with its circuit

Filters for phonocardiogram.

Fig (a) shows the RC filter where the gradual slope is obtained. Fig(b) shows the active filter where a sharp cutoff is achieved.

Relationship between heart sounds and functions of cardiovascular



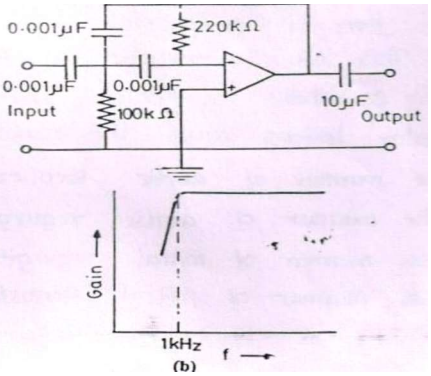
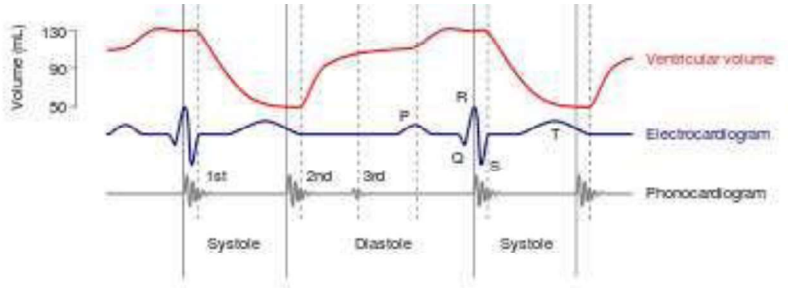


Fig : R.C filter **Fig: Active filter**

Relationship between heart sounds and function of cardiovascularvsystem

ECG wave occurrence	PCG wave occurrence
QRS Complex	1st heart sound
End of T wave	2nd heart sound
Beginning of P wave	3rd heart sound



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

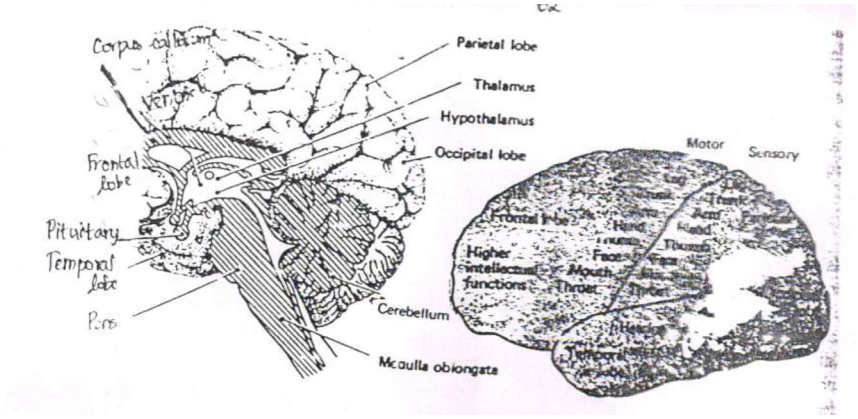
1) Fetal phonocardiogram
2) Esophageal phonocardiogram
3) Tracheal phonocardiogram

1.7.4 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. These voltage are about 10 mV on the surface of brain and they are attenuated from 1 to 100 μV. Frequency range is from 0.5 to 3000 Hz. During recording, the electrodes are placed around the frontal parietal, temporal and occipital lobes of brain. Electroencephalogram is the record of brain waves made by an electroencephalograph.

1)Anatomy of brain

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



Cerebrum consists of two hemispheres and the hemisphere are divided into frontal lobe, parietal lobe, occipital lobe and temporal lobe. The frontal lobe is for intelligence. The upper side of temporal lobe consists of hearing center. The posterior part of occipital lobe consists of viston center. The anterior part of parietal lobe has sensory center and motor center. The temporal lobes are for storage process in the long term memory.

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 (IPSP)

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. The receptor neuron is more likely to discharge and produces a spike potential. This induced charge is called an EPSP.

Evoked potentials

Evoked potential are the potentials developed in the brain as the responses to external stimuli like sound, light etc. The external stimuli are detected by sense organs which causes changes in electrical activity of brain. Now – a - days evoked potential is termed as 'event related potential' because some changes that are evoked by an external stimulus but are related to an event.

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. The intensities of brain waves range from 0 – 300 μV and their frequencies range from few seconds to 50 per seconds. Brain waves are irregular and it has no general pattern. They can be classified into alpha, beta, theta and delta waves.

