

TYPICAL WAVEFORMS AND SIGNAL CHARACTERISTICS

P wave :

During normal atrial depolarization, the main electrical vector is directed from the SA node towards the AV node, and spreads from the right atrium to the left atrium. This turns into the P wave on the ECG, which is upright in II, III, and aVF (since the general electrical activity is going toward the positive electrode in those leads), and inverted in aVR (since it is going away from the positive electrode for that lead). A P wave must be upright in leads II and aVF and inverted in lead aVR to designate a cardiac rhythm as Sinus Rhythm.

- The relationship between P waves and QRS complexes helps distinguish various cardiac arrhythmias.
- The shape and duration of the P waves may indicate atrial enlargement.
- Absence of the P wave may indicate atrial fibrillation. A saw tooth formed P wave may indicate atrial flutter
- The QRS complex is a structure on the ECG that corresponds to the depolarization of the ventricles.

Because the ventricles contain more muscle mass than the atria, the QRS complex is larger than the P wave. In addition, because the His/Purkinje system coordinates the depolarization of the ventricles, the QRS complex tends to look "spiked" rather than rounded due to the increase in conduction velocity. A normal QRS complex is 0.08 to 0.12 sec (80 to 120 ms) in duration represented by three small squares or less, but any abnormality of conduction takes longer, and causes widened QRS complexes.

PR/PQ interval:

The PR interval is measured from the beginning of the P wave to the beginning of the QRS complex. It is usually 120 to 200 ms long. On an ECG tracing, this

corresponds to 3 to 5 small boxes. In case a Q wave was measured with a ECG the PR interval is also commonly named PQ interval instead

ST segment:

The ST segment connects the QRS complex and the T wave and has a duration of 0.08 to 0.12 sec (80 to 120 ms). It starts at the J point (junction between the QRS complex and ST segment) and ends at the beginning of the T wave. However, since it is usually difficult to determine exactly where the ST segment ends and the T wave begins, the relationship between the RT segment and T wave should be examined together. The typical ST segment duration is usually around 0.08 sec (80 ms). It should be essentially level with the PR and TP segment

T wave:

The T wave represents the repolarization (or recovery) of the ventricles. The interval from the beginning of the QRS complex to the apex of the T wave is referred to as the absolute refractory period. The last half of the T wave is referred to as the relative refractory period (or vulnerable period).

QT interval :

The QT interval is measured from the beginning of the QRS complex to the end of the T wave. Normal values for the QT interval are between 0.30 and 0.44 seconds. The QT interval as well as the corrected QT interval are important in the diagnosis of long QT syndrome and short QT syndrome. Long QT intervals may also be induced by antiarrhythmic agents that block potassium channels in the cardiac myocyte. The QT interval varies based on the heart rate, and various correction factors have been developed to correct the QT interval for the heart rate. The QT interval represents on an ECG the total time needed for the ventricles to depolarize and repolarize.

U wave :

The U wave is not always seen. It is typically small, and, by definition, follows the T wave. U waves are thought to represent repolarization of the papillary muscles or Purkinje fibers. Prominent U waves are most often seen in hypokalemia, but may be present in hypercalcemia, thyrotoxicosis, or exposure to digitalis, epinephrine, and Class 1A and 3 antiarrhythmics, as well as in congenital long QT syndrome and in the setting of intracranial hemorrhage. An inverted U wave may represent myocardial ischemia or left ventricular volume overload.

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EC 8073 – MEDICAL ELECTRONICS

UNIT – I

ELECTRO – PHISIOLOGY AND BIO POTENTIAL RECORDING

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 form 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 $-R_d'$.

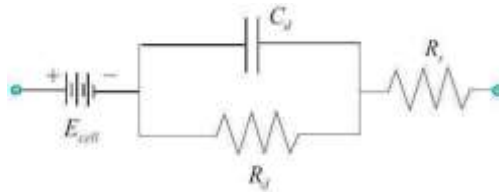


Fig 1.12: surface electrode equivalent circuit

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 depends 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

$$E = \frac{RT}{NF} \ln \frac{C_1 \cdot f_1}{C_2 \cdot f_2}$$

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.

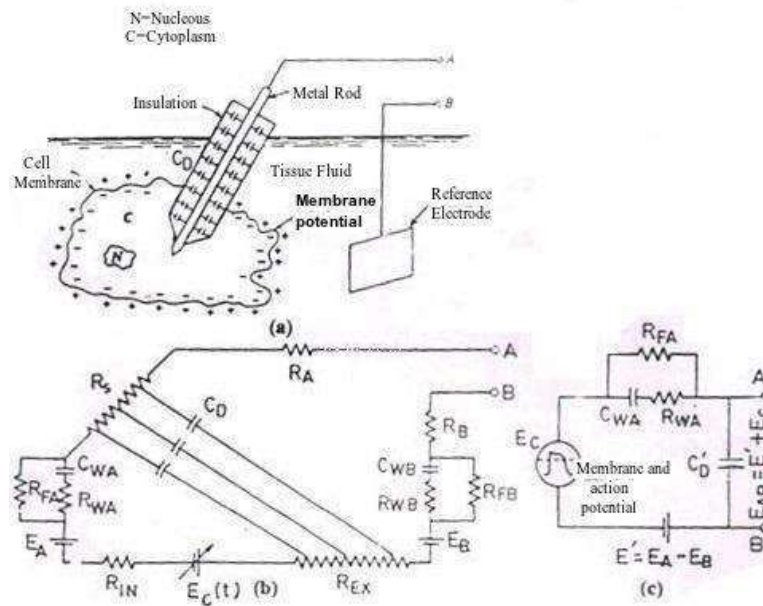


Fig 1.13: Metal Microelectrode

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 about 1 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

