Mohamed Sathak A.J College of Engineering
Department of Electronics and Communication Engineering

MEDICAL ELECTRONICS

UNIT 1 : BIO POTENTIAL ELECTRODES

Dr.M.Sivakumar,
Associate Professor/ECE
Mohamed Sathak AJ College of Engineering

SYLLABUS

1. BIO POTENTIAL ELECTRODES
2. ELECTRODE CONFIGURATIONS
3. BIO AMPLIFIER
4. MEASUREMENT OF NON-ELECTRICAL PARAMETERS
5. BIO-CHEMICAL MEASUREMENT

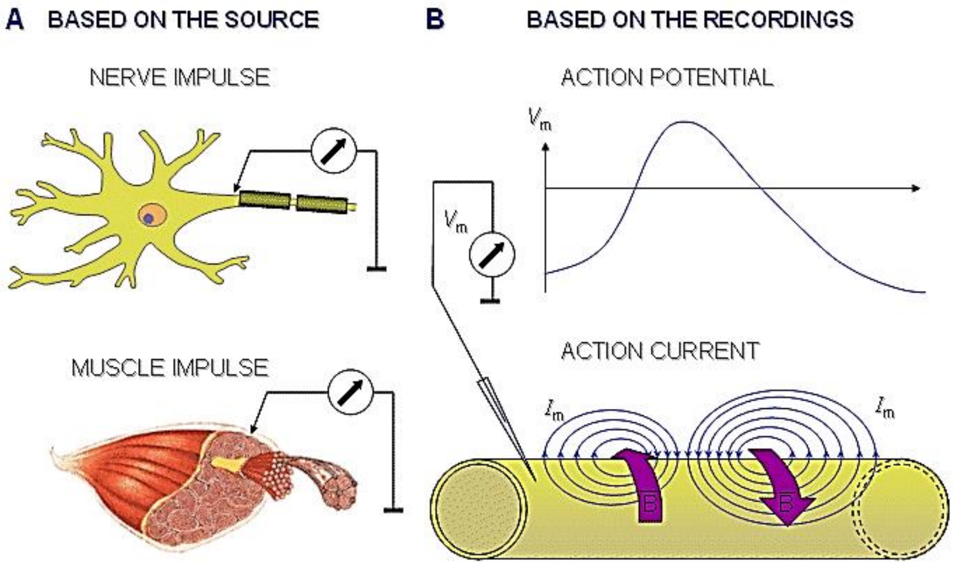
UNIT 1 : BIO POTENTIAL ELECTRODES

- ❖ Origin of bio potential and its propagation
- ❖ Electrode-Electrolyte Interface, Electrode–skin Interface
- ❖ Half cell potential & Impedance
- ❖ Polarization effects of electrode
- ❖ Non polarisable electrodes.
- ❖ Types of electrodes - Surface, Needle and Micro Electrodes & their Equivalent Circuits
- ❖ Recording problems - Measurement With Two Electrodes.

BIO ELECTRIC POTENTIAL

❖ What is bio electric potential?

An electric potential that is measured between points in living cells, tissues, and organisms, and which accompanies all biochemical processes.



- ECG (Electrocardiogram),
- EMG (Electromyogram),
- EEG (Electroencephalogram),
- ENG (Electroneurogram),
- EOG (Electro-oculogram),
- ERG (Electroretinogram), etc. are some examples of biopotentials.

✓ Certain systems of the body generate their own monitoring signals conveying useful information about the functions they represent.

✓ Such signals are bio electric potentials and are related to Nerve Conduction, Brain Activity, Heart Beat etc.

What are 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.

- Bio Potential Electrodes used for measuring the ECG, EEG, EMG, and intracellular potentials.

There are three main types of electrodes:

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

BIO POTENTIAL ELECTRODES

❖ What is electrode? List out the types

✓ It is a component used to pickup the bio potential signals.

✓ Basically there are Two types of electrode Polarizable Electrode & Non Polarizable Electrode.

What is electrode potential? The voltage developed by an electro-electrolyte interface is called electrode potential.

❖ **Polarizable electrode**

Polarizable electrode are those in which no actual charge across the electrode electrolyte interface when current is applied.

❖ **Non polarizable electrode**

Non polarizable electrode are those in which curent passes freely across the electrode electrolyte interface requiring no energy to make the transition.

Classification of Non Polarizable Electrodes:

There are 2 types of Non Polarizable Electrode

1) Internal Electrode 2) External Electrode

✓ Internal Electrode – The electrode are inserted depth to body

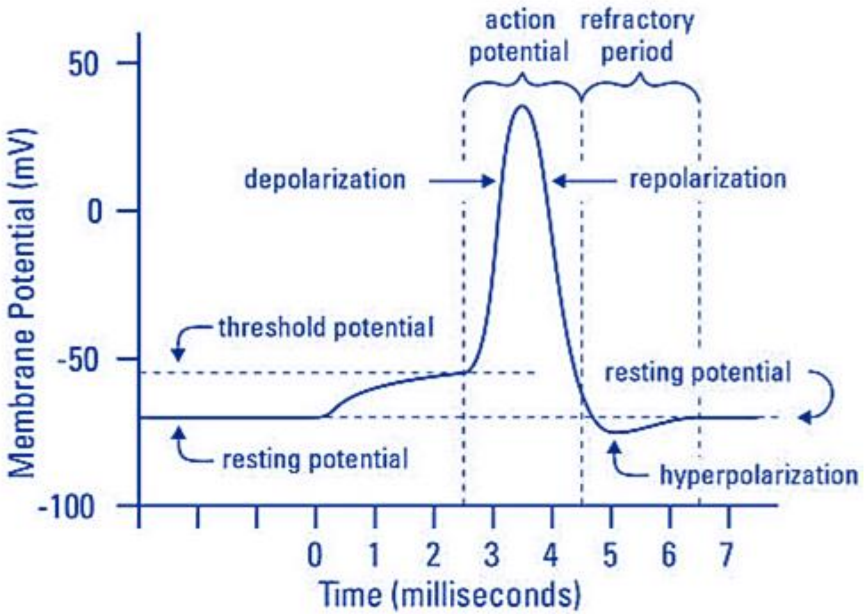
✓ External Electrode – The electrodes are placed to the surface of the skin.

Bio Electric Potential

- 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 semipermeable 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)
- 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 polarized 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.

Action Potential Wave form



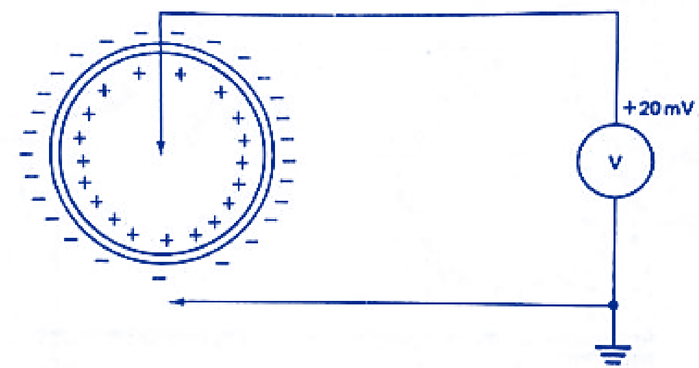


Fig: Depolarization cell during an action potential

- ❖ A typical action-potential waveform, beginning at the resting potential, depolarization, and returning to the resting potential after repolarization.
- ❖ 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.
- ❖ 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.
- ❖ 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.

Half-cell Potential (Or) Electrode Potential

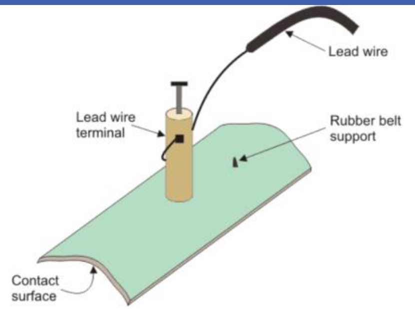
- The voltage development at an electrode – electrolyte interface is designated as the Half-cell potential.
- In metal solution interface, an electrode potential results from two processes.
  - The passage of ions from metal into solution
  - The combination of metallic ions in solution with electrons in metal to from atoms of metal.

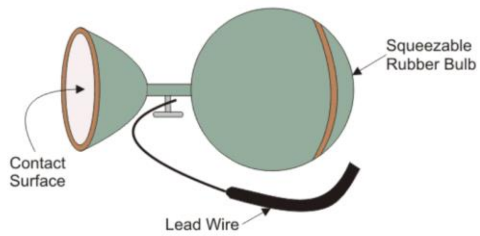
- Electrodes in which no net transfer of charge occurs across the metal electrolyte interface are called as perfectly polarized electrodes.
- Electrodes in which unhindered exchange of charge is possible across the metal electrolyte interface are called perfectly non-polarizable electrode.
- The electrode potential is not a stable and its variations constitute a source of variable noise voltage called artifact.

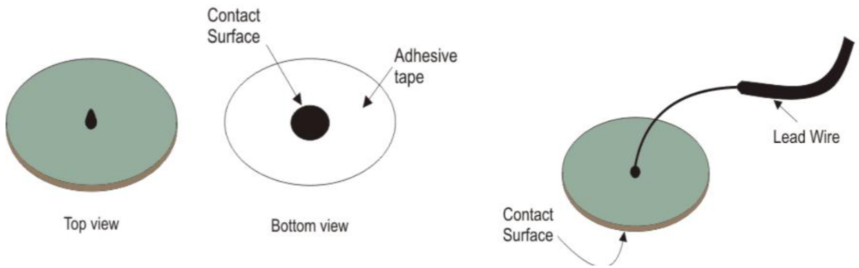
Polarization effects of electrode

- How will you reduce the polarization effects of electrodes?
- A depolarizer or depolariser, in electrochemistry, according to an IUPAC definition, is a synonym of electroactive substance, i.e., a substance which changes its oxidation state, or partakes in a formation or breaking of chemical bonds, in a charge-transfer step of an electrochemical reaction.
- In the battery industry, the term "depolarizer" has been used to denote a substance used in a primary cell to prevent buildup of hydrogen gas bubbles.
- A battery depolarizer takes up electrons during discharge of the cell; therefore, it is always an oxidizing agent.
- The term "depolarizer" can be considered as outdated or misleading, since it is based on the concept of "polarization" which is hardly realistic in many cases .

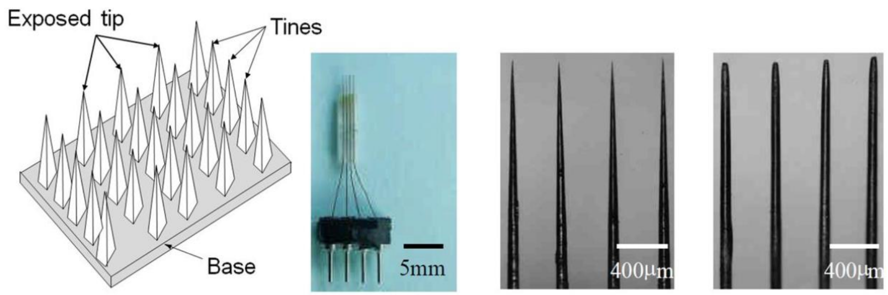
DIFFERENT TYPES OF SURFACE ELECTRODES

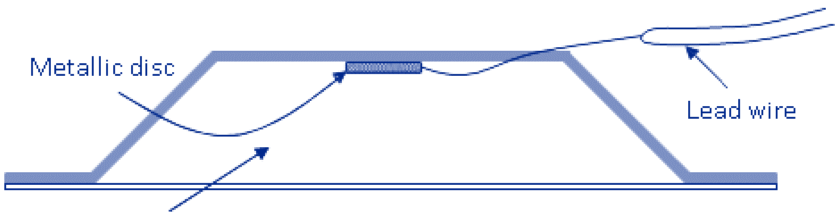






- Metal Plate electrodes
- Suction cup electrodes
- Adhesive tape electrodes





- Multi point electrodes
- Floating electrodes

Microelectrodes : Metal Microelectrode

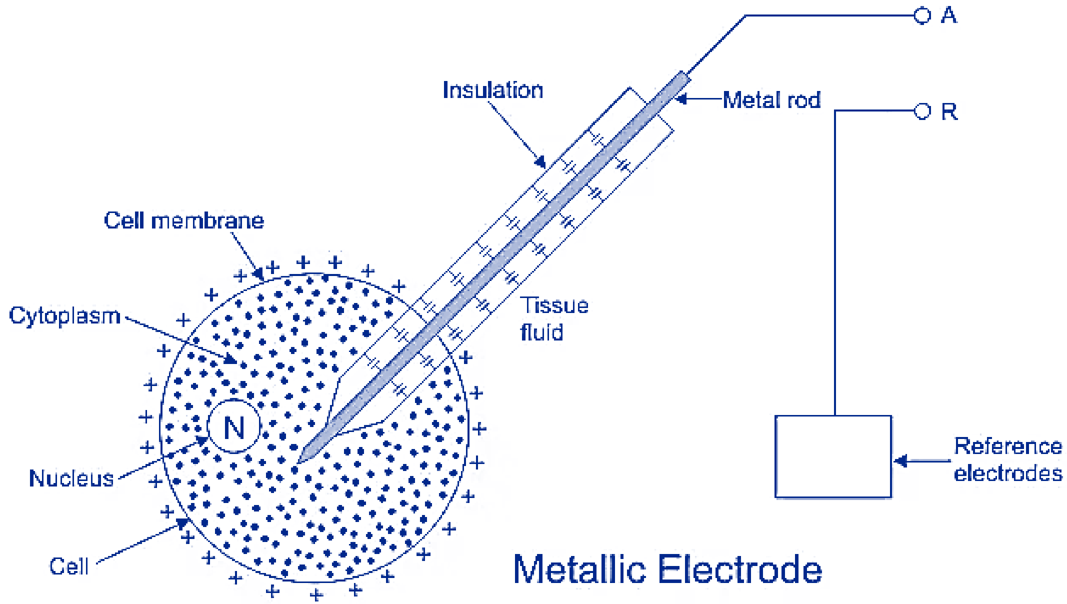
➢ **Microelectrode measures the electric potential from within a single cell.**

Two types of microelectrode are

1. Metal Microelectrode
2. Non- Metallic (Micropipette)

➢ Metal Microelectrode

- The tungsten filament or stainless steel wire made into minute structure forms the tip of the microelectrode.



Non-Metal Microelectrode (Micropipet)

➢ **This electrode uses Non – metallic material to measure the potential from a single cell.**

<u>Two types of microelectrode are</u>

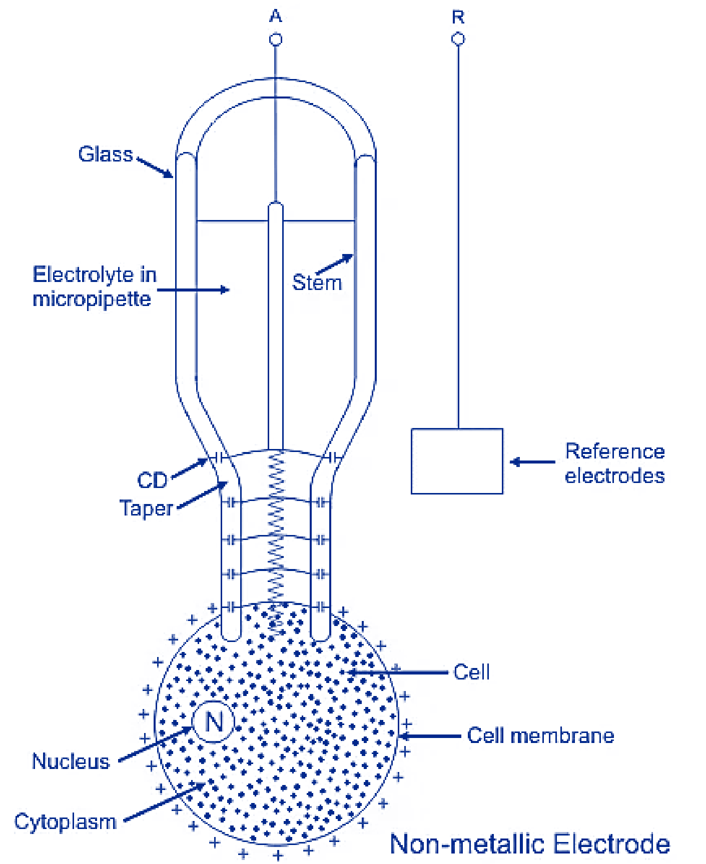
1. Metal Microelectrode
2. Non- Metallic (Micropipette)

➢ Non-Metal Microelectrode (Micropipet)

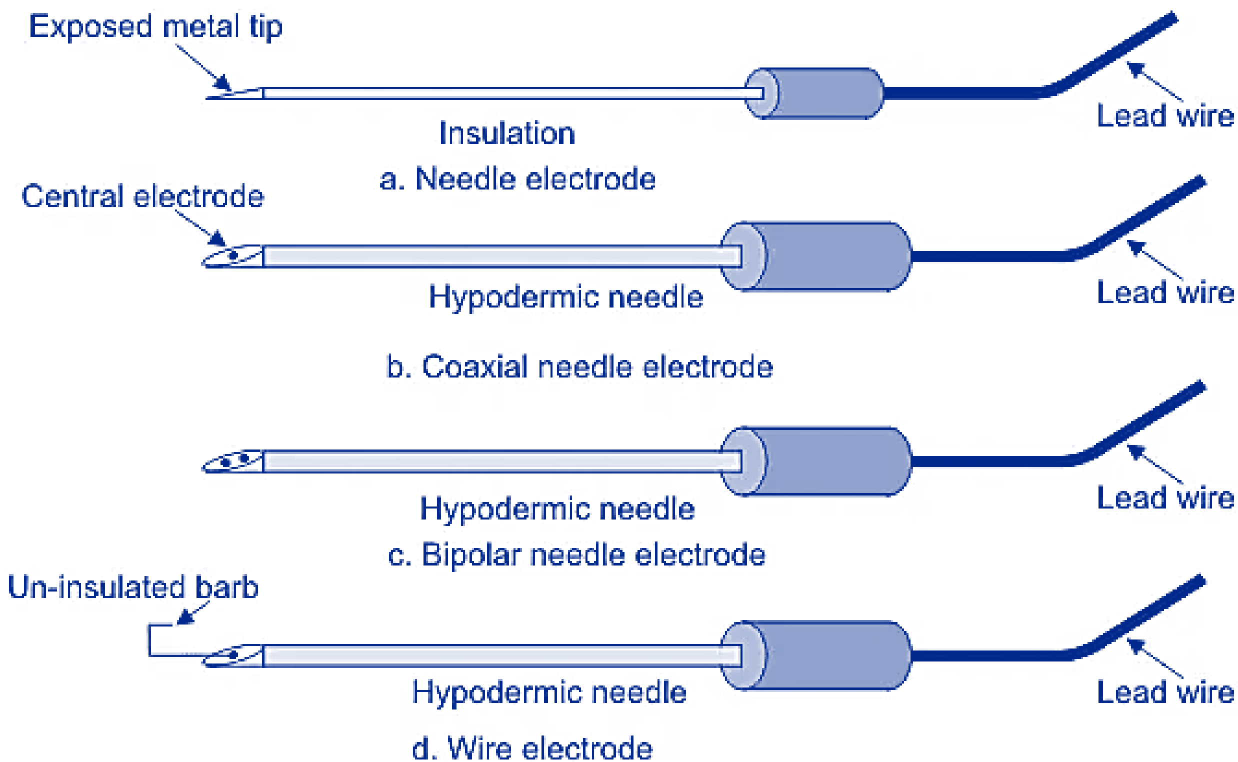
❖ Micropipet filled with electrolyte solution that is compatible with cellular fluids is used.

❖ 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.

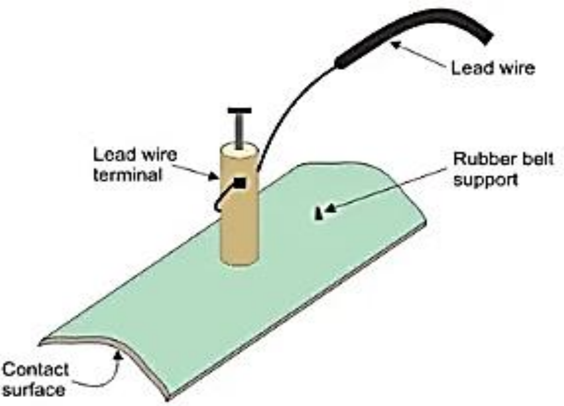


Needle Electrodes

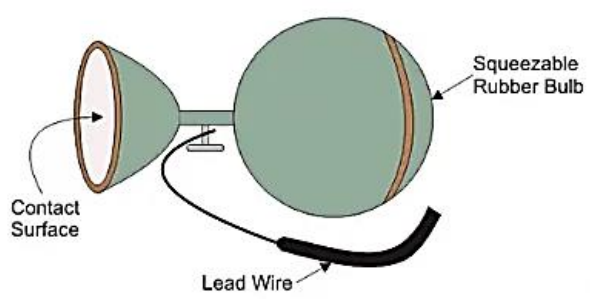


- **Needle electrode records the peripheral nerve action potential. It resembles a medicinal syringe.**
- Needle electrodes are mostly used in the measurement of EEG and EMG signals.

Body Surface electrodes (Floating, Metal Plate & Multipoint)



Metal Plate Electrode:



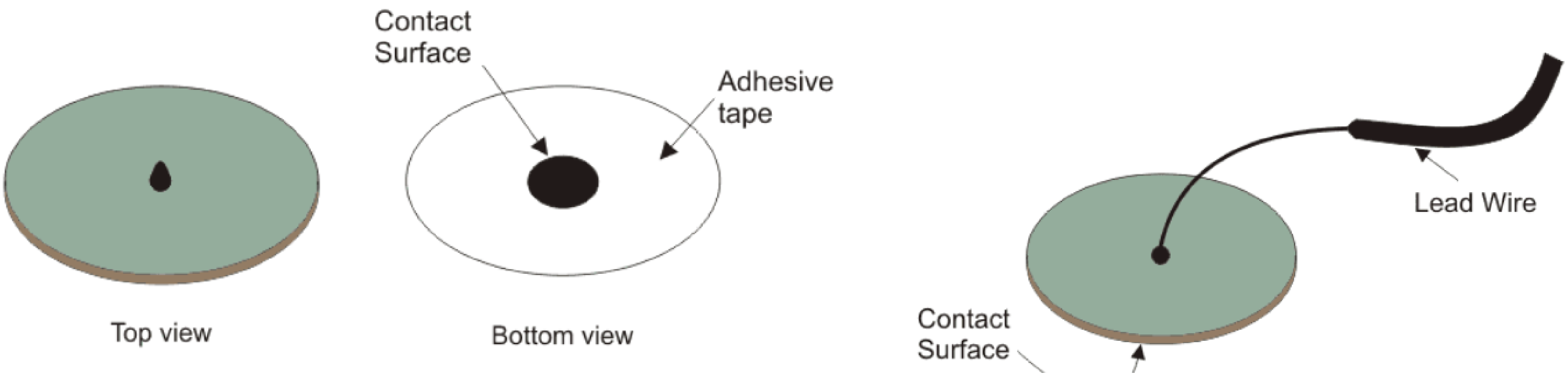
Suction Cup Electrodes Or Welsh Cup Electrodes

- Since it is suitable for application on four limbs of the body, they called limb electrodes.
- During surgical procedure since patient's legs are immobile, limb electrodes are preferred.
- Chest electrodes interfere with the surgery, so not used for ECG measurement.

- To measure ECG from various positions on the chest, Suction cup electrodes are used.
- It suits well to attach electrodes on flat surface of the body and on soft tissue regions.
- They have a good contact surface.
- Physically they are large but the skin contacts only the electrode rim.
- It has high contact impedance.

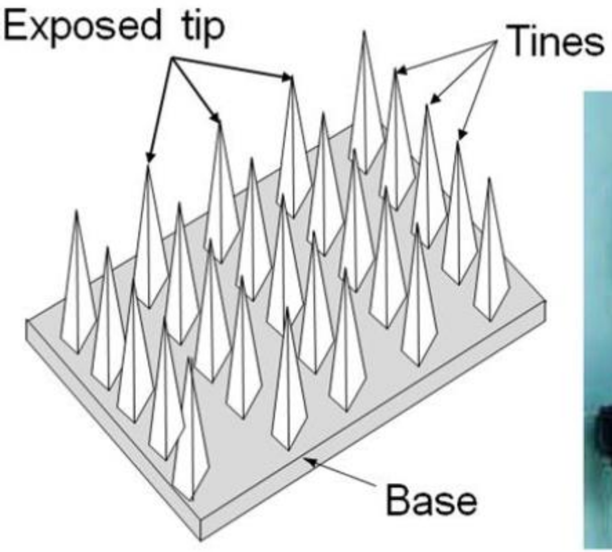
Adhesive Type Electrodes

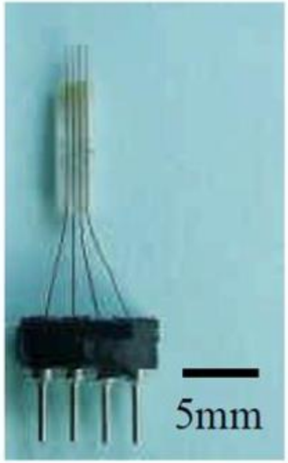
- In the surface electrode, the pressure of surface electrode against the skin squeezes out the electrode paste.
- To avoid this problem, adhesive electrodes are used. It has a lightweight metallic screen.
- It has a lightweight metallic screen.
- They have a pad at behind for placing electrode paste. This adhesive backing hold the electrode on place and tight. It also helps to avoid evaporation of electrolyte present in the electrode paste.

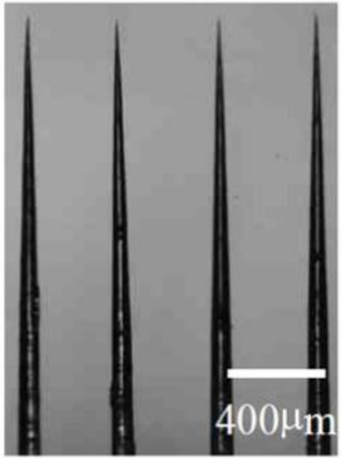


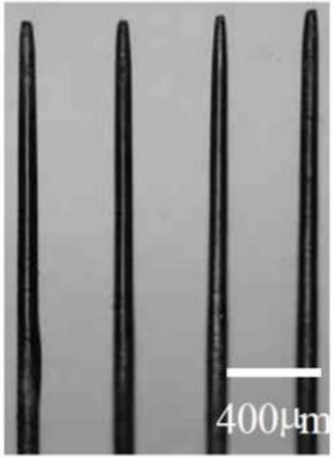
Multipoint Type Electrodes

- Multipoint electrodes are very practical electrode setup for ECG measurements.
- It has more than 1000 active contact points.
- This helps to establish low resistance contact with the human.
- Under any environmental condition, doctors can use multipoint electrode.



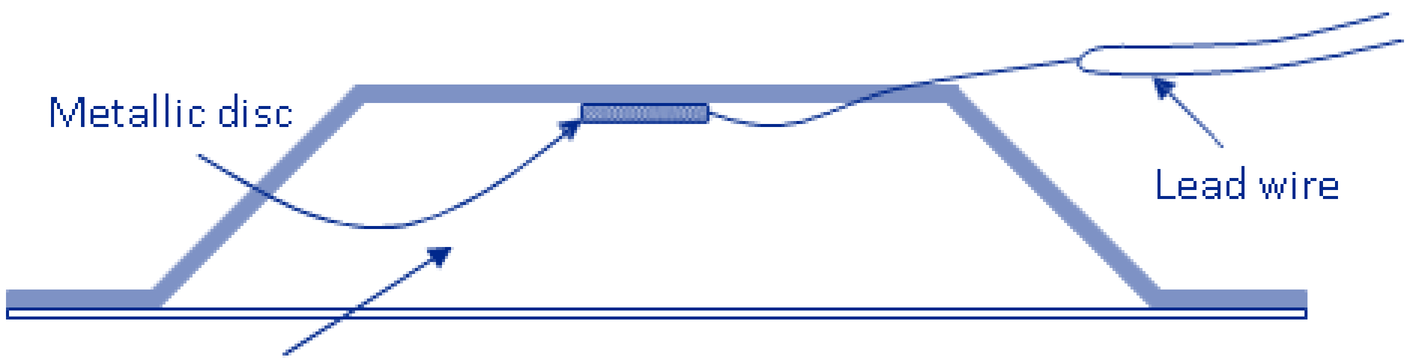






Floating Electrodes

- In metal plate or limb electrodes, the major disadvantage is the movement errors.
- Motion artifact occurs due to the motion at the interface between electrode and electrolyte.
- The interface gets stabilized using Floating electrodes.
- The floating electrodes do not contact the human subject directly.
- They contact the subject via electrolytic paste or jelly. The advantage of this type is the mechanical stability.

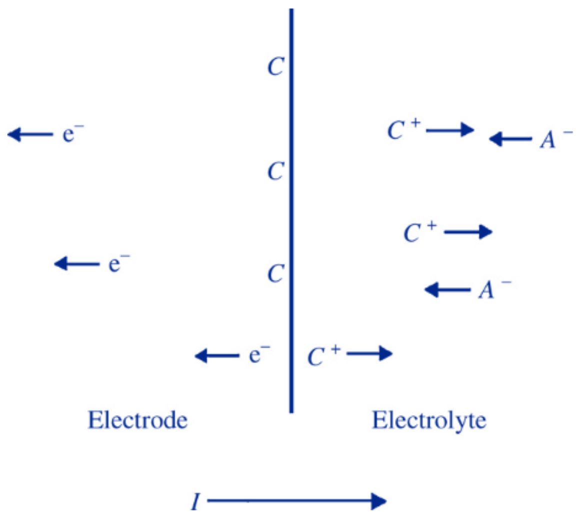


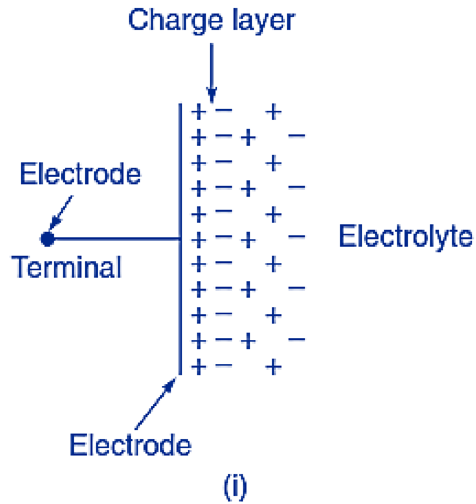
Ear Clips and Scalp Electrodes

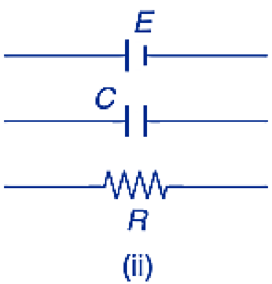
- In the measurement of EEG, ear clip electrodes are used.
- Scalp electrodes provide EEG signals easily when placed on bare head.
- Generally, in 10 – 20 electrode system EEG measurement scalp electrodes are used.
- This type avoids measurement errors. During labor, fetal scalp electrode monitors baby's heart beat

THE ELECTRODE–ELECTROLYTE INTERFACE

- In order to measure and record potentials and, hence, currents in the body, it is necessary to provide some interface between the body and the electronic measuring apparatus.







