

MAR GREGORIOS COLLEGE OF ARTS & SCIENCE

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DEPARTMENT OF ELECTRONICS & COMMUNICATION SCIENCE

SUBJECT NAME: MEDICAL ELECTRONICS

SUBJET CODE: TEGAE

SEMESTER: VI

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MEDICAL ELECTRONICS

UNIT-1

BIO-AMPLIFIERS: Bio potentials - bio - electricity, Necessity for special types of amplifiers for biological signal amplifications - different types of Bio-OP-AMPS.

UNIT-2

BIO-POTENTIAL RECORDING: ECG - EEG - EMG - ERG - Specific types of electrodes used - different lead systems - their waveforms.

UNIT-3

MEASUREMENT OF BIOLOGICAL PARAMETERS -Measurement of respiration rate - measurement of heart beat rate - measurement of temperature - measurement of blood pressure - patient monitoring set up - blood flow meters EM and plethsmographic technique.

UNIT-4

HIGH ENERGY RADIATION APPLICATIONS : Applications of X-ray and isotopes for diagnostics and therapeutic applications - application of Lasers in biological medium.

UNIT-5

HIGH FREQUENCY APPLICATIONS: Diathermy effect - Short wave diathermy - Ultrasonic diathermy - Microwave diathermy.

UNIT I

ORIGIN OF BIO-POTENTIALS

Bioelectric potentials are ionic voltages produced as a result of electrochemical activity of certain special types of cells such as nerve cell or muscle cells. Special types of cells like nerve and muscle cells in the body are encased in semi-permeable membrane that permits some substance to pass through the membrane while others are kept out.

The cells are surrounded by fluid. The fluid contains ions such as sodium, potassium, chloride etc. The fluid outside the cell membrane is called as Extracellular fluid (ECF) and the fluid inside the cell membrane is called as Intracellular fluid (ICF). ICF is rich in K^+ , Mg^{++} , phosphates and ECF is rich in Na^+ , Cl^- .

In normal condition when the semi-permeable membranes are in polarised state, Sodium (Na^+) ions will be outside the membrane. Since the size of Na^+ ions is more than the size of holes in semi-permeable membrane, they cannot enter inside whereas other ions like potassium (K^+) and Chloride (Cl^-) can enter the membranes and exhibits resting potential. The sodium ions can enter the membrane when the holes of it are increased by stimulation (excitation). After stimulation of membrane, all sodium ions can enter inside by its increased diameter of pores or holes. It constitutes depolarisation and gives action potential.

Resting Potential:

Fluids surrounding the cells of the body are conducting. These conductive solutions contain atoms known as ions. Principal ions present are: Sodium- Na^+ , Potassium- K^+ and Chloride- Cl^- . The membrane of excitable cells readily permits entry of K^+ and Cl^- , but effectively blocks Na^+ ions. According to concentration and electric charge, various ions seek a balance between inside and outside of cell. Due to inability of Na^+ , to penetrate the membrane results two conditions:

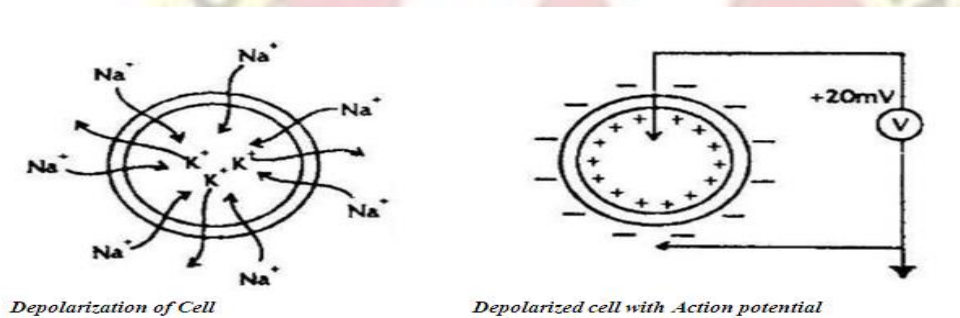
The Na^+ ions inside the cell become much lower than in the Extracellular fluid outside. (Sodium ions are +ve. It tends to make outside of cell more +ve than inside). In an attempt to balance the electric charge, additional potassium ions, which are also +ve, enter the cell causing a higher concentration of potassium on the inside than on the outside. But, this charge balance cannot achieve, due to imbalance concentration of K^+ ions.

Equilibrium is reached with a potential difference across the membrane, -ve on inside and +ve on the outside. And this membrane potential is known as **resting potential** of cell. This

potential is maintained until some disturbance upsets the equilibrium. The membrane potential is made from inside the cell w.r.to the body fluids. Therefore, the resting potential is -ve rating from -60mV to -100mV. The figure below shows the cross section of cell with resting potential and the state is said to be *polarized state*.

Action potential:

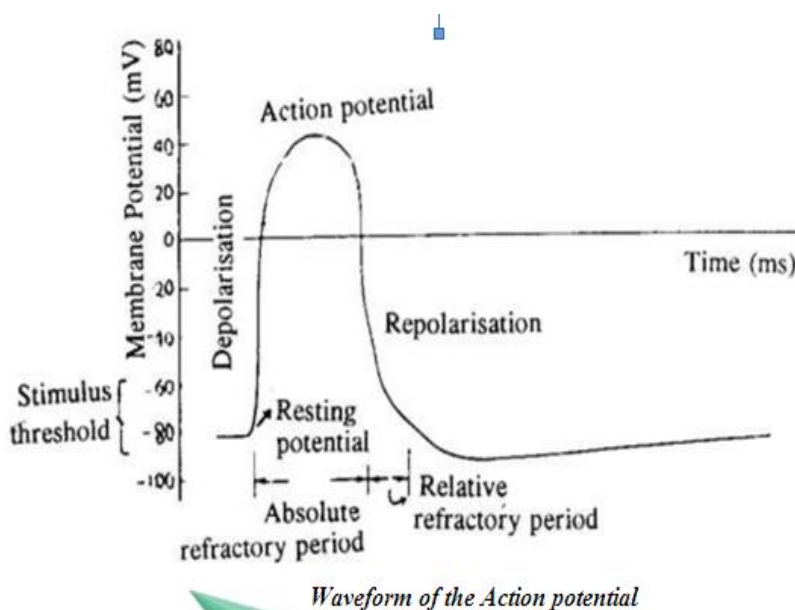
Due to some external energy or by the flow of ionic current, a section of cell membrane changes its characteristics and begins to allow some of sodium ions to enter. This movement of sodium ions into cell constitutes an ionic current flow that further reduces the balance of membrane to sodium ions. The net result is avalanche effect and tries to balance with ions outside. At the same time, K^+ ions, in higher concentration inside the cell during resting state, try to leave cell, but are unable to move as fast as Na^+ ions. The result is cell attains small +ve potential on the inside due to imbalance of K^+ ions, known as **action potential**. The action potential is nearly +20 mV



When a cell is excited and displays an action potential, it is said to be "**depolarized**" and the process of changing from resting state to action potential is called as *depolarization*. Once the rush of sodium ions through the cell membrane has stopped (a new state of equilibrium is reached), the ionic currents that lowered the barrier to sodium ions are no longer present and the membrane reverts back to its original, selectively permeable condition. Now passage of sodium ions from the outside to inside of the cell is again blocked. However, it would take a long time for a resting potential to develop again.

By an active process, called *sodium pump*, the sodium ions are quickly transported to the outside of the cell, and the cell again becomes polarized and assumes its resting potential. This process is called **Repolarization**. The rate of pumping is directly proportional to the sodium concentration in the cell. It is also believed that the operation of this pump is linked with the influx of potassium into the cell, as if a cyclic process involving an exchange of sodium for potassium existed.

The Figure below shows a typical action-potential waveform, beginning at the resting potential, depolarization, and returning to the resting potential after repolarization. The time scale for the action potential depends on the type of cell producing the potential. In nerve and muscle cells, repolarization occurs so rapidly following depolarization that the action potential appears as a spike of as little as 1msec total duration.



Heart muscle, on the other hand, repolarizes much more slowly, with the action potential for heart muscle usually lasting from 150 to 300msec. Regardless of the method by which a cell is excited or the intensity of the stimulus (provided it is sufficient to activate the cell), the action potential is always the same for any given cell. This is known as the **all-or-nothing law**. The **net height** of the action potential is defined as the difference between the potential of the depolarized membrane at the peak of the action potential and the resting potential.

Following the generation of an action potential, there is a brief period of time during which the cell cannot respond to any new stimulus. This period is called the **absolute refractory period**, lasts about 1msec in nerve cells. Following the absolute refractory period, there occurs a **relative refractory period**, during which another action potential can be triggered, but a much stronger stimulation is required. In nerve cells, the relative refractory period lasts several milliseconds.

Why is Bio Amplifier Required?

Generally, biological/bioelectric signals have low amplitude and low frequency. Therefore, to increase the amplitude level of biosignals amplifiers are designed. The outputs from these

amplifiers are used for further analysis and they appear as ECG, EMG, or any bioelectric waveforms. Such amplifiers are defined as Bio Amplifiers or Biomedical Amplifiers.