$$E = E_A + E_B + E_D$$

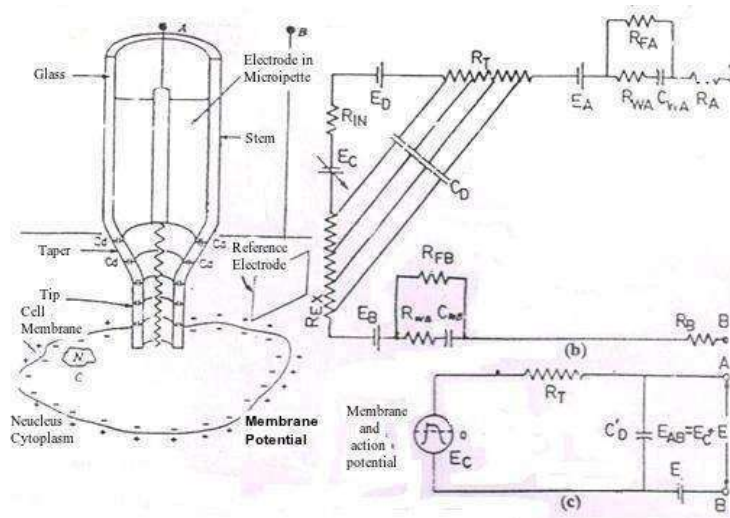


Fig 1.14: Micropipet

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 neurons 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.

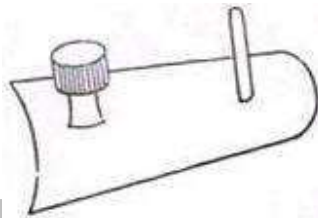


Fig 1.15: Metal plate Electrodes ii) Suction Cup Electrode

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.

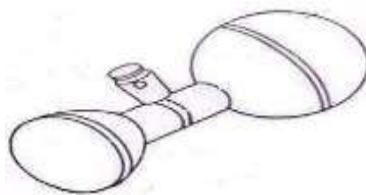


Fig 1.16: Suction Cup electrode iii) Adhesive Tape Electrode

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

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.

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.

EC 8073 – MEDICAL ELECTRONICS

UNIT – I

ELECTRO – PHYSIOLOGY AND BIO POTENTIAL RECORDING

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 chambers are atria and lower two chambers are ventricles.

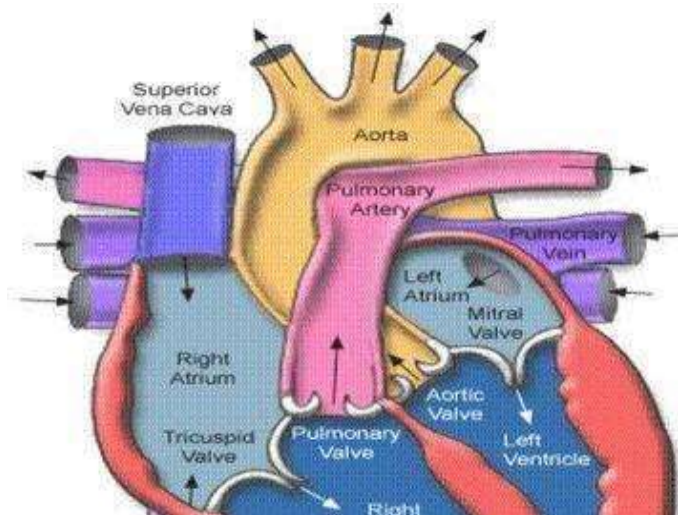


Fig 1.18: Cross Section of the Interior of the Heart

Table 1.1 Physiological Nature of ECG Waveform

	Origin	Amplitude mV	Duration sec
P Wave	Atrial depolarization or contraction		0.12 to 0.22 (P-R interval)
R wave	Repolarisation of the atrial and the depolarization of the ventricles	1.60	0.07 to 0.1
S-T interval	Ventricular repolarisation (Relaxation of myocardium)	0.1 to 0.5	0.05 to 0.15 (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 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 potentials 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 limb lead positions and the corresponding wave patterns.

Lead I position – gives 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)

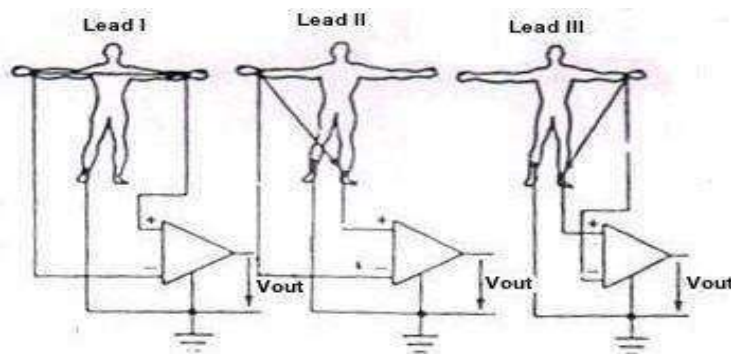


Fig 1.20: Standard Bipolar Limb Leads and the Corresponding

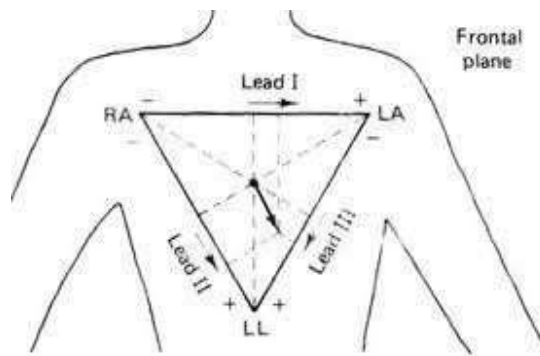


Fig 1.21: Einthoven Triangle

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 an exploratory electrode and the central terminal.