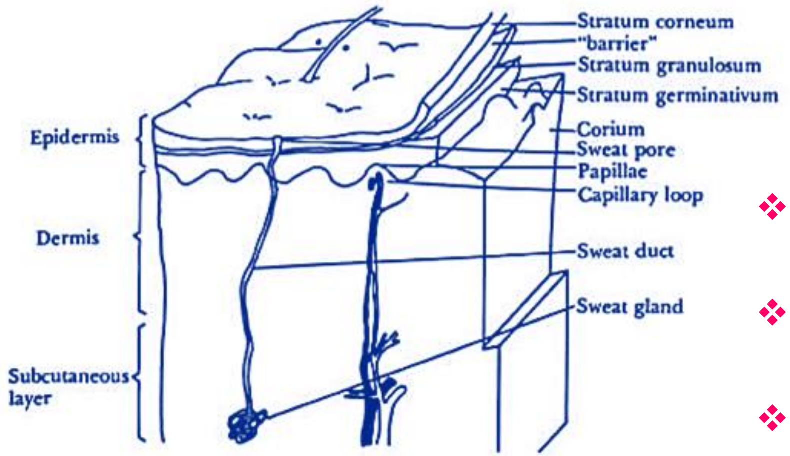
(i) Charge distribution at electrode-electrolyte interface
(ii) Three components representing the interface

Fig : Electrode–electrolyte interface The current crosses it from left to right.

- The passage of electric current from the body to an electrode can be under- stood by examining the electrode–electrolyte interface that is schematically illustrated in Figure

THE ELECTRODE–SKIN INTERFACE AND MOTION ARTIFACT

Transparent electrolyte gel containing Cl^- is used to maintain good contact between the electrode and the skin.



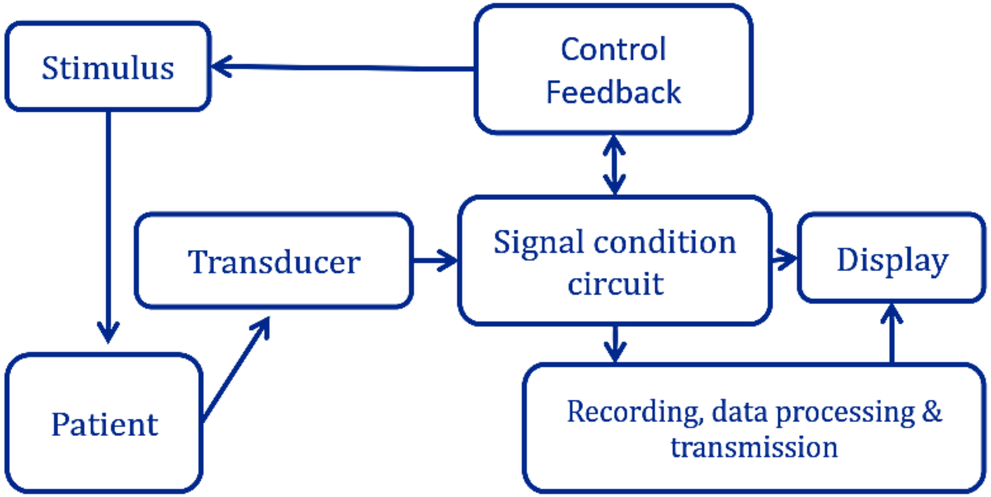
- ❖ Motion artefact is a problem in biopotential measurements.
- ❖ The problem is greatest in cardiac stress laboratories where the exercise ECG is recorded.

- ❖ Motion artefact is reduced to a negligible magnitude by skin abrasion.
- ❖ However, when the skin is abraided, it is more susceptible to irritants.
- ❖ The possible sources for skin irritation include the electrode, the paste and the adhesive.

❖ When bio potentials are recorded from the surface of the skin, we must consider an additional interface—the interface between the electrode–electrolyte and the skin—in order to understand the behavior of the electrodes.

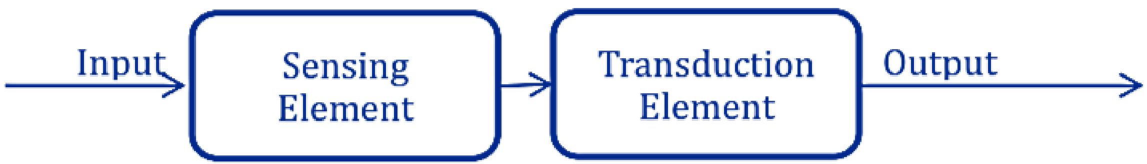
- In coupling an electrode to the skin, we generally use transparent electrolyte gel containing Cl^-as the principal anion to maintain good contact.
- Alternatively, we may use an electrode cream, which contains $Cl^-$and has the consistency of hand lotion.

Recording problems - Measurement With Two Electrodes.



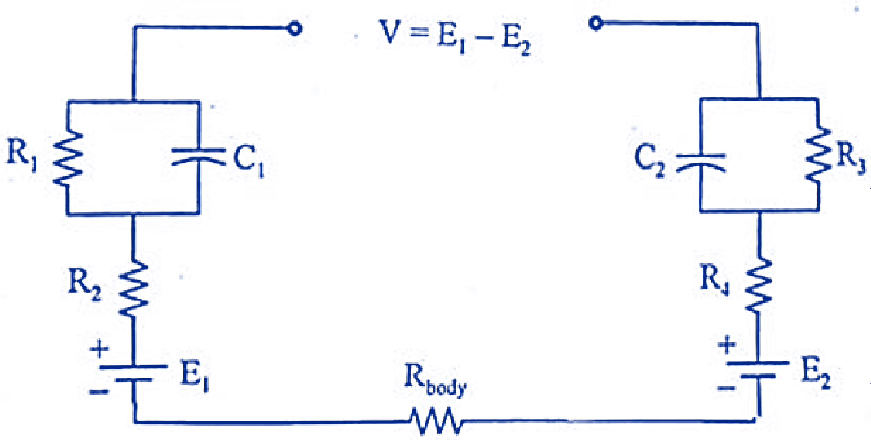
Components of man-instrument system

Transducer consists of two main parts, that is,



- Sensor or Sensing Element: This part is responsible for generating measurable response with respect to the change in physical quantity to be measured.
- Transduction Element: Sensor output is carried on to the transduction element which converts the non-electrical signal to electrical signal in proportion to the input.

Recording problems - Measurement With Two Electrodes.



- Measurement of the bioelectric potentials requires two electrodes.
- The voltage measured is really the difference between the instantaneous potential of the two electrodes.
- If two electrodes are of same type the difference is usually small and depends essentially on the actual difference of ionic potential between the two points of the body from which measurements are being taken.
- If two electrodes are of different type they produce a significant dc voltage that can cause current to flow through both electrodes as well as through the input circuit of the amplifier to which they are connected

The resistance capacitance networks shown in the above figure represent the impedance of the electrodes as fixed value of resistance and capacitance unfortunately the impedance is not constant.

- The DC voltage due to the difference in electrode potential is called offset voltage of electrode the two Electrodes of same material may also produce small electrode offset voltage.
- Chemical activity takes place within an electrode can cause voltage fluctuations to appear without any physiological input.
- Such Variations may appear as noise on bioelectric signal. It may reduce by proper choice of materials or by coating the electrodes to improve stability, the best material for this is Silver-silver chloride

2 Marks Q & A

What are resting potential?

The membrane potential measured when a equilibrium is reached with a potential difference across the cell membrane negative on the inside and positive on the outside is called resting potential.

What is action potential?

When a stimulus is applied to a cell at the resting stage, there will be a high concentration of the positive ions inside the cell. So there will be slightly high potential on the inside of the cell due to imbalance of potassium ions. This is called action potential.Range:20Mv.

What is bio electric potential?

Certain systems of the body generate their own monitoring signals conveying useful information about the functions they represent. Such signals are bio electric potentials and are related to nerve conduction, brain activity, heart beat etc.

List the types of bioelectric potentials.

Bio electric potential related to

- Heart – ElectroCardioGram (ECG)
- Brain – ElectroEncephaloGram (EEG)
- Muscle – ElectroMyoGram (EMG)
- Eye (Retina) – ElectroRetinoGram (ERG)
- Eye (Cornea - Retina)– ElectroOculoGram (EOG)

Define electrode and list its types.

The device that convert ionic potential into electronic potential are called as electrode. The types of electrode are

- ✓ Micro electrode
- ✓ Depth and needle electrode
- ✓ Surface electrode

2 Marks Q & A

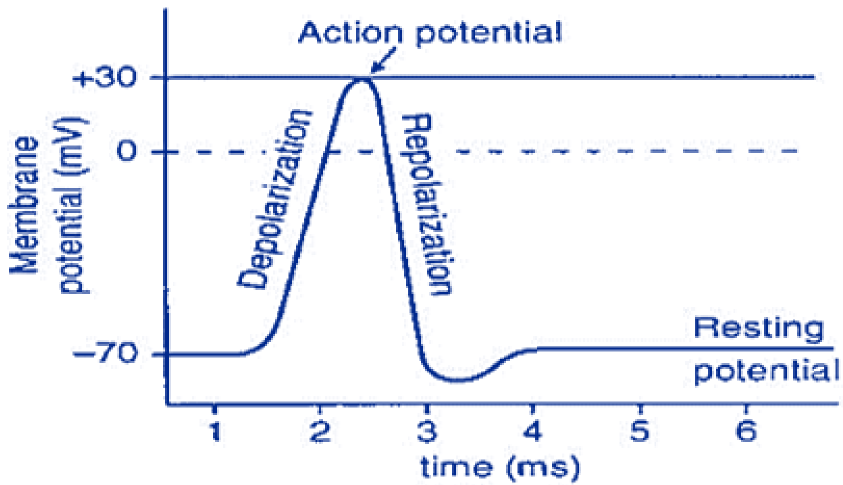
What are perfectly polarized and perfectly non polarized electrodes?

- Electrodes in which no net transfer of charge occurs across the metal electrolyte interface is called perfectly polarized electrode.
- Electrodes in which unhindered exchange of charge occurs across the metal electrolyte interface is called perfectly non polarized electrode.

What are the basic components of biomedical systems?

- Patient
- Transducer
- Signal processing equipment
- Display
- Control unit
- Stimulus

Draw the Wave form of the resting and action potential.




THANK YOU

MEDICAL ELECTRONICS

ELECTRODE CONFIGURATIONS

ELECTRODE CONFIGURATIONS

- ❖ Bio signals characteristics - Frequency and amplitude ranges.
- ❖ ECG – Einthoven's triangle.
- ❖ Standard 12 Lead ECG system.
- ❖ EEG – 10-20 Electrode system.
- ❖ Unipolar, Bipolar & Average Mode.
- ❖ EMG– Unipolar and bipolar mode.

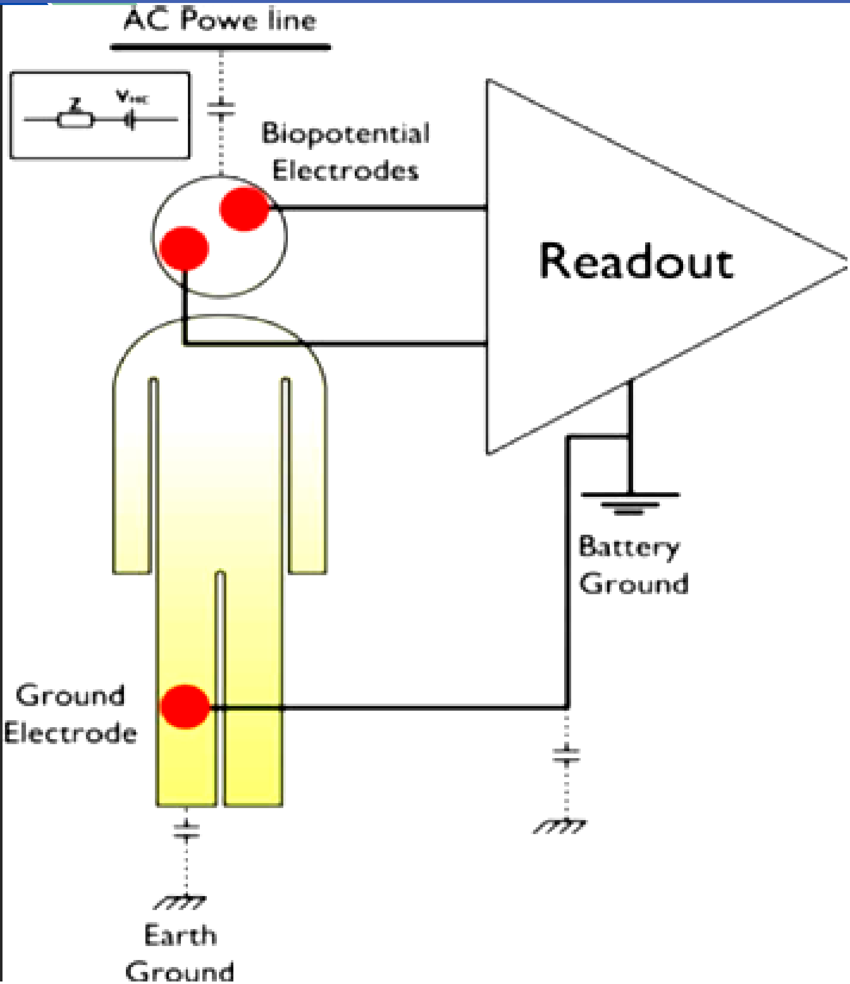
Bioelectric Signals

- Traditional Bioelectric Signals
  - Electro cardiogram ECG (or EKG): Heart action - Surface Electrodes used
  - Electro myogram EMG, ENG: Muscles Movement - Surface & Needle Electrodes used
  - Electro Encephalogram EEG, ECoG: Activity of Brain - Miniature Surface Electrodes
- Non Traditional Bioelectric Signals
  - Electrogastrogram EGG: Measuring potential value @ Stomach - Surface Electrodes
  - Electro oculogram EOG: Eyeball movement
  - Electro Retinogram ERG: Retina – Corneal Electrode
  - Galvanic Skin Response GSR: Skin Response
- Some other signals such as Breathing, Temperature, Movement etc.

Classification of biosignals

- According to the physical nature of bio signals
  - Electric
  - Magnetic
  - Chemical
  - Mechanical (acoustic)
  - Optical
  - Thermal
- According to the system of origin of biosignals
  - Endocrine system
  - Nervous system (Central and Peripheral)
  - Cardiovascular system
  - Vision system
  - Auditory system
  - Musculoskeletal system
  - Respiratory system
  - Gastrointestinal System - Blood system

Types of Bio Electrical signals



Neural cells

- ENG – electroneurogram
- EEG – electroencephalogram
- ERG – electroretinogram

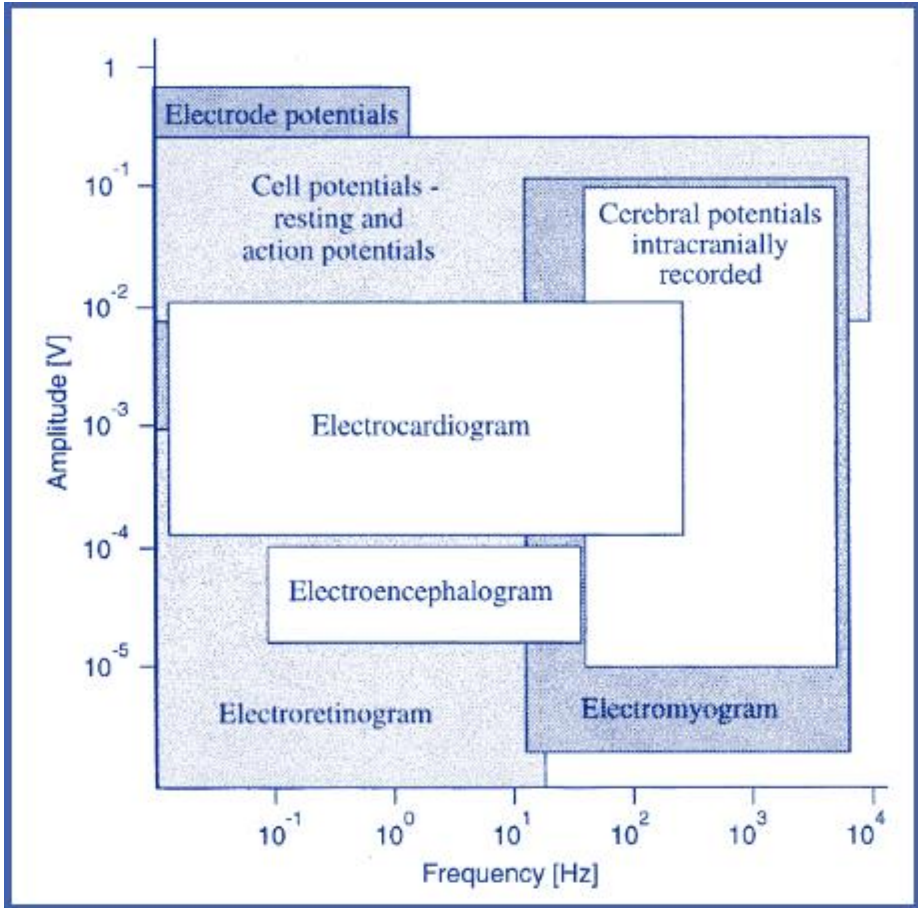
Muscle cells

- ECG – electrocardiogram
- EMG – electromyogram

Other cells

- EOG – electrooculorgam
- GSR – galvanic skin response

Amplitude and spectral ranges of bioelectric signals



Primary Characteristics of Bio electric signals

Parameter	Frequency range	Amplitude	Type of Electrode
Electrocardiogrpahy (ECG)	0.05 to 120 Hz	0.1 to 5μV 1μV	Surface
Electroencephalography (EEG)	0.1 to 100 Hz	2 to 200μV 50μV	Scalp
Electromyography (EMG)	5 to 2000 Hz	0.1 to 5μV	Needle
Electroretinography (ERG)	Dc to 20Hz	0.5 to 1μV	Contact
Electro-oculography (EOG)	Dc to 100 Hz	10 to 3500μV	Contact

Electrocardiogram (ECG)

❖ECG stands for electrocardiograph.

❖It gives a graphical representation of the electrical activity of the heart during a cardiac cycle which helps to further detect the abnormalities and help us to measure the functioning of the heart.

❖To obtain a standard ECG graph, a patient is connected to the machine with three electrical leads, one to each wrist and to the left ankle, that continuously monitor the heart activity and functioning.

❖The human heart produces an electrical impulse passing through our heart, it generates an electrical impulse by itself.

Why is an ECG Done?

<u>ECG is done to determine or detect</u>

- Abnormal heart rhythm (arrhythmias)
- If there are any blocked or narrowed arteries in your heart (coronary artery disease) are causing chest pain or a heart attack.
- To find weather you have had a previous heart attack or not.
- To monitor if the medicines are causing any side-effects to our body system.

Medical Use of ECG

The main function of ECG is to obtain information regarding the heart impulse.

There is a great medical use of this information regarding your health issues like:

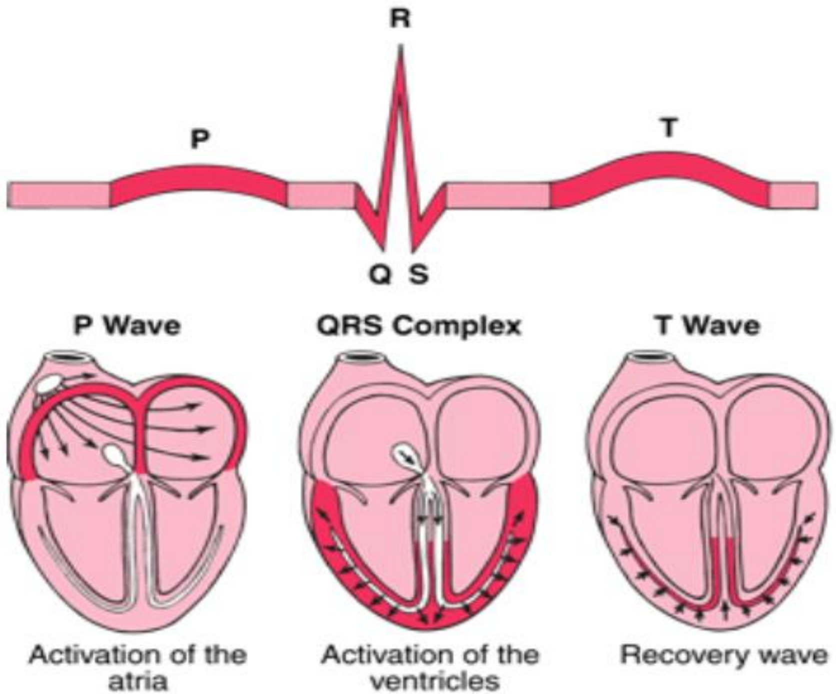
- ✓ Chest pain
- ✓ Shortness of breath
- ✓ Lightheadedness
- ✓ Dizziness
- ✓ Fainting spells
- ✓ It is also required prior to any type of heart surgery, including surgery for pacemaker placement.

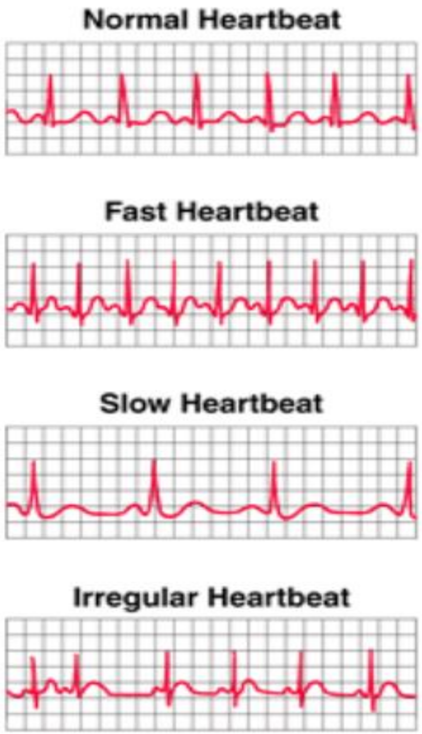
Electrocardiogram (ECG)

ECG : The ECG is the recording of the electrical activity of the heart.

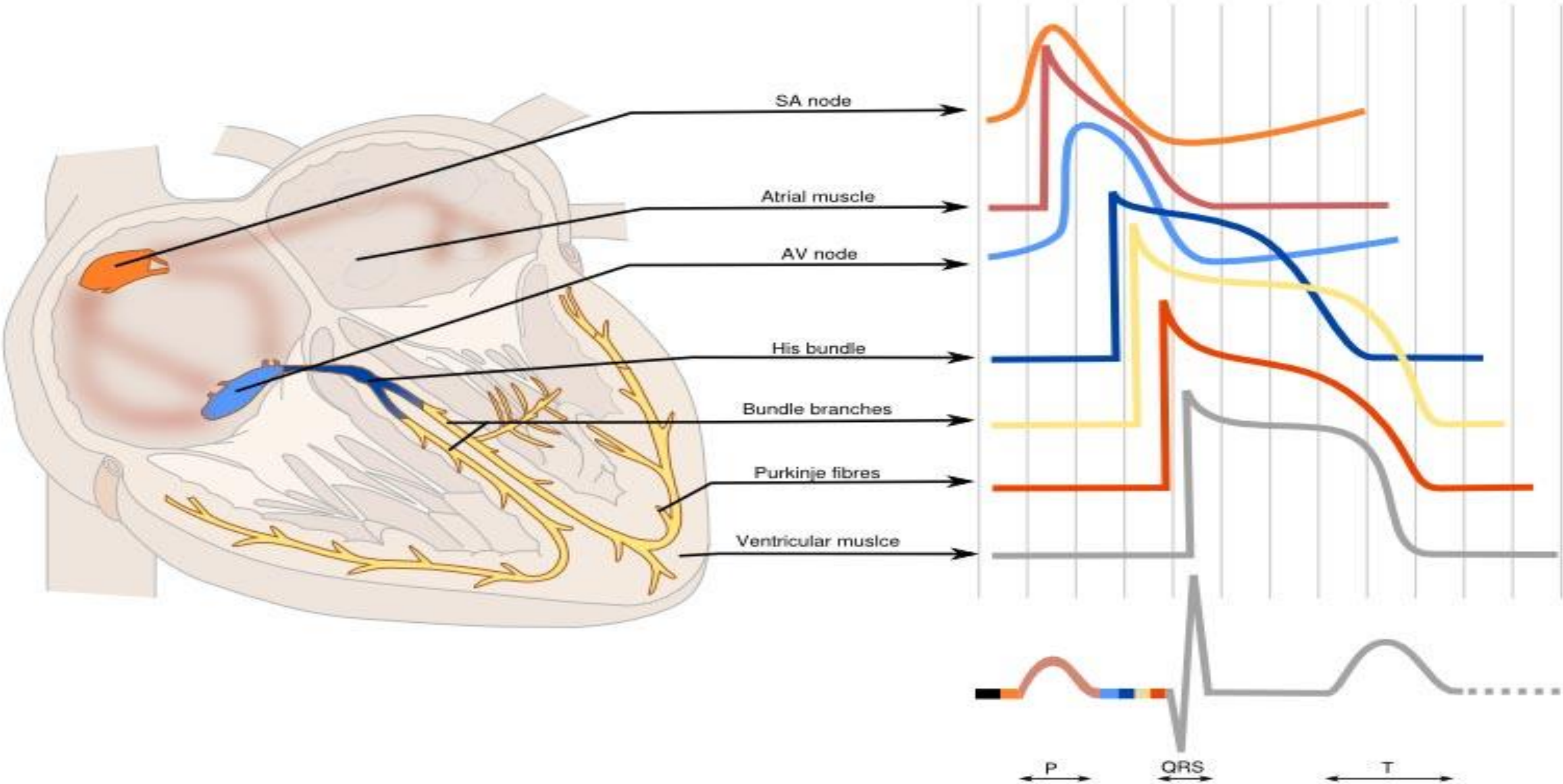
- ❖ Electrocardiography deals with the study of the electrical activity of heart muscles.
- ❖ The potentials originated in the individual fibres of heart muscle are added to produce ECG waveform.

These are the bipotentials generated by the muscles of the heart known as electrocardiogram.

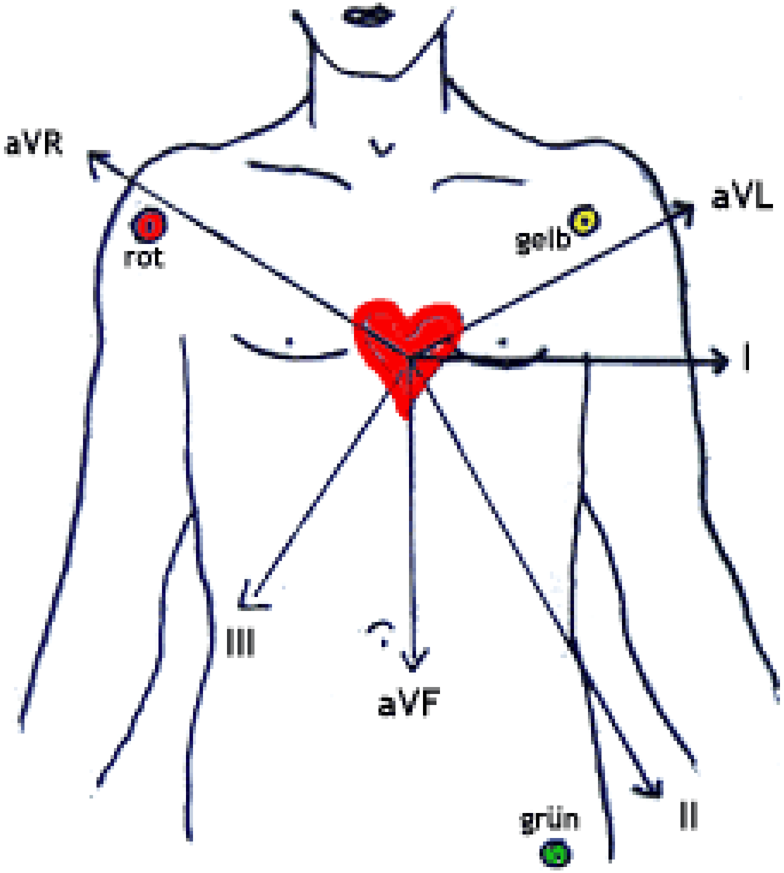


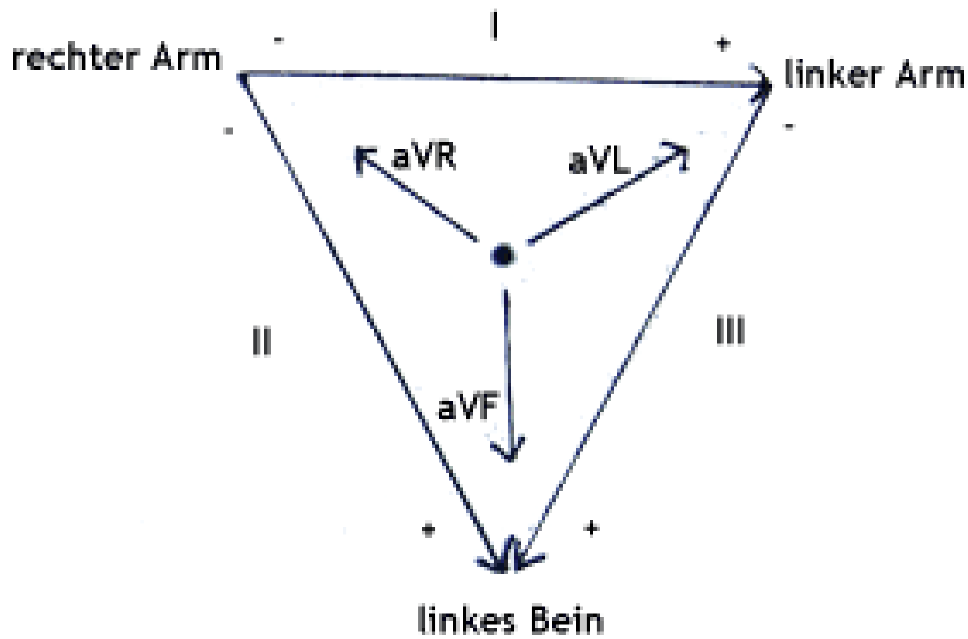


Composition of ECG Signal



ECG measurement

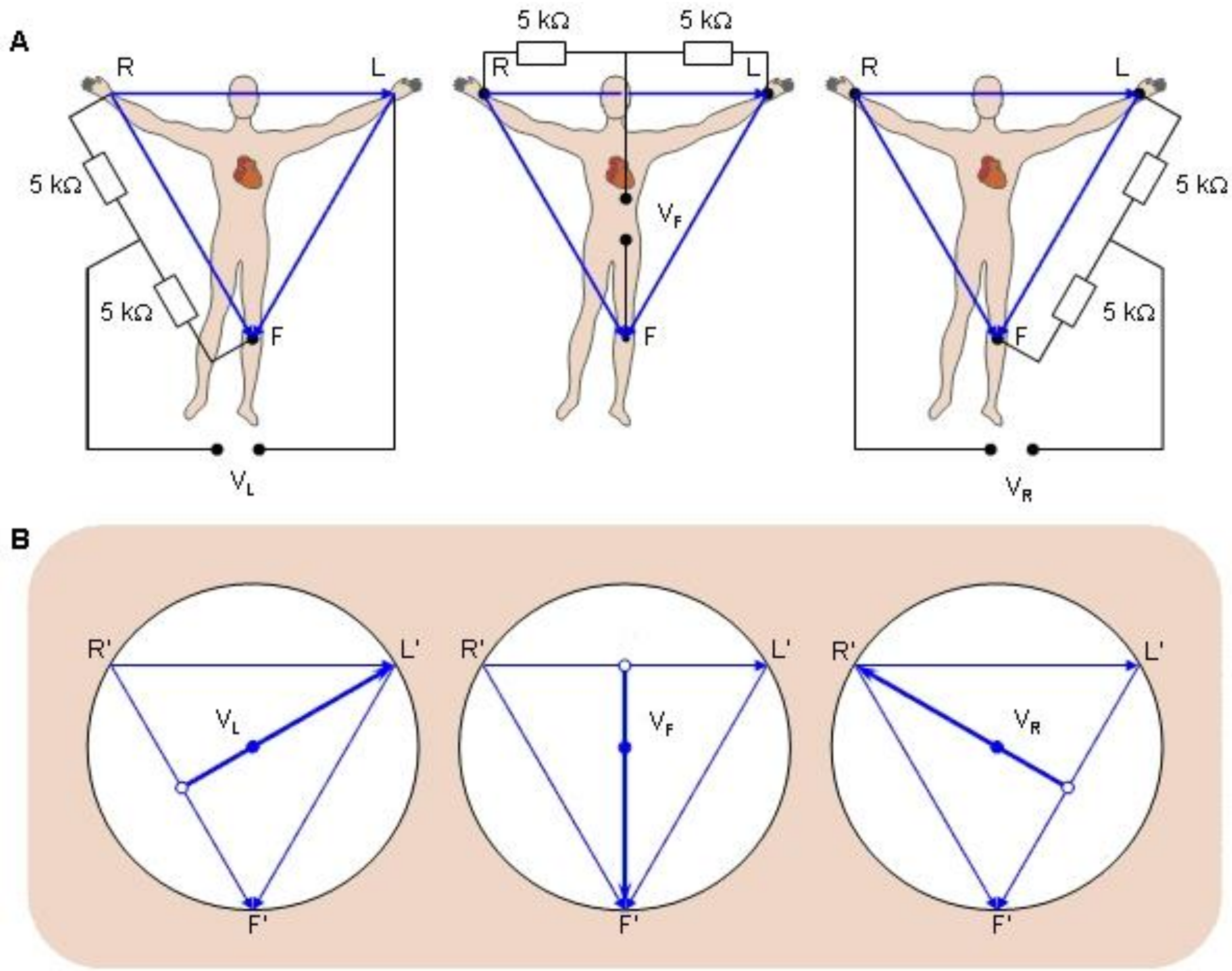




Goldberger (left) Einthoven (right)