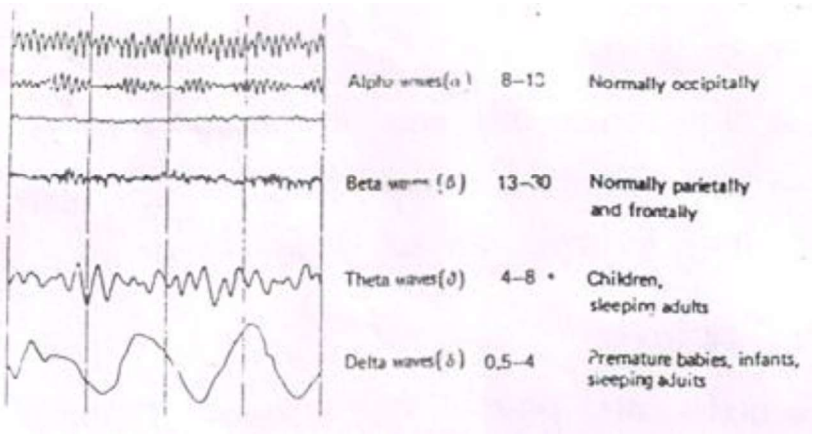


Fig:Brain Waves

Alpha waves

Frequency : 8 – 13 Hz

Occurrence : They found in normal persons when they are awake in a quiet, resting 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

In adults, they occur during emotional stress particularly during disappointment and frustration.

Delta waves

Frequency : 0.5 – 4 Hz

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.

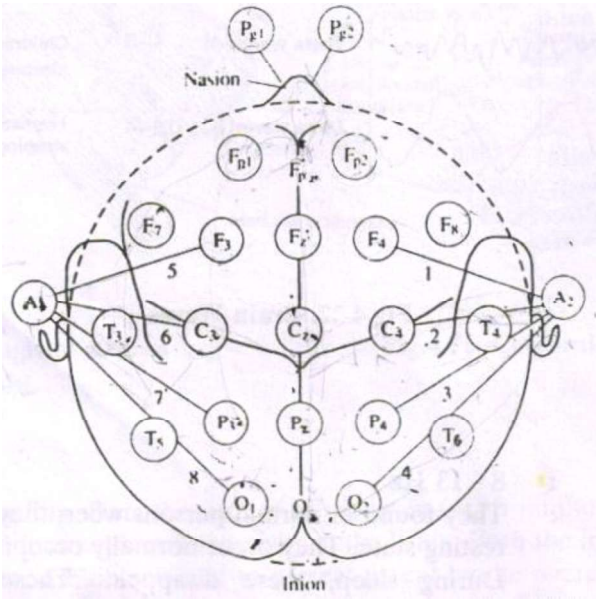


Fig : Placement Of electrode

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. The electrode systems are used to facilitate the location of foci, (ie) cortical areas from which abnormal waves spread.

In bipolar technique, the different in potential between two adjacent electrodes is measured. In monopolar (unipolar) technique, the potential of each electrode is measured w.r.t a reference electrode attached to ear lobe or nostrils. In Wilson technique, potential is measured between one of the electrode and the central terminal.

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.

EEG unit is covered with ferrous metal screen to reduce a,c interference.The input impedance of preamplifier should be more than 10MΩ to prevent reduction of signal amplitude. By cascading gain can be increased to drive the recorder or imaging CRT.

The output voltage from the amplifier is applied to the eight channel display through the filter bank.

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.

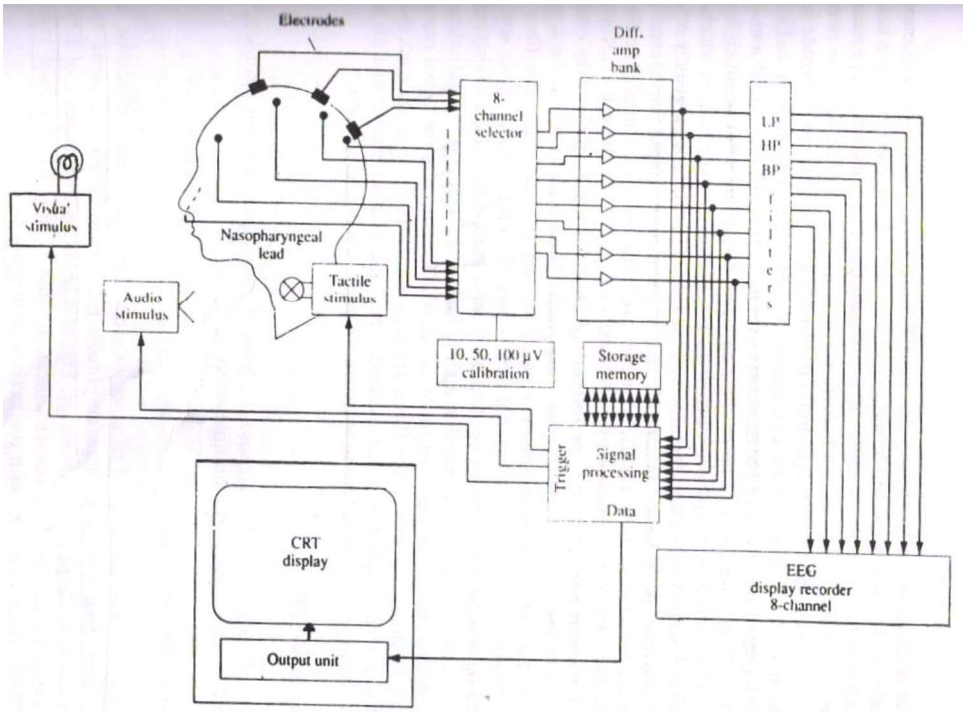


Fig : Modern EEG Unit

5) 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. As anaesthesia is applied, brain wave frequency decreases and the amplitude increases. Thus theta and delta waves appear. In cerebral (brain) death, EEG shows a permanent absence of brain wave.

ii) Brain Tumors

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 an 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.
(i) 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.