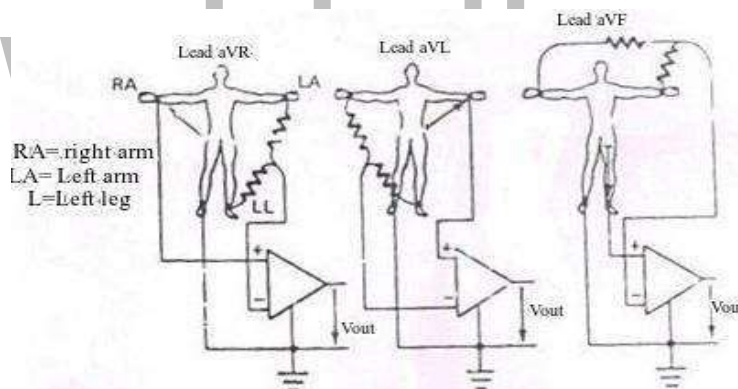


Fig.1.22: Augmented Unipolar Limb Leads

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

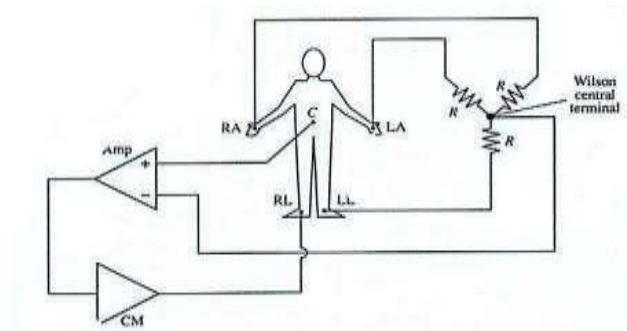


Fig.1.23: Unipolar Chest Leads

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.

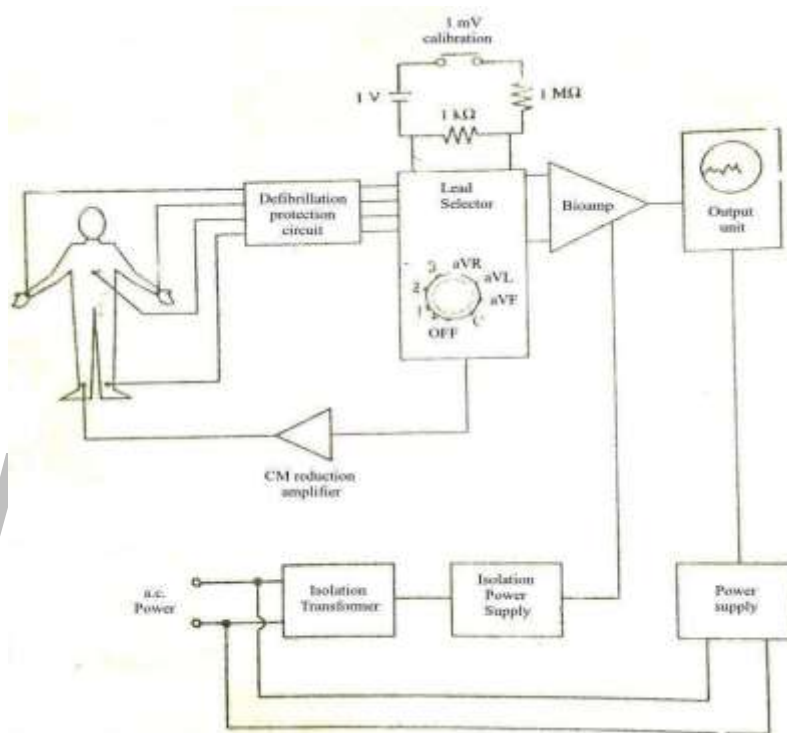


Fig1.24: ECG Recording Setup iv) Bio-Amplifier

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.

$$\text{Output power } p_{out} = V_{out}^2 / R_L$$

Amplifier efficiency $\eta = P_{out} / (P_{out} + P_{loss})$

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 .

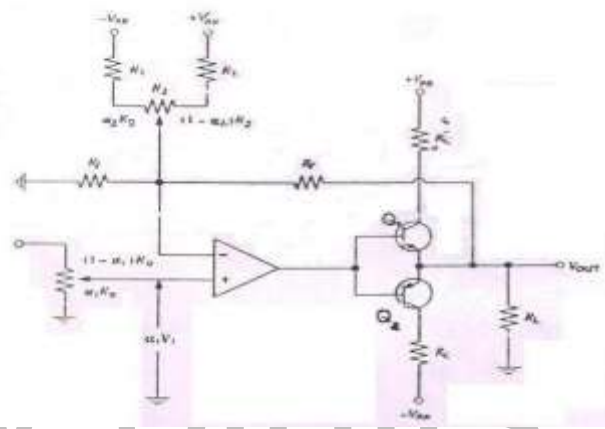


Fig.1.25: Push-Pull Power Amplifier with Crossover Compensation and Offset Control

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

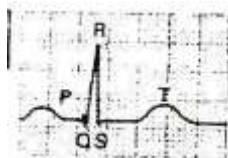
In paper chart recorder, the power amplifier or pen amplifier supplies the required power to drive pen motor. Pen motor records the ECG trace on the wax coated heat paper. A position control is used to position the pen at the center on the recording paper.

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 Signal

Fig. shows the analysis of different ECG signals.