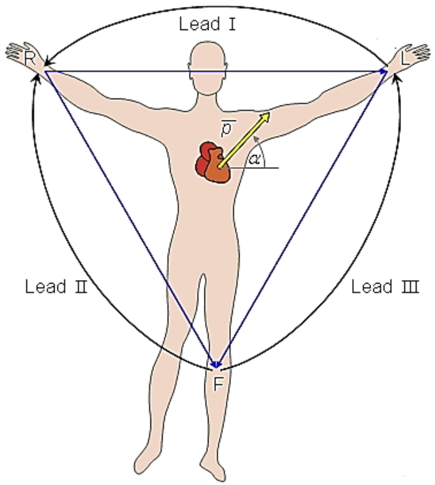
12-Lead ECG measurement

Goldberger augmented leads: V_R, V_L & V_F

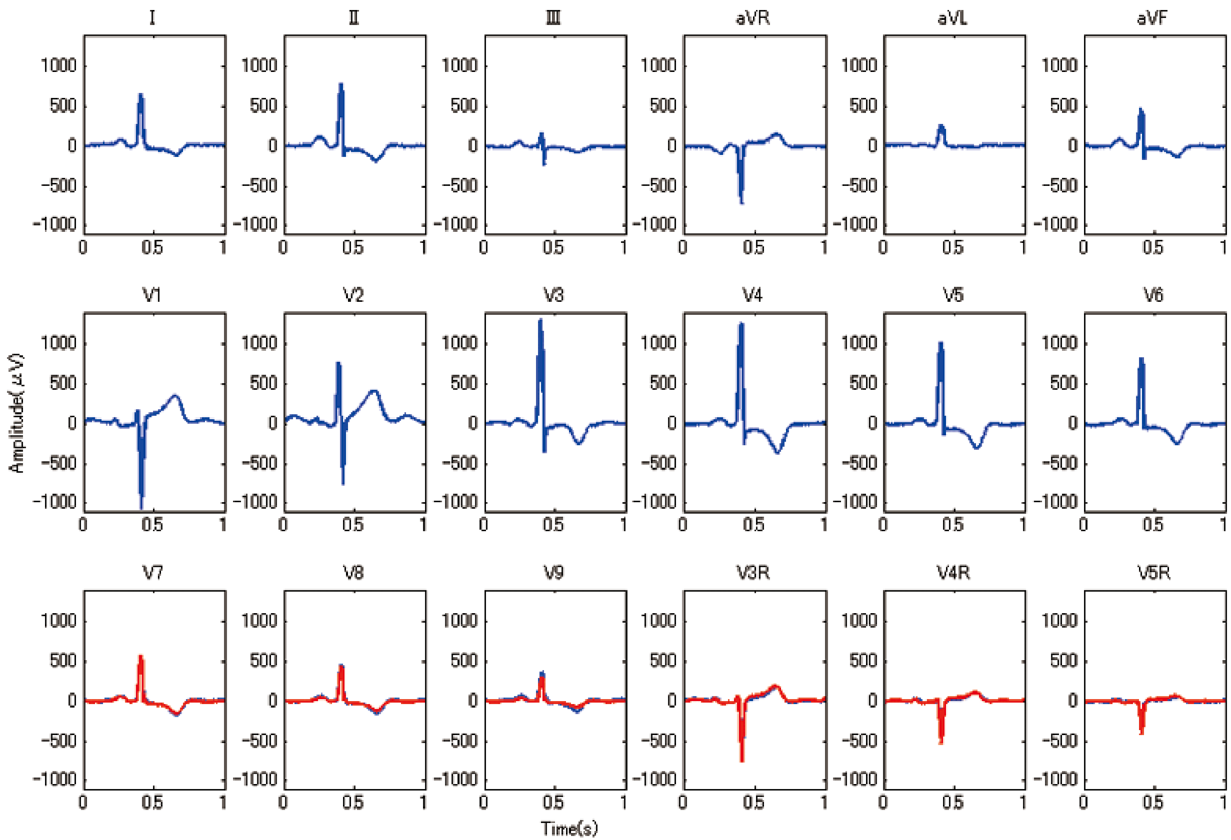


12-Lead ECG measurement

- Most widely used ECG measurement setup in clinical environment
- Signal is measured non-invasively with 9 electrodes.

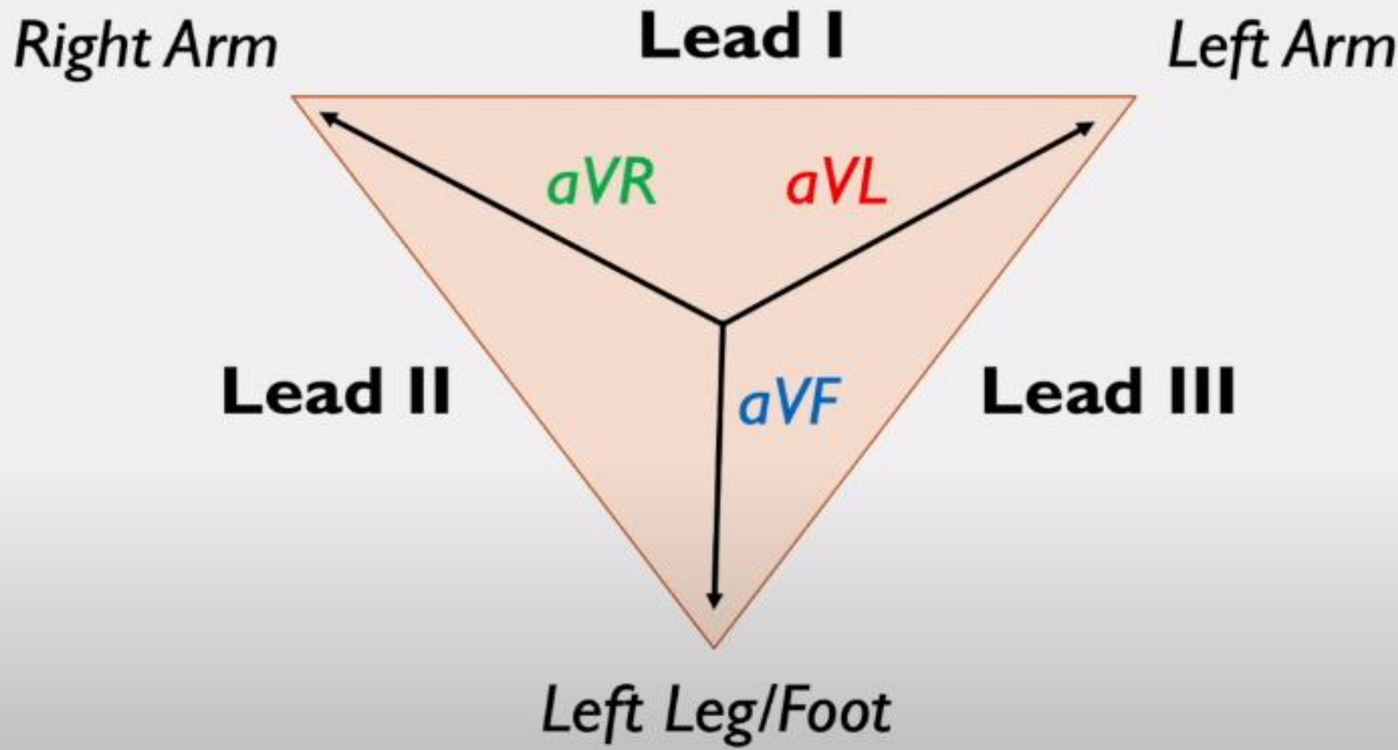


Einthoven leads: I, II & III

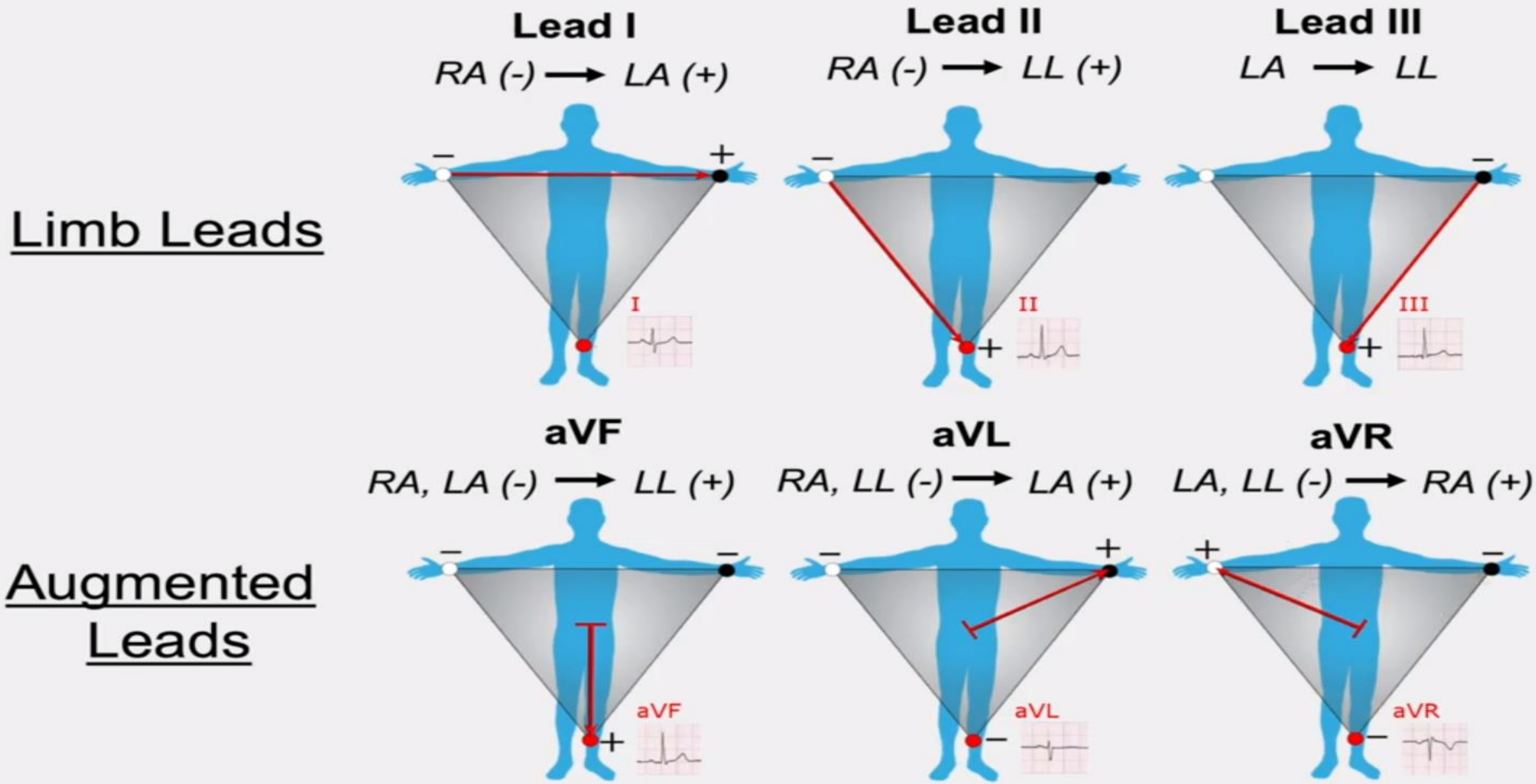


12 (and beyond) Lead ECG

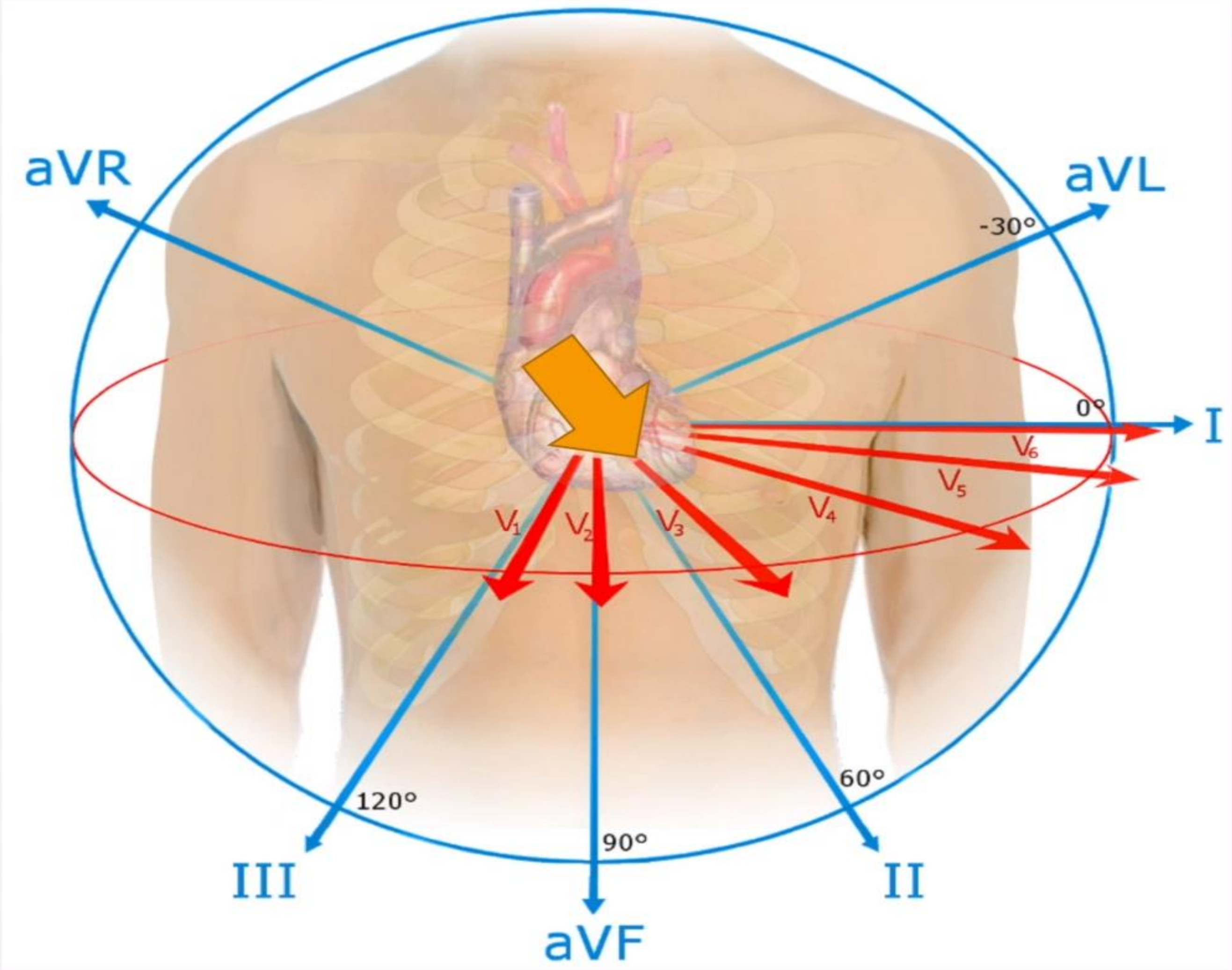
ECG Leads: Einthoven's Triangle



ECG Leads: Einthoven's Triangle



Precordial Leads



PQRST Wave

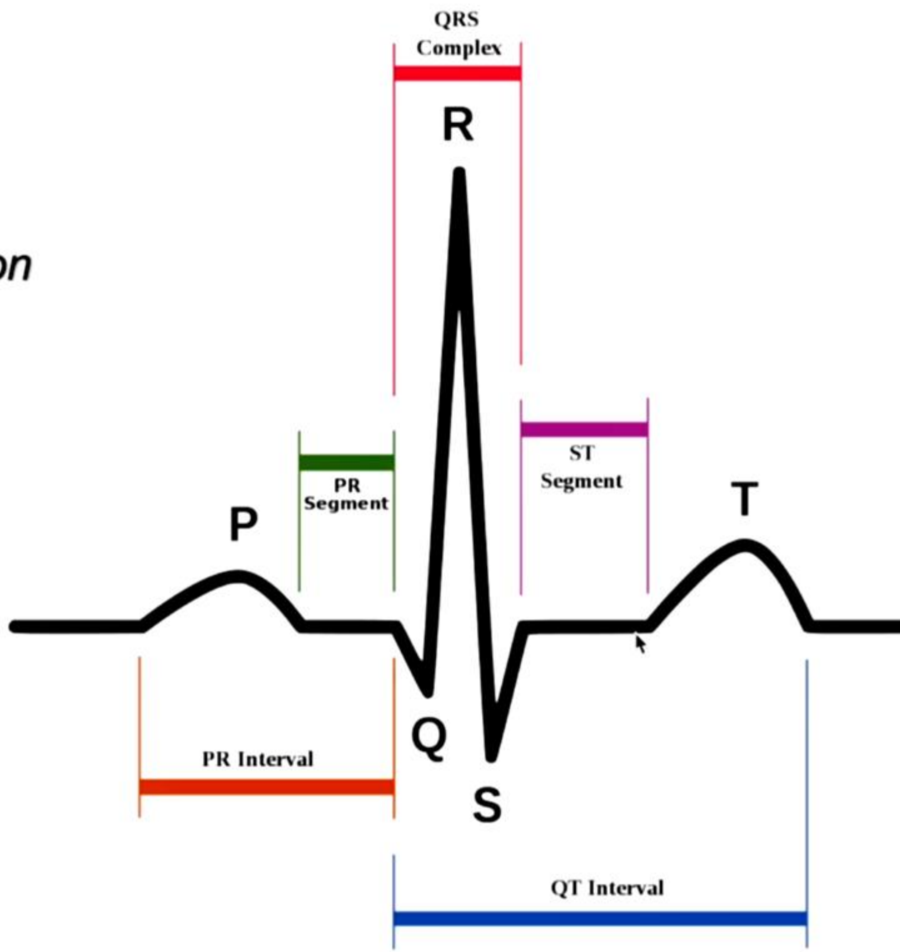
- *P Wave = Atrial Depolarization*
- *QRS Complex = Ventricular Depolarization*
- *T Wave = Ventricular Repolarization*
- *U Wave = Purkinje Fiber Repolarization*

Intervals & Segments

PR Interval
Beginning of P Wave to beginning of QRS

QRS Complex
Beginning of Q Wave to End of S Wave

QT Interval
Beginning of Q Wave to End of T Wave



Heart Rate

- *Normal rate: 60-100 BPM*
- *Bradycardia: <60 BPM*
- *Tachycardia: >100 BPM*

How to Calculate

1) *QRS complexes x 6 = BPM*
2) *Rate = 60/(R-R Interval Time)*
3) *Rate = 300/(# of large boxes between R-R interval)*

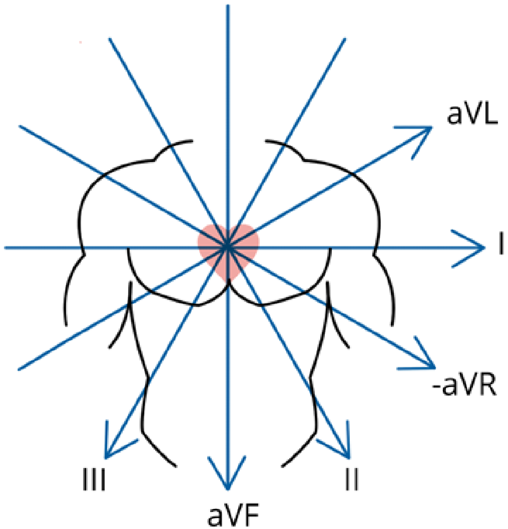
Sinus Bradycardia

Sinus Tachycardia

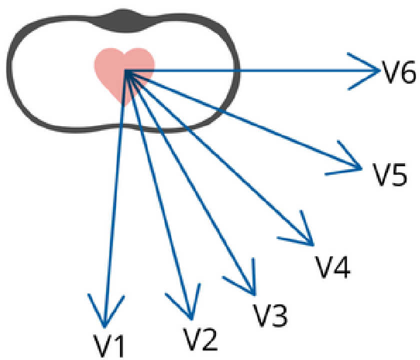
12-Lead ECG Measurement

- The standard 12-lead electrocardiogram is a representation of the heart's electrical activity recorded from electrodes on the body surface.

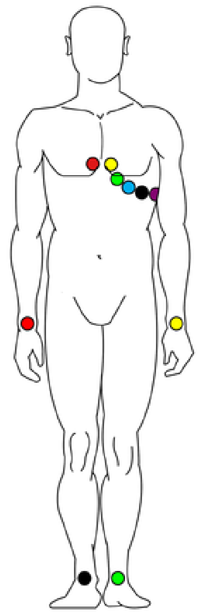
- 6 vertical and 6 horizontal visual axes



Extremities: I, II, III, aVR, aVL, aVF



Chest wall: V1, V2, V3, V4, V5, V6

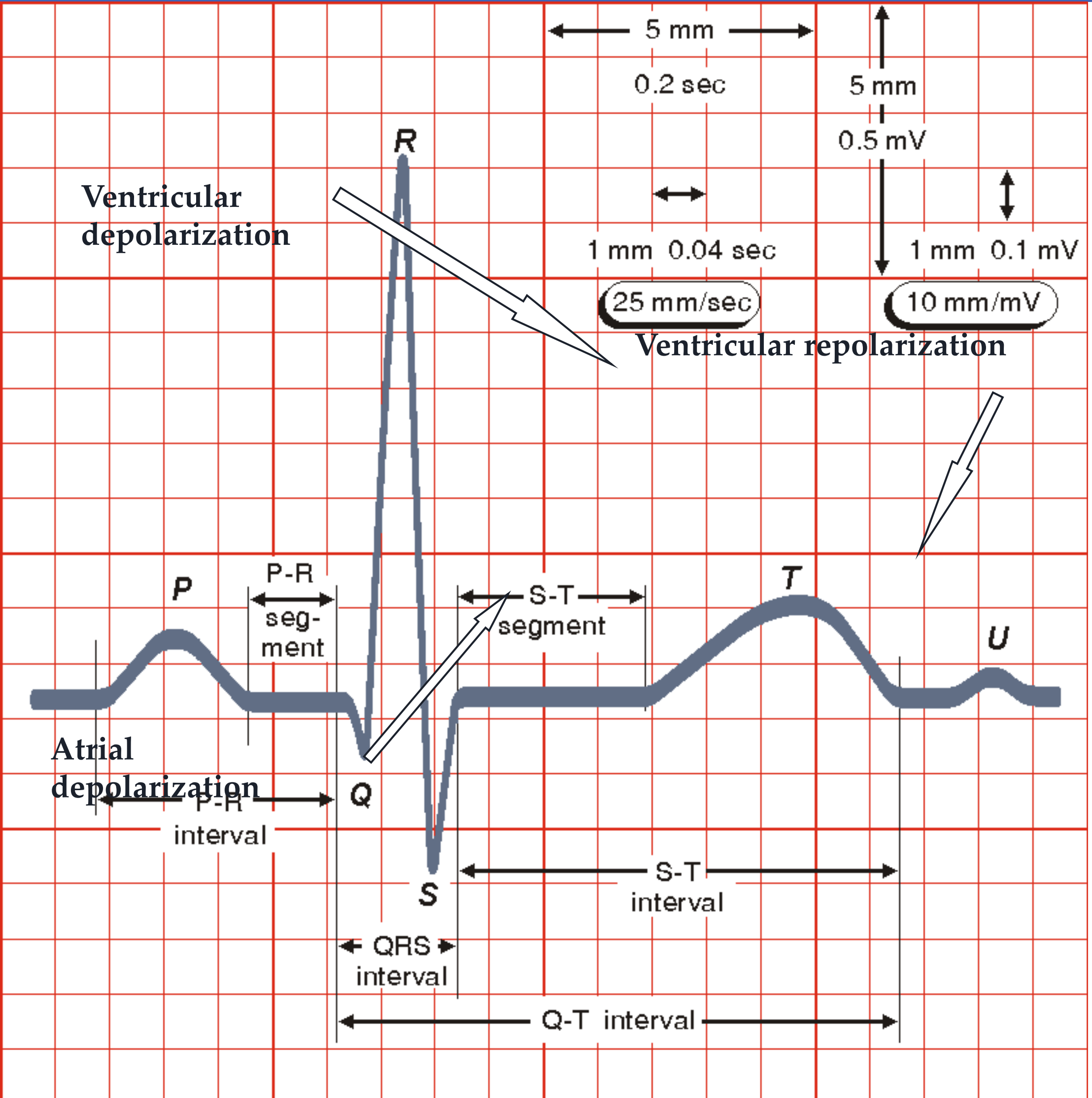


- ❖ A 12-lead ECG combines the lead systems from Einthoven, Goldberger and Wilson, thereby providing information about vertical and horizontal axes.
- ❖ The 12-lead ECG is the gold standard for ECG diagnosis and is used for both resting and stress ECGs.

- The 12-lead ECG displays, as the name implies, 12 leads which are derived by means of 10 electrodes.

- Three of these leads are easy to understand, since they are simply the result of comparing electrical potentials recorded by two electrodes; one electrode is exploring, while the other is a reference electrode.

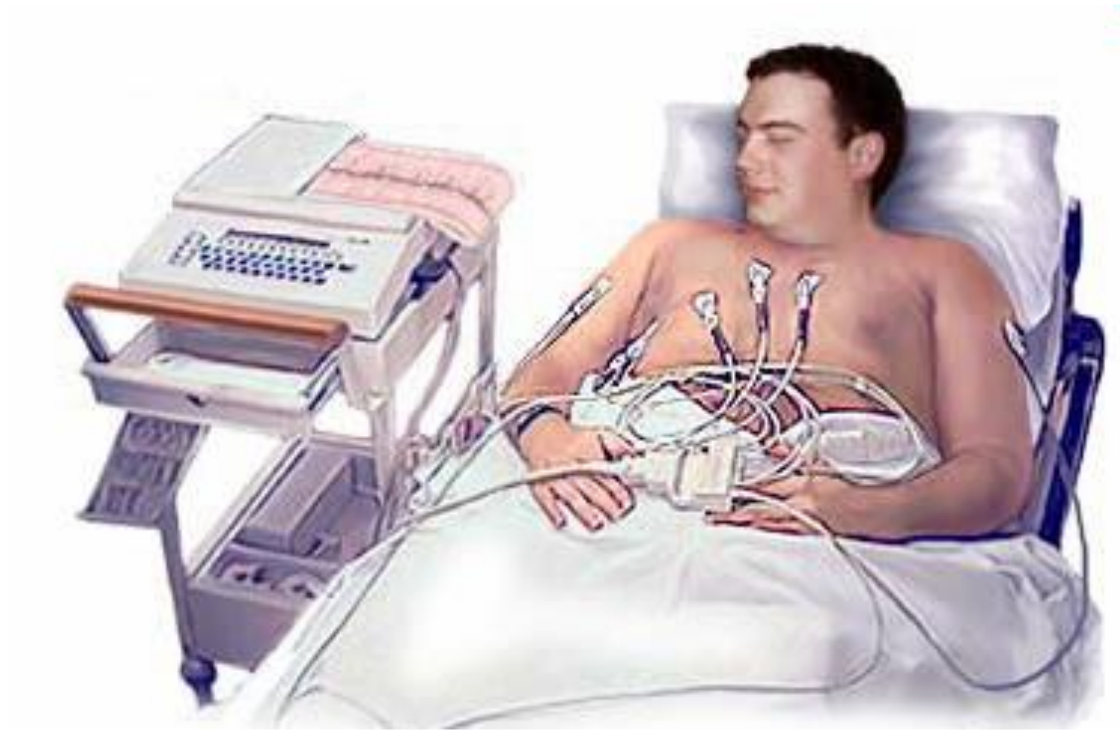
Electrocardiography (ECG)



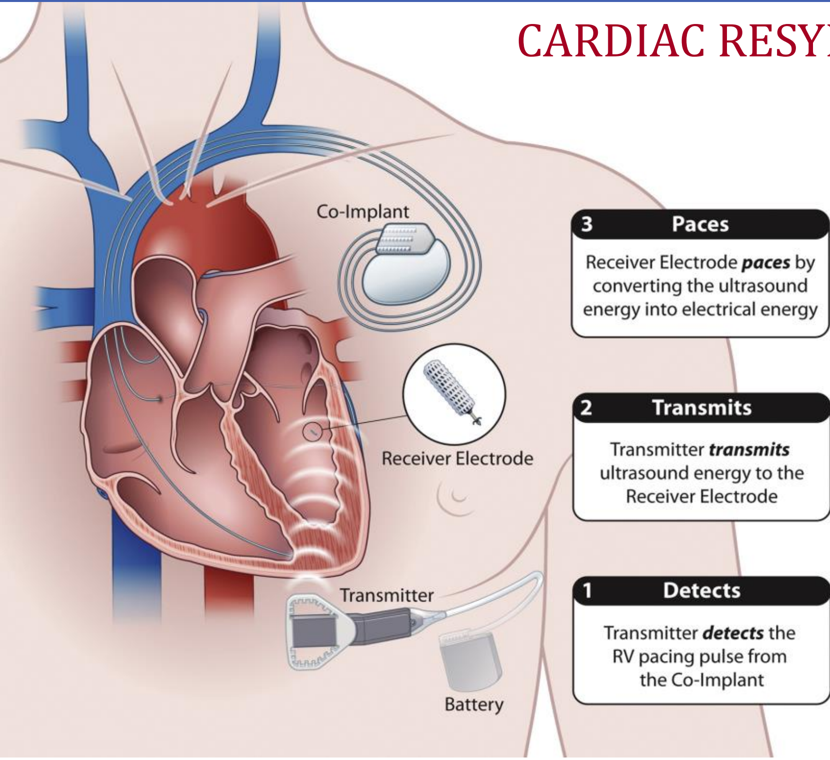
- **P wave:** the sequential activation (depolarization) of the right and left atria
- **QRS complex:** right and left ventricular depolarization (normally the ventricles are activated simultaneously)
- **ST-T wave:** ventricular repolarization
- **U wave:** origin for this wave is not clear - but probably represents "afterdepolarizations" in the ventricles.
- **PR interval:** time interval from onset of atrial depolarization (P wave) to onset of ventricular depolarization (QRS complex)
- **QRS duration:** duration of ventricular muscle depolarization
- **QT interval:** duration of ventricular depolarization and repolarization
- **RR interval:** duration of ventricular cardiac cycle (an indicator of ventricular rate)
- **PP interval:** duration of atrial cycle (an indicator of atrial rate)

Why is 12-lead system obsolete?