Basic Requirements for Biological Amplifiers

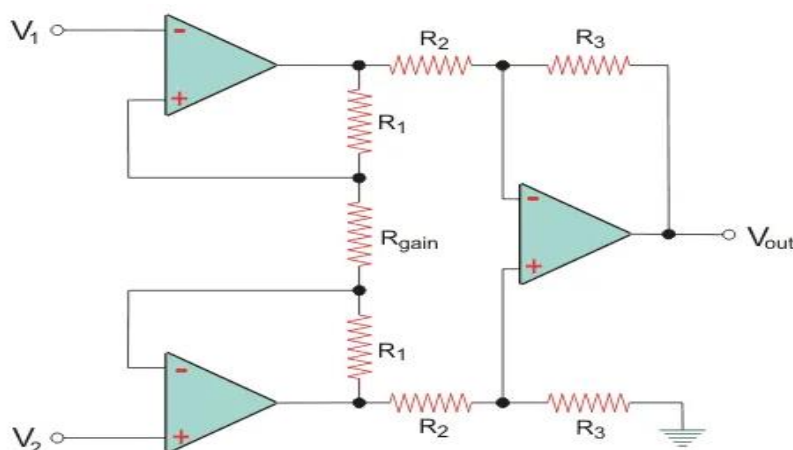
1. The **biological amplifier** should have a high input impedance value. The range of value lies between 2 M Ω and 10 M Ω depending on the applications. Higher impedance value reduces distortion of the signal.
2. When electrodes pick up biopotentials from the human body, the input circuit should be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

Types of Bio Amplifiers

1. **Differential Amplifier**
2. **Operational Amplifier**
3. Instrumentation Amplifier
4. **Chopper Amplifier**
5. Isolation Amplifier

Instrumentation Amplifier

In biomedical applications, high gain and the high input impedance are attained with an instrumentation amplifier. Usually, a 3-amplifier setup forms the instrumentation amplifier circuit. The output from the **transducer** is given as input to the instrumentation amplifier.



Before the signal goes to the next stage, a special amplifier is required with high CMRR, high input impedance and to avoid loading effects. Such a special amplifier is an instrumentation amplifier, which does all the required process.

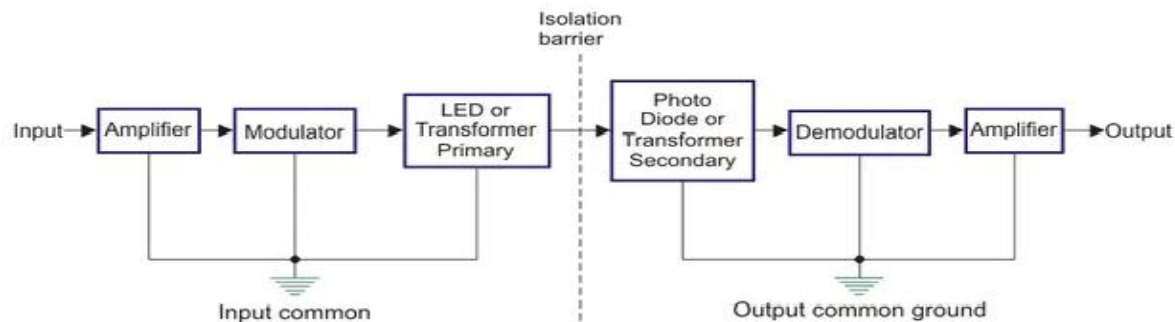
To each input of the [differential amplifier](#), the non-inverting amplifier is connected. They are combined together to form the input stage of the instrumentation amplifier. The third [op-amp](#) is the difference amplifier, and it is the output of the instrumentation amplifier.

The output from the difference amplifier V_{out} is the difference between two input signals given at the input points. V_{O1} is the output from op-amp 1 and V_{O2} is the output from op-amp 2.

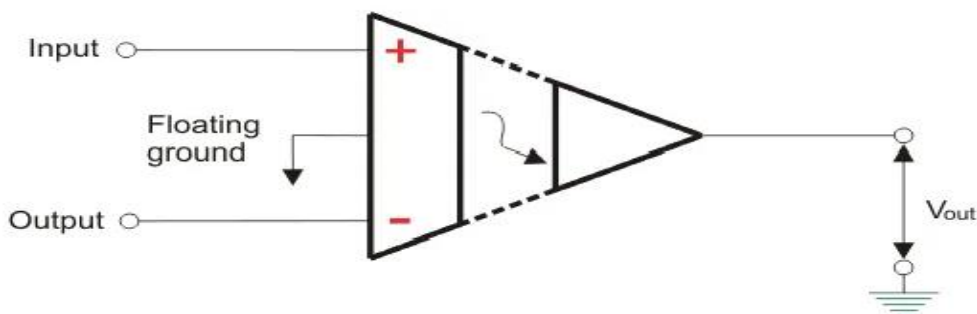
$$V_{out} = \frac{R_3}{R_2} (V_{O1} - V_{O2})$$

Isolation Amplifier

Isolation amplifiers are known as Pre-amplifier isolation circuits. An isolation amplifier increases the input impedance of a patient monitoring system. It also helps to isolate the patient from the device. Using the isolation amplifier prevents accidental internal cardiac shock. It provides up to 1012 Ω insulation between the patient and the power line in the hospital.



Block Diagram of Isolation Amplifier

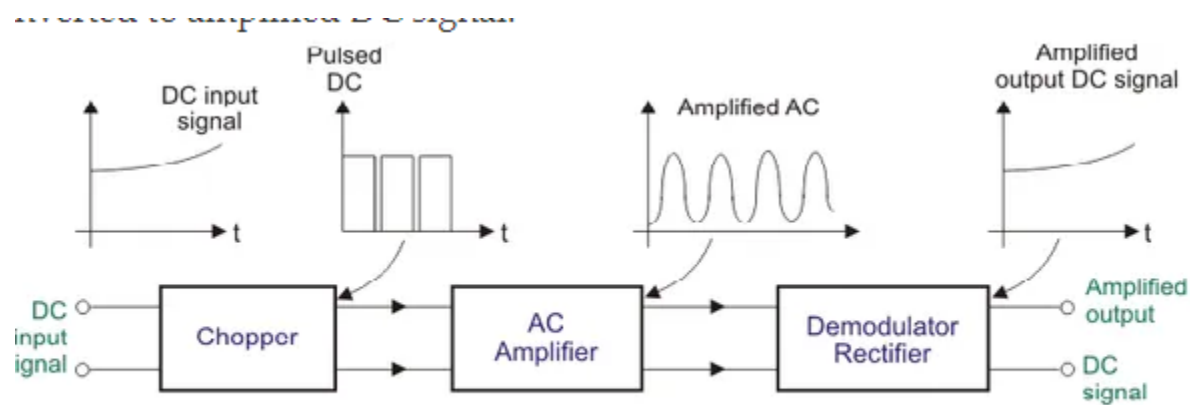


Symbol of Isolation Amplifier

The electrical signals are obtained with electrodes. The signals received goes to the amplifier block, where signals amplification occurs. After amplification, the signal enters the modulation block. When either it goes to the isolation barrier, optical cable or transformer can be used. If in case of optical cable, modulator output travels to LED. The LED converts electrical signals into light energy. If the transformer acts an isolation barrier, modulator output connects the primary winding of the transformer. Energy from the primary is transferred to the secondary winding based on the mutual induction principle. At the next stage, secondary output enters the demodulation block. Finally, the amplified demodulated signal is obtained.

Chopper Amplifier

When recording biopotentials noise and drift are the two problems encountered. Noise is due to the recording device and by the patient when they move. Drift is a shift in baseline created due to various thermal effects. A DC amplifier has a shift or sudden peak in the output when the input is zero. Therefore, a chopper amplifier solves the problems of drift in DC amplifiers. The name Chop means to sample the data. The amplifier circuit samples the analog signal. So it is known as **chopper amplifier**.



Schematic Diagram of a Chopper Amplifier

The first block chopper accepts the DC input signal and converts them to an AC signal. The AC amplifier block amplifies the chopped AC signal.

Next, in the demodulator rectifier block, an amplified chopped AC signal is converted to amplified DC signal. The **chopper** converts DC or low-frequency signal to high-frequency signal. An AC amplifier amplifies the modulated high-frequency signal. The amplified signal is demodulated and filtered to obtain the low frequency or DC signal.

Bio Potential Electrodes

Electrodes are defined as a solid electric conductor through which an electric current enters or leaves an electrolytic cell. It converts ionic potentials to electronic potentials. Different types of electrodes used for biological measurements depend on the anatomical locations, from where the bioelectric signals are measured. Bioelectric electrodes acquire signals like ECG, EEG, EMG, etc. There are three main types of electrodes:

1. Microelectrodes
2. Needle electrodes
3. Body Surface electrodes

Microelectrodes

Microelectrode measures the electric potential from within a single cell. It has very small diameter tips that can penetrate deep into the cell without damaging the human cell. The functions of microelectrodes are potential recording to inject medicines.

Generally, when microelectrode is inside cell, reference electrode is outside the cell. It has high impedances in range of mega ohm due to their small size. Two types of microelectrode are

- Metal Microelectrode
- Non- Metallic (Micropipette)

Metal Microelectrode

The tungsten filament or stainless steel wire made into minute structure forms the tip of the microelectrode. This technique is electropointing. The insulating material covers the entire electrode for safety purpose.

Few electrolytic processing is done to reduce the impedance. Measurement of bioelectric potentials requires two electrodes. The resulting voltage potential is the difference between the potential of microelectrode and reference electrode. The total sum of the three potentials is as follows.

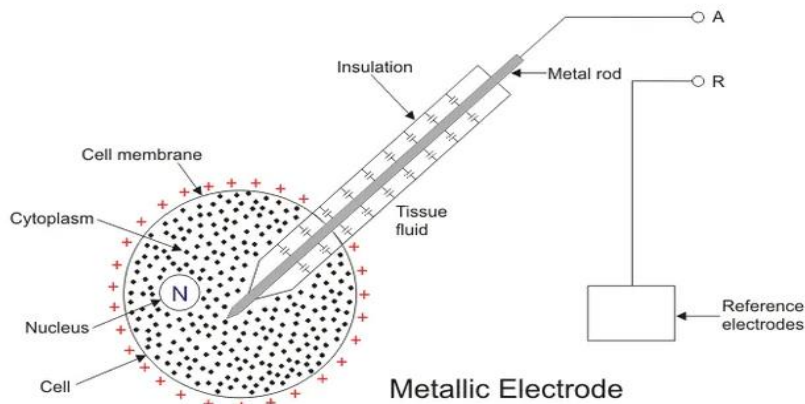
$$E = E_A + E_B + E_C$$

Where,

E_A – metal electrode-electrolyte potential at microelectrode tip.

E_B – Reference electrode-electrolyte potential.

E_C – Variable cell membrane potential.