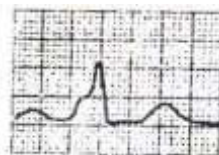


Normal ECG



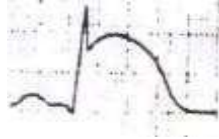
Here the PQ segment has prolonged conduction time i.e greater than 0.22second

Result: First degree AV block



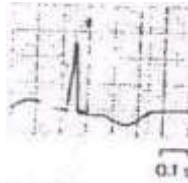
Here QRS complex is widened i.e QRS interval is greater than 0.1 second

Result: Bundle block



Here ST segment is elevated

Result: Myocardial infraction



Here 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 is called heart block.

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 skull 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.

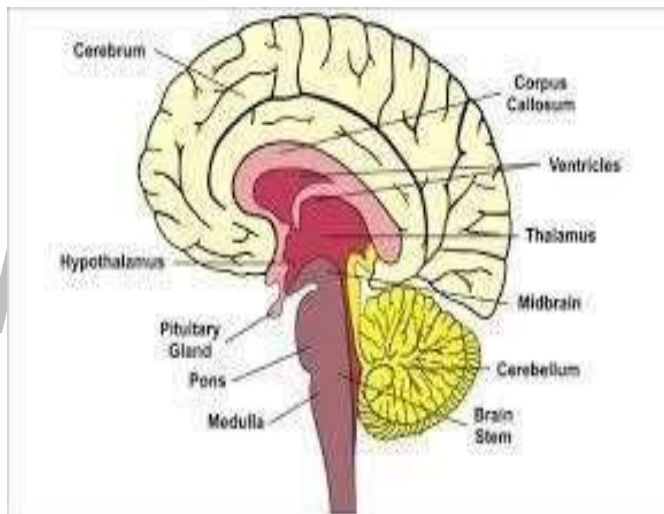


Fig 1.6.1: Internal structure of Human brain

[Source: Khandpur, R.S., —Handbook of Biomedical Instrumentation]

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

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.

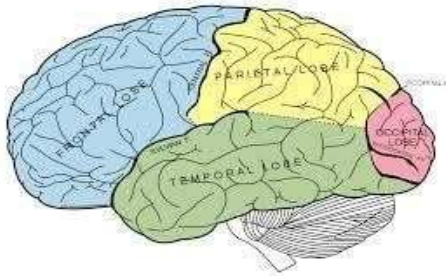


Fig 1.6.2: Human Brain

[Source: Khandpur, R.S., —Handbook of Biomedical Instrumentation]

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.

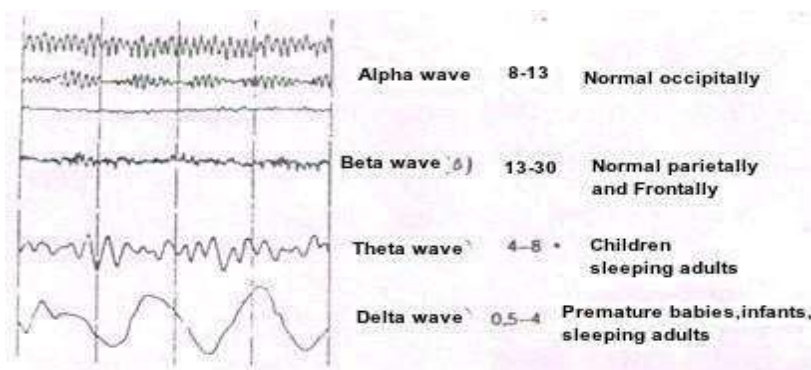


Fig 1.6.3: Brain Waves

[Source: Khandpur, R.S., —Handbook of Biomedical Instrumentation]

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 sleep, 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 skull in an arrangement called 10 – 20 system. The electrodes are arranged as follows.

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

- 1) Draw a similar line from the left preauricular (ear) point to the right preauricular point.
- 2) Mark the intersection of two lines as Cz which is the midpoint of distance

nasion andinion.

- 3) Mark points Fpz, Fz, Cz, Pz and Oz at 10, 20, 20, 20, and 10% of total nasion – inion distance. Mark points T3, C3, Cz, C4, and T4 at 10, 20, 20, 20 and 10% of total distance between preauricular points. Measure the distance between Fpz and Oz along the circle passing through T3, and mark points as Fp1, F7, T3, T5, and O1 at 10, 20, 20, 20 and 10% of this distance.
- 4) Repeat this procedure on right side and mark the positions as Fp2, F8, T4, T6, and O2.

Measure the distance between Fp1, and O1 along the circle passing through C3 and mark point as F3, C3, and P3 at 25% intervals.

- 5) Repeat this procedure on right side and mark as F4, C4 and P4.

Check that F7, F3, Fz, F4 and F8 are equidistant along transverse circle passing through F7, Fz, and F8 check that T5, P3, Pz, P4, and T6, are equidistant along transverse circle passing through T5, Pz, & T6

Pg1 AND Pg2 are nasopharyngeal electrodes and A1 and A2 are ear electrodes.

Pg1 and Pg2 are nasopharyngeal electrodes and A1 and A2 are ear electrodes.