- ✓ Only 3 orthogonal components need to be measured, which makes 9 of the leads redundant.



CARDIAC RESYNCHRONIZATION THERAPY



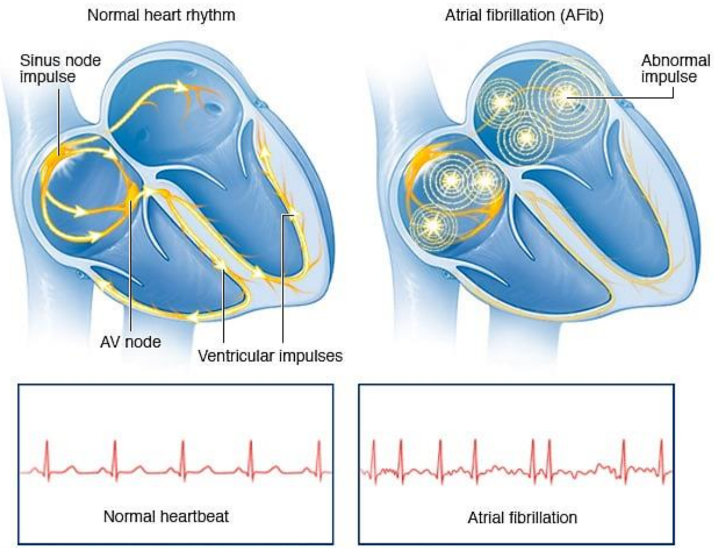
- Heart-failure patients can be treated by "resynchronization therapy" with a biventricular pacemaker.
- Unfortunately, several pertinent disease parameters affect the same electrocardiogram features.
- We are presently creating several highly detailed and physiologically accurate patient-tailored heart models with which we attempt to reproduce the electrocardiographic development of these patients during treatment.
- By combining electrocardiographic, imaging, and simulation data we attempt to improve understanding of the physiological changes in these patients and their effects on the electrocardiogram.

Ex.Topic: Real-world experience of leadless left ventricular endocardial cardiac resynchronization therapy

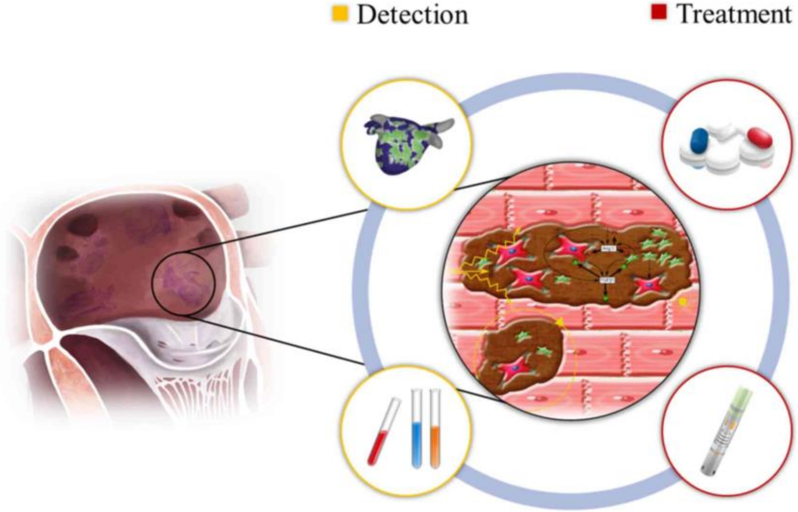
Source: CLINICAL DEVICES| VOLUME 17, ISSUE 8, P1291-1297, AUGUST 01, 2020

https://www.youtube.com/watch?v=FAGno7PZaQs

Research Topics – ECG : Atrial fibrillation



Diagnosis of Atrial Fibrillation Substrate & Atrial Fibrillation-Detection and management



Ex: Atrial fibrosis underlying atrial fibrillation

- Atrial fibrillation is a common disease that affects many individuals.
- Atrial firregular and often rapid heart rate that occurs when the two upper chambers of your heart experience chaotic electrical signals.
- The result is a fast and irregular heart rhythm.
- fibrillation is an The heart rate in atrial fibrillation may range from 100 to 175 beats a minute.

https://www.youtube.com/watch?v=pgOHs3NTmIY&t=1s

Source: International Journal of Molecular Medicine
Published online on: December 31, 2020 https://doi.org/10.3892/ijmm.2020.4842

Latest Research Papers – ECG

Journal of Electrocardiology

Official Journal of the International Society for Computerized Electrocardiology and the International Society of Electrocardiology

About the journal

- ✓ The *Journal of Electrocardiology* is devoted exclusively to clinical and experimental studies of the **electrical activities** of the **heart**. It seeks to contribute significantly to the accuracy of diagnosis and prognosis and the effective treatment, prevention, or delay of **heart disease**.
- ✓ Papers includes **electrocardiography**, **vectorcardiography**,
- ✓ **arrhythmias**, **membrane action potential**, **cardiac pacing**, **monitoring defibrillation**, **instrumentation**, **drug effects**, and computer applications.

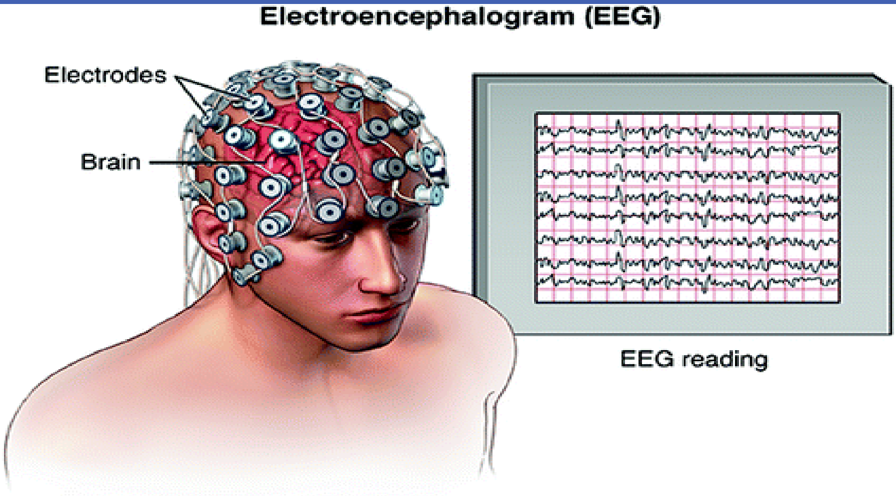
❖ Electrocardiogram lead selection for intelligent screening of patients with systolic heart failure - Open Access Published: 21 January 2021

New research on ECG data in real-time by IIT- Hyderabad

- CVD MONITORING DEVICE
- Indian Institute of Technology Hyderabad Researchers have developed a low-power device that can monitor electrocardiogram (ECG) and alert patients and doctors in real-time about the risk of cardiovascular diseases (CVD).

Electroencephalogram (EEG) – Brain Vision

Electroencephalogram (EEG)



- Electroencephalogram (EEG) is a test that records electrical patterns in your brain called brain waves.
- These are the bipotentials generated by neuronal activity of the brain known as electroencephalogram.
  - Greek words
  - Encephalo (Brain)
  - Gram (Picture)
  - Picture of electrical activities of Brain

- The full form of EEG is Electroencephalogram.
- It is a procedure that is carried out to evaluate the brain's electrical behaviour.
- EEG includes a brain wave metric, which is how the brain functions throughout time.
- It detects brain wave patterns of the brain's electrical impulses and records them.

- The electrodes are mounted on the scalp from where it passes signals to the computer to track the result.
- It produces a standard or identifiable pattern for familiar brain activity, but the pattern can be altered or unrecognizable for abnormal brain activity.Recording the electrical activity of the brain from the scalp.

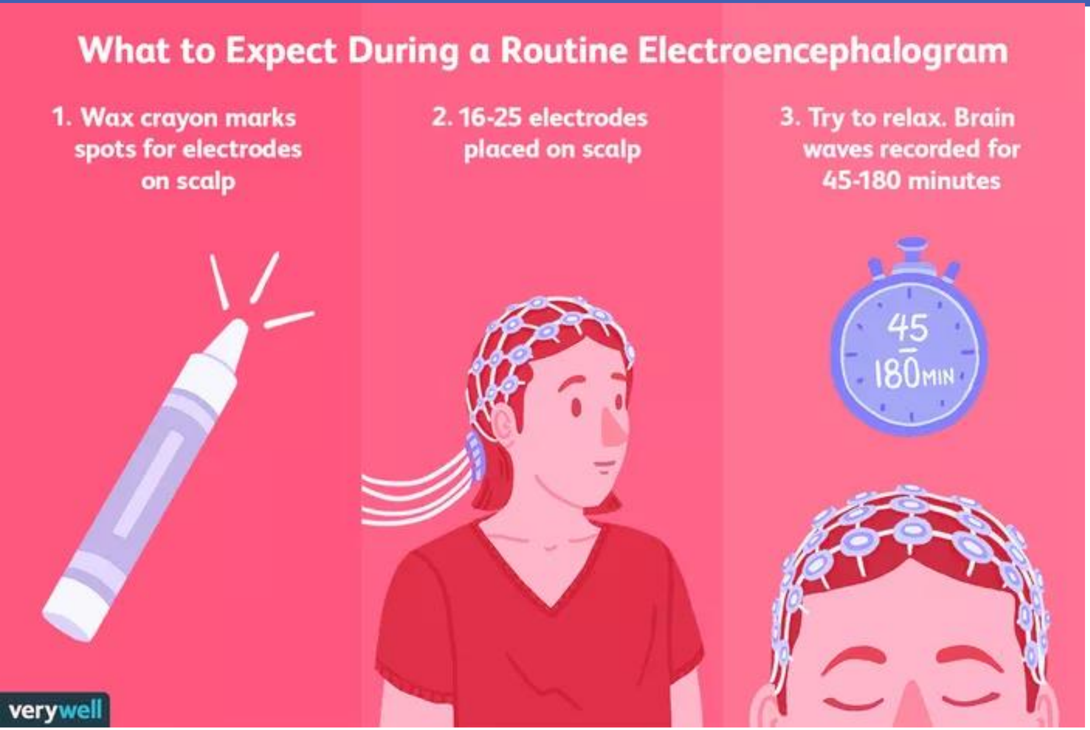
Working principle of EEG

- ❖ The EEG procedure is safe and pain-free.
- ❖ The electrodes mounted on the scalp collect electrical activity within your brain from the brain cells known as neurons and forward it to a system where they are seen as a series of lines registered or shown on a computer monitor (running paper).
- ❖ Our brain wave sequence recordings can be studied by a doctor specializing in the brain, like a neurologist.

The EEG is carried out to treat the specific health conditions or in the following cases:

- ➢ To diagnose and track seizure diseases (problem in the electrical system of the brain)
- ➢ To detect sleep disorders & epilepsy (Epilepsy is a disorder of the brain in which seizures occur repeatedly)
- ➢ To figure out the source of several other issues, like sleep disorders and behavioural changes issues.
- ➢ After a major head injury or before a liver or heart transplant, to determine brain activity.

Purpose of EEG Test



- ❖ An EEG is a measurement of the continuous electrical activity of the brain.
- ❖ This is detected via small metal discs called electrodes that are positioned in standardized patterns on the scalp.
- ❖ EEGs most often are used to evaluate the presence or risk of seizures -abnormal electrical discharges in the brain that can cause confusion, agitation, uncontrolled movements.
- ❖ An EEG might also be used to determine why someone is in a coma or state of delirium
- ❖ Each electrode has wires that attach to a computer.
- ❖ The electrodes detect electrical activity produced by the brain and transmit this information to a computer, where it is processed and saved electronically or printed out.
- ❖ Brain waves are recorded as squiggly lines called traces, and each trace represents a different area in the brain.

Frequency spectrum of normal EEG.

Typical EEG Signal

- ✓ Normal EEG signal
- ✓ Amplitude: 10-50 micro volts
- ✓ Frequency content: 0.1-30 Hz

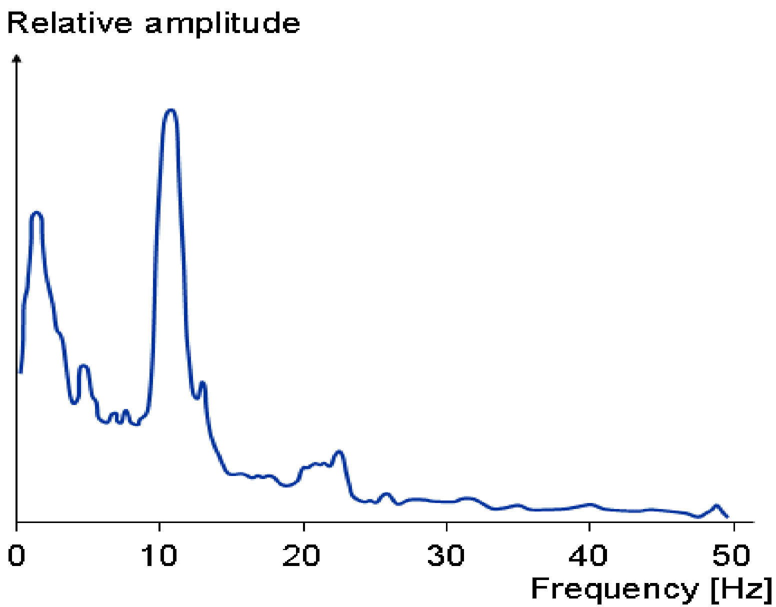


Fig: Frequency spectrum of normal EEG.

Diagnosis

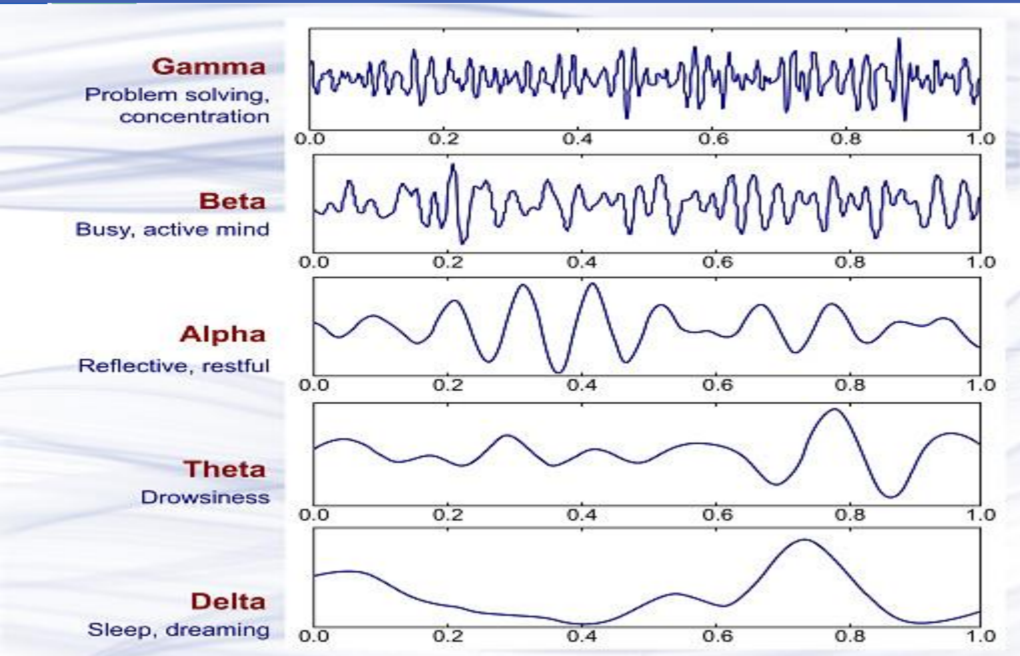
- Electrodes are placed on both sides of brain
- Activities are measured
- If both are not symmetrical then there may be something happening inside e.g. tumor

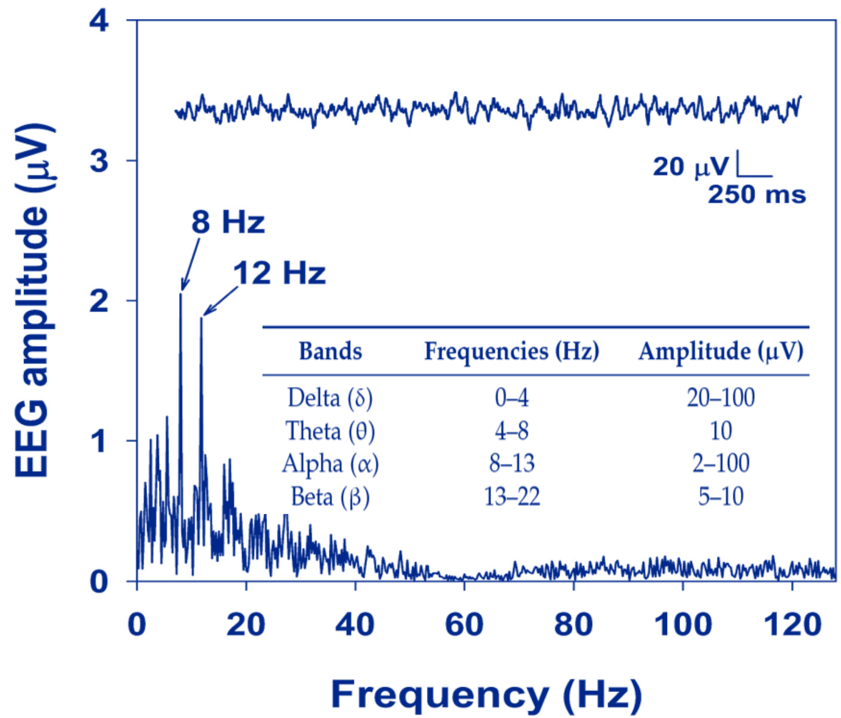
<u>What conditions can be diagnosed using an EEG?</u>

some of the other conditions for which doctors may want to perform an EEG include:

- ✓ head injury;
- ✓ brain tumour;
- ✓ encephalitis (inflammation of the brain);
- ✓ stroke; or
- ✓ sleep disorders.

Main frequencies of the human EEG waves





- To record the electrical activity of the brain, 8 to 16 pairs of electrodes are attached to the scalp.
- Each pair of electrodes transmits a signal to one of several recording channels of the electroencephalograph.
- This signal consists of the difference in the voltage between the pair.
- The rhythmic fluctuation of this potential difference is shown as peaks and troughs on a line graph by the recording channel.

EEG Waveform Types

Brain wave	Frequency range	Mental State	Voltage range	Region of activity
Alpha	8 to 13 Hz	Awake, quiet, resting state	20-200µV	Occipital Also from parietal and frontal regions of the scalp
Beta	14 to 30 Hz	High mental activity (tension)	"	Parietal & temporal regions
Theta	4 to 7	Emotional stress, Disappointment, Frustration		"
Delta	< 3.5 Hz	Deep sleep (infancy), serious organic brain disease,		Within the cortex

Main frequencies of the human EEG waves

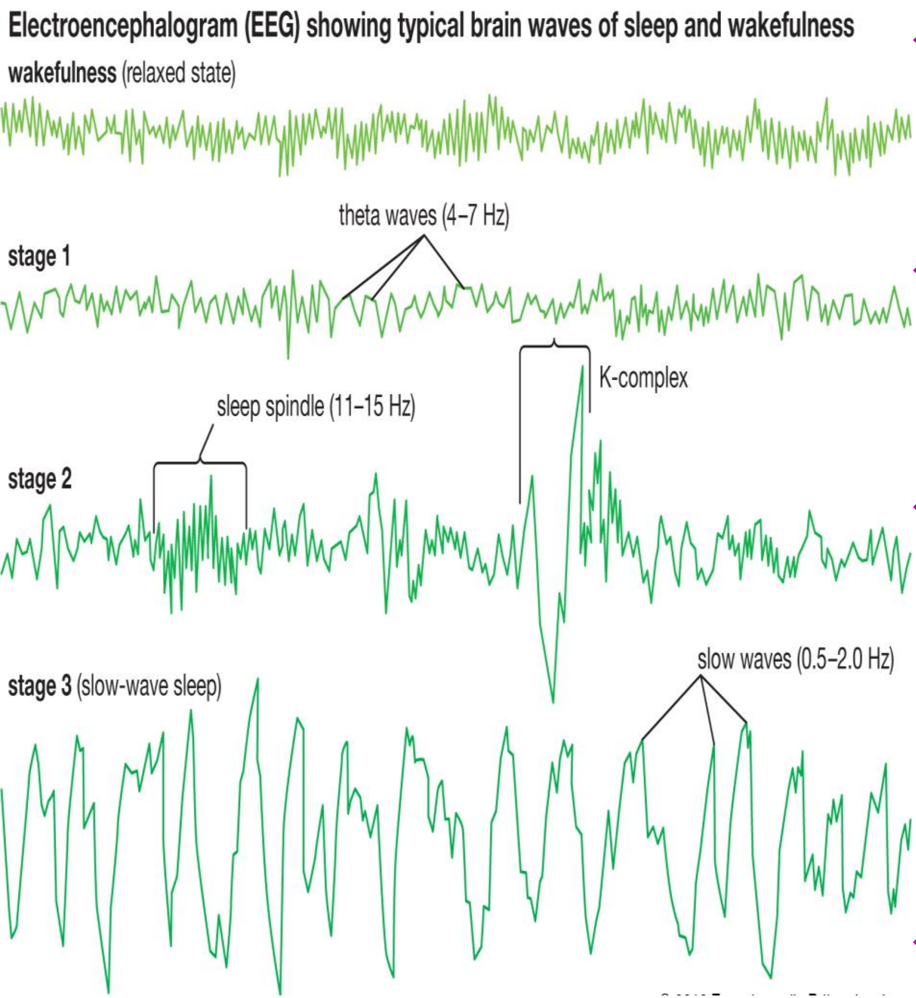
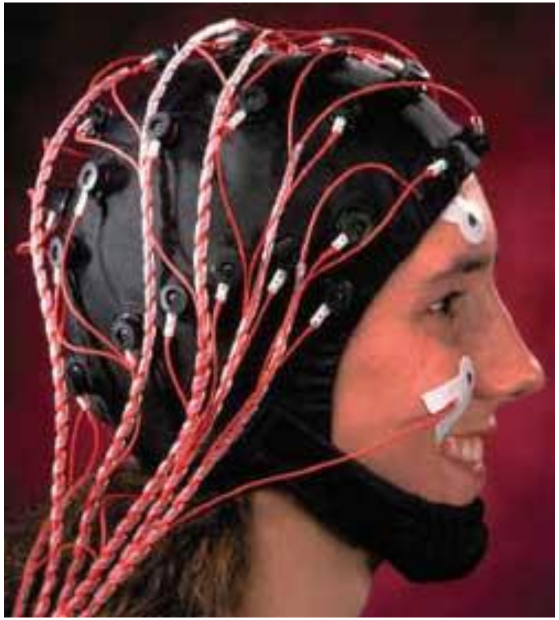


Fig: Main frequencies of the human EEG waves

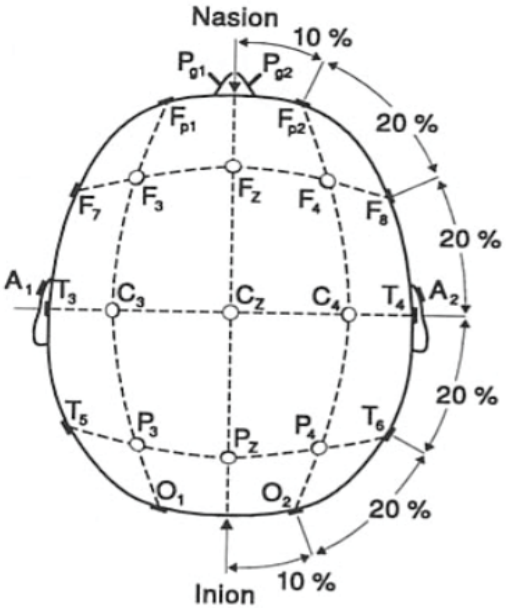
- ❖**Delta**: has a frequency of 3 Hz or below. It tends to be the highest in amplitude and the slowest waves. (irregular slow waves known as delta waves arise from the vicinity of a localized area of brain damage)
- ❖**Theta:** has a frequency of 3.5 to 7.5 Hz and is classified as "slow" activity. It is perfectly normal in children up to 13 years and in sleep but abnormal in awake adults.
- ❖**Alpha:** has a frequency between 7.5 and 13 Hz. Is usually best seen in the posterior regions of the head on each side, being higher in amplitude on the dominant side. It appears when closing the eyes and relaxing, and disappears when opening the eyes or alerting by any mechanism (thinking, calculating).(relaxed state is made up of regularly recurring oscillating waves known as alpha waves)
- ❖**Beta:** beta activity is "fast" activity. It has a frequency of 14 and greater Hz. It may be absent or reduced in areas of cortical damage.

EEG LEAD SYSTEMS

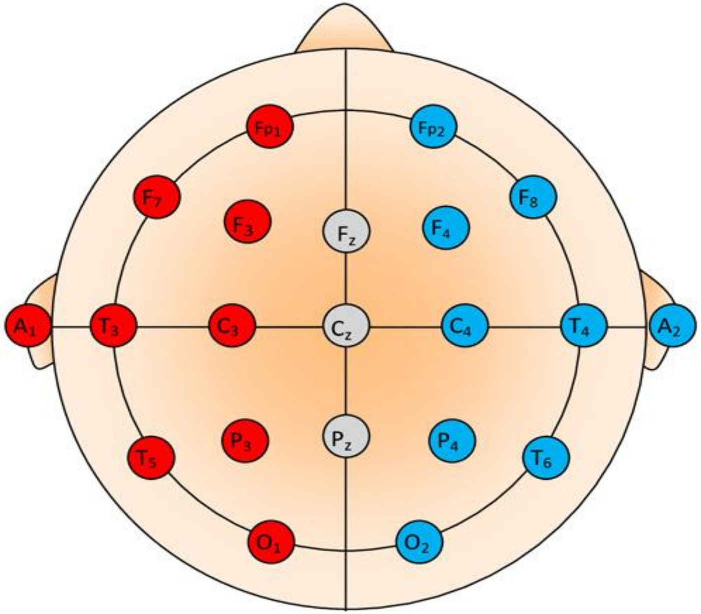
- The recording of the spontaneous electrical activity of the brain over a period of time is known as electroencephalography (EEG).
- Electroencephalography deals with the recording and study the electrical activity of brain .
- By means of electrode attached to the skull of a patient the brain waves can be picked up and recorded.



EEG Electrode – cap

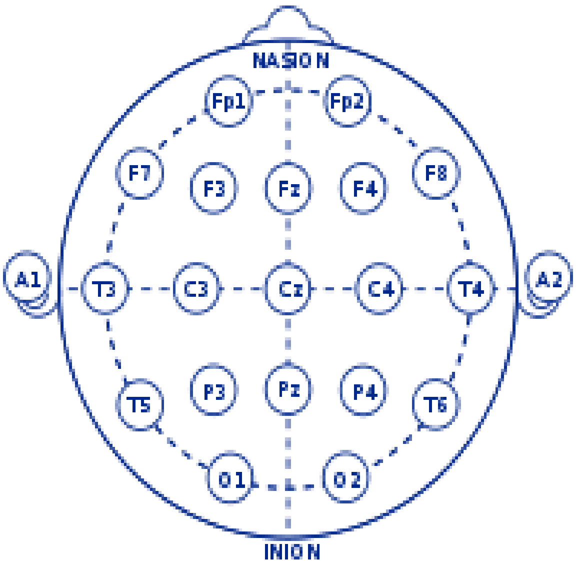


Locations Of The 10/20 System



10/20 System of electrode placement

EEG – 10-20 Electrode system.

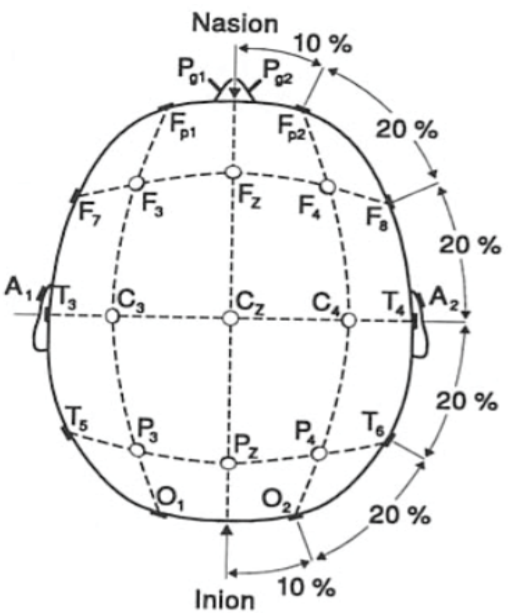


Electrode locations of International 10-20 system for EEG (electroencephalography) recording

- The 10-20 System of Electrode Placement is a method used to describe the location of scalp electrodes.
- These scalp electrodes are used to record the **electroencephalogram (EEG)** using a machine called an **electroencephalograph**.
- The EEG is a record of brain activity.
- This record is the result of the activity of thousands of neurons in the brain.
- The pattern of activity changes with the level of a person's arousal - if a person is relaxed, then the EEG has many slow waves; if a person is excited, then the EEG has many fast waves.
- The EEG is used to record brain activity for many purposes including sleep research and to help in the diagnosis of brain disorders, such as epilepsy.

EEG LEAD SYSTEMS & Applications

- F - Frontal lobe T - Temporal lobe
- C - Central lobe P - Parietal lobe
- O - Occipital lobe
- Even numbers denote the right side of the head
- Odd numbers denote the left side of the head.



Locations Of The 10/20 System

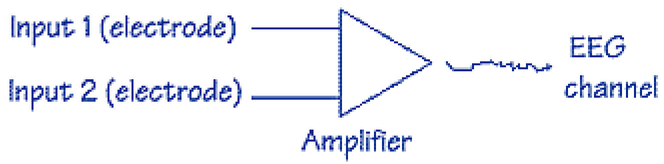
EEG – applications

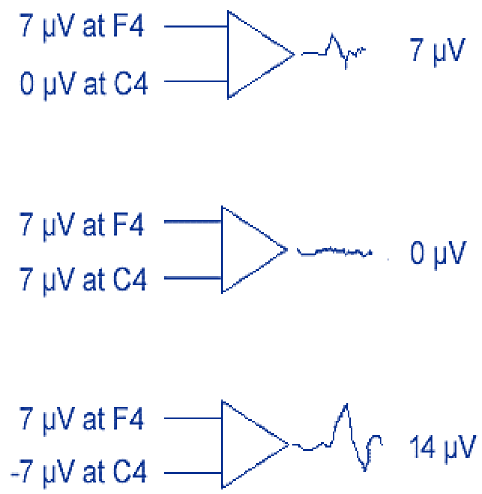
- ❖ Diagnostics (Epilepsy, Oncology, ..)
- ❖ Cognitive Sciences
- ❖ Sleep studies & Analysis
- ❖ Human Computer Interfaces BCIs)
- ❖ Pharmacology
- ❖ Intensive Care, Monitoring

- ❖ One of the major roles of EEG is as an aid to diagnose epilepsy. (abnormal electrical activity in the brain)
- ❖ EEG studies can also be used in patients who are deeply unconscious, to distinguish between brain death and possible reversible conditions.
- ❖ The EEG is also used to investigate other conditions that may affect brain function such as strokes, brain injuries, liver and kidney disease and dementia.

EEG Lead Systems : Montages

- ➢ EEG machines use a differential amplifier to produce each channel or trace of activity.
- ➢ Each amplifier has two inputs. An electrode is connected to each of the inputs.