Non-Metal Microelectrode (Micropipet)

This electrode uses Non – metallic material to measure the potential from a single cell. It consists of glass micropipette of diameter 1 micrometer. Micropipet filled with electrolyte solution that is compatible with cellular fluids is used. Stem of Micropipet has a thin flexible wire made out of chloride silver, stainless steel or tungsten. One end of the Micropipet attaches to the rigid support and other free end rests on the cell.

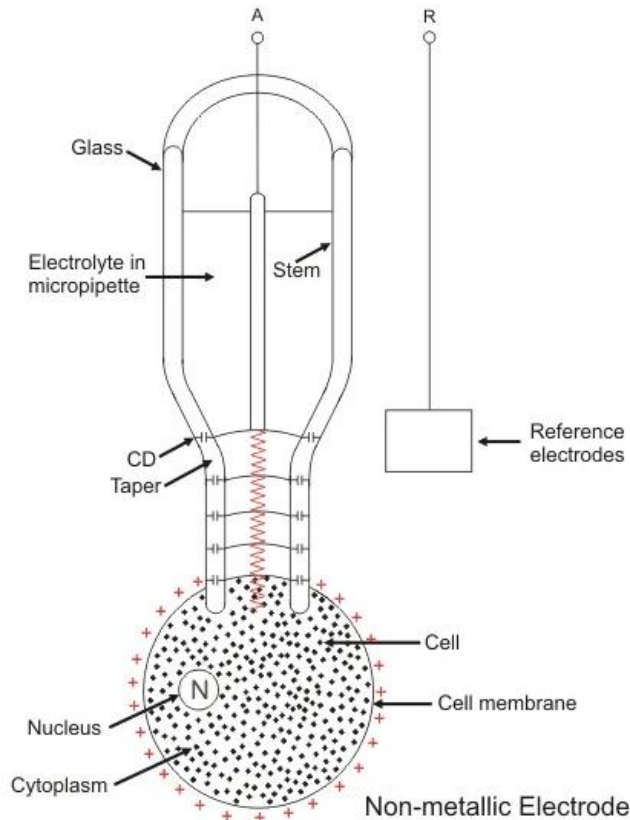
$$E = E_A + E_B + E_C + E_D$$

E_A – potential voltage between the metal wire and an electrolyte filled inside Micropipette.

E_B – potential between the reference electrode and extracellular fluid.

E_C – variable cell membrane potential.

E_D – potential at the tip due to electrolytes present inside the pipet and the cell.



Depth and Needle Electrodes

When electrode gets closer to the bioelectric generator, it penetrates into the skin. Therefore, the electrode should be sharp for penetration to obtain and record the bioelectric events.

Depth Electrodes

Depth electrode studies the electrical activity of the neurons in the surface of the brain. This type of electrode consists of bundle of Teflon insulated platinum and iridium alloy wires.

For easy insertion of the electrodes into the brain, the end of the supporting wire is round-shaped.

The number of individual electrodes forms the electrode array or bundle. In the bundle of electrodes, the end of each individual wires has the individual electrode.

Applications of Depth Electrodes

1. To inject medicines into the brain.
2. To measure oxygen tension.

Needle Electrodes

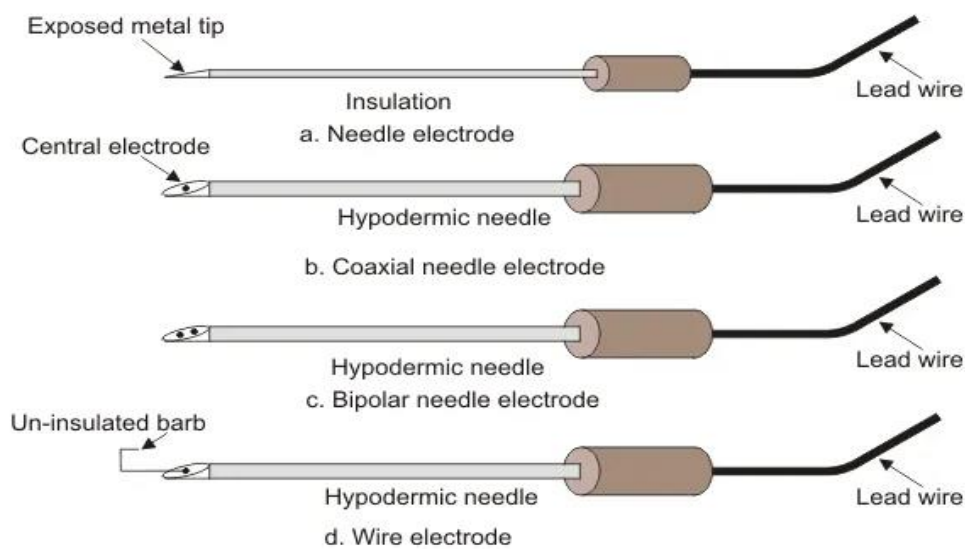
Needle electrode records the peripheral nerve action potential. It resembles a medicinal syringe. At one end a short insulated wire is bent. The bent portion passes through the lumen of the needle. This setup goes into the muscle. Now the needle is withdrawn. The bent wire remains inside the muscle. Two type of needle electrodes namely

Mono-polar Electrode: This type uses single reference electrode placed on the skin.

Bi – polar Electrode: This type has one reference electrode and one active electrode.

Applications of Needle Electrodes

Needle electrodes are mostly used in the measurement of EEG and EMG signals.

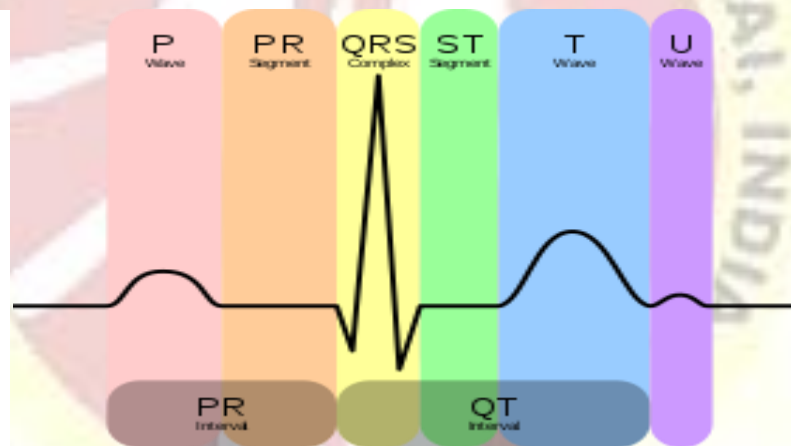
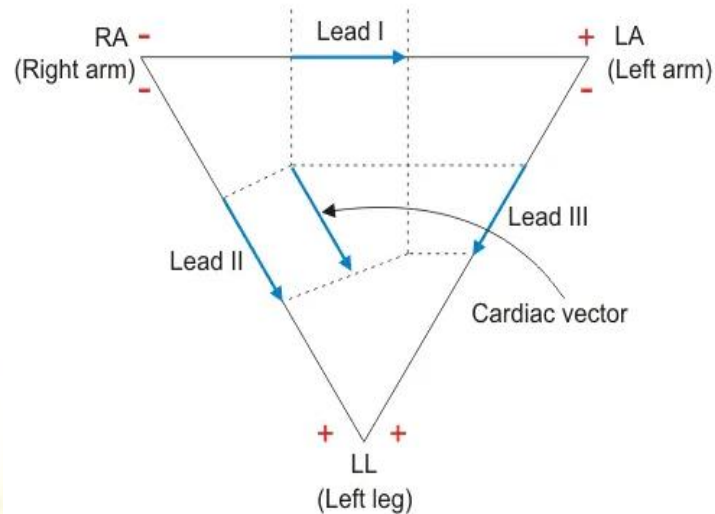


ECG

The **electrocardiogram** is a graphical representation of the bio-electrical currents generated by the myocardial cells. By placing a pair of electrodes on the body, an ECG voltage potential between them can be measured and recorded. This graphical representation (ECG) can be either printed on a paper or displayed on a monitor. The device capable of recording and printing the ECG on paper is called **electrocardiograph**. The device which displays the ECG on a screen is called **monitor or cardiac monitor**.

Einthoven was the inventor of the first device capable of printing the ECG on paper. Einthoven named the waves using five capital letters from the alphabet: P, Q, R, S, and T. **Einthoven triangle** is the closed path formed between right arm, left arm, left leg and right arm. Einthoven has defined that cardiac electric vector is two dimensional along the frontal plane

of the body. Along the projections of the triangle, vector sums on three sides of triangle is zero. the amplitude of R wave along the lead III is equal to the summation of amplitude of R wave along lead I and lead II.



An upward deflection of a wave is called **positive deflection** and a downward deflection is called **negative deflection**. A typical representation of the ECG waves is as shown in the figure below. The description of the five ECG waveforms is as follows:

P wave : represents the depolarization impulse across the atria

Q, R and S waves : all these three waves represent the ventricular depolarization (the downward stroke followed by an upward stroke is called Q wave, the upward stroke is called R wave and any downward stroke preceded by an upward stroke is called S wave)

T wave : represents the repolarization of the ventricles

Table: Waves of normal ECG

S. No	Wave/Segment	Cause	Amplitude (mV)	Duration (sec)
1	P Wave	Depolarisation of atria	0.25	0.12 to 0.22
2	R Wave (QRS Complex)	Repolarisation of atria and Depolarisation of ventricles	1.6	0.07 to 0.1
3	T Wave	Repolarisation of ventricles	0.1 to 0.5	0.05 to 0.15
4	U Wave	Slow repolarisation of intraventricular (Purkinje fibers) system	<0.1	0.2

The ECG Lead Configuration

Bipolar limb leads (frontal plane):