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

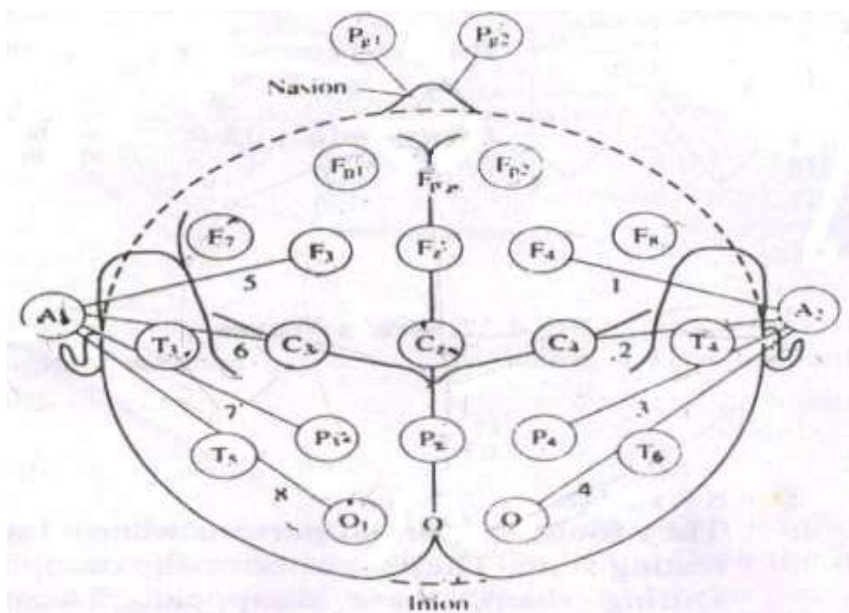


Fig 1.6.4: Placement of Electrodes on the Scalp for the EEG Recording

[Source: Khandpur, R.S., —Handbook of Biomedical Instrumentation]

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 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.

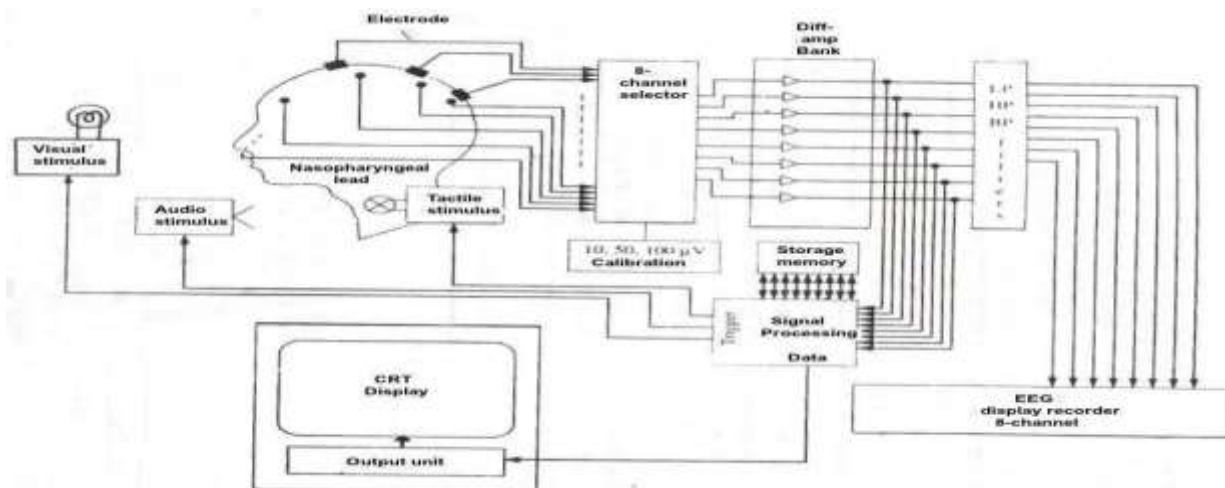


Fig 1.6.5: Fig: Modern EEG Unit

[Source: Khandpur, R.S., —Handbook of Biomedical Instrumentation]

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.

ii) Epilepsy

Epilepsy is a symptom for brain damage. It may be 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

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

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

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.

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

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

The person has to do yoga for some time. After some period, once again EEG is recorded for same person.

Then it is compared with previous wave form different gives the effect of yoga

During EMG test

- Small flat metal discs called electrodes are attached to the scalp with wires. The electrodes analyze the electrical impulses in the brain and send signals to a computer that records the results.
- The electrical impulses in an EEG recording look like wavy lines with peaks

and valleys. These lines allow doctors to quickly assess whether there are abnormal patterns.

- EEGs are safe and painless.
- During EEG test avoid anything with caffeine on the day of the test because it can affect the test results.
- During test, patient should wash the hair in night before or the day of the test, but patient should not use conditioners, hair creams, sprays or styling gels. Hair products can make it harder for the sticky patches that hold the electrodes to adhere to the scalp.

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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

Electrodes used

- EMG is usually recorded by using surface electrodes or needle electrodes, which are directly inserted into the muscles.
- Surface electrodes or needle electrodes pick up the potentials produced by contracting muscle fibers.
- The surface of the skin is cleaned and electrode paste is applied.
- The needle is inserted into the muscle to record the action potentials from a single nerve, microelectrodes are used.

Some symptoms which make to test EMG include:

- Pain or cramping Tingling or numbness Muscle weakness Setup of EMG
- The surface electrode or needle electrodes pick up the potentials produced by contracting muscle fibers.
- After an electrode has been inserted, patient may be asked to contract the muscle, for example, by lifting or bending your leg. The action potential (size and shape of the wave) that this creates on the oscilloscope provides information about the ability of the muscle to respond when the nerves are stimulated