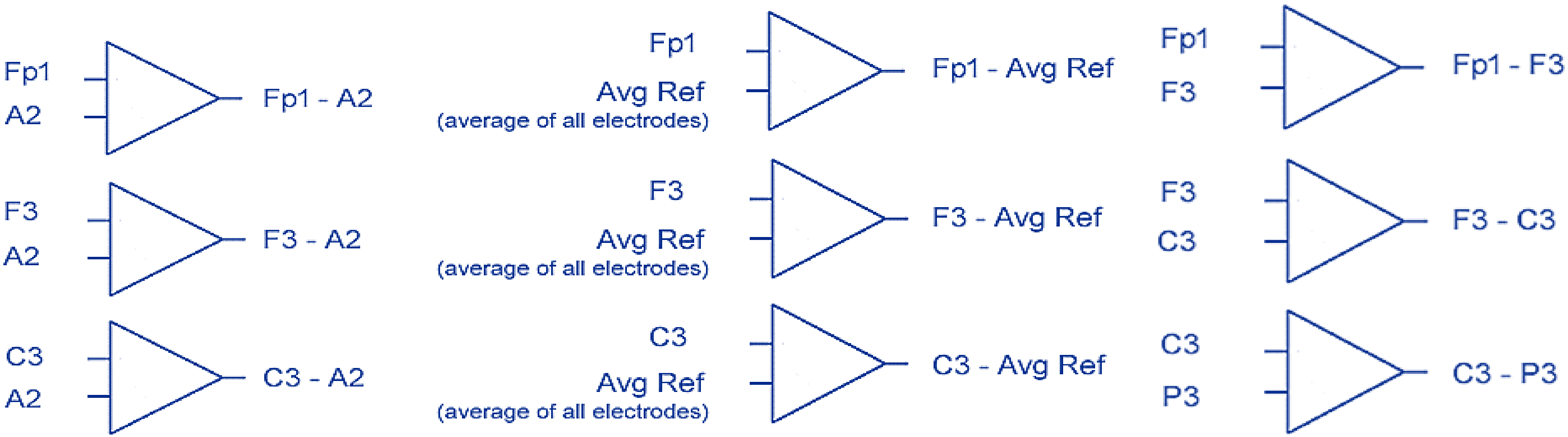




- ✓ Differential amplifiers measure the voltage difference between the two signals at each of its inputs.
- ✓ The resulting signal is amplified and then displayed as a channel of EEG activity.

- ❖ The manner in which pairs of electrodes are connected to each amplifier of the EEG machine is called a montage.
- ❖ Each montage will use one of three standard recording derivations, common reference, average reference or bipolar.

Three standard recording derivations



Common reference derivation

Average reference derivation

Bipolar derivation

- Common reference derivation :Electrodes frequently used as the reference electrode are A1, A2, the ear electrodes, or A1 and A2 linked together.
- Average reference derivation: Activity from all the electrodes are measured, summed together and averaged before being passed through a high value resistor. The resulting signal is then used as a reference electrode and connected to input 2 of each amplifier and is essentially inactive.
- Bipolar derivation: These sequentially link electrodes together usually in straight lines from the front to the back of the head or transversely across the head. For example the first amplifier may have electrodes FP1 and F3 connected to it and the second amplifier F3 and C3 connected to it.

EEG Lead Systems : Montages

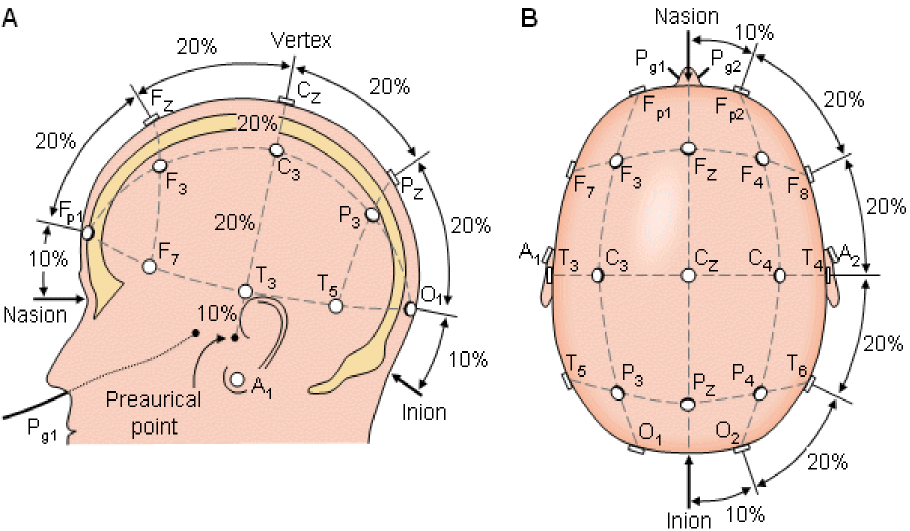
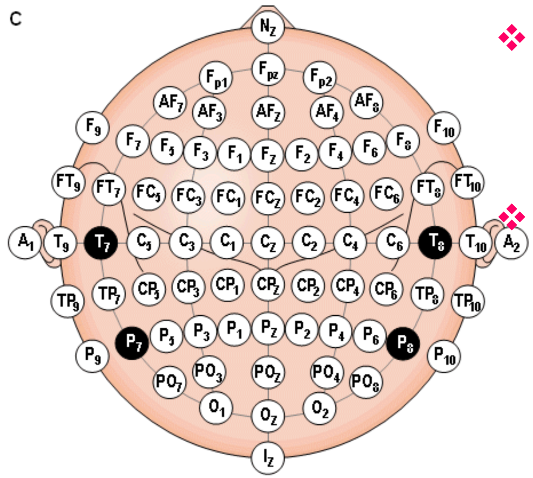


Fig. The international 10-20 system seen from (A) left and (B) above the head. A = Ear lobe, C = central, Pg = nasopharyngeal, P = parietal, F = frontal, Fp = frontal polar, O = occipital.



(C) Location and nomenclature of the intermediate 10% electrodes, as standardized by the American Electroencephalographic Society.

- ❖ Electrode locations are determined by dividing these perimeters into 10% and 20% intervals.
- ❖ Three other electrodes are placed on each side equidistant from the neighboring points, as shown in Figure B

- ❖ The internationally standardized *10-20 system* is usually employed to record the spontaneous EEG.
- ❖ In this system 21 electrodes are located on the surface of the scalp, as shown in Figure A and B.
- ❖ The positions are determined as follows: Reference points are nasion, which is the delve at the top of the nose, level with the eyes; and inion, which is the bony lump at the base of the skull on the midline at the back of the head. From these points, the skull perimeters are measured in the transverse and median planes.

EEG Measurement Modes

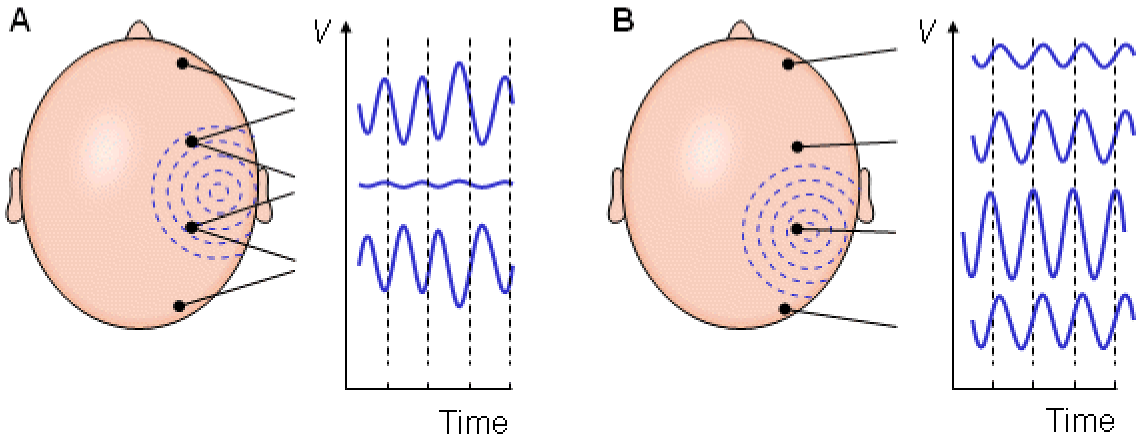


Fig. (A) Bipolar and (B) unipolar measurements.
Note that the waveform of the EEG depends on the measurement location.

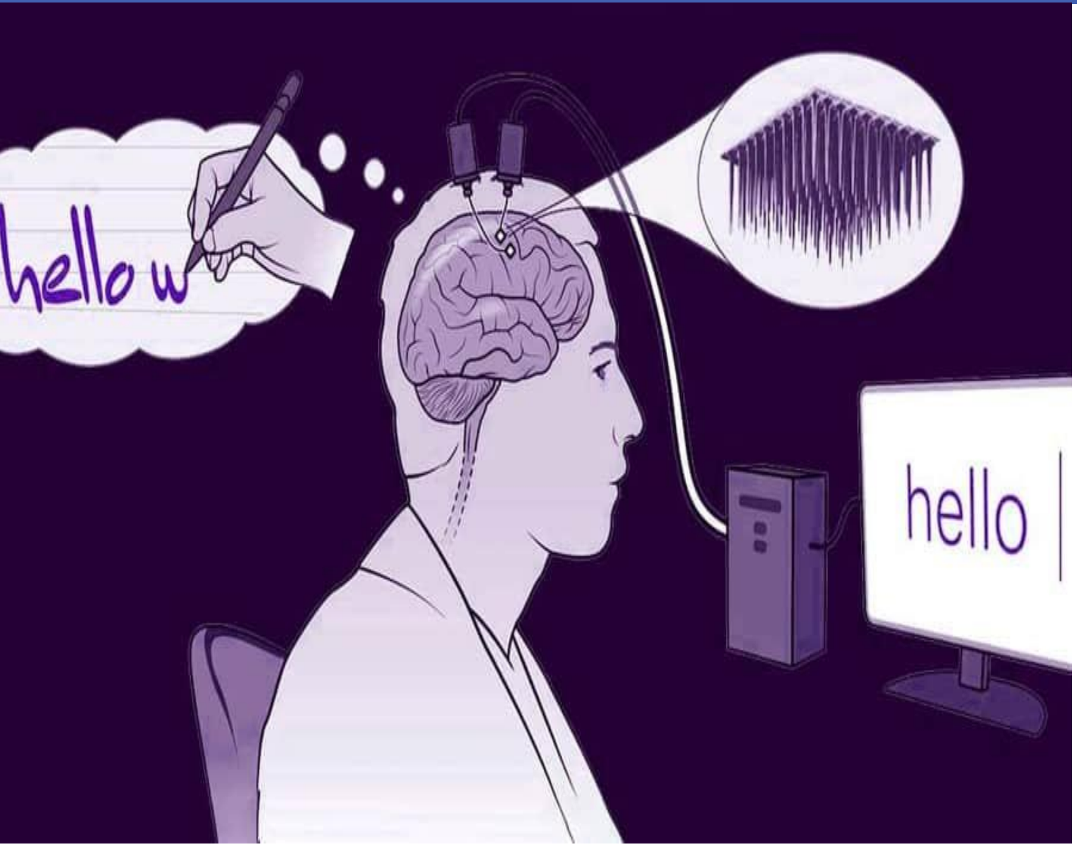
- ❖ Bipolar or unipolar electrodes can be used in the EEG measurement.
- ❖ In the Bipolar method the potential difference between a pair of electrodes is measured.
- ❖ In the Unipolar method the potential of each electrode is compared either to a neutral electrode or to the average of all electrodes (see Figure).

Research Topics –EEG

❖ Neuromarketing:

In the field of neuromarketing, economists use EEG research to detect brain processes that drive consumer decisions, brain areas that are active when we purchase a product/service, and mental states that the respective person is in when exploring physical or virtual stores.

Research Topics –EEG



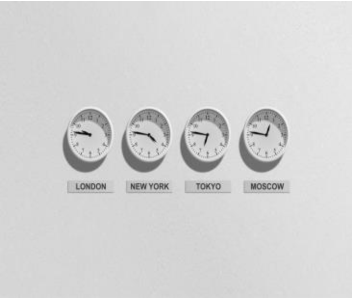
- ❖ Brain Computer Interfaces (BCI): TRANSFORMING MENTAL HANDWRITING TO TEXT ON SCREEN
- ❖ Next-Gen Brain Interface Computer Changes the Writing Mechanism

- ❖ A relatively new but emergent field for EEG is brain-computer interfaces.
  - ➢ Today, we know in much more detail which brain areas are active when we perceive stimuli, when we prepare and execute bodily movements, or when we learn and memorize things.
  - ➢ This gives rise to very powerful and targeted EEG applications to steer devices using brain activity.
  - ➢ This can, for instance, help paralyzed patients steer their wheelchairs or move a cursor on a screen, but BCI technology is also used for military scenarios where soldiers are equipped with an exoskeleton and EEG cap, allowing them to move, lift and carry very heavy items simply based on brain activity.

Top 5 EEG Research Articles

- EEG Alpha and Theta Oscillations Reflect Cognitive and Memory Performance: a Review and Analysis
- Cyclic Variations in EEG During Sleep and their Relation to Eye Movements, Body Motility, and Dreaming
- EEG Alpha Oscillations: The Inhibition–Timing Hypothesis
- A review of classification algorithms for EEG-based brain-computer interfaces
- Meditation States and Traits: EEG, ERP, and Neuroimaging Studies





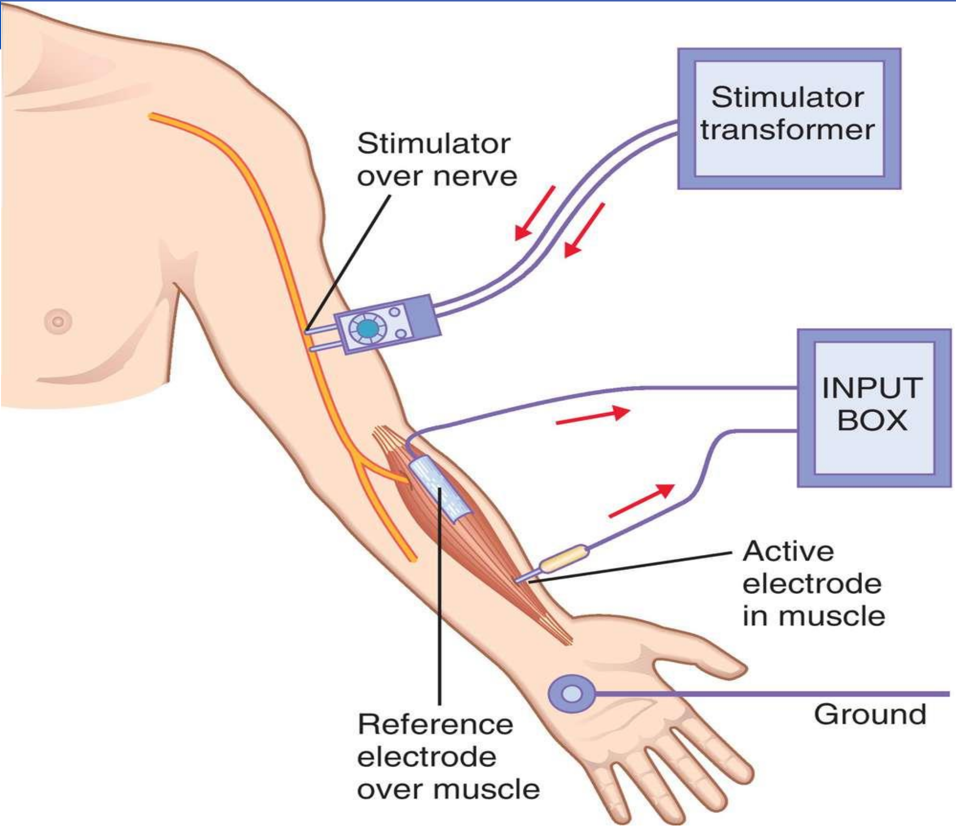

Automates the Detection and Diagnosis of Epileptic Seizures

- Dutch Epilepsy Clinics Foundation Automates the Detection and Diagnosis of Epileptic Seizures

Aim : Develop an automated method of detecting and diagnosing epileptic seizures using video

- Diagnosing and treating epilepsy requires trained specialists to accurately identify the physical signs of epileptic seizures.
- This is typically accomplished by reviewing EEG results with synchronized video observation.

Electromyogram (EMG)



- Electromyography (EMG) is a method to record the electrical activity of skeletal muscle.
- It uses a thin needle electrode inserted into the muscle through the skin and can be used to diagnose neurological and other disorders that affect muscle function.

Basics - Electromyogram (EMG)

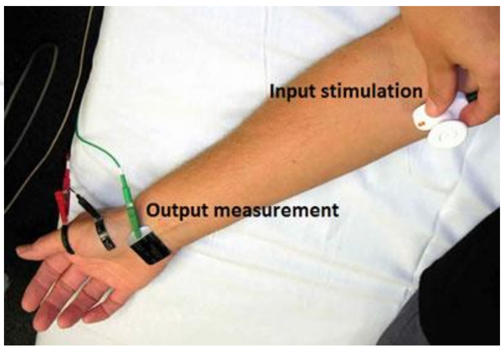
- ❖Electromyography (EMG) is an electro-diagnostic medicine technique for evaluating and recording the electrical activity produced by skeletal muscles.
- ❖The EMG is performed using an instrument called an electromyograph to produce a record called an electromyogram.
- ❖ An electromyograph detects the electrical nerve signals (potentials) generated by muscle cells when these cells are electrically or neurologically activated.
- ❖The signals can be analyzed to detect medical abnormalities, activation level, or recruitment order, or to analyze the biomechanics of human or animal movement.
- ❖EMG is most often used when people have symptoms of weakness, and examination shows impaired muscle strength.
- ❖It can help to differentiate primary muscle conditions from muscle weakness caused by neurological disorders.
- ❖EMG can be used to differentiate between true weakness and reduced use because of pain or lack of motivation.

Electromyogram (EMG)

❖EMG is the recording of the electrical potential generated by the skeletal muscles

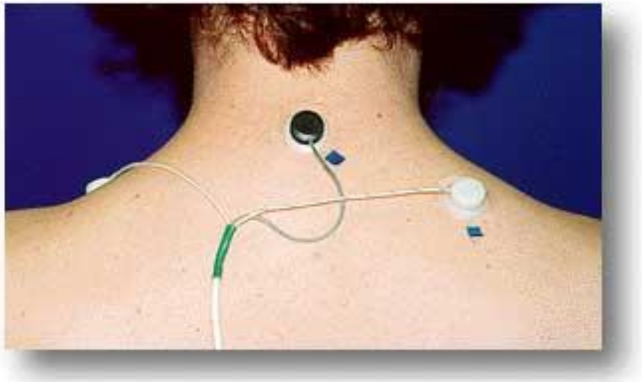
❖Electromyography is the study of electrical activity of muscle fibres with the help of this the nerve conduction velocity is obtained.

❖These are bipotentials generated by muscles known as electromyogram.



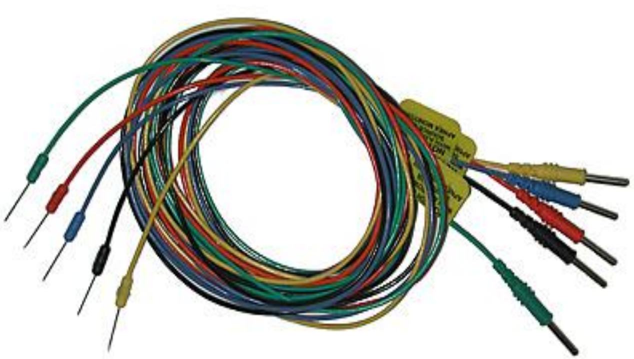
❖ EMG equipment consists of recording electrodes, preamplifiers (which are normally placed very close to the patient to avoid pick-up of electrical interference), amplifiers to provide the correct gain, calibration and frequency characteristics, a display system (usually a CRT), a range of integrators and averagers - partly to achieve some data compression (chart records may be very long and difficult to read), and a recording medium, which is often a photographic (fibre-optic) system.

EMG Electrodes



EMG electrodes (passive)

EMG electrodes (active)

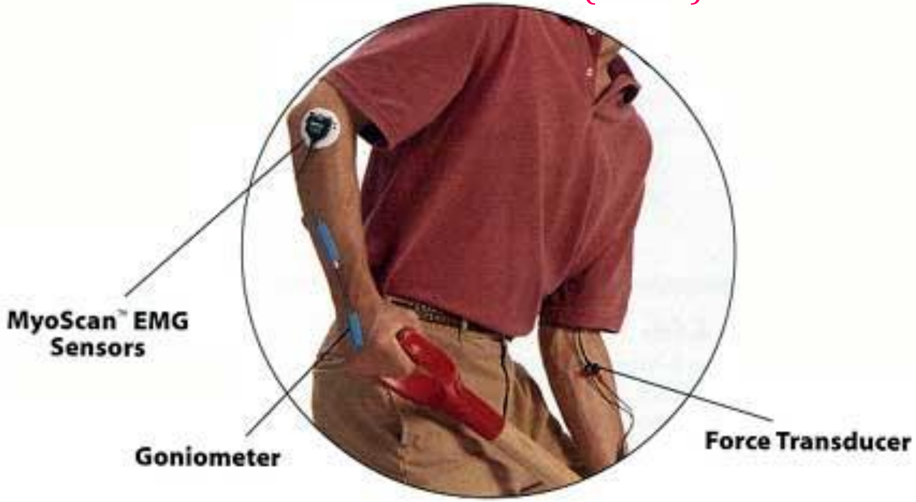


Needle electrodes

adhesive electrode

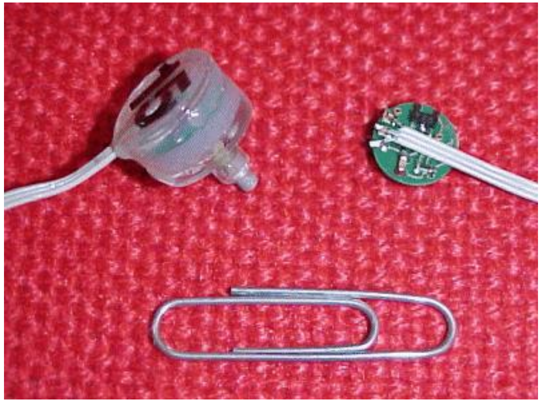
EMG – applications

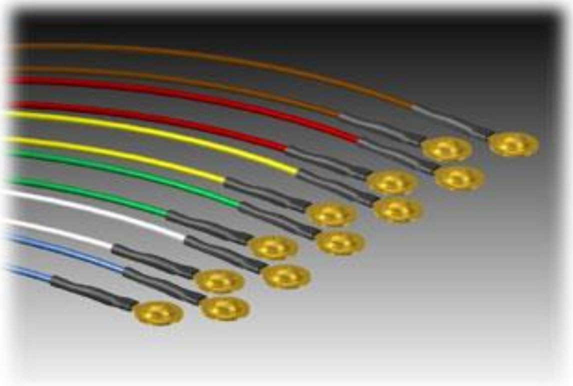
EMG electrodes (active)



<u>EMG – applications</u>

- Rehabilitation
- Functional analysis
- Active Prothetics, Orthesis
- Biomechanics, Sports medicine

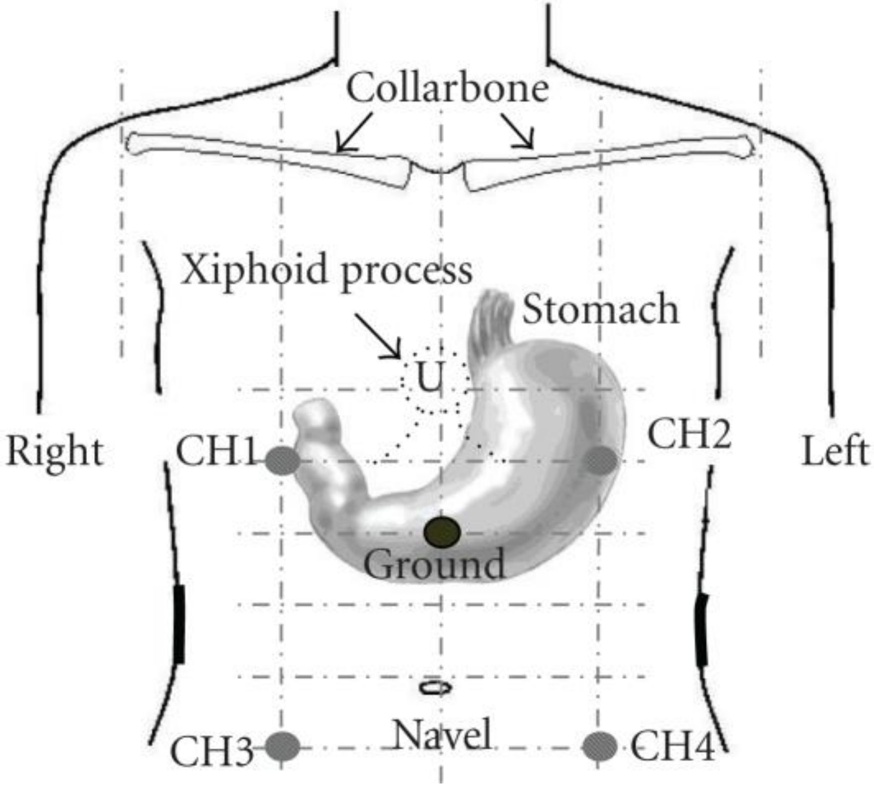


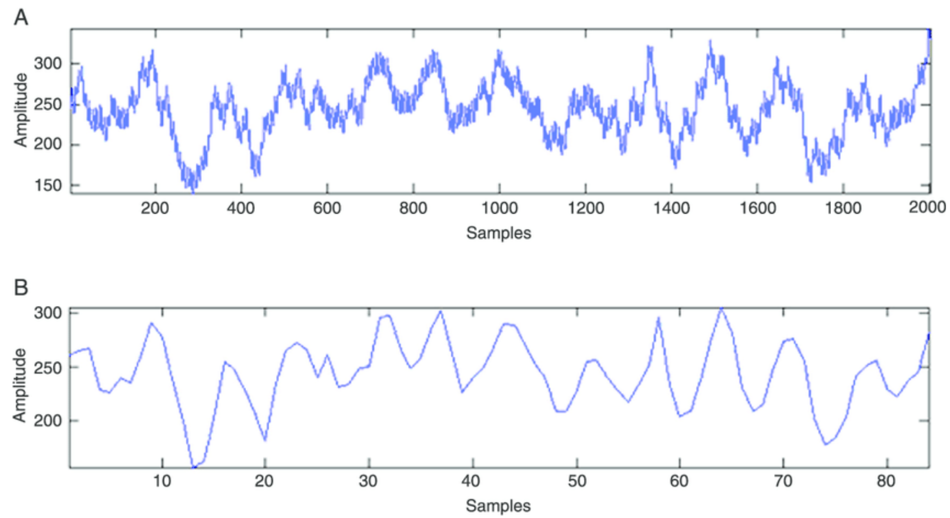


Singe disk gold plated electrodes

Ear clip electrode

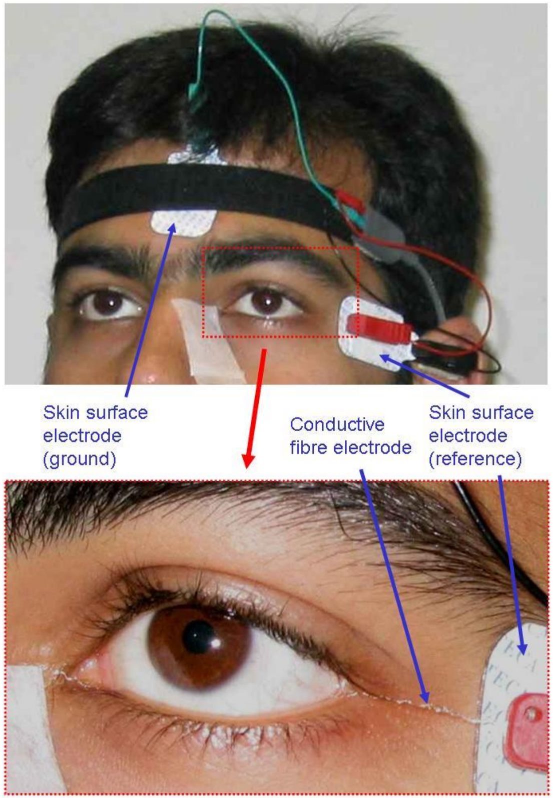
Other (nonelectric) Biosignals : EGG





Electrogastrogram (EGG)- Gastric Myoelectric Activity

Other (nonelectric) Biosignals : ERG



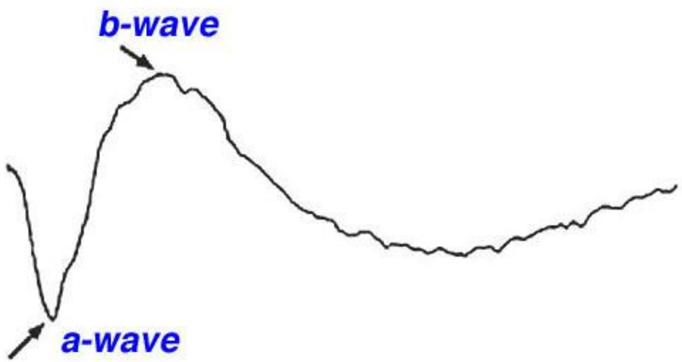
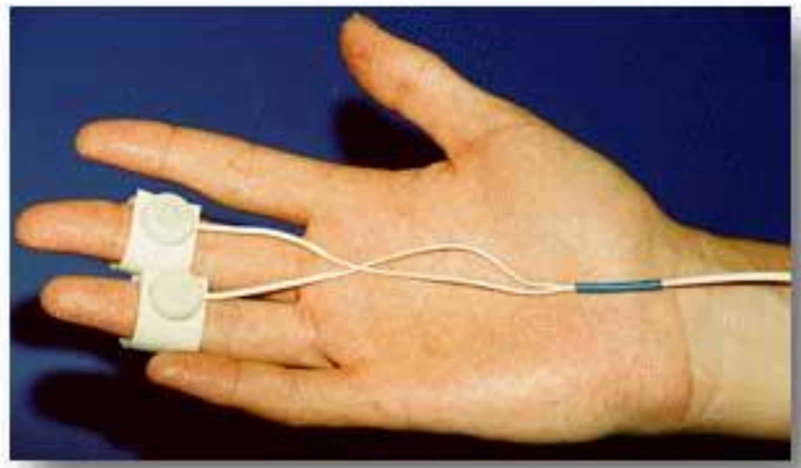


Fig.1 The biphasic waveform of the ERG of a normal patient.