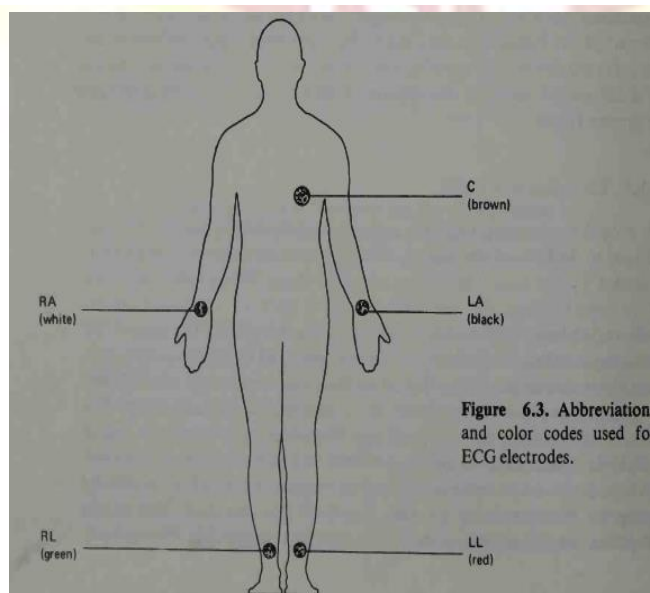
- Lead I: RA (-) to LA (+) (Right Left, or lateral)
- Lead II: RA (-) to LL (+) (Superior Inferior)
- Lead III: LA (-) to LL (+) (Superior Inferior)

Augmented unipolar limb leads (frontal plane):

- Lead aVR: RA (+) to [LA & LL] (-) (Rightward)
- Lead aVL: LA (+) to [RA & LL] (-) (Leftward)
- Lead aVF: LL (+) to [RA & LA] (-) (Inferior)

Unipolar (+) chest leads (horizontal plane):

- Leads V1, V2, V3: (Posterior Anterior)
- Leads V4, V5, V6: (Right Left, or lateral)



Bipolar limb leads or Standard Leads or Einthoven lead system:

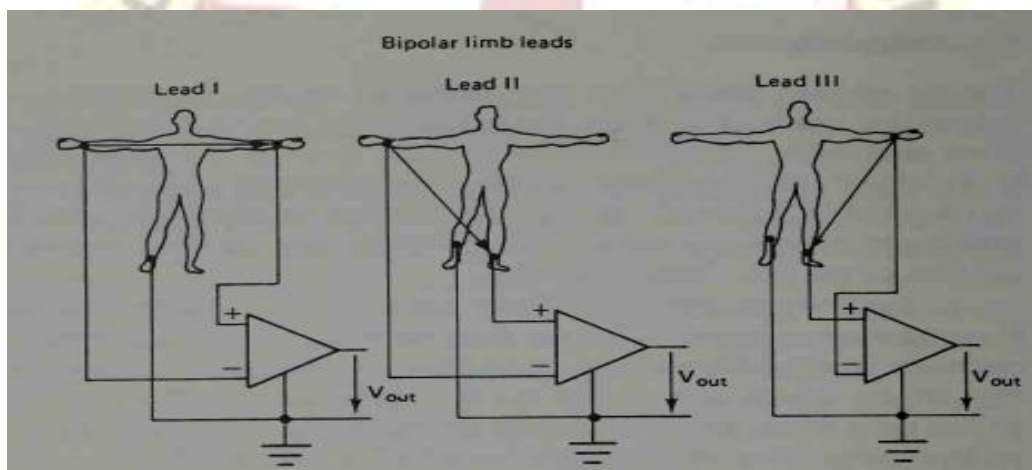
In this lead system, the potentials are tapped from four locations of our body. They are

i) Right arm ii) Left arm iii) Right Leg iv) Left Leg The Right Leg (RL) electrode acts as the reference electrode.

Lead I: It is a lead obtained between a negative electrode placed on the right arm and a positive electrode placed on the left arm. It gives voltage V_I , the voltage drop from the left arm (LA) to the right arm (RA).

Lead II: It is a lead obtained between a negative electrode placed on the right arm and a positive electrode placed on the left foot. It gives voltage V_{II} , the voltage drop from the left leg (LL) to the right arm (RA).

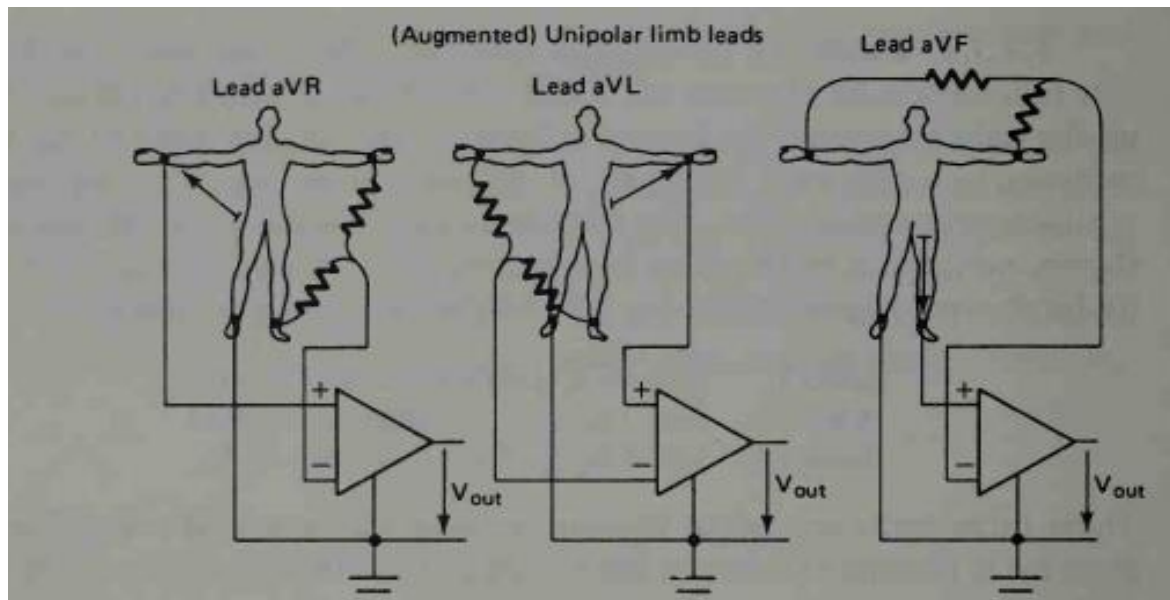
Lead III: It is a lead obtained between a negative electrode placed on the left arm and a positive electrode placed on the left foot. It gives voltage V_{III} , the voltage drop from the left leg (LL) to the left arm (LA).



Augmented Unipolar Limb Leads:

Augmented unipolar limb lead system was introduced by Wilson. The electrocardiogram is recorded between a single electrode and the central terminal which has a potential corresponding to the center of the body. Thus two equal and large resistors are connected to a pair of limb electrodes and the center of this resistive network. The remaining limb electrode acts as exploratory single electrode. By means of augmented ECG lead connections, a small increase in the ECG voltage can be realized. The augmented lead connections are,

- augmented voltage Right arm (aVR)
- augmented voltage Left arm (aVL)
- augmented voltage Foot arm (aVF)



aVR: is a lead obtained between the average signal obtained from three negative electrodes (left arm, left leg and right foot) and the signal obtained from a positive electrode placed on the right arm.

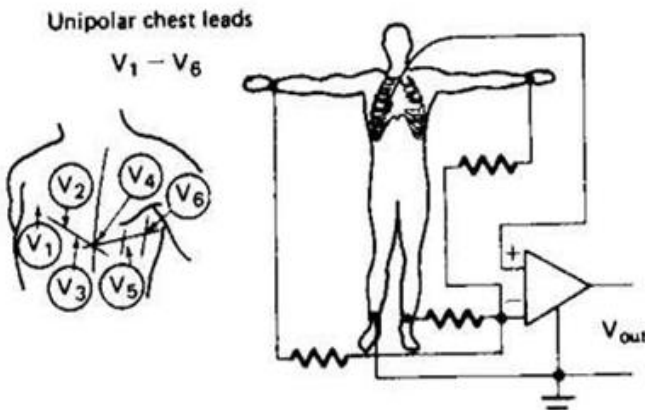
aVL: is a lead obtained between the average signal obtained from three negative electrodes (right arm, left foot and right foot) and the signal obtained from a positive electrode placed on the left arm

aVF: is a lead obtained between the average signal obtained from three negative electrodes (left arm, right arm and right foot) and the signal obtained from a positive electrode placed on the left foot

Unipolar Chest Lead:

In unipolar chest leads, the exploratory electrode is obtained from one of the chest electrodes. The chest electrodes are placed at six different points on the chest close to the heart. By connecting 3 equal large resistors to RA, RL, LL, a central terminal is obtained. This lead system is known as Wilson lead system.

- V₁ Fourth intercostal space, at right sternal margin.
- V₂ Fourth intercostal space, at left sternal margin.
- V₃ Midway between V₂ and V₄.
- V₄ Fifth intercostal space, at mid-clavicular line.
- V₅ Same level as V₄, on anterior axillary line.
- V₆ Same level as V₄, on mid-axillary line.



V1: is a lead obtained between the reference negative electrode and a positive electrode placed on the chest in the V1 position

V2: is a lead obtained between the reference negative electrode and a positive electrode placed on the chest in the V2 position

V3: is a lead obtained between the reference negative electrode and a positive electrode placed on the chest in the V3 position

V4: is a lead obtained between the reference negative electrode and a positive electrode placed on the chest in the V4 position

V5: is a lead obtained between the reference negative electrode and a positive electrode placed on the chest in the V5 position

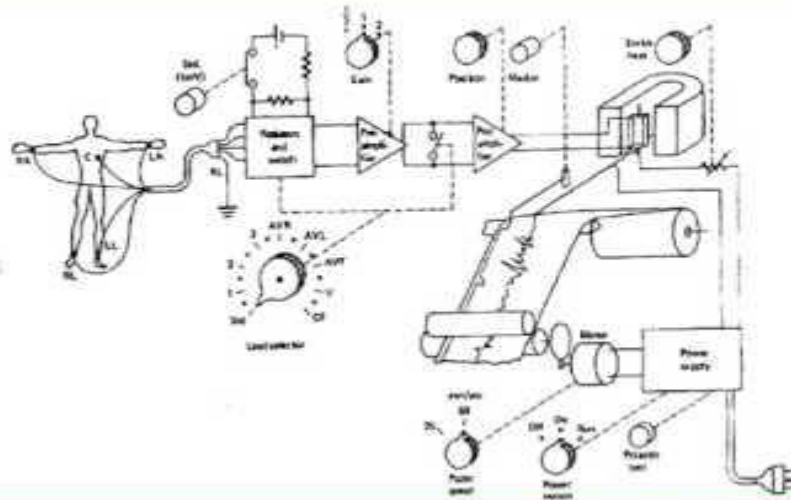
V6: is a lead obtained between the reference negative electrode and a positive electrode placed on the chest in the V6 position.