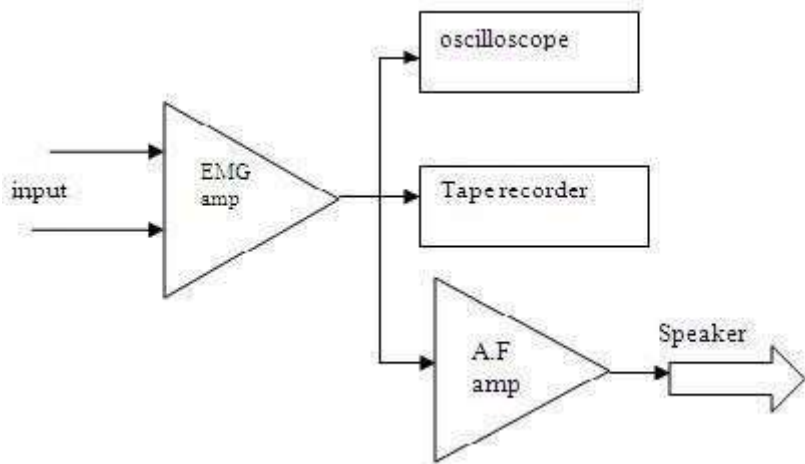


Fig:1.71 Block Diagram for EMG Recording Setup

[Source: Khandpur, R.S., —Handbook of Biomedical Instrumentation]

- EMG recording instruments includes audio amplifier and loud speaker to permit the operator to hear.
- The audio presentation helpful in placement of needle or wire electrodes into a muscle.
- The oscilloscope displays EMG waveform.
- The tape recorder is used to study of EMG sound waveforms.
- Related procedure that may be performed is nerve conduction study (NCS) can be done by nerve conduction measurement.
- NCS is a measurement of the amount and speed of conduction of an electrical impulse through a nerve.
- The technician puts electrode patches on the skin over the nerve. A stimulating electrode sends a mild electrical impulse to the nerve. The other electrodes record the nerve's response.

- NCS can determine nerve damage and destruction, and is often performed at the same time as EMG.
- Both procedures help to detect the presence, location, and extent of diseases that damage the nerves and muscles.

EMG and NCS are helpful in diagnosing:

- Neuromuscular diseases, such as muscular dystrophy.
- Nerve problems in the spine, such as a herniated disk
- Nerve problems elsewhere in the body, such as carpal tunnel syndrome.
- Peripheral nerve problems in your arms or legs
- Pinched nerves.
- Guillain-Barré syndrome, a disease in which the immune system attacks the nerves in your legs and arms.

During this EMG measurement

- When the study is underway, the surface electrodes will at times transmit a tiny electrical current that patient may feel as a twinge or spasm.
- The needle electrode may cause discomfort or pain that usually ends shortly after the needle is removed.

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 . 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.

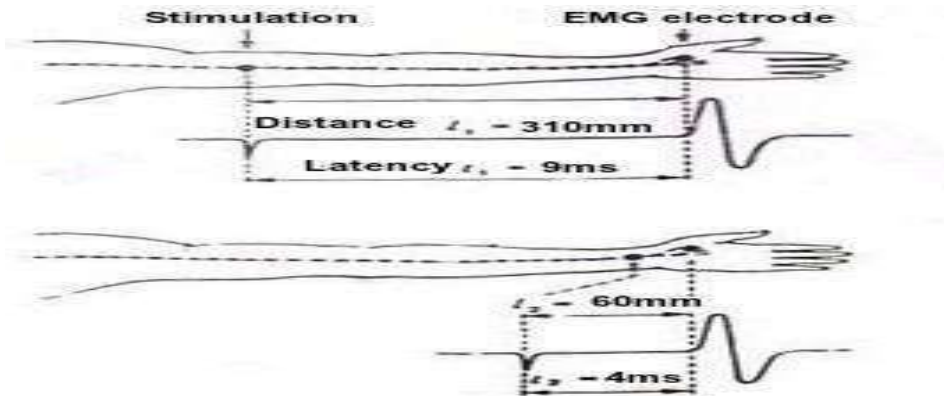


Fig 1.7.2 : Determination of Conduction Velocity in a Motor Nerve

[Source: Khandpur, R.S., —Handbook of Biomedical Instrumentation]

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

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) Auscultatory Area: It is best heard in the aortic and pulmonary areas.

2) **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) Auscultatory Area: It is best heard at the apex and left lateral position after lifting the legs.

3) **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) Auscultatory 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 chest.

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.

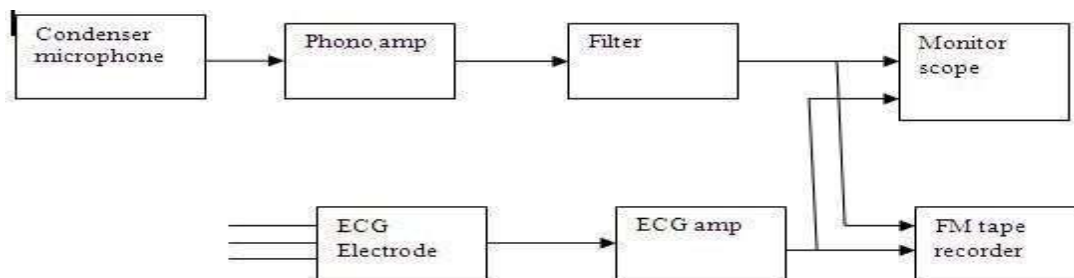


Fig.1.7.1: Block diagram of recording setup

[Source: Leslie Cromwell, —Biomedical Instrumentation and Measurement, Prentice Hall of India, New Delhi, 2007. – Page: 227]

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.