Electroretinogram (ERG)

Other (nonelectric) Biosignals

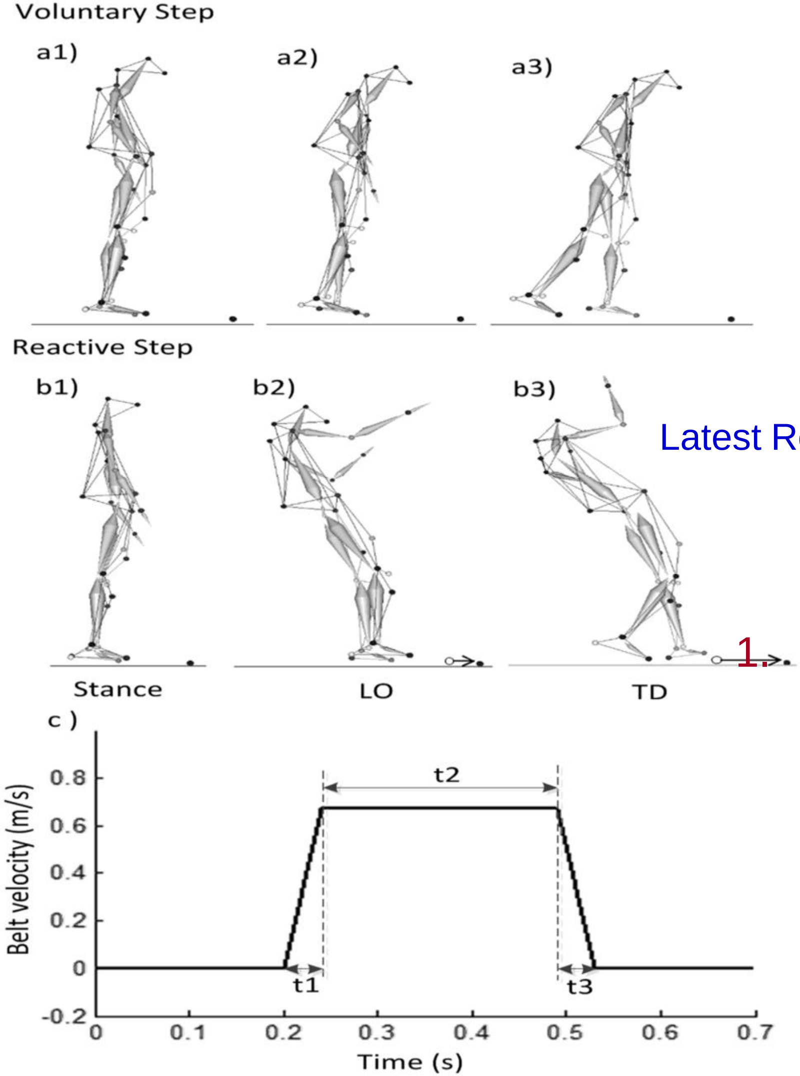


Galvanic Skin response (GSR)

Electrodermal Activity (EDA)

Skin Conductance Level (SCL)

How is EMG used in research?



Latest Research and Reviews

- ❖ EMG is used as a diagnostics tool for identifying neuromuscular diseases, or as a research tool for studying kinesiology, and disorders of motor control.
- ❖ EMG signals are sometimes used to guide botulinum toxin or phenol injections into muscles.

1. Muscle synergy differences between voluntary and reactive backward stepping

Summary bioelectric signals

Summary bioelectric signals		
Bio Electric Signals	Frequency	Amplitude (mV)
ECG	0.2 – 300	0.1 - 3
EEG	DC – 100	0.005 - 0,2
EEG (cortical)	10 – 100	0.015 - 0,3
EMG	10 – 1000	0.1 - 5
EMG (needle)	10 – 10000	0.05 - 5
EOG	DC – 30	0.1 - 2

Analyze Biomedical Signals with Signal Processing Techniques

- Biomedical signal processing involves acquiring and preprocessing physiological signals and extracting meaningful information to identify patterns and trends within the signals.
- Sources of biomedical signals include neural activity, cardiac rhythm, muscle movement, and other physiological activities.
- Signals such as electrocardiogram (ECG), electroencephalogram (EEG), electromyography (EMG) can be captured non-invasively and used for diagnosis and as indicators of overall health.

The biomedical signal processing workflow involves:

Workflow for processing biomedical signals.

Biomedical Signal Processing using Matlab

❖ MATLAB® provides many signal processing capabilities for this workflow, especially for Signal Preprocessing and Feature Extraction.

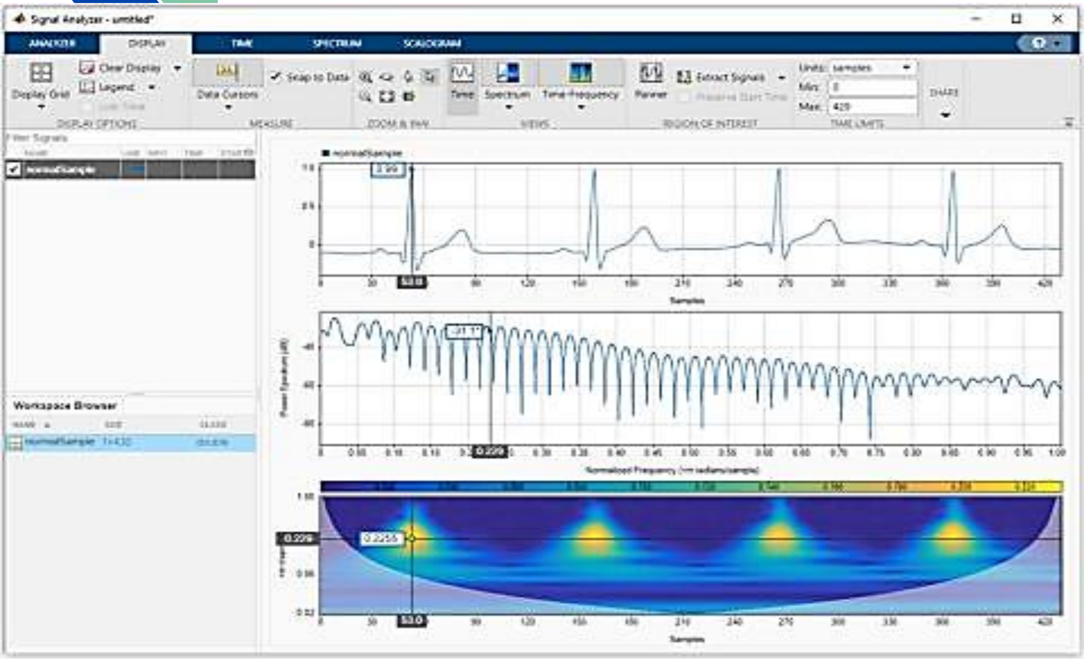


Fig: Analyzing an ECG signal in time, frequency and time-frequency domains with the Signal Analyzer app in MATLAB.

❖ Signal Acquisition:

✓ With MATLAB, We can interface with hardware equipment to acquire physiological signals.

✓ For instance, with the Raspberry Pi and Arduino Support Packages, we can interface with embedded boards like Raspberry Pi, Arduino, and EKGShield to collect data from these sensors.

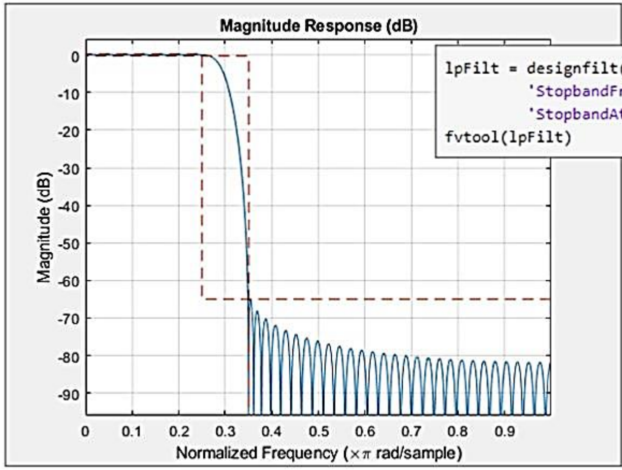
✓ We can also access and analyze signals stored in files such as from EDF, Excel® files and MAT-files.

❖ Signal Visualization and Annotation:

✓ MATLAB provides built-in apps to help we analyze and visualize signals in time, frequency, and time-frequency domains without writing any code.

Biomedical Signal Processing using Matlab

❖ Artifact Removal and Signal Filtering:

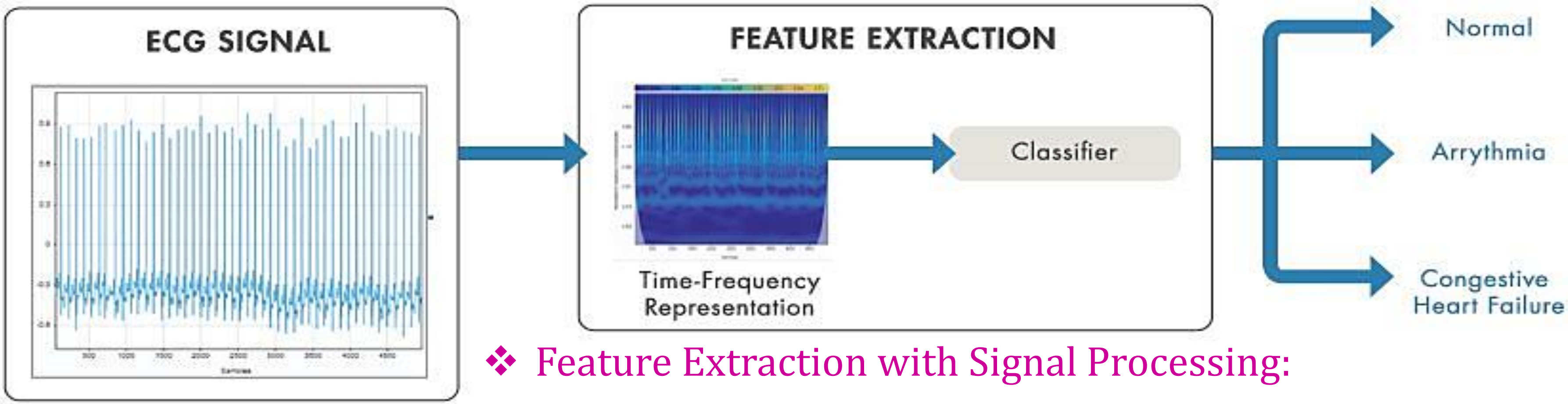



```
lpFilt = designfilt('lowpassfir','PassbandFrequency',0.25, ...
         'StopbandFrequency',0.35,'PassbandRipple',0.5, ...
         'StopbandAttenuation',65,'DesignMethod','kaiserwin');
fvtool(lpFilt)
```

Fig: Digital filter used for signal preprocessing.

- ✓ Biomedical signals often contains noise or unwanted artifacts that can distort the analysis of the signals.
- ✓ For instance, while measuring EKG signals, activities such as breathing and walking can add unwanted components.
- ✓ One of the main challenges in preprocessing biomedical signals is to remove unwanted artifacts while preserving the sharp features within signals.
- ✓ Most popular techniques for artifact removal are Digital Filtering, Adaptive Filtering, Independent Component Analysis (ICA), and Recursive Least Square.
- ✓ A combination of preprocessing techniques may also be used to address the limitations of individual techniques.

Biomedical Signal Processing using Matlab



- ❖ Feature Extraction with Signal Processing:

Fig: Time-frequency analysis used to extract features from ECG signals for classification.

- ❖ Feature extraction can be accomplished manually or automatically.
- ❖ Signal processing techniques like AR modeling, Fourier analysis, and spectral estimation can be used to manually compute key features from signals.
- ❖ Time-frequency transformations, such as the short-time Fourier transform (STFT) can be used as signal representations for training data in machine learning and deep learning models.
- ❖ Automatic feature extraction techniques like wavelet scattering can be used to reduce dimensionality and extract important features.
  - ✓ These features can be used directly for diagnosis or as input to machine learning and deep learning classifiers.

AI-Based Digital Health Applications with Matlab

- ❖ Artificial intelligence techniques such as Deep Learning And Machine Learning to build Digital Health Applications that comply with Global Medical Regulations.

Digital Health includes

- ❖ mobile health (mHealth),
- ❖ wearable devices,
- ❖ telehealth and telemedicine,
- ❖ Health Information Technology (IT), and personalized medicine.

- ❖ The use of smart phones, AI, and internet applications can provide new ways to monitor our health and provide greater access to health information.
- ❖ It can empower consumers and providers to make more informed decisions and enable early diagnoses.

AI-Based Digital Health Applications with Matlab

- ❖ Developing and Deploying AI Models on Biomedical Data Sets
  - ✓ There are many approaches for building predictive models on biomedical data sets such as EKG signals, medical images, and biomedical text data.
  - ✓ Using MATLAB, We can interactively develop and deploy predictive models on biomedical data sets by using machine or deep learning algorithms.

- ❖ We can deploy the models on embedded devices or on the cloud.
- ❖ Using Simulink, you can combine powerful signal processing techniques and convolutional neural networks to classify biomedical signals.
- ❖ You can also generate CUDA code automatically from Simulink models for deploying on NVIDIA® GPU devices.

MATLAB and Simulink for Medical Devices

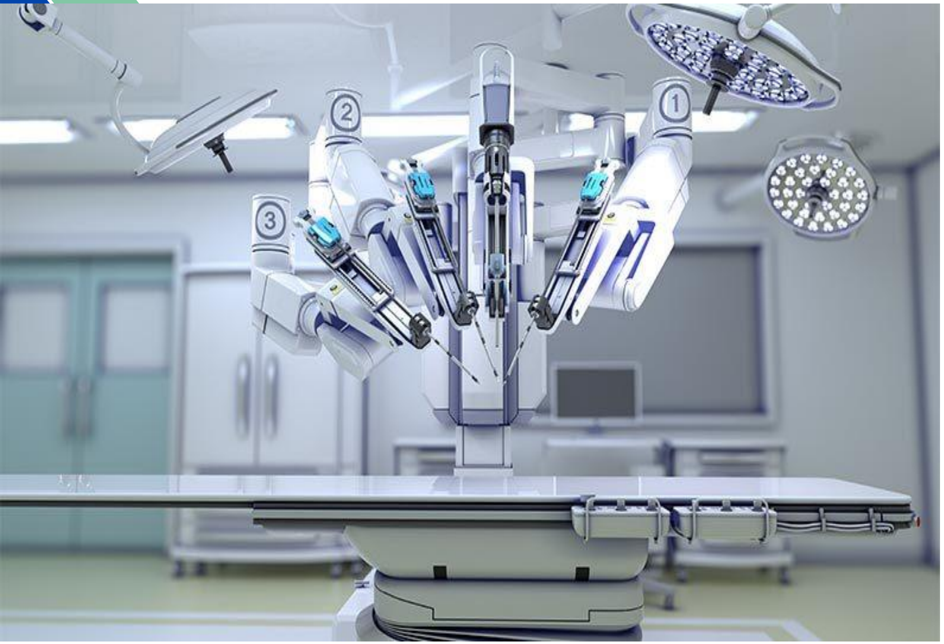
❖ Design, simulate, and build next-generation medical devices

❖ MATLAB® and Simulink® enable engineers to speed up medical device software and hardware development by efficiently integrating and automating the various phases of design, implementation, and verification.

With MATLAB and Simulink, We can:

- ✓ Develop and test advanced algorithms and entire systems before implementation
- ✓ Simulate and test embedded software alongside mechatronic systems early in the design phase
- ✓ Prototype designs and create proof-of-concepts by automatically generating real-time code
- ✓ Use static analysis to find software bugs and prove correctness of your models and code
- ✓ Automate reporting to prove and accelerate compliance with FDA/CE regulations and industry standards such as IEC 62304

Design and Development of Medical Devices



- ❖ Dynamic system modeling and simulation can speed up product development times as well as the validation and verification phases for complex diagnostic and therapeutic devices such as surgical robots, ventilators, hemodialysers, infusion pumps, and pacemakers.

- ❖ Designs of multidomain closed-loop systems that combine advanced electro-mechanical-fluidic components with complex control software can be error prone and hard to develop and certify.

- ❖ Using Model-Based Design with MATLAB and Simulink is a modular development approach that enables engineering teams to move from internal research and development to design and implementation in a single environment.

Biomedical Data Analysis and Algorithm Development

- ❖ Design, simulate, and build next-generation medical devices

- ❑ Whether you're analyzing biomedical datasets or developing advanced algorithms for diagnostic and therapeutic medical devices, MATLAB provides you with the flexibility and power to work with complex data and derive engineering insights.

As an engineer or researcher working with biomedical data, we can:

- ✓ Import and analyze data from existing programs like Microsoft® Excel®
- ✓ Automate the acquisition and analysis of images, video, and signals from hardware
- ✓ Develop, test, and verify algorithms including artificial intelligence (AI) and machine learning models
- ✓ Deploy MATLAB code on processors, GPUs, and FPGAs for production or prototyping

MCQs on Electrocardiography or ECG

1) The frequency range of ECG is ___________

a) 0.05-150 HZ

b) 500-1500 Hz

c) 5-500 kHz

d) 0.5-150 MHz

Answer: a

Explanation: The diagnostically useful frequency range is usually accepted as 0.05 to 150 Hz. Although the electric field generated by the heart can be best characterized by vector quantities, it is generally convenient to directly measure only scalar quantities, i.e. a voltage difference of mV order between the given points of the body.

MCQ –ECG

2) Which of the following amplifier circulatory is employed to reduce the hum noise generated by the power supply in the ECG circuit?

a) band pass filters

b) high pass filters

c) notch filters

d) low pass filters

Answer: c

Explanation: A notch filter is employed to suppress the hum noise generated by the power supply in the ECG circuit.

CMRR of the order of 100–120 dB with 5 kW unbalance in the leads is a desirable feature of ECG machines.

The instability of the baseline, originating from the changes of the contact impedance, demands the application of the automatic baseline stabilizing circuit.

MCQ –ECG

3) The sensitivity of an electrocardiograph is typically set at 10 mm/mV.

a) True

b) False

Answer: a

Explanation: It is true.

The sensitivity of an electrocardiograph is typically set at 10 mm/mV. For routine work, the paper recording speed is 25 mm/s.

Amplitude measurements are made vertically in millivolts.

Time measurements and heart rate measurements are made horizontally on the electrocardiogram.

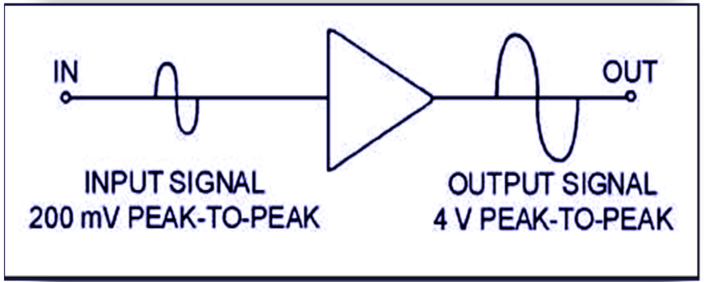

THANK YOU

MEDICAL ELECTRONICS

BIO AMPLIFIER

UNIT 3 : BIO AMPLIFIER

- ❖ Need for bio-amplifier
- ❖ Single ended bio-amplifier & Differential bio-amplifier
- ❖ Right leg driven ECG amplifier.
- ❖ Band pass filtering,
- ❖ Isolation amplifiers : transformer and optical isolation
- ❖ Isolated DC amplifier and AC carrier amplifier.
- ❖ Chopper amplifier
- ❖ Power line interference



What is an amplifier? & Classifications

❖ Amplifier is an electronic device that gives an *output signal of having the same characteristics and morphology of the input signal* but will generally be *larger than the input signal on the basis of voltage, current or power.*

Amplifiers are classified on the basis of the following types.

1. Power/Current Amplifier

The power amplifier is an amplifier in which the power of output signal is greater than the power of input signal.

2. Frequency Amplifier

The frequency amplifier increases the frequency component of that system according to its designed power of amplification.

3.Voltage Amplifier

The voltage amplifier amplifies (increases) the input voltage and gives larger output signal voltage. Or simply in a voltage amplifier the output signal voltage is larger (amplified) than the input signal voltage.

Bio Amplifier & Need for Bio Amplifier

- A Bio amplifier is an electrophysiological device, a variation of the instrumentation amplifier, *used to gather and increase the signal integrity of physiologic electrical activity for output to various sources.*
- It may be an independent unit, or integrated into the electrodes.

Need for Bio Amplifier

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

Basic Requirements for Biological Amplifiers

- The biological amplifier should have a high input impedance value. The range of value lies between 2 MΩ and 10 MΩ depending on the applications. Higher impedance value reduces distortion of the signal.
- 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.
- 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.
- Throughout the entire bandwidth range, a constant gain should be maintained.
- A bio-amplifier should have a small output impedance.
- A good bio-amplifier should be free from drift and noise.
- Common Mode Rejection Ratio (CMRR) value of amplifier should be greater than 80dB to reduce the interference from common mode signal.
- The gain of the bio-amplifier should be calibrated for each measurement.

Types of Voltage Amplifiers

- ❖ Differential Amplifier
- ❖ Operational Amplifier
- ❖ Instrumentation Amplifier
- ❖ Chopper Amplifier
- ❖ Isolation Amplifier

Pre-amplifier (Buffer Amplifier):

- ➢ All small input signals are received at pre-amplifier circuit which has the ability to pick the signal of 5uV-100uv. It has the following properties;
- ➢ High input impedance (resistance): Which reduces distortion of the source waveform by minimizing the input reactance and limiting the current drawn by the source.
- ➢ If the DC potentials from the input terminals of a bio-potential are not minimized, the patient can get micro or macro-shocks.
- ➢ Low output impedance (resistance): Which allows to pass the received actual signal (activity) to maintain maximal fidelity (accuracy of a description, translation) and range in readout.

Types of Voltage Amplifiers

Differential amplifier

- The differential amplifier that subtracts one signal voltage (input I) from another signal (input II) & amplifies the difference of these signals as output signal.
- This type of amplification is called differential or balanced amplification.

Common Mode Rejection (CMR):

- The differential amplifier cancels out (rejects) those signals which are common to both inputs (**I &ll**), this is called common mode rejection and signals are said to be “in Phase or in Common Mode”.
- In EEG machines the polarities of both inputs (**I &II**) work with convention as :
  - ✓ If Input **I** is more negative than Input **II** deflection would be upward.
  - ✓ Input **I** is less negative than Input **II** deflection would be downward.
  - ✓ Signal have equal potentials on both input **l** and **ll** will be canceled out and there would be no deflection.

Common Mode Rejection Ratio (CMRR):

- ✓ The common-mode rejection ratio (CMRR) of a **differential amplifier** measures the ability of the device to reject the input signal common in both input leads (1 & 2).
- ✓ Good EEG amplifiers should have CMMR ratio of 10,000:1 or more.

Types of Voltage Amplifiers

- ❖ Pre-amplifier (Buffer Amplifier)
- ❖ Differential Amplifier
- ❖ Single ended amplifier

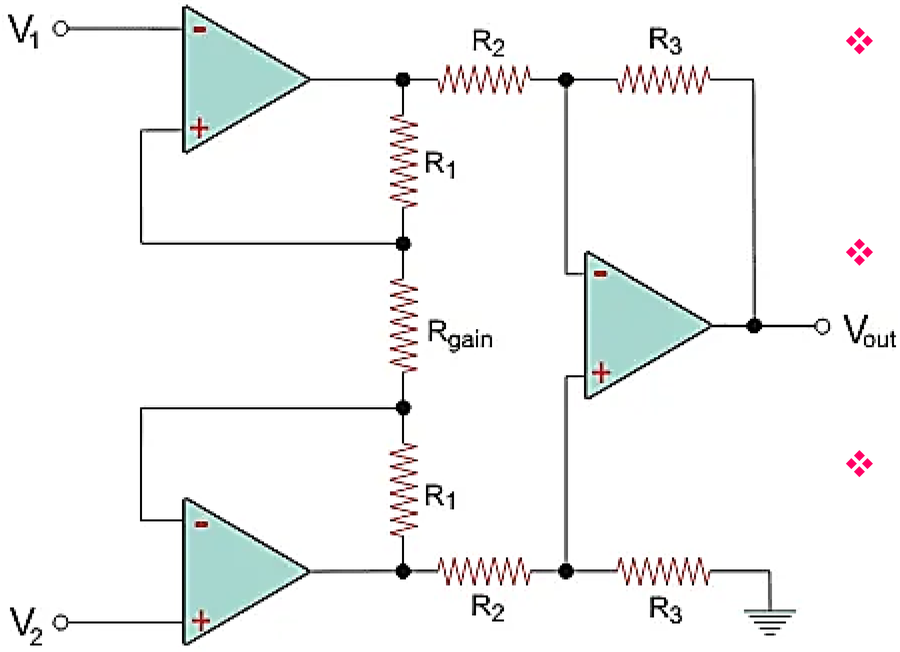
SINGLE ENDED AMPLIFIER

- ➢ Amplifier that doesn't have the ability to subtract one input from another is considered as Single Ended Amplifier because It just compares the difference b/w a single input and the electrical ground, which has a voltage close to zero.
- ➢ These amplifiers actually have the signals which already been amplified.

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.

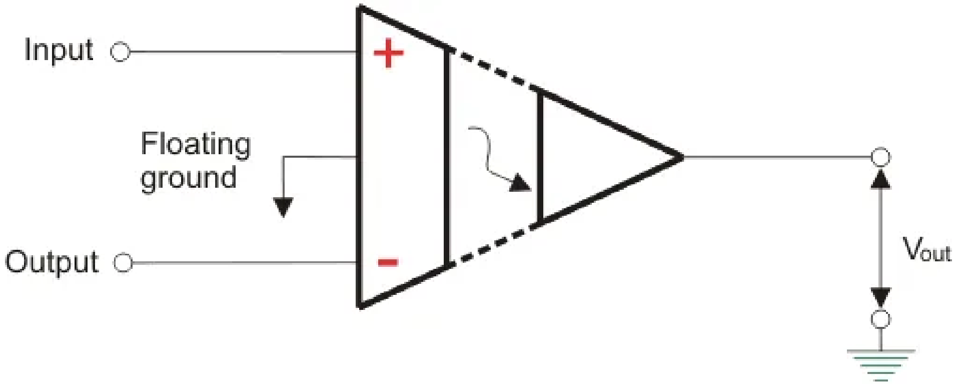
Instrumentation Amplifier



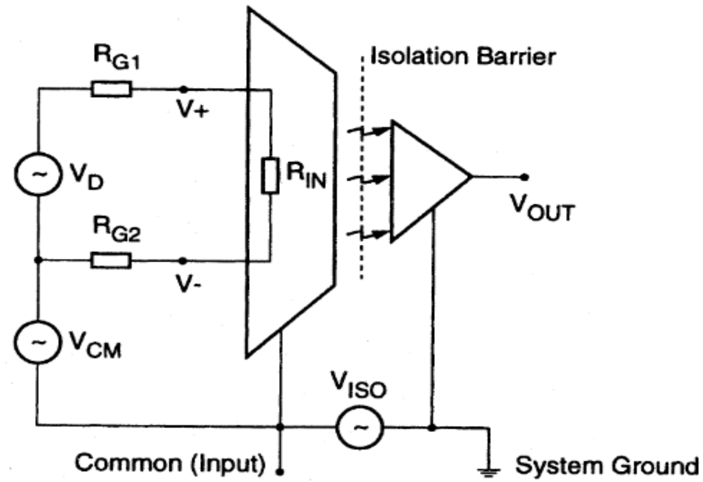
- To each input of the differential amplifier, the non-inverting amplifier is connected. From the figure, the amplifier on the left side acts as non-inverting amplifiers.
- They are combined together to form the input stage of the instrumentation amplifier. The third op-amp is the difference amplifier, and it is the output of the instrumentation amplifier.
- The output from the difference amplifier Vout is the difference between two input signals given at the input points. V_{01} is the output from op-amp 1 and V_{02} is the output from op-amp 2.

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

Isolation Amplifier



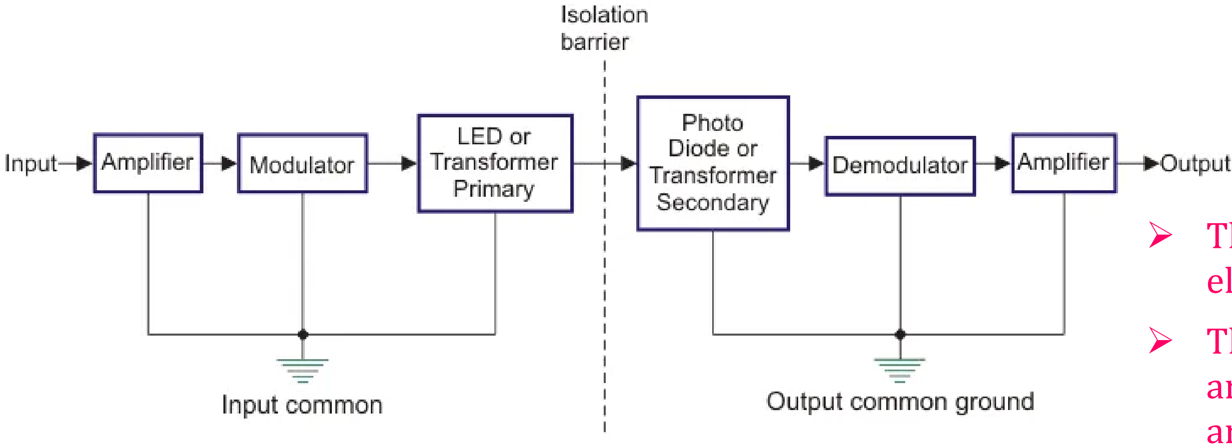
Symbol of Isolation Amplifier



- ❖ Symbol & Equivalent circuit of an isolation amplifier.
- ❖ The differential amplifier on the left transmits the signal through the isolation barrier by a transformer, capacitor, or an opto-coupler.

- ❖ 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.

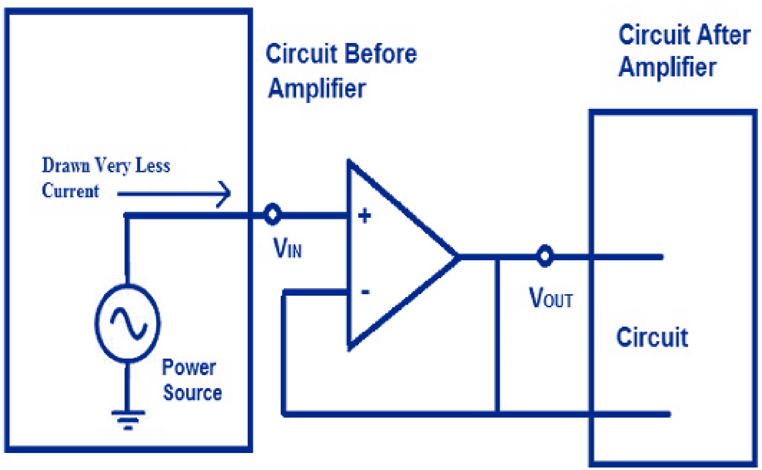
Isolation Amplifier



Block Diagram 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 primary transfers 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.

ISOLATION AMPLIFIER IN BIOMEDICAL INSTRUMENTATION



How to Achieve Isolation?

This amplifier works as an isolation device.

- When the input impedance of an op-amp is extremely high then the isolation can be caused.
- As this circuit includes high input impedance, then minute current can be drawn from the amplifier circuit.
- According to Ohms law, when the resistance is high, then the current will be drawn less from the power supply.
- Here, isolation amplifier works like a buffer and they do not strengthen signals although provide to isolate divisions of circuits.

- Isolation amplifiers are used in the biomedical section in order to protect the patient and the equipment, if a patient is being monitored for example ECG the protection is needed in both ways, patient must be protected from electrical shocks and if the patient's heart stops the protection is needed for the ECG machine because the voltage applied to the patient for the monitoring purpose.
- Isolation amplifiers protect the patient from electric shocks by using an isolation amplifier a galvanic separation can be done to the patient from the input side and from all equipment on the output side

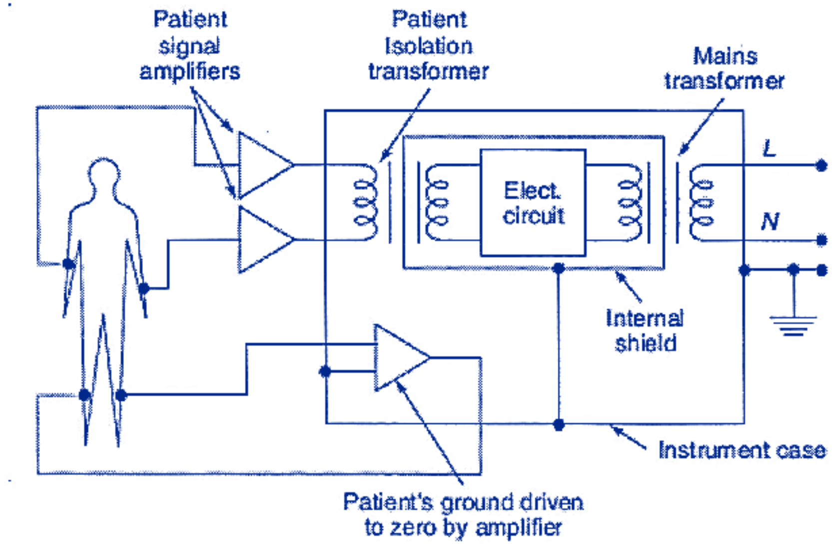
Isolation Amplifier Design Methods

There are three kinds of design methods are used in isolation amplifiers which include the following.