ECG Recorder

Electrocardiography (ECG) is the most commonly conducted diagnostic technique for detecting heart's electrical activity via electrodes/receivers attached to body surface which produces a graphical tracing known as Electrocardiogram.

The recorded ECG signals are influenced by a variety of noises and artefacts that are within the bandwidth of interest. Extracting useful information from the noisy potentials, the raw ECG signals have to be processed which involves mainly two stages. The first stage is the pre-processing stage for attenuation and removing the disturbances from the recorded noisy ECG signals. The second stage is the feature extraction stage during which all the features of the ECG signal are extracted and analysed further.

ECG RECORDER PRINCIPLE



Presented by : DEVANSHU PRAVEEN SAHOO (EI200119140)

The connecting wires for the patient electrodes originate at the end of a patient cable, the other end of which plugs into the ECG recorder. The wires from the electrodes connect to the lead selector switch, which also incorporates the resistors necessary for the unipolar leads.

A **push button** allows the insertion of a standardization voltage of 1mV to standardize or calibrate the recorder.

Changing the setting of the **lead selector switch** introduces an artifact on the recorded trace. A special contact on the lead selector switch turns off the amplifier momentarily whenever this switch is moved and turns it on again after the artifact has passed.

From the lead selector switch the ECG signal goes to a **preamplifier**, a differential amplifier with high common-mode rejection. It is ac-coupled to avoid problems with small dc voltages that may originate from polarization of the electrodes.

The preamplifier is followed by a dc amplifier called the **pen amplifier**, which provides the power to drive the **pen motor** that records the actual ECG trace. The input of the pen amplifier is usually accessible separately, with a special **auxiliary input** jack at the rear or side of the ECG recorder. Thus, the ECG recorder can be used to record the output of other devices.

A **position** control on the pen amplifier makes it possible to center the pen on the recording paper. All modern ECG recorders use heat-sensitive paper, and the pen is actually an electrically heated **stylus**, the temperature of which can be adjusted with a **stylus heat control** for optimal recording trace.

Beside the recording stylus, there is a **marker** stylus that can be actuated by a pushbutton and allows the operator to mark a coded indication of the lead being recorded at the margin of the electrocardiogram.

Normally, electrocardiograms are recorded at a **paper speed** of 25 mm/sec, but a faster speed of 50 mm/sec is provided to allow better resolution of the QRS complex at very high heart rates or when a particular waveform detail is desired.

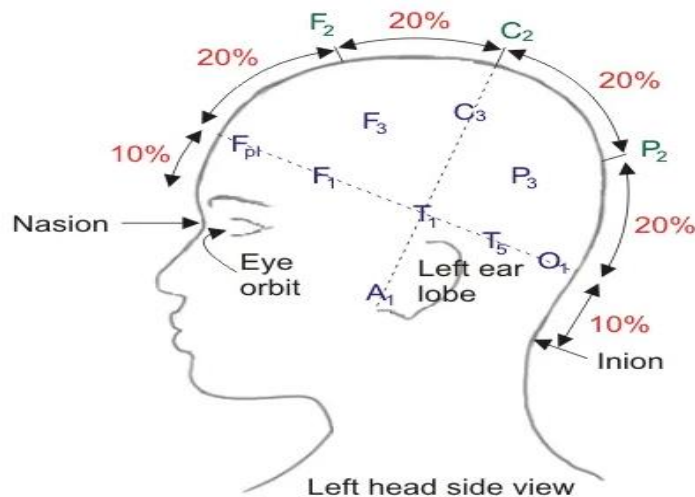
The **power switch** of an ECG recorder has three positions. In the **ON** position the power to the amplifier is turned on, but the paper drive is not running. In order to start the paper drive, the switch must be placed in the **RUN** position.

EEG

Electroencephalography is used to measure the electrical activity of the brain. Since clinical EEG measurements are obtained from electrodes placed on the surface of the scalp, these waveforms represent a very gross type of summation of potentials that originate from an extremely large number of neurons in the vicinity of the electrodes. The electrical patterns obtained from the scalp are actually the result of the graded potentials on the dendrites of neurons in the cerebral cortex and other parts of the brain.

EEG potentials have random-appearing waveforms with peak-to-peak amplitudes ranging from less than 10 μV to over 100 μV . The required bandwidth for adequately handling the EEG signal is from below 1 Hz to over 100 Hz.

Electrodes for measurement of the EEG are surface or subdermal needle electrodes. The ground reference electrode is often a metal clip on the earlobe. A suitable electrolyte paste or jelly is used in conjunction with the electrodes to enhance coupling of the ionic potentials to the input of the measuring device.



Placement of electrodes on the scalp is a standard pattern, called the 10-20 electrode placement system, is generally used. Electrode spacing is based on intervals of 10 and 20 percent of the distance between specified points on the scalp.

The measurement of the electroencephalogram requires a readout or recording device and sufficient amplification to drive the readout device from the microvolt-level signals obtained from the electrodes. Because of the low-level input signals, the electroencephalograph must have high-quality differential amplifiers with good common-mode rejection. The differential preamplifier is generally followed by a power amplifier to drive the pen mechanism for each channel. In nearly all clinical instruments, the amplifiers are ac-coupled with low-frequency cutoff below 1 Hz and a bandwidth extending to somewhere between 50 and 100 Hz. Stable dc amplifiers can be used. Most modern EEG includes adjustable upper and lower-frequency limits to allow the operator to select a bandwidth suitable for the conditions of the measurement. In addition, some instruments include a fixed 60-Hz rejection filter to reduce powerline interference. To reduce the effect of electrode resistance changes, the input impedance of the amplifier should be as high as possible. For this reason, most modern electroencephalographs have input impedances greater than 10 M Ω .

The readout in a clinical electroencephalograph is a multichannel penrecorder with a pen for each channel. The standard chart speed is 30 mm/sec, but most electroencephalographs also provide a speed of 60 mm/sec for improved detail of higher-frequency signals. Some have a third speed of 15 mm/sec to conserve paper during setup time. Oscilloscope readout for the EEG is also possible, but it does not provide a permanent record. In some cases, particularly in research applications, the oscilloscope is used in conjunction with the pen recorder to edit the signal until a particular feature or characteristic of the waveform is observed. In this way, only the portions of

interest are recorded. Many electroencephalographs also have provisions for interfacing with an analog tape recorder to permit recording and playback of the EEG signal.

Electromyographic(EMG)Measurements

Like neurons, skeletal muscle fibers generate action potentials when excited by motor neurons via the motor end plates. They do not, however, transmit the action potentials to any other muscle fibers or to any neurons. The action potential of an individual muscle fiber is of about the same magnitude as that of a neuron. The measurement of these action potentials, either directly from the muscle or from the surface of the body, constitutes the electromyogram.

The signal is a summation of all the action potentials within the range of the electrodes, each weighted by its distance from the electrodes. Since the overall strength of muscular contraction depends on the number of fibers energized and the time of contraction,

There is a correlation between the overall amount of EMG activity for the whole muscle and the strength of muscular contraction.

The EMG potentials from a muscle or group of muscles produce a noise like waveform that varies in amplitude with the amount of muscular activity. Peak amplitudes vary from 50 μV to about 1 mV, depending on the location of the measuring electrodes with respect to the muscle and the activity of the muscle. A frequency response from about 10 Hz to well over 3000 Hz is required for faithful reproduction.

Surface, needle, and fine-wire electrodes are all used for different types of EMG measurement. Surface electrodes are generally used where gross indications are suitable, but where localized measurement of specific muscles is required, needle or wire electrodes that penetrate the skin and contact the muscle to be measured are needed. Both unipolar and bipolar measurements of EMG are used.

The amplifier for EMG measurements must have high gain, high input impedance and a differential input with good common-mode rejection. Also, the EMG amplifier must accommodate the higher frequency band. In many commercial electromyographs the upper-frequency response can be varied by use of switchable lowpass filters.

The typical electromyograph has oscilloscope readout instead of a graphic pen recorder. The reason is the higher frequency response required. Sometimes a storage cathode-ray tube is provided for retention of data, or an oscilloscope camera is used to obtain a permanent visual record of data from the oscilloscope screen. Most electromyographs include an audio amplifier and loudspeaker in addition to the oscilloscope display to permit the operator to hear the "crackling" sounds of the EMG. This audio presentation is especially helpful in the placement of needle or wire electrodes into a muscle. A trained operator is able to tell from the sound not only that his electrodes are making good contact with a muscle but also which of several adjacent muscles he has contacted.

UNIT III

RESPIRATION RATE:

The exchange of gases in any biological process is termed as respiration to sustain life the human body must take in oxygen which combines with carbon hydrogen and various nutrients to produce heat and energy for the performance of work.

The entire process of taking in oxygen from the environment, transporting the oxygen to the cells, removing the carbon dioxide from the cells and giving out this waste product to the atmosphere is called respiration.

There are two types of respiration:

INTERNAL RESPIRATION:

The cells contain certain fluids. The absorb oxygen from this fluid the circulating blood is the medium by which oxygen is brought to the internal environment CO_2 is also carried from the tissues fluids through the circulating bloods. This is considered as internal respiration.

EXTERNAL RESPIRATION:

The exchange of gases between the blood and external environment takes place in the lungs and is termed as external respiration. The function of the lungs is to oxygenate the blood and to eliminate CO_2 . The entire process of inhaling and exhaling of air, exchange of gases, distribution of oxygen to the cells and collection of CO_2 from the cells is done by the cells respiration rate is termed as number of breaths per minute.

HEART BEAT RATE:

The heart pumping cycle is divided into two major parts

- 1) SYSTOLE
- 2) DIASTOLE

Systole is defined as period of contraction of the heart muscles at which time the blood is pumped into the pulmonary artery.