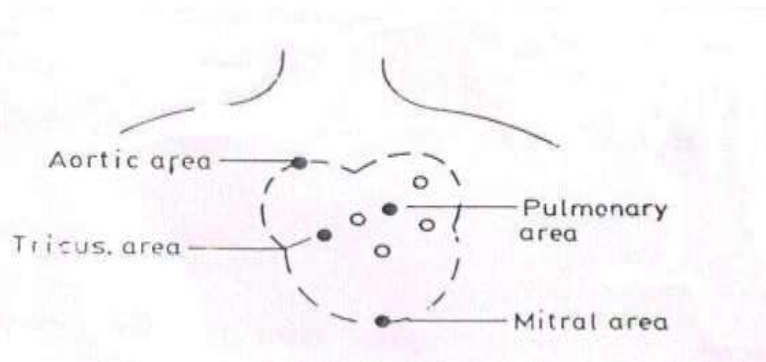


Fig1.7.2: Placement of Microphone on Different Areas of the chest for Recording PCG Heart Sound Microphone

[Source: Leslie Cromwell, —Biomedical Instrumentation and Measurement, Prentice Hall of India, New Delhi, 2007. – Page: 228]

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 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

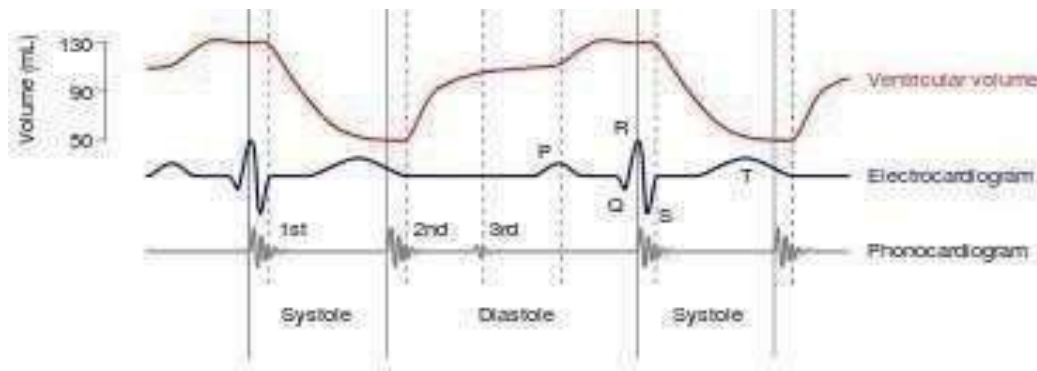


Fig 1.7.3: ECG waveform vs PCG waveform

[Source: Leslie Cromwell, —Biomedical Instrumentation and Measurement, Prentice Hall of India, New Delhi, 2007. – Page: 229]

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.

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

EC 8073 – MEDICAL ELECTRONICS

UNIT – I

ELECTRO – PHYSIOLOGY AND BIO POTENTIAL RECORDING

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.

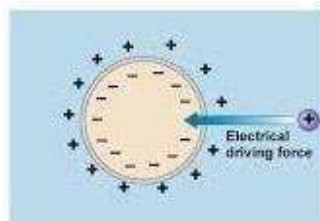


Fig 1.1: Polarized cell with its resting potential

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 varies from 60 to 100mV. The resting potential V_r 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- Charge of electron

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

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

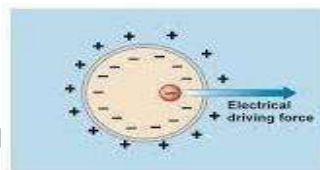


Fig 1.2: Depolarized cell with action potential

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.

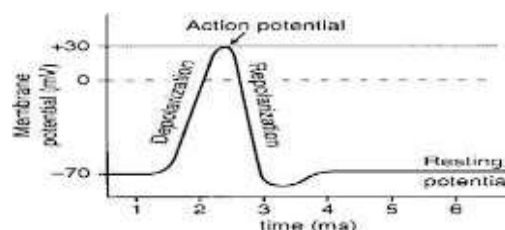


Fig 1.3: waveform of the action potential, (Time scale varies with type of cell)

The net height of action potential 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:** 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.

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.

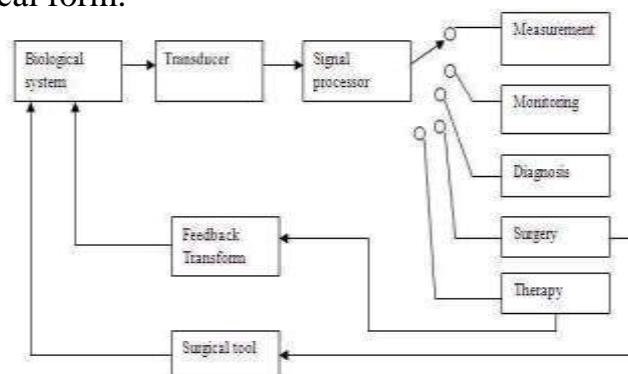


Fig 1.4: Block Diagram of a Generalized Bio-Medical Instrument System

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 $Z_i = \beta^2 Z_0$; β - Current amplification factor. The emitter of θ_1 is connected to base of θ_2 and both collectors share a common load 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.