- Transformer Isolation, Optical Isolation & Capacitive Isolation

1) Transformer Isolation

The transformer approach is shown in Fig.(3.5.1) It uses either a frequency-modulated or a pulse width modulated carrier signal with small signal bandwidths up to 30 kHz to carry the signal. It uses an internal dc–to-dc converter comprising of a 20 kHz oscillator, transformer, rectifier and filter to supply isolated power.



Isolation Amplifier Design Methods : 1) Transformer Isolation

There are three kinds of design methods are used in isolation amplifiers which include the following.

- Transformer Isolation, Optical Isolation & Capacitive Isolation

- This type of isolation uses two signals like PWM or frequency modulated.
- Internally, this amplifier includes 20 KHz oscillator, rectifier, filter, and transformer to give supply to every isolated stage.

- ✓ The rectifier is used as an input to the main op-amp.
- ✓ Transformer links the supply.
- ✓ The oscillator is used as an input to the secondary op-amp.
- ✓ An LPF is used for removing the components of other frequency.

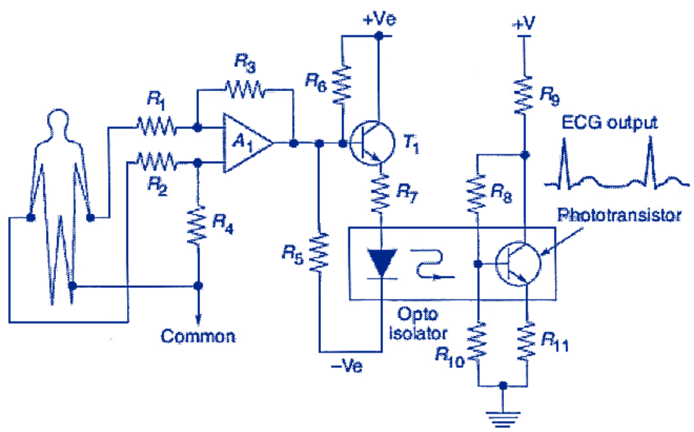
- **The advantages of transformer isolation mainly include high CMRR, linearity, and accuracy.**
- **The applications of transformer isolation mainly include medical, nuclear and industrial.**

Isolation Amplifier Design Methods : 2). Optical Isolation

- In this isolation, the signal can be changed from biological to light signal with LED for further process.

Isolation could also be achieved by optical means in which the patient is electrically connected with neither the hospital line nor the ground line. A separate battery operated circuit supplies power to the patient circuit and the signal of interest is converted into light by a light source (LED).

This light falls on a phototransistor on the output side, which converts the light signal again into an electrical signal (Fig. 3.5.2), having its original frequency, amplitude and linearity. No modulator/ demodulator is needed because the signal is transmitted optically all the way.



Isolation Amplifier Design Methods

2). Optical Isolation

- ❖ In this isolation, the signal can be changed from biological to light signal with LED for further process.

- ➢ In this, the patient circuit is input circuit whereas the output circuit can be formed by a phototransistor.
- ➢ These circuits are operated with a battery.
- ➢ The i/p circuit changes the signal into the light as well as the o/p circuit changes the light back to the signal.

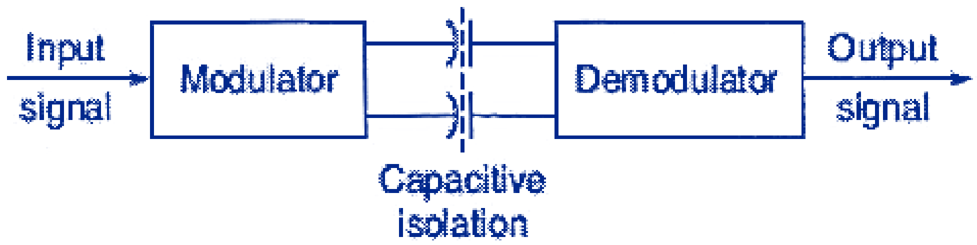
The advantages of optical isolation mainly include;

- ✓ By using this we can obtain amplitude and original frequency.
- ✓ It connects optically without the need of modulator otherwise demodulator.
- ✓ It improves the safety of the patient.

- ❖ The applications of transformer isolation mainly include process control in industries, data acquisition, measurements of biomedical, monitoring of the patient, interface element, test equipment, controlling of SCR, etc.

Isolation Amplifier Design Methods : 3). Capacitive Isolation

The capacitive method (Fig. 3.5.3) uses digital encoding of the input voltage and frequency modulation to send the signal across a differential capacitive barrier. Separate power supply is needed on both sides of the barrier. Signals with bandwidths up to 70 kHz can be conveniently handled in this arrangement.



- It uses digital encoding of the input voltage and frequency modulation.
- The input voltage is converted to proportional charge on the switched capacitor.
- It has modulator and demodulator circuits.
- The signals are sent across a differential capacitive barrier.

Isolation Amplifier Design Methods : 3). Capacitive Isolation

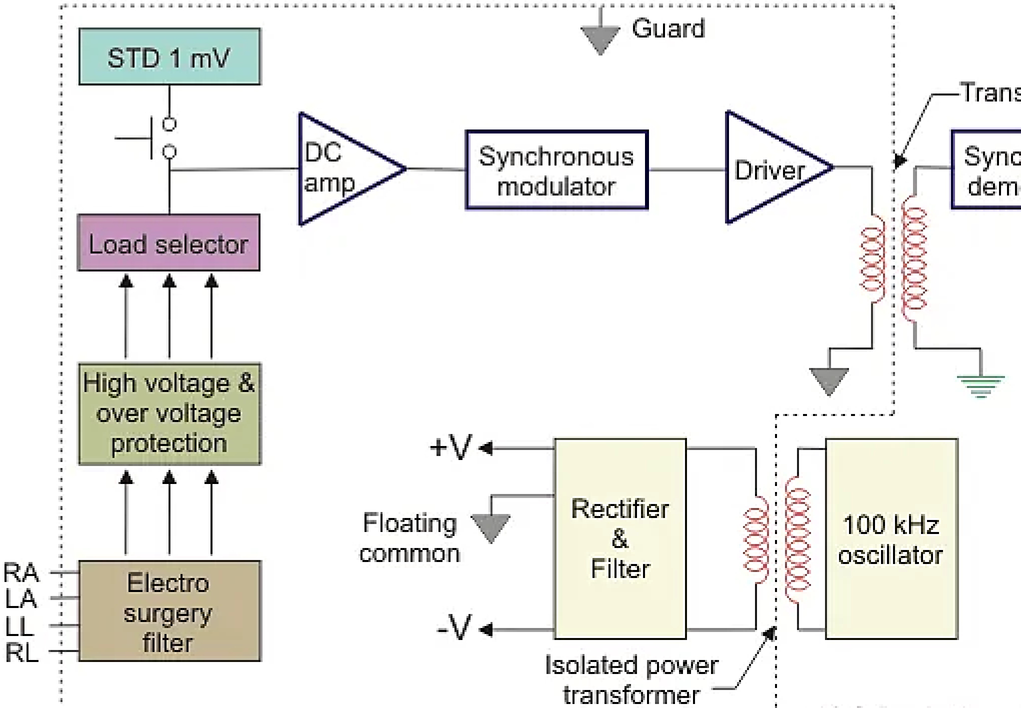
- It uses frequency modulation and the input voltage's digital encoding.
- The input voltage can be changed to relative charge over the switched capacitor.
- It includes circuits like modulator as well as a demodulator.
- The signals are sent across a differential capacitive barrier.
- For both sides, separate supplied are given.

The advantages of Capacitive isolation mainly include;

- ✓ This isolation can be used to remove ripple noises
- ✓ These are used for analog systems
- ✓ It includes linearity and high-gain stability.
- ✓ It gives high immunity to magnetic noises
- ✓ By using this, noise can be avoided.

- ❖ The applications of capacitive isolation mainly include data acquisition, interface element, monitoring of the patient, EEG, and ECG.

ECG Isolation Amplifier



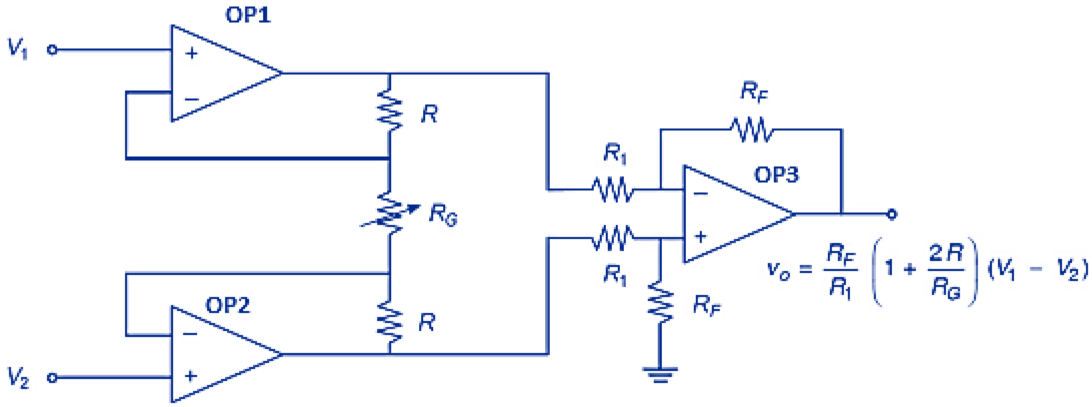
ECG Isolation Amplifier Circuit

- ❖ Defibrillation is **an emergency treatment for ventricular fibrillation and other life-threatening arrhythmias** (abnormal heartbeats).

- ➢ During ECG measurement, signals generated from all leads are sent to the low pass filter.
- ➢ This filter is named as Electro surgery filters because it decreases the interference between electrosurgery and radio frequency.
- ➢ Next block is the high voltage and overvoltage protection that can withstand large voltage during defibrillation.

- ❖ Proceeding further, it goes to Lead Selector Switch block, which selects the required configuration. Lead selection output goes to the DC amplifier.
- ❖ We have a transformer, whose primary winding is connected to the oscillator and secondary to rectifier and filter.
- ❖ ECG signal is modulated with the Synchronous modulator. The second transformer delivers the output from the synchronous modulator to the synchronous demodulator. The output from the demodulator is fed as input to the power amplifier.

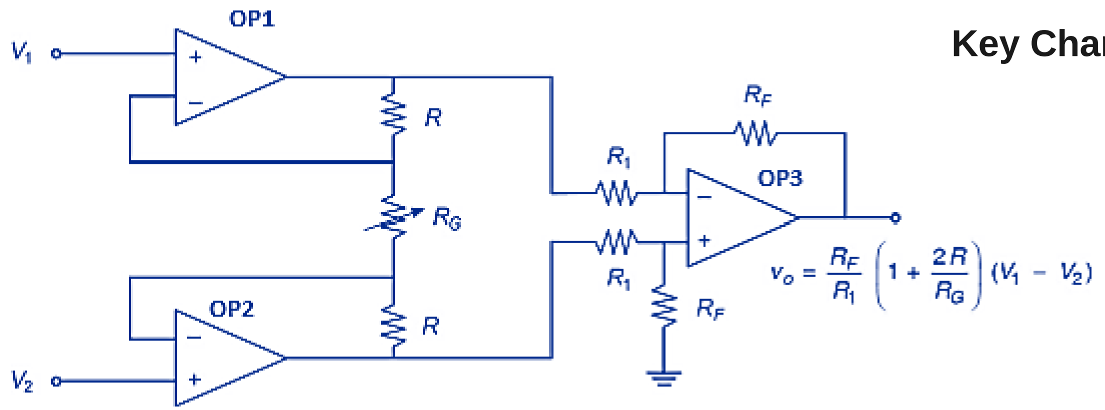
Instrumentation Amplifiers



Reasons why Differential amplifier is preferred over other electronic amplifiers

- Its ability to reject common-mode interferences which are invariably picked up by electrodes from the body along with the useful bioelectric signals.
- As a direct coupled amplifier, it has good stability and versatility.
- High stability is achieved because it can be insensitive to temperature changes which is often the source of excessive drift in other configurations
- It is versatile in that it may be adapted for many applications e.g. applications requiring floating inputs and outputs or applications where grounded inputs and or outputs are desirable.
- In order to minimize effects of changes occurring in the electrodes impedances, it is necessary, to use an input stage amplifier or preamplifier with a high input impedance. It has been established that a low value of input impedance give rise to a considerable distortions of the data recordings.

Reasons why Differential amplifier is preferred over other electronic amplifiers



Key Characteristics of Instrumentation Amplifiers

- ✓ Voltage gain from differential input (V_1-V_2) to single ended output is set by one resistor (RG).
- ✓ The input resistance of both inputs is very high and does not change as the gain is varied.
- ✓ V_o does not depend on common-mode voltage but only on their difference i.e. output voltage is proportional to the difference between the two input voltages.

- ❖ They have high input impedance
- ❖ They have high common mode rejection ratio (CMRR)
- ❖ Low bias and offset currents
- ❖ Low power consumption
- ❖ High slew rate
- ❖ Less performance deterioration if source impedance changes
- ❖ Possibility of independent reference levels for source and amplifier

- ❑ The instrumentation amplifier is made up of 2 parts: a buffered amplifier (OP1, OP2) and a basic differential OP3.

Power line interference

What is a power line interference?

- ❖ The powerline interference (PLI), with the fundamental PLI component of 50 Hz/60 Hz and its harmonics, is one of the most disturbing noise sources in biopotential recordings that hampers the analysis of the electrical signals generated by the human body.

What causes powerline interference in ECG?

- ❖ Power line interference is easily recognizable since the interfering voltage in the ECG may have frequency 50 Hz.
- ❖ The interference may be due to stray effect of the alternating current fields due to loops in the patient's cables.
- ❖ Other causes are loos e contacts on the patient's cable as well as dirty electrodes.

How do I remove powerline interference?

- ✓ The power line interference (50Hz) from ECG signal can be removed by adaptive filtering while it's harmonics and high frequency noise can be removed by implementing general notch rejection filters.

Interferences in ECG Waveform

Power line interference is easily recognizable since the interfering voltage in the ECG would have a frequency of 50 Hz (Fig3.7(a)). This interference may be due to the stray effect of the alternating current on the patient or because of alternating current fields due to loops in the patient cable.

Other causes of interference are loose contacts on the patient cable as well as dirty electrodes. When the machine or the patient is not properly grounded, power line interference may even completely obscure the ECG waveform.

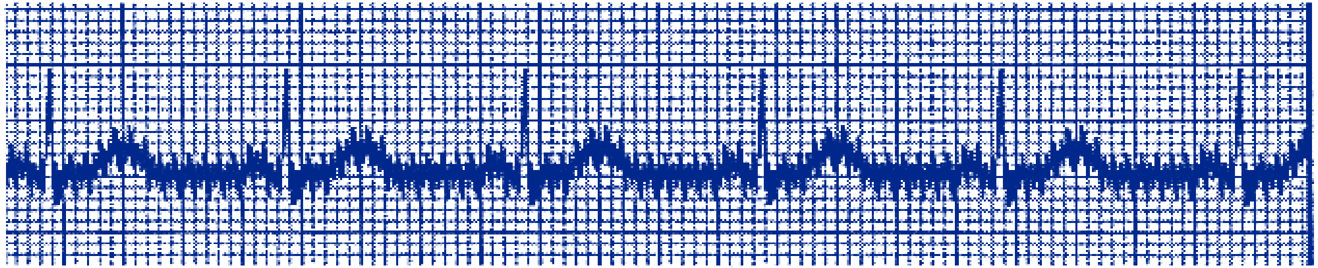


Figure 3.7 (a) ECG wave due to power line interference

The most common cause of 50 Hz interference is the disconnected electrode resulting in a very strong disturbing signal. It is often strong enough to damage the stylus of an unprotected direct writing recorder, and therefore needs quick action.

Techniques to Eliminate the Interferences in ECG Wave form

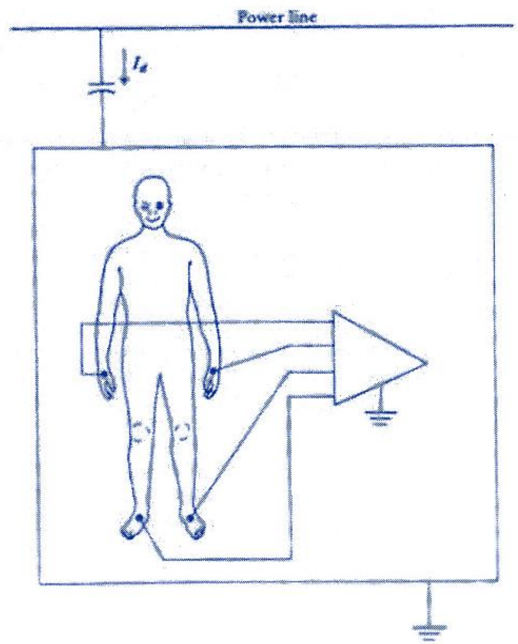
Shielding techniques to eliminate the interferences in ECG waveform.

1. Electro static shielding:- Place a ground conducting plane between the source of the electric field and the measurement system.

2. Magnetic shield: Use high permeability materials.

3. Use twisted cables to reduce magnetic flux and loop area.

Electro static shielding:



Electrostatic shielding used to remove electric field interference on an electrocardiograph.

Isolation capacitor used to isolate patient from power line.

BAND PASS FILTERING : Need for band pass filters in biological pre-amplifiers?

In general, the ECG signal is nature weak and only around 1mV amplitude. Therefore filter and amplifier circuits were designed into 3 stages with a total gain of 1000 to bring the signal to around 1V. Circuit designed included of instrumentation amplifier, bandpass filter and notch filter. The frequency bandwidth of ECG is between 0.05Hz until 100Hz.

Band pass filter is designed by cascading High pass filter with low pass filter.

- Based on power spectra estimation of the QRS complex, that a band pass filter with the center frequency 17HZ,and a Q of five ,yield the best signal to noise ratio.
- By using a bandpass filter rather than a lowpass filter, the amplitude of low frequency noise as well as the low frequency components of the ECG will be reduced without affecting the QRS.
- Pacemaker sensing amplifiers employ bandpass filters to discriminate between R-wave and T-wave.
- A consequence of this is that R-waves of smaller slew rate are also attenuated and therefore, it is likely that an R-wave with an amplitude exceeding the R-wave sensitivity of the sensing amplifier may not be sensed.
- This is of critical importance in cases of low amplitude R-waves (under 5 mV) where even moderate attenuation could lead to sensing problems.

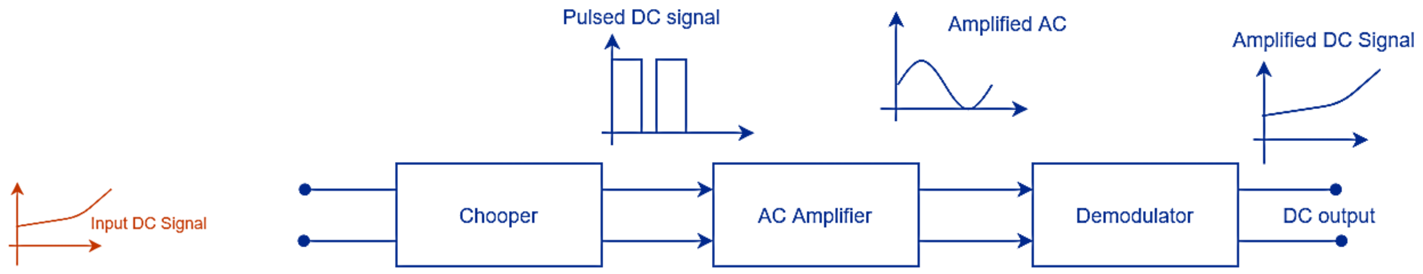
What is a Chopper Amplifier?

- A chopper amplifier is an electric circuit that implements a modulation methodology to minimize both the low-frequency noise signals and DC offset conditions in the op-amp.

- These days of chopper amplifiers use various scenarios to accomplish this, but the main principle is that a chopper amplifier works in combination with that of the main amplifier.

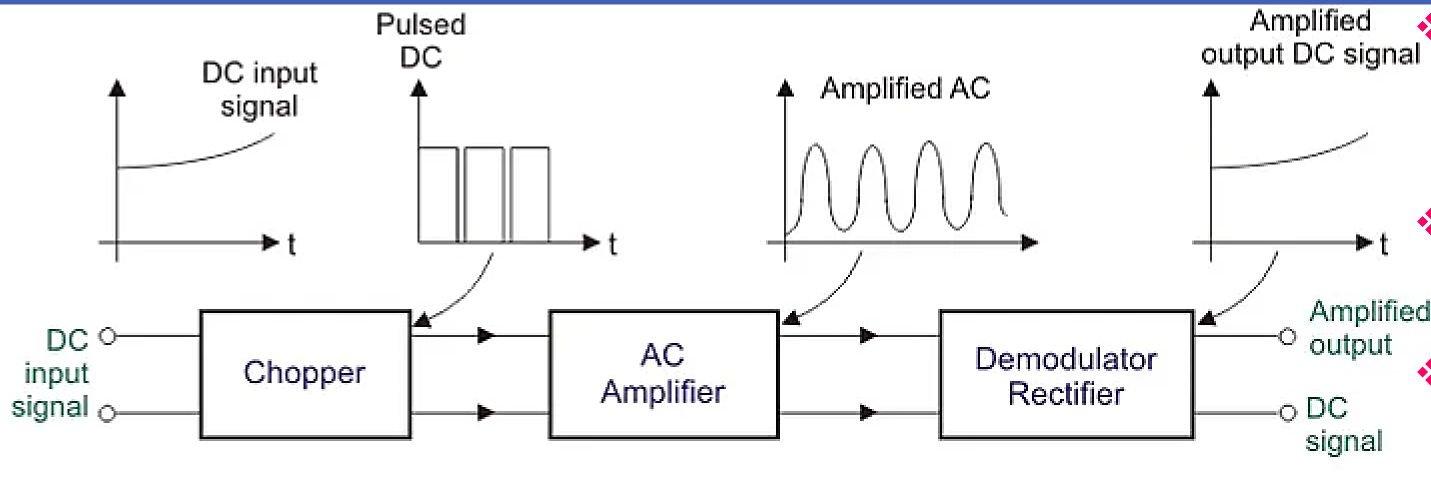
- These amplifiers use switches for modulating and chopping purposes.

- Then the resultant signal is sent across filters, summed up and fed as input to the chopper and main amplifiers.



The fundamental diagram of a chopper amplifier used in biomedical instrumentation is shown above

Chopper Amplifier for Biomedical Instrumentation

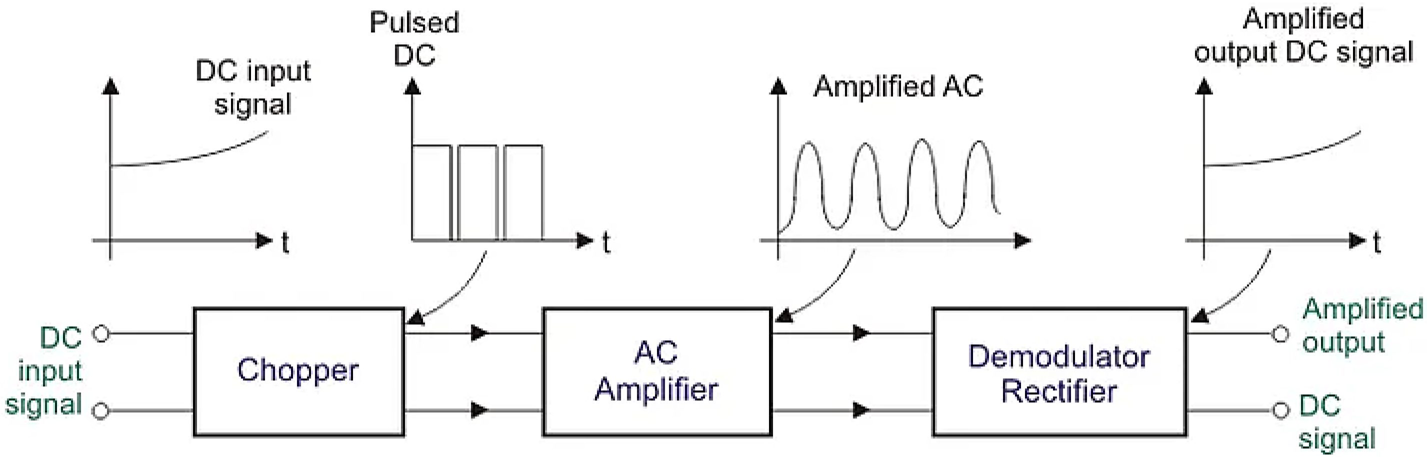


Schematic Diagram of a Chopper Amplifier

- 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 & filtered to obtain the low frequency or DC signal.

- 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.**

Chopper Amplifier for Biomedical Instrumentation



Schematic Diagram of a Chopper Amplifier

- The general diagram of a chopper amplifier is as shown above.
- 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.

Types of Chopper Amplifier : Mechanical Chopper Amplifier

❖ Chopper amplifier is classified into three types. – Mechanical, Non-mechanical choppers & Differential Chopper Amplifier

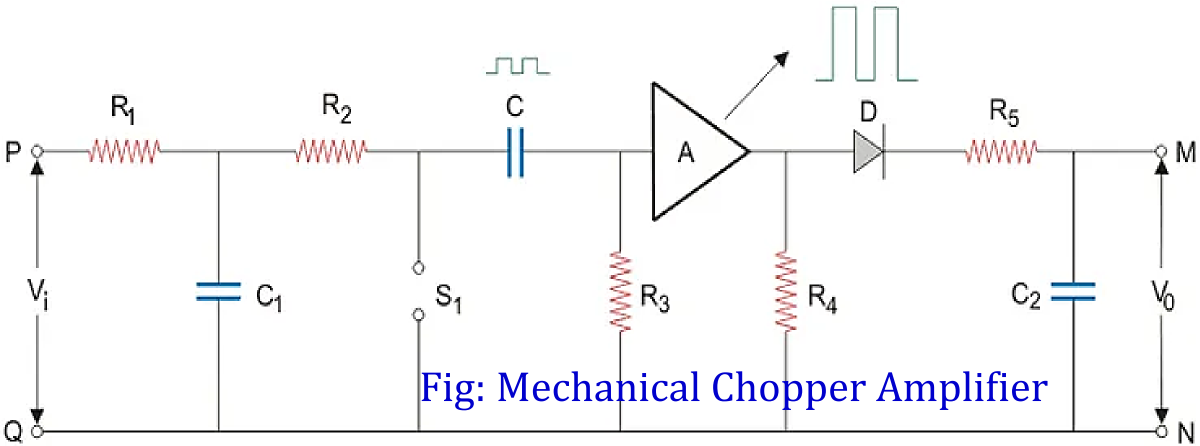


Fig: Mechanical Chopper Amplifier

❖ From the figure, chopper S_1 acts as electromagnetically operated switch or relay. Chopper acts a switch, so it connects the amplifier input terminal alternatively to reference term Q.

❖ 'A' is the AC amplifier that has an input terminal and a ground terminal & 'Q' acts as reference term.

❖ Diode 'D' rectifies the chopped signal.

❖ Chopping or sampling rate determines the chopper response time.

➢ Consider a condition in which chopper S_1 is closed.

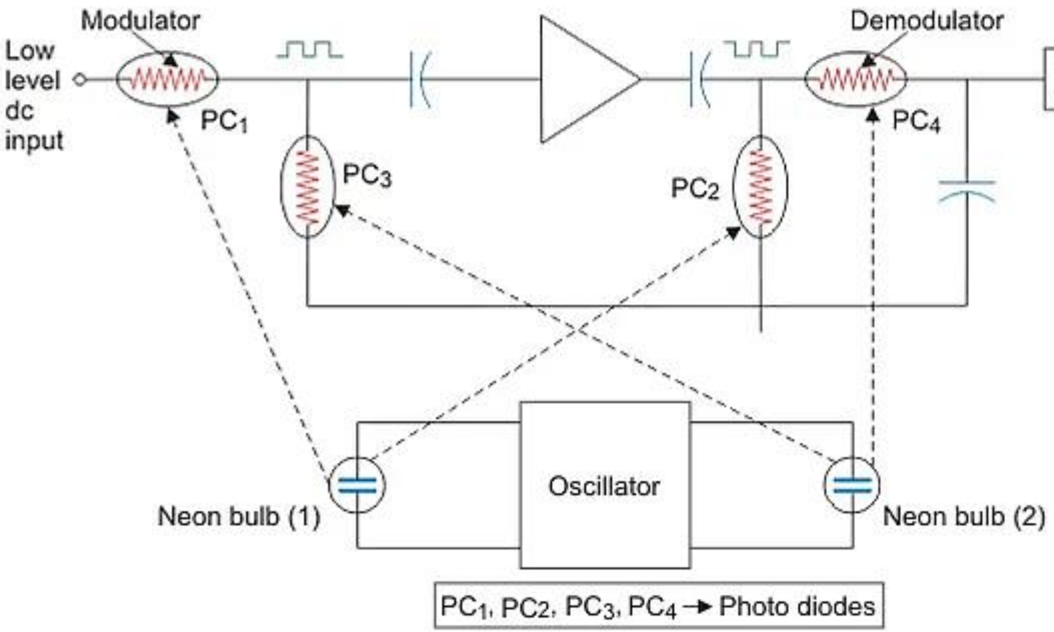
➢ At this position, the amplifier input terminal connects to Q_1. The entire circuit is short-circuited, so input voltage is zero. Now, let us consider the reverse operation when chopper S_1 is open.

➢ The AC amplifier starts receiving the signal from P terminal. Finally, the amplifier input has an alternating voltage that varies between zero and input voltage.

➢ At this stage, conversion of DC signal to square wave pulse occurs with amplification. Diode 'D' rectifies the chopped signal.

➢ After rectification, the rectified signal is filtered and amplified. At the output terminal M and N, the amplified DC output signal occurs.