Diastole is the period of filling the blood in the heart chambers. The heart beats at an average rate of about 75 beats per minute in a normal person. The heart rate increases when a person stands up and decreases when he sits down. For child the heart rate may be as high as 140 beats per minute under normal conditions. The heart pumps about 5 liters of blood per minute.

TEMPERATURE MEASUREMENT:

Body temperature is one of the oldest known indicators of the general well being of a person. Two basic types of temperature measurements can be obtained from the human body.

SYSTEMIC TEMPERATURE:

This method gives the temperature of internal organs of the body. This temperature is maintained through a controlled balance between the heat generated by active tissues of the body and the heat lost by the body to the environment. The temperature is sensed by placing the device in the mouth or under the armpit. The normal oral temperature of a healthy person is about 37°C (98.6°F). The under arm temperature is about 1 degree less than the oral reading. The body temperature does not remain constant over a 24hr period and varies up to 1 ½.

The temperature control center for the body is located deep within the brain. The body is located deep within the brain. The body acts as radiator and secretes heat with the help of sweat glands. If the external temperature becomes too low the body conserves heat by reducing blood flow to the minimum required level for the maintenance of the cell.

The only deviation from normal temperature control is arise in temperature called fever this is experienced with certain types of infection and also due to shut down of the mechanisms for heat elimination. At the beginning of fever the skin is pale and dry and usually shivering takes place and the skin and muscles react to the coolness. At the conclusion of fever the body temperature is lowered to normal increases sweating is noted by which the additional body heat is eliminated.

The internal or systemic body temperature is a good indicator of a health of the patient. In case of continuous monitoring the temperature measurement does not cause discomfort to the patient.

The mercury thermometer is still the standard method of measurement of temperature and it is inexpensive, easy to use and accurate. Electronic thermometers are available as replacement for mercury thermometer.

SURFACE OR SKIN TEMPERATURE:

This is also due to the balance of heat generated by the tissues and heat lost to the environment. But here the balance is between the heat supplied by blood circulation in a local area and the cooling of that area by conduction, radiation, and evaporation. To obtain the skin temperature measurement it is necessary to expose the region with no clothing and in a cool temperature. The range is usually from 30 to 35 C (85 to 95 F).

This measurement is often used to detect problems in the circulating systems. The measurement is made by using small, flat thermistor probes connected to the skin.

Sphygmomanometer

A sphygmomanometer is an instrument used to measure blood pressure which is also known as a blood pressure meter or blood pressure gauge or blood pressure monitor. The word sphygmomanometer is derived from the Greek word 'sphygmos' meaning beating of the heart or the pulse and manometer mean the device used for measuring the pressure or tension.

Parts of sphygmomanometer

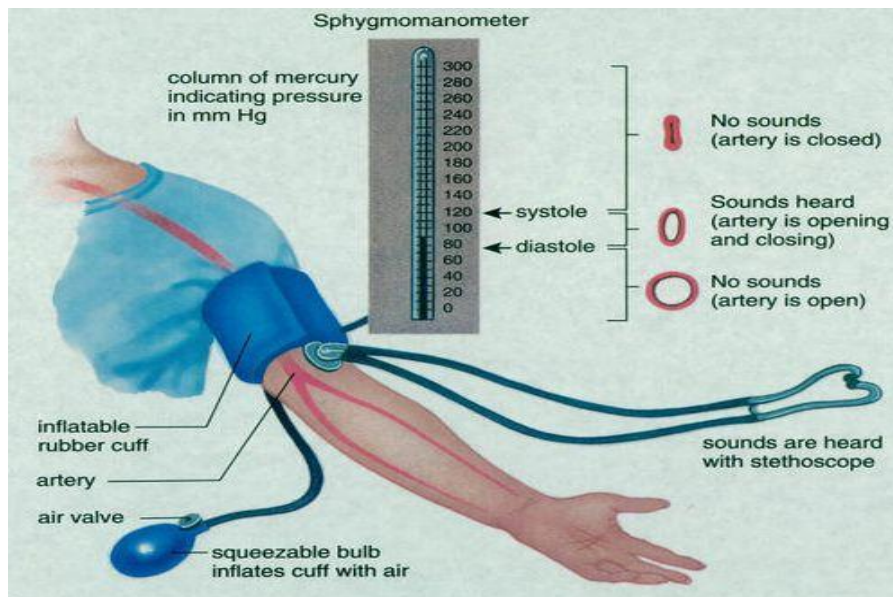
Bladder: This is an inflatable bag that is used to compress the arm to occlude the artery. To ensure full arterial compression, bladders must have specific sizing parameters.

Cuff: This is designed to hold the bladder around the arm during the measurement. For accurate measurement, the cuff must be designed properly with respect to placement and the position.

Manometer: This is a device used to measure the air pressure in mmHg. The manometer used in an aneroid sphygmomanometer consists of a watch-like movement to measure the air pressure applied to the cuff. To expand the diaphragm, the gauge has a series of copper or beryllium and there are gears to convert the linear movement of the diaphragm to get the readings in mmHg.

Valve: This used as a deflation valve to control the cuff. This plays a vital role in getting an accurate measurement.

Bulb: This is used to pump the air into the cuff.



Following is the procedure to be followed to use a sphygmomanometer:

- The length of the cuff bladder used for the measurement of blood pressure should be equal to 80% of the circumference of the upper arm.
- Wrap the cuff around the upper arm such that the lower edge of the cuff is one inch above the antecubital fossa.
- Press the stethoscope's bell lightly over the brachial artery which is below the cuff's edge.
- Release the air from the cuff at a moderate rate to 180mmHg.
- Monitor the first knocking sound by listening with the help of a stethoscope and also by observing the mercury gauge.
- This should be done for both the arms and the pressure, the position of the subject and the size of the cuff should be recorded.
- If the pressure is more, then the blood pressure should be measured with few minutes of gaps between the two measurements.
- If the blood pressure is more than 180/120mmHg, immediate actions should be taken.

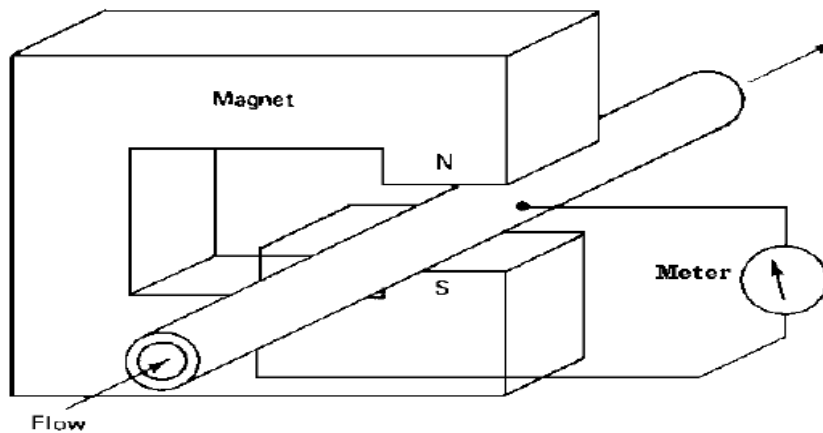
BLOOD FLOW METERS

An adequate blood supply is necessary for all organs of the body; in fact, an impaired supply of blood is the cause of various diseases. The ability to measure blood flow in the vessel that supplies a particular organ would therefore be of great help in diagnosing such diseases. The rate of flow of a liquid or gas in a pipe is expressed as the volume of the substance that passes

through the pipe in a given unit of time. Flow rates are therefore usually expressed in liters per minute or milliliters per minute (cm^3/min).

Magnetic Blood Flow Meters:

Magnetic blood flow meters are based on the principle of magnetic induction. When an electrical conductor is moved through a magnetic field, a voltage is induced in the conductor proportional to the velocity of its motion. The same principle applies when the moving conductor is not a wire, but rather a column of conductive fluid that flows through a tube located in the magnetic field.



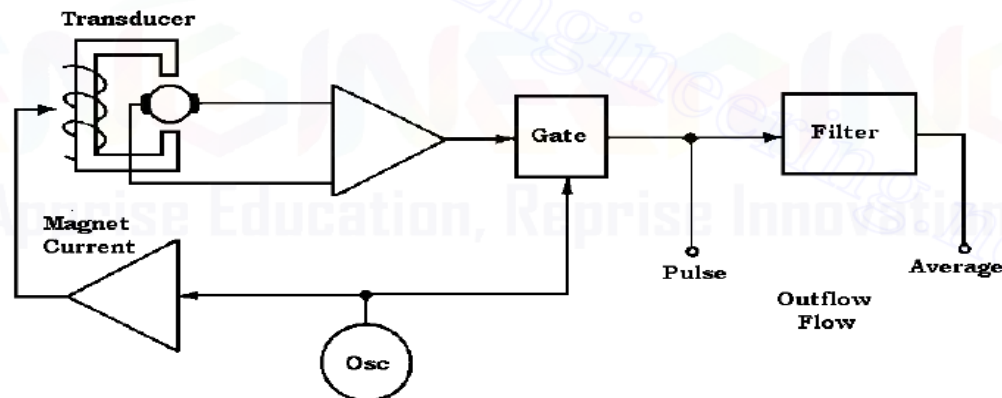
Magnetic Blood flow meter, Principle

A permanent magnet or electromagnet positioned around the blood vessel generates a magnetic field perpendicular to the direction of the blood flow. The voltage induced in the moving blood column is measured with stationary electrodes located on opposite sides of the blood vessel and perpendicular to the direction of the magnetic field.

The most commonly used types of implantable magnetic blood flow probes are shown in Figures below. The *slip-on* or *C type* is applied by squeezing an excised blood vessel together and slipping it through the slot of the probe. In some transducer models the slot is then closed by inserting a keystone-shaped segment of plastic. Contact is provided by two slightly protruding platinum disks that touch the wall of the blood vessel. For proper operation, the orifice of the probe must fit tightly around the vessel. For this reason, probes of this type are manufactured in sets, with diameters increasing in steps of 0.5 or 1 mm from about 2 to 20 mm.