1.7.5 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.

The electrical activity of the muscle can be measured by placing surface electrodes on the skin. To record the action potentials of individual motor units, needle electrode is inserted into the muscle.

EMG indicates the amount of activity of a given muscle or a group of muscles and not an individual nerve fiber. The action potentials occurs both positive and negative polarities at a given pair of electrodes, so they add or cancel each other.

Thus EMG appears like a random noise waveform. The contraction of a muscle produces action potential. In a relaxed muscle, there is no action potential.

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.

The electrodes are kept in place by means of elastic bands. Hence the contact impedance is reduced below 10 kΩ. There are two types of conventional electrodes bipolar & unipolar. In bipolar electrode, the potential difference between the two surface electrodes on the skin is measured.

In unipolar electrode, the reference electrode is placed on the skin and the needle electrode is inserted into the muscle.

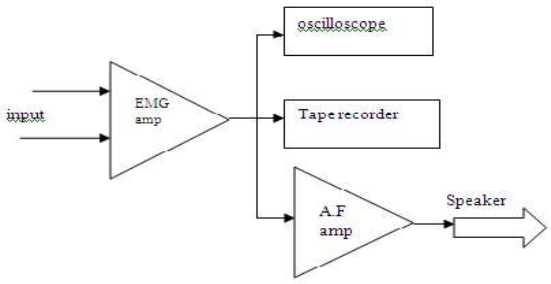


Fig : Block diagram for EMG recording setup

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. Needle electrode picks up the voltage from a single muscle fiber. EMG signals range from 0.1 to 0.5 mV.

They contain frequency components from 20 Hz to 10 kHz. By using LPF, EMG restricts to 20 Hz to 200 Hz for clinical purpose.

The normal frequency of EMG is about 60 Hz. The signals are displayed on a cathode ray oscilloscope and photographic recordings are made. There are two cathode ray tubes, one for viewing and other one for recording.

A light sensitive paper moves over the recording cathode ray tube and the image is produced on that paper. After developing it, we can see the visible image.

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.

The myographer can listen the sounds from the loud speaker and from that he can diagnose the neuromuscular disorders. EMG is very useful for studying the neuromuscular function, reflex responses and diagnosing the muscular diseases.

Determination of conduction velocities in motor nerves.

The measurement of conduction velocity is used to indicate the location and type of nerve lesion. The nerve function is examined directly by stimulation it with a electric shock having a pulse duration of 0.2 – 0.5 ms and measuring the latencies, by that we can calculate the

conduction velocity in that peripheral nerve. Latency is defined as the elapsed time between the stimulating impulse and muscle's action potential

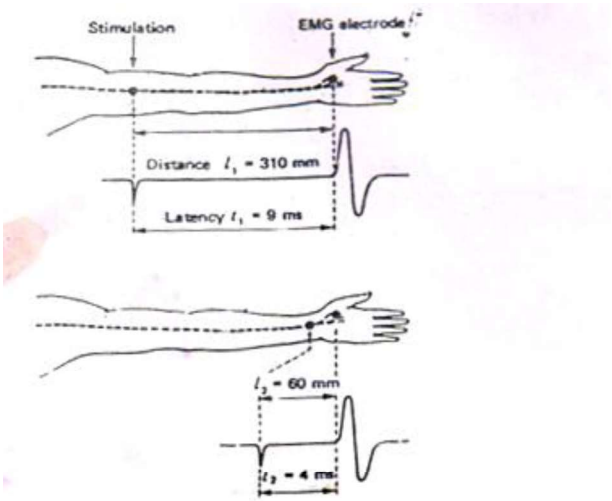
The EMG electrode and stimulating electrode are placed at two points on the skin, separated by a known distance l_1.An electrical pulse is applied through the stimulating electrode.

All the nerve fibers are stimulated at the same time and the conduction velocity is same in all nerve fibers. Hence there is a synchronous activation of muscle fiber. This action potential of the muscle is picked by the EMG electrode and is displayed on the oscilloscope along with the stimulating impulse.

The elapsed time 't_1' (latenoy) between the stimulating impulse and muscle's action potential is measured. Now the two electrodes are repositioned with a distance of l_2m. now $l_2 < l_1$. 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.



Determination of conduction velocity in a motor nerve