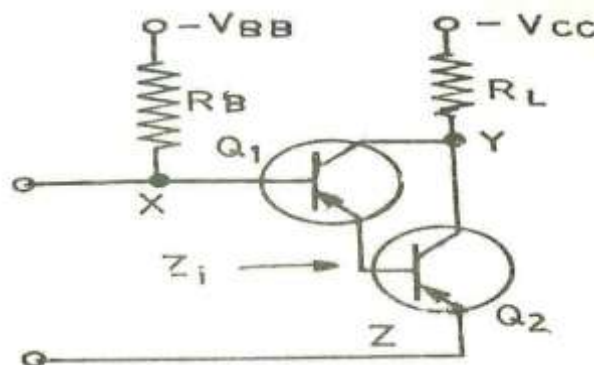
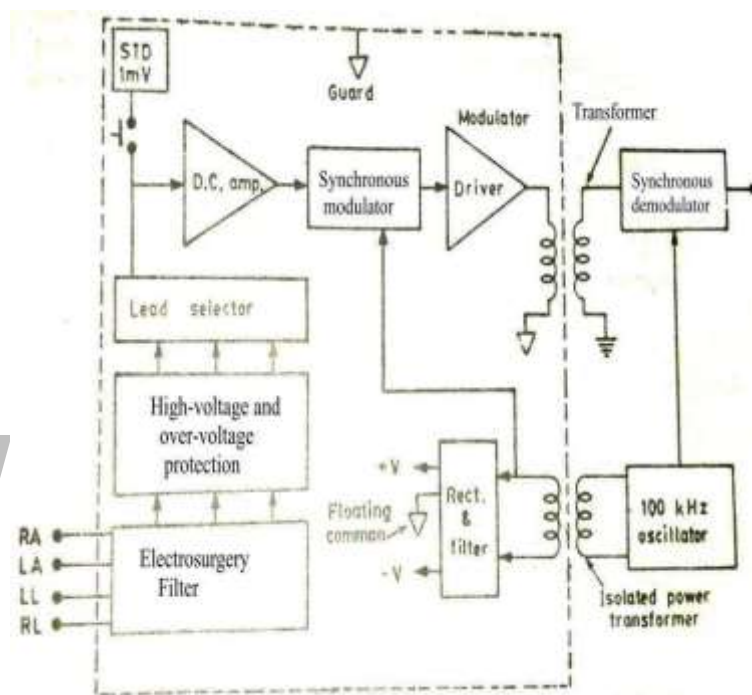


Fig 1.5: Darlington Pair

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



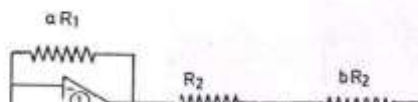
output is given to a d.c amplifier.

Fig1.6: Block Diagram of Transformer Coupled ECG Isolation Amplifier Circuit

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_o^{11} is the output of second op-amp.

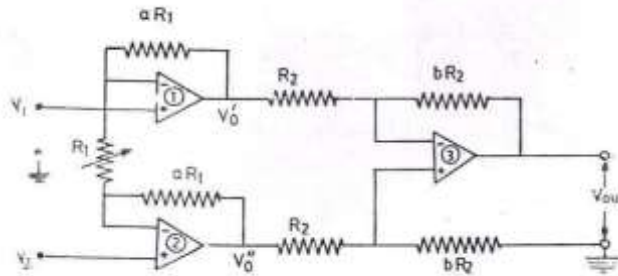


Fig1.7: Medical Preamplifier Bridge amplifiers:

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

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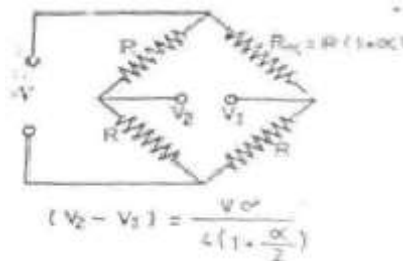


Fig 1.8: Bridge Amplifier for Voltage Readout

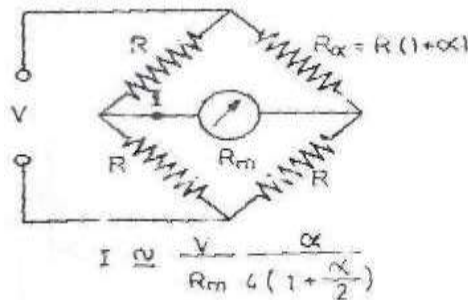


Fig1.9: Bridge Amplifier for Current Readout

In both bridge, the unbalance is measured by measuring the unbalance voltage or unbalance current. It is a measure of fractional change $\frac{\Delta R}{R}$ in resistance of transducer R . 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 of mechanical and non-mechanical chopper.

i) Mechanical Chopper Amplifier:

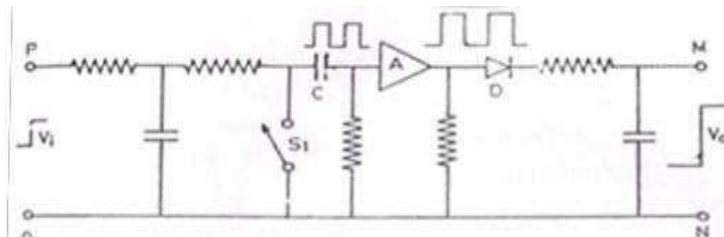


Fig 1.10: Chopper amplifier using a mechanical switch

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 .

ii) Non mechanical Chopper Amplifier:

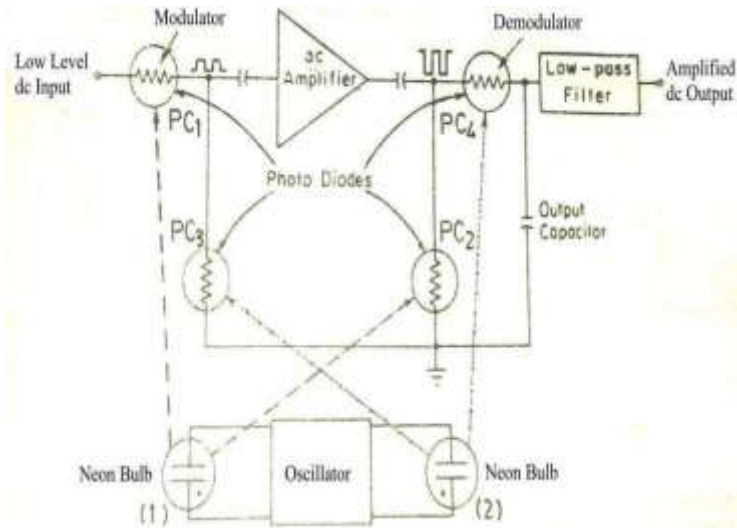


Fig 1.11: Non Mechanical Photoconductive Chopper Amplifier

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.