Magnetic blood flow meters actually measure the mean blood velocity. Because the cross-sectional area at the place of velocity measurement is well defined with either type of transducer, these transducers can be calibrated directly in units of flow.

The output voltage of a magnetic blood flow transducer is very small, typically in the order of a few microvolts. In early blood flow meters, a constant magnetic field was used, which caused difficulties with electrode polarization and amplifier drift. To overcome these problems, all contemporary magnetic blood flow meters use electromagnets that are driven by alternating currents. But, the change of the magnetic field causes the transducer to act like a transformer and induces error voltages that often exceed the signal levels by several orders of magnitude. Thus, for recovering the signal in the presence of the error voltage, amplifiers with large dynamic range and phase-sensitive or gated detectors have to be used. To minimize the problem, several different waveforms have been advocated for the magnet current, as shown in figure below. With a sinusoidal magnet current, the induced voltage is also sinusoidal but is 90° out of phase with the flow signal.



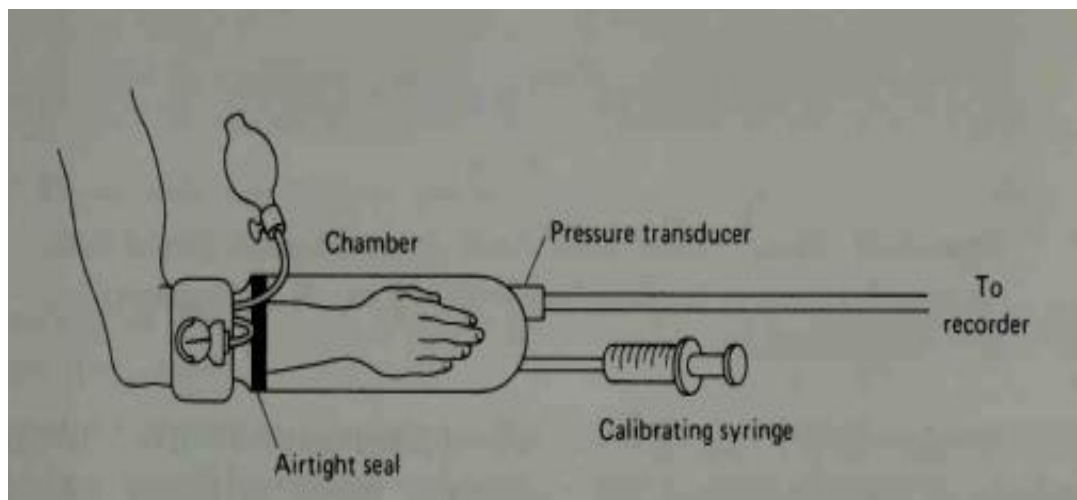
The block diagram of a magnetic blood flow meter is shown in above figure. The oscillator, which drives the magnet and provides a control signal for the gate, operates at a frequency of between 60 and 400 Hz. The use of a gated detector makes the polarity of the output signal reverse when the flow direction reverses. The frequency response of this type of system is usually high enough to allow the recording of the flow pulses, while the mean or average flow can be derived by use of a low-pass filter.

PLETHYSMOGRAPHY

Related to the measurement of blood flow is the measurement of volume changes in any part of the body that result from the pulsations of blood occurring with each heartbeat. Such measurements are useful in the diagnosis of arterial obstructions as well as for pulse-wave velocity measurements. Instruments measuring volume changes or providing outputs that can be related to them are called plethysmographs, and the measurement of these volume changes, or phenomena related thereto, is called plethysmography.

A "true" plethysmograph is one that actually responds to changes in volume. Such an instrument consists of a rigid cup or chamber placed over the limb or digit in which the volume

changes are to be measured. The cup is tightly sealed to the member to be measured so that any changes of volume in the Umb or digit reflect as pressure changes inside the chamber. Either fluid or air can be used to fill the chamber.



Plethysmographs may be designed for constant pressure or constant volume within the chamber. In either case, some form of pressure or displacement transducer must be included to respond to pressure changes within the chamber and to provide a signal that can be calibrated to represent the volume of the Umb or digit. The baseline pressure can be calibrated by use of a calibrating syringe. This type of plethysmograph can be used in two ways. If the cuff, placed upstream from the seal, is not inflated, the output signal is simply a sequence of pulsations proportional to the individual volume.

The plethysmograph can also be used to measure the total amount of blood flowing into the limb or digit being measured. By inflating the cuff (placed slightly upstream from the seal) to a pressure just above venous pressure, arterial blood can flow past the cuff, but venous blood cannot leave. The result is that the limb or digit increases its volume with each heartbeat by the volume of the blood entering during that beat.

UNIT IV

APPLICATIONS OF XRAY:

Skeletal Structures:

The skeletal structures are easy to visualize since there is no need to administer a contrast medium into the body. In all fracture examinations two exposures taken in perpendicular directions are required for reliable determination of the position of the fracture.

Respiratory Organs:

Chest radiography is taken mainly for examination of lungs and heart. In order to reduce skeletal shadows in lung examination high anode voltage are chosen. Because the air is enclosed in the respiratory track the longer bronchi and the pulmonary vessels are seen against the air filled lung tissue.

Bronchial Carcinoma:

Lung tumor may be primary or secondary in type. Bronchial carcinoma occurs as a primary growth in the lungs and is difficult to diagnose at an early stage. A special method of examination used in case of lung tumor is bronchography. Water soluble contrast medium containing iodine is injected into the bronchi of one lung.

Circulatory Organ:

Heart examinations are performed by taking frontal and lateral x-ray film images. The evaluation is performed partly by calculating the total heart volume and on the basis of change in shape.

Angiography:

It is a special x-ray imaging technique in which better contrast can be obtained. The outline of the blood vessels are made visible by injecting the contrast medium which is normally organic compound of iodine and it is directly injected in to an artery or vein in the region to be investigated. Injection is made through the catheter placed in the blood vessel. Injection is made through the angiocardiology is related with the study of heart using x-ray pictures.

Digestive Organs:

The whole gastrointestinal tract can be imaged by using a contrast medium made of barium sulphate. The contrast medium is swallowed or given by means of an enema depending on which part of the track is to be examined. Ulcers, tumors, swallowed foreign bodies can be diagnosed.

LASER IN MEDICAL APPLICATION:

Within a very short time and amazing period of research and development of optical fibers changed the area of communications completely. Applications of fibers in medicine depend mainly on the interaction of the light transmitted through the fiber and the part of the human body to be treated. With respect to the interaction between light and tissues, a lot of investigations have been made. Besides the light wavelength, the light power and the type of tissue to be treated is also important. Lasers in medicine have wide applications under different specialties as listed below

Laser in Ophthalmology:

The laser heating of tissues is used for 2 distinct surgical functions, cutting and photocoagulation. First medical application of laser was in ophthalmology. Ophthalmologist used to treat variety of eye problems including retinal bleeding, the excessive growth of blood vessels in the eye caused by diabetes and also for spot welding –reattaching retinas that have become partly detached from the back surface of the eye, the choroid.

The argon ion lasers, which emit blue green light, that is readily absorbed by the blood are preferred for photocoagulation of small blood vessels in the eye. Nd-YAG lasers are also used for blood vessels and tissue coagulation and have found wide applications in ophthalmology.

Lasers are used for tissue interaction like,

- i) Photocoagulation therapy
- ii) Photo disruption therapy
- iii) Photo fragmentation therapy

i) Photocoagulation therapy:

In the case to stop bleeding or to burn retinal layer, this type of therapy is used. The patients with sugar complaint are treated. The laser can burn retina layer 4 to 5 micron for each shot.

ii) Photo disruption therapy

In this type of therapy, treatment is given to posterior capsule, just behind intraocular lens.

iii) Photo fragmentation therapy

In this technique using a small inclusion on the eye, the laser is guided through a fiber optic cable. The laser energy is delivered to vaporize the nucleus of the cataractous lens.

Laser in Dermatology:

The uses of laser in Dermatology are,

1. To use laser as investigative tools for the study of skin exposures.
2. To use laser as tools for studies on the optical properties of the skin.
3. To evaluate the effect of acute and chronic laser exposures in the development of laser safety program
4. To evaluate lasers for dermatological surgery.
5. To determine the role of the laser as a research tool in the combined fields of biomedical engineering and dermatology.

Lasers used:

All types of lasers have been used for investigative studies in dermatology. These include pulsed ruby laser, Neodymium, Argon, Krypton, Helium-neon and CO₂.

Port-wine lesions – Pulsed ruby laser

Tattoos - Q-Switched ruby laser, Argon laser, YAG Laser.

Laser in Cancer research:

A Laser is a powerful source of monochromatic light, Because of its coherent properties; it can be used with precision in many phases of cancer research. Cancer research program have shown that laser energy may be of value because of the following properties.

1. Due to its enormous power, laser energy can cause coagulation necrosis of any tissue.
2. Because the beam is highly collimated and may be finely focused, it may be used as a cutting instrument.
3. Due to the monochromatic nature of the beam, darkly pigmented tissues will more readily absorb the beam from most visible transition lasers in a selective manner.
4. Due to the enormous power density of the focused beam, the laser produces tissue cuts with a rapid cauterizing effect. i.e., the cuts are almost bloodless.

Laser Used:

Pulsed ruby laser and CO₂ laser is used.

Laser in Neurosurgery:

Laser can also be used where other forms of surgery such as cryosurgery cannot be used. Some examples are,

1. Laser thalamotomy
2. Relief of intractable pain by delivering laser doses to the spinal cord.

Laser in Dentistry:

Another significant field of laser research is the use of laser in dentistry.

1. Initially laser dentistry is used for selective destruction of calculus and dental caries.
2. Used to prevent caries.
3. Used in study of enamel and dentine.
4. Used in examining the composition and change of the structures of the teeth.

Laser Used:

The most popular and result oriented lasers used in dental treatment are,

1. Ruby laser
2. CO₂ Laser

3. Neodymium Laser.

6) Laser transillumination:

Transillumination with intense incoherent light source is a recognized procedure in clinical medicine.

1. It is used primarily for visualization of foreign bodies, paranasal sinuses and transillumination of the infant skull.
2. Used in diagnosis of breast tumours and location of foreign bodies in soft tissues.

Laser Used:

Helium-Neon and Krypton lasers are used.

7) Laser exposures done in the pituitary gland:

1. Ruby laser exposures cause diffuse necrosis, sometimes in depth in a nonhomogenous manner.
2. Argon laser exposure will give highly specific reactions to red coloured vessels. Deep penetrations may be seen in vascular areas.
3. CO₂ lasers will have a highly specific absorption at the outer surface of the pituitary.

Laser Used:

Pulsed Ruby laser, Argon laser and CO₂ Laser.

UNIT V

Diathermy

The term diathermy means “thorough heating” or producing deep heating directly in the tissues of the body. Applying heat to a particular area of the body increases the temperature of the tissues and the flow of the blood in that area because of dilating the blood vessels.

There are several methods of raising the tissue temperature below burning levels.

1. **Conductive heating**, which raises skin temperature but does not penetrate very deeply.

Eg: Hot compresses, Infrared heat lamp.

The externally applied sources of heat like hot towels, heat lamps and electric heating pads often produce discomfort and skin burns before the heat has penetrated to the deep tissues.

Diathermy, deep heat is produced without direct neuromuscular stimulation. With diathermy technique, the subject's body becomes a part of the electrical circuit and the heat is produced within the body and not transferred through the skin. Another advantage of diathermy is that the treatment can be controlled precisely.

The amount of heat can be closely adjusted by means of circuit parameters, thus using higher frequency energy for deeper lying tissues. Eg: muscles, bones, internal organs etc. can be provided with heat.

Surgical Diathermy:

In therapeutic applications, high frequency currents are used. Apart from this, it can also be used in operating rooms for surgery. This diathermy is used for cutting, coagulation and blending in operating room.

In surgical diathermy a high frequency current of 300 – 3000 KHz is applied on the skin surface. This frequency is much higher when compared to therapeutic diathermy machines. When this high frequency current flows through sharp edge of a wire or a needle, the concentration of current at point is higher. Now if this wire or electrode is placed on the skin surface, the tissues are heated to such an extent that the cells which are immediately under the electrode are boiled.

The indifferent electrode establishes a large contact area with the patient. Therefore the RF current is dispersed and only a little heat is developed at the electrode tip.

Types of Diathermy

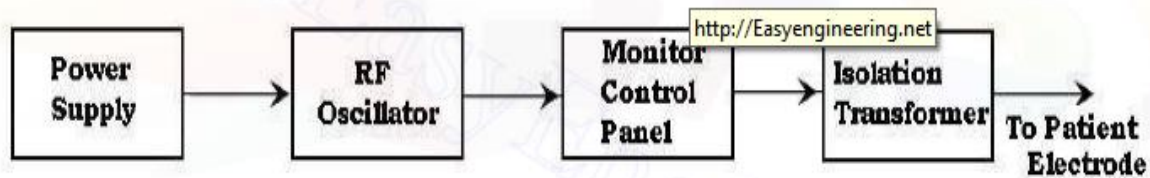
Three types of diathermy used for conventional heating are,

1. Shortwave diathermy
2. Microwave diathermy
3. Ultrasonic diathermy

The first two involve electromagnetic effects and the third involves a mechanical effect.

Shortwave Diathermy:

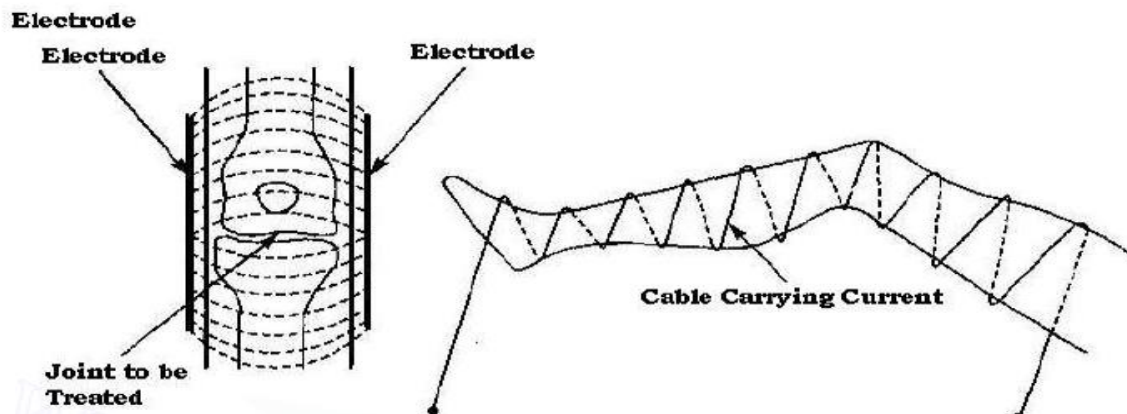
Here, the heating of the tissue is carried out at a high frequency of 27.12 MHz and a wavelength of 11 m. When we use currents with very high frequencies, the motor or sensory nerves are not stimulated and there is no contraction of the muscles. Thus, there is no discomfort to the patient. In this method, the output of the oscillator is applied to the pair of patient electrodes.



Block Diagram of a shortwave Diathermy

The RF energy heats the tissues and promotes the healing of injured tissues and inflammations. The power delivered by the unit is about 500 W. There are several provisions to regulate the intensity of the current passed through the patient circuit. The electrodes or pads are not directly in contact with the skin. Usually, layers of towels are interposed between the metal and the surface of the body. The pads are placed so that the portion of the body to be treated is sandwiched between them. The pads form capacitor plates and the body tissues between the pads act as a dielectric. Thus, the whole arrangement forms a capacitor. When the RF current is applied to the pads, the dielectric loss of the capacitor produces heat in the intervening tissues. This technique is called the condenser or capacitor method.

Further, there is also an inductive method, in which a flexible cable is coiled around the arm or knee or any other portion of the patient's body, where plate electrodes are inconvenient to use. When a RF current is passed through the cable, deep heating in the tissue results from the electrostatic field set up between its ends and the superficial tissues are heated by eddy currents set up by the magnetic field around the cable, as shown in Figure below. This technique is known as *Inductothermy*.



Methods of Applying Electrodes in Short-wave Diathermy Treatment. (a) Condenser Method, (b) Inductive Method

Microwave Diathermy

Heating of the tissues is produced due to absorption of the microwave energy. Better Therapeutic results are obtained by using microwave diathermy rather than short-wavediathermy. Here, there is no pad-shaped electrode. Instead, the microwaves are transmitted into the portion of the body to be treated directly from the director of the unit. Normally, magnetrons are used to produce microwaves.

The frequency used is 2450 MHZ and the wavelength is 12.25 cm. A delay of about 3 or 4 minutes is required for the warming of the magnetron. An arrangement is made such that a lamp lights up after 4 minutes indicating that the magnetron is ready to deliver its output to the director. Proper cooling of the magnetron is provided. Further, the interference suppression filter in the circuit bypasses the high-frequency current pick-up.

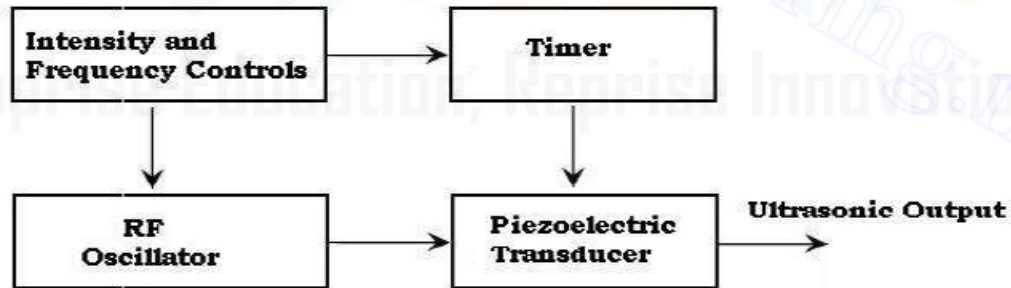
Excessive dosage can cause skin burns and, in all cases, the sensation experienced by the patient is the primary guide for application. The skin should be dry as these waves are rapidly absorbed by water. The durations of irradiation generally range from 10 to 25 Minutes.

Like all active devices, there are some hazards in using high-frequency energy.

Patients with implanted metal objects, such as pacemakers, should not receive treatment in that area because of the possibility of overheating. Care should be exercised to restrict treatment near the eyes and to avoid having the eyes to come in the line of sight.

Ultrasonic Diathermy

Ultrasonic therapy is used where short-wave treatment has failed and in cases where localization of the heat effect is desired. The ultrasonic diathermy units are very helpful in curing the diseases of the peripheral nervous system like neuritis, of the skeletal muscle system like arthritis and of skin ulcers. The heating effect is produced because of the absorption of ultrasonic energy by the tissues. The effect of ultrasonics on the tissues is a high speed vibration of micromassage. Micromassage is used in the treatment of soft tissue lesions. Ultrasonic massage is better than manual massage because of the greater depth of massage that can be obtained without any pain to the patient.



Block Diagram of an Ultrasonic Diathermy Unit

The RF oscillator produces a high-frequency alternating current which excites the piezoelectric transducer. The transducer is made of barium titanate or lead zirconate titanate crystal with 5-6 cm² effective radiating area. The ultrasonic waves can be applied in the continuous or pulsed mode. In the case of the pulsed mode, micromassage is obtained effectively without any thermal effect.

In front of the crystal, there is a metal face-plate which is made to vibrate by the oscillations of the crystal and the ultrasonic waves are emitted from this plate. The amount of ultrasonic energy absorbed by the tissues depends upon the frequency of the ultrasonic waves. Normally, a frequency ranging from 800 KHz to 1 MHz is the suitable frequency for ultrasonic therapy. The output power can be varied from 0 to 3 W/cm². Thus, the intensity of the ultrasonic waves is monitored in terms of electric power converted into acoustic power.

The treatment timer is an electrically-operated contact which can be set from 1 to 15 minutes. Thus, it switches off the output power after the preset time.