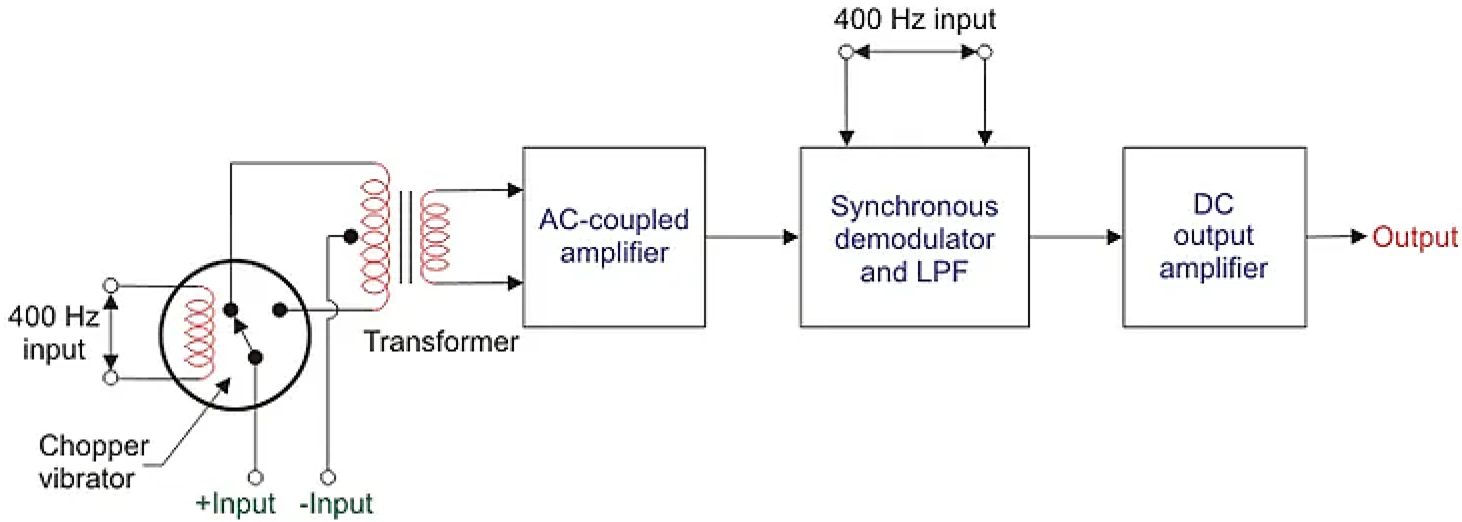
Types of Chopper Amplifier : Non-Mechanical Chopper Amplifier



- ❖ From the figure, an oscillator has two neon bulbs, which operates on half cycles of oscillation.
- ❖ PC1, PC2, PC3, and PC4 are photodiodes.
- ❖ Neon lamp 1 flashes light on PC_1 and PC_2.
- ❖ Neon lamp 2 flashes light on PC3 and PC4.
- ❖ When light falls on PC1, its resistance value reduces making the capacitor to charge.
- ❖ Light falls on PC3 making the input to flow through it when there is no light on PC1.

- ✓ Therefore, the light incidence on PC_1 and PC_3 takes place alternatively to generate a square wave pulse across the output capacitor.
- ✓ The generated square wave pulse is the input for the AC amplifier. The amplifier output is an amplified square wave pulse. The other two photodiodes PC2 and PC4 are in the output circuit. It recovers DC signal and makes the capacitor fully charged to the peak value of output voltage.
- ✓ At the final stage, a low pass filter removes the unwanted noise and ripples. The output is an amplified DC signal.
- ➢ In comparison with mechanical type, a non-mechanical chopper uses photodiodes or photoconductors for modulation (convert DC signals to AC signals) and demodulation (convert AC signals to DC signals).

Types of Chopper Amplifier : Differential Chopper Amplifier



- A type of chopper used for EEG measurement is a differential chopper. It has a transformer.
- A chopper vibrator connects the input of the transformer.
- The center tap of the transformer acts as one of the terminals for the input connector.
- The chopper switch acts as another terminal.
- AC coupled amplifier provides the gain.
- The output from this amplifier goes to filter and demodulator block. Finally, an amplified DC output signal is obtained.


THANK YOU

MEDICAL ELECTRONICS

MEASUREMENT OF
NON-ELECTRICAL PARAMETERS

Dr.M.Sivakumar,

Contents

- Basic Measurements: Temperature, Respiration Rate & Pulse Rate
- Blood Pressure Measurements:
  - Indirect methods : Auscultatory method, oscillometric method,
  - Direct methods: Electronic Manometer
- Pressure amplifiers - Systolic, Diastolic, Mean Detector circuit.
- Blood flow and cardiac output measurement:
  - Indicator Dilution, Thermal Dilution & Dye Dilution method
- Electromagnetic and ultrasound blood flow measurement.

What is Electrical & Non-Electrical Parameters?

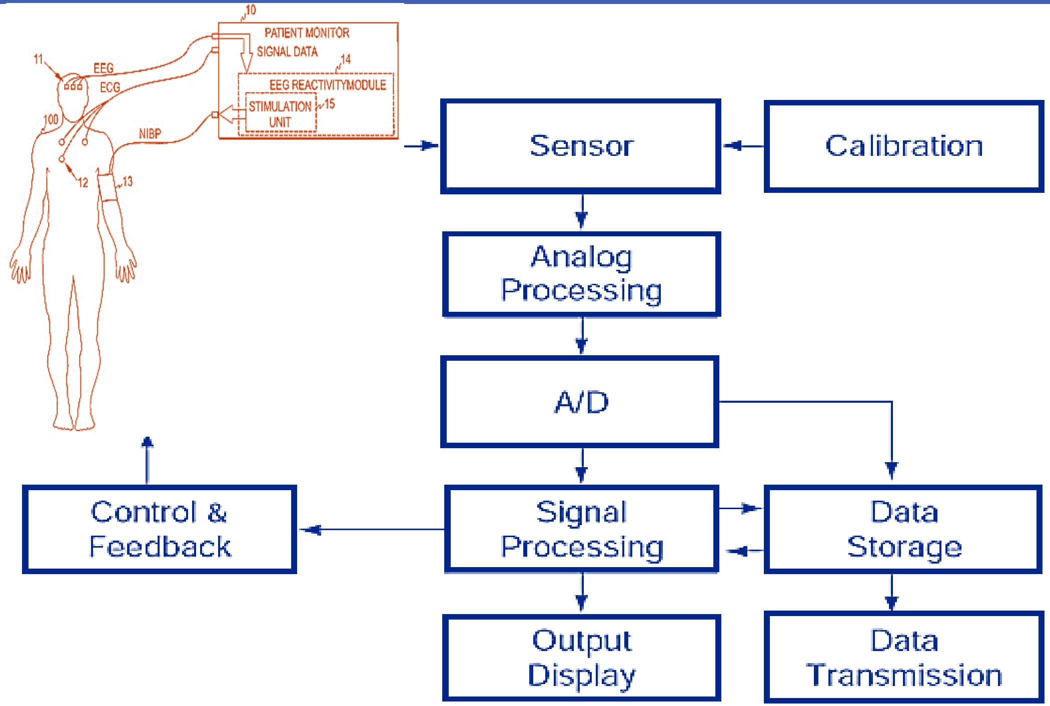
- <u>Electrical Parameters</u>
  - Electrical parameters include Pulse Waveform, Pulse Rate, Duration, the number of pulses and the voltage used.
- Mostly quantities to be measured are non-electrical such as temperature, pressure, displacement, humidity, fluid flow, speed etc., but these quantities cannot be measured directly.

- Biosignals can be measured directly from their biological source, but often external energy is used to measure the interaction between the physiological system and external energy.
- Measuring a biosignal entails converting it to an electric signal using a device known as a biotransducer.
- The resultant analog signal is often converted to a digital (discrete-time) signal for processing in a computer.

What is mean by transducer?

- It is a device which detects or senses the bio signal and converts it in to an electrical signal for bio signal processing

What are biomedical measurements?



- ❖ Biomeasurement system is composed of sensor, analog processing circuit, A/D conversion, digital signal processing, output display, and data storage.
- ❖ A/D conversion is used in bioinstrumentation to acquire the enough system gain.

❖ Fig: Basic bio measurement system using sensors to measure a biological signal with data acquisition, storage and display capabilities, data transmission, along with control and feedback

The biomeasurement system is shown in figure to measure some biological signals such as quantity, property, or condition which are bioelectrical signal generated by muscles or the brain, or a chemical or mechanical signal that is converted into an electrical signal.

TEMPERATURE MEASUREMENT

- The variation in the temperature is a direct result of the variation in blood pressure.

- Basically two types of temperature measurement cam be obtained from the human body : 1. Systemic 2. Skin surface

1. Systemic Temperature:
   - Systemic temperature is measured by using temperature sensing devices placed in mouth, under the armpits or in the rectum.
   - The normal oral (mouth) temperature of a healthy person is 37°C.
   - The normal under arm temperature of a healthy person is 36°C and The normal rectum temperature of a healthy person is 38°C.
   - The systemic body temperature can be measured more accurately at the tympanic membrane in the ear.

2. Surface or Skin temperature:
   - Surface or skin temperature is a result of a balance but here the balance is between the heat supplied by blood circulation in the local area and the cooling of that area by conduction, radiation, convection and evaporation.
   - Thus skin temperature is a function of the surface circulation, environmental temperature, air circulation around the area from which the measurement is to be taken and perspiration.

Measurement of systemic Body temperature

- **Mercury Thermometer:**
  - Mercury thermometer is the standard method of temperature measurement.
  - Mercury thermometer is used where continuous recording of temperature is not required.
  - Mercury thermometers are inexpensive, easy to use and sufficiently accurate.
- **Electronic Thermometer:**
  - Now-a-days electronic thermometers are available as a replacement of mercury thermometer.
  - It has disposable tip and requires only less time for reading and also much easier to read the value.
  - Electronic thermometers are used where continuous recording and accuracy of the temperature is necessary.

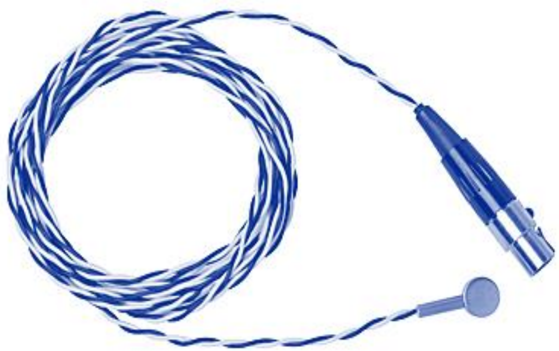
Measurement of systemic Body temperature

- Two types of electronic temperature sensing devices are found in biomedical applications. They are, a) Thermocouple b) Thermistor

- Thermistors are variable resistance devices formed into disks, Beads, Rods or other desired shapes.
- They are manufactured from mixtures of oxides of various elements such as nickel, copper, magnesium, manganese, cobalt, titanium and aluminium.

Skin temperature Measurement:

- skin temperature measurements can be used to detect or locate defects in the circulatory system by showing differences in the pattern from one side of the body to the other.
- Skin temperature measurements from specific locations on the body are frequently made by using small, flat thermistor probes taped to the skin.
- The simultaneous readings from a number of these probes provide a means of measuring changes in the spatial characteristics of the circulatory pattern over a time interval or with a given stimulus.



RESPIRATION RATE MEASUREMENT

- The Function of Respiratory System is to supply oxygen and remove carbon dioxide from tissues. The action of breathing is controlled by a muscular action causing the volume of the lungs to increase and decrease.

Techniques used for the measurement

- Displacement method , Thermistor method, Impedance Pneumography
- Carbondioxide method & Apnoea detector

1) Displacement Method

- During each respiratory cycle, the thoracic volume changes. These changes can be sensed by means of displacement transducer. The transducer is held by an elastic band which goes around the chest.
- The respiratory movement results in resistance changes of the strain gauge element connected as one arm of a Wheatstone bridge circuit.
- Bridge output varies with chest expansion and yields signals corresponding to respiratory activity. Changes in the chest circumference can also be detected by a rubber tube filled with mercury. The tube is fastened firmly around the chest .
- During inspiration, the chest expands and the rubber tube increases in length and the resistance of the mercury from one end of the tube to the other end changes. The change in resistance can be measured by sending a constant current through it and measured in terms of change in voltage during each respiratory cycle.

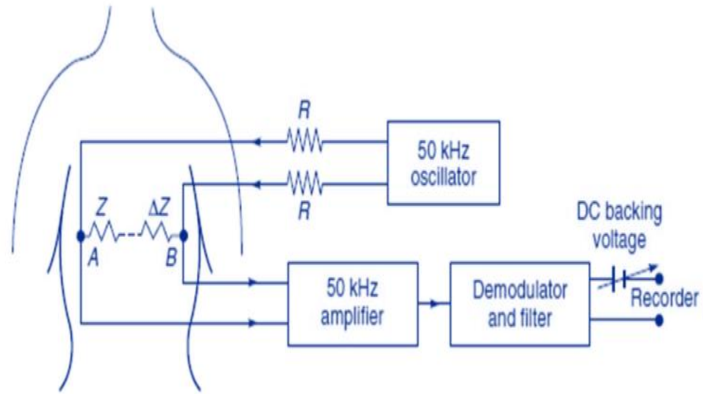
RESPIRATION RATE MEASUREMENT

Thermistor Method

- ❖ In this method a thermistor is placed in front of the nostrils by means of a suitable holding device to detect the difference in temperature between the inspired and expired air.
- ❖ Since the inspired air passes through the lungs and respiratory tract, its temperature is increased while coming out. This change in temperature is detected by using thermistor.

Impedance Pneumography

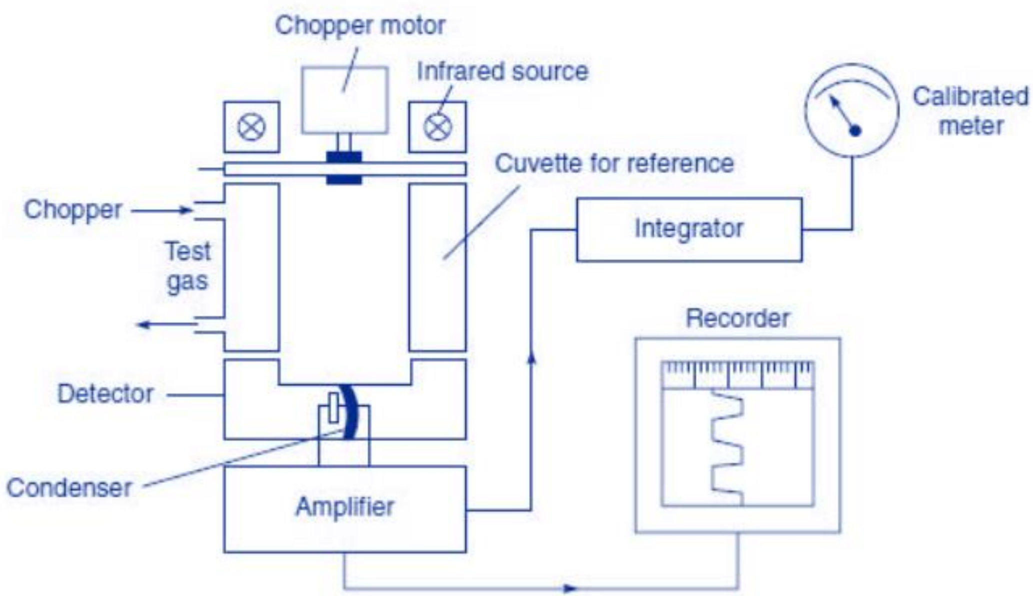
- ❖ This is an indirect technique for the measurement of respiration rate.
- ❖ Impedance Pneumograph is based on the fact that the impedance across the chest changes during each respiratory cycle.



- ❖ In this method, a low voltage 50 to 500KHz AC signal is applied to the chest of the patient through surface electrodes and the modulated signal is detected.
- ❖ The signal is modulated by changes in the body impedance accompanying the respiratory cycle.

Carbondioxide Method

Respiration rate can also be measured by continuously monitoring the CO_2 contained in the subject's alveolar air.

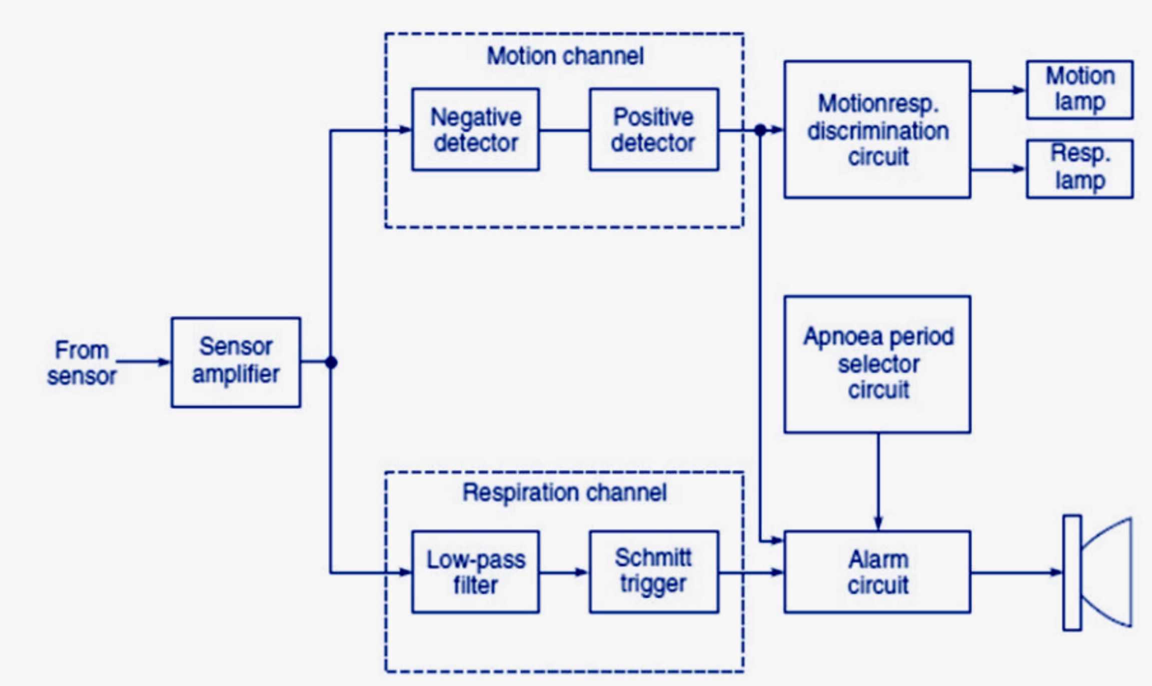


- The measurement is based on the absorption property of infrared rays by certain gases.
- Suitable filters are used to determine the concentration of specific gases (like CO, CO_2, and NO_2) present in the expired air.

- The detector converts this heat loss of the rays into an electrical signal.
- This signal is used to obtain the average respiration rate.
- The arrangement for detection of CO_2 in the expired air is shown in the above figure.

Apnoea Detectors

Apnoea is the stopping of breathing. It leads to the arrest of the circulation.



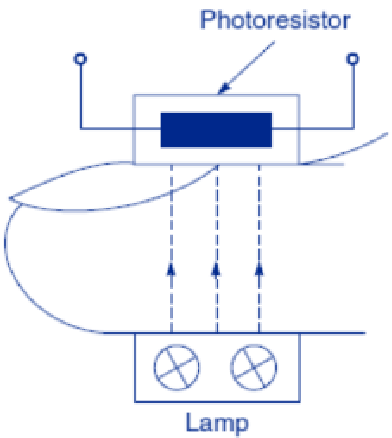
- ❖ It can be occurred at the conditions like head injury, drug overdose, etc.
- ❖ It can also occur in premature babies during the first week of life because of their immature nervous system.
- ❖ If Apnoea persists for a prolonged period, then brain functions can be severely damaged.
- ❖ So Apnoea patients are closely monitored.

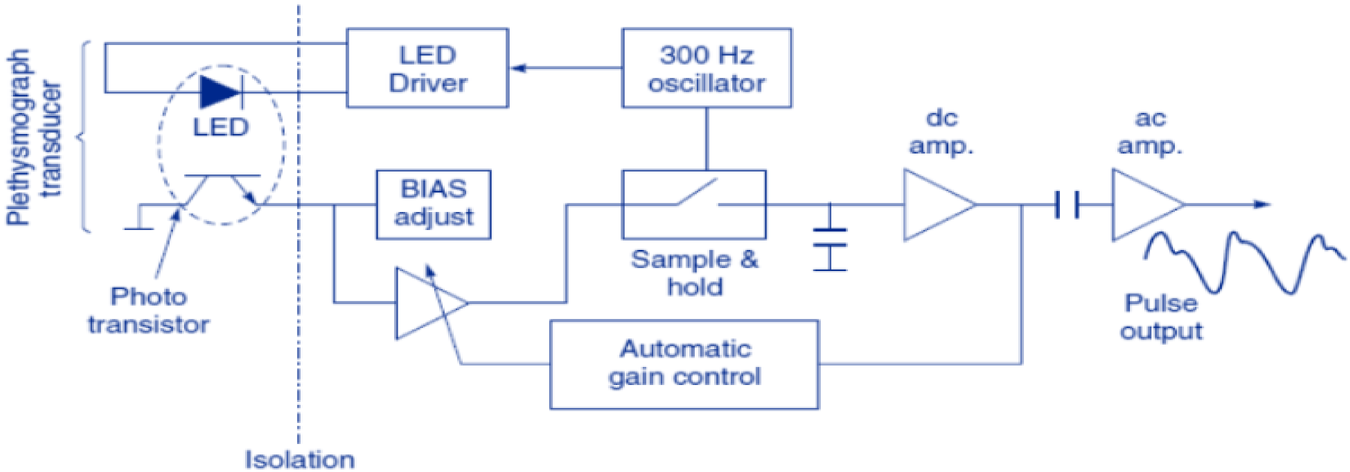
- ❖ Apnoea monitor is used to watch the Apnoea patients respiration rate.
- ❖ Apnoea monitor gives audio signals and visual signals, when no inspiration occurs for a particular period of time.
- ❖ Input from the sensor is connected with the amplifier circuit having high input impedance.

PULSE RATE MEASUREMENT

Whenever the heart muscle contracts, blood is ejected from the ventricles and a pulse of pressure is transmitted through the circulatory system.

- ❖ The pulse can be felt by placing the finger tip over the radial artery in the wrist or some other locations where an artery seems just below the skin.
- ❖ The pulse pressure and waveform are indicators for blood pressure and blood flow.
- ❖ The instrument used to detect the arterial pulse and pulse pressure waveform is called as plethysmograph.
- ❖ The pulse waveform travels at 5 to 15 m/sec depending up on the size and rigidity of arterial walls.





BLOOD PRESSURE MEASUREMENT

- ❖ Pressure is defined as force per unit area $P = F / A$

  P = pressure in Pascal, F= force, A=Area

Types:

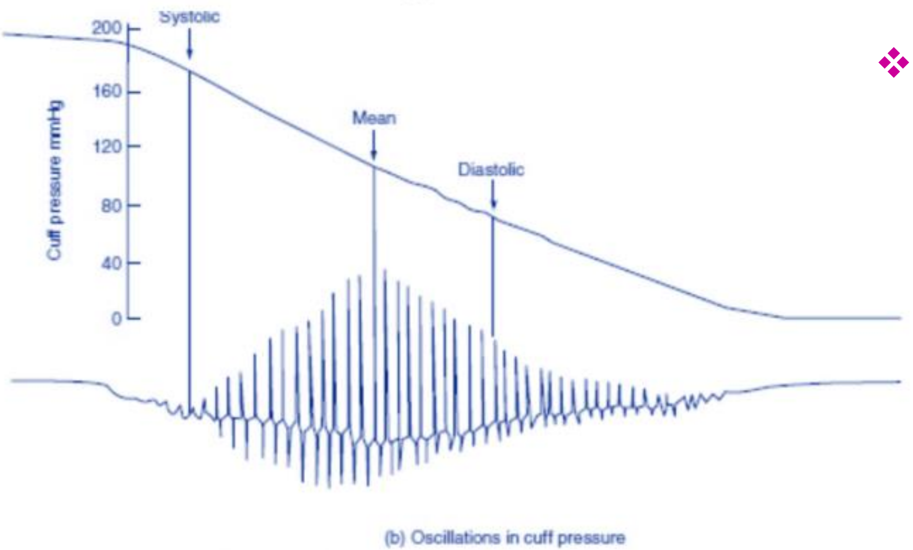
- ➢ Hydrostatic pressure: If the force in a system under pressure is not varied then pressure is known as Hydrostatic pressure

- ➢ Hydrodynamic pressure: If the force in a system under pressure is varied then pressure is known as Hydrodynamic pressure

Methods :

1) Direct Method (Probe Used in direct Method)
   - ❖ If we want to know blood pressure in deep region indirect method is not useful. so direct method is used.
2) Indirect method using sphygmomanometer
   - ❖ In this method Sphygmomanometer is used to measure blood pressure indirectly.
   - ❖ It consists of inflatable rubber bladder which is known as cuff, rubber squeeze ball pump & valve assembly. Pressure is measured using manometer with mercury column.

BLOOD PRESSURE MEASUREMENT



Illusration of oscillometric method of blood pressure measurement

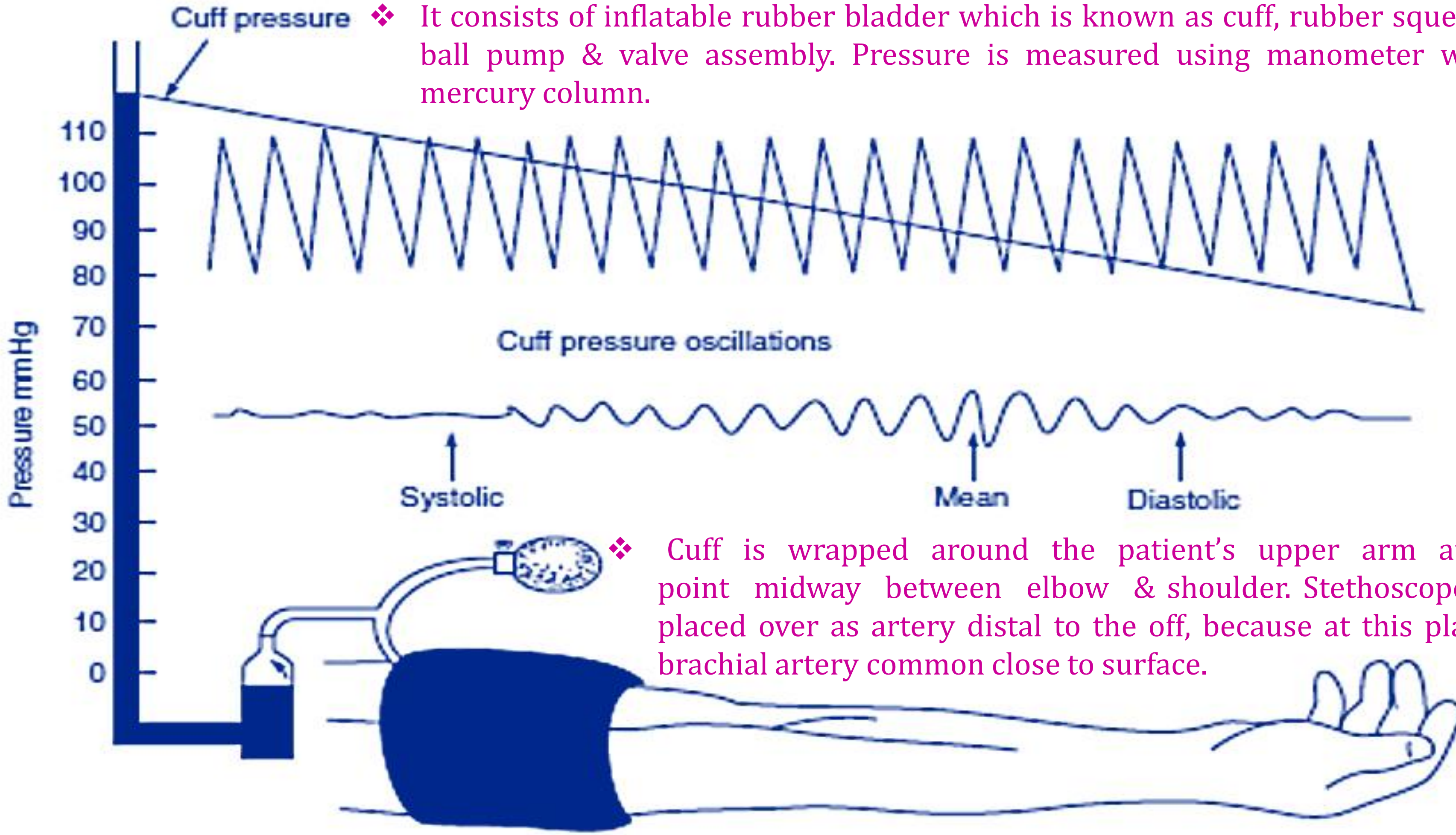
- Diastole and systole are two phases of the cardiac cycle.
  - The terms diastole and systole refer to when the heart muscles relax and contract.
  - The balance between diastole and systole determines a person's blood pressure.
  - The heart is a pump that supplies all tissues and organs of the body with oxygen-rich blood.

Classification	BP (mm Hg)
Normal	**systolic: less than** 120 **diastolic: less than** 80
Pre-hypertension	120-139/80-89
Stage 1 hypertension	140-159 (systolic) or 90-99 (diastolic)
Stage 2 hypertension	equal or more than 160 (systolic) equal or more than 100 (diastolic)

- The heartbeat is caused by the heart muscles relaxing and contracting.
- During this cycle, the period of relaxation is called diastole and the period of contraction is called systole.

BLOOD PRESSURE MEASUREMENT
Indirect method using sphygmomanometer

- It consists of inflatable rubber bladder which is known as cuff, rubber squeeze ball pump & valve assembly. Pressure is measured using manometer with mercury column.



- Cuff is wrapped around the patient's upper arm at a point midway between elbow & shoulder. Stethoscope is placed over as artery distal to the off, because at this place, brachial artery common close to surface.

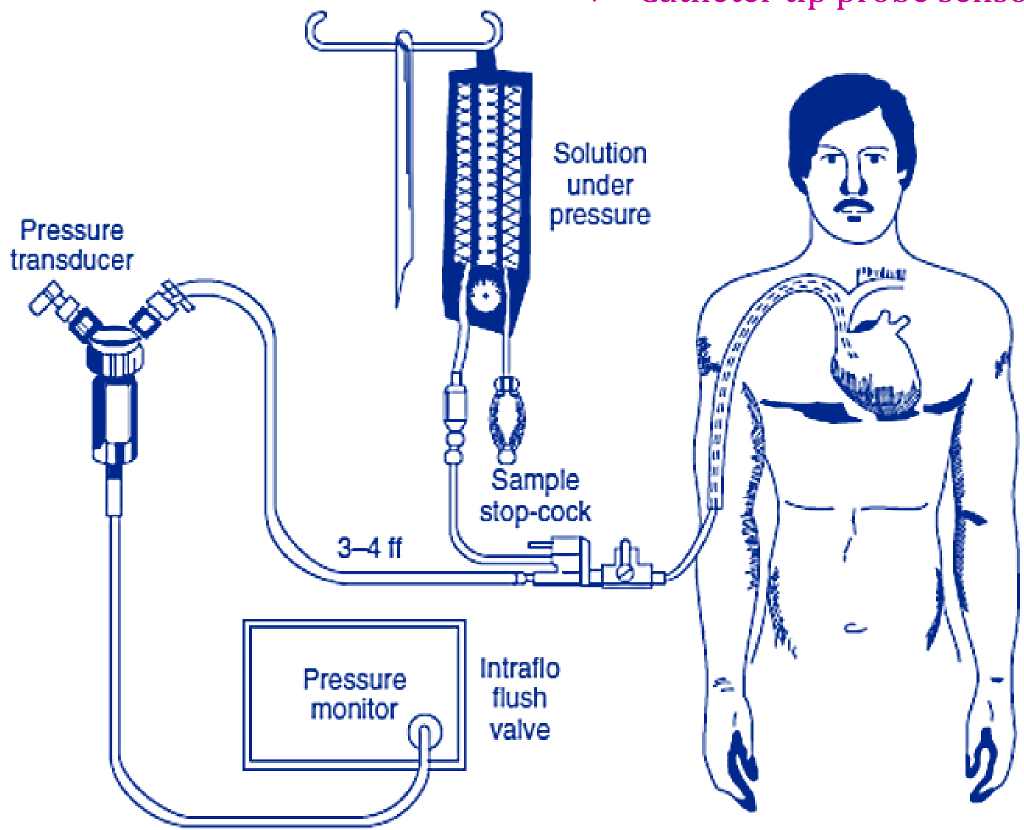
- Pressure reading in the mercury column during onset of korotkoff sound is noted as systolic pressure usually 120 mmHg.

(a) Oscillometric method

BLOOD PRESSURE MEASUREMENT

Direct method using Probe

- Catheter tip probe sensor mounted at the tip of the probe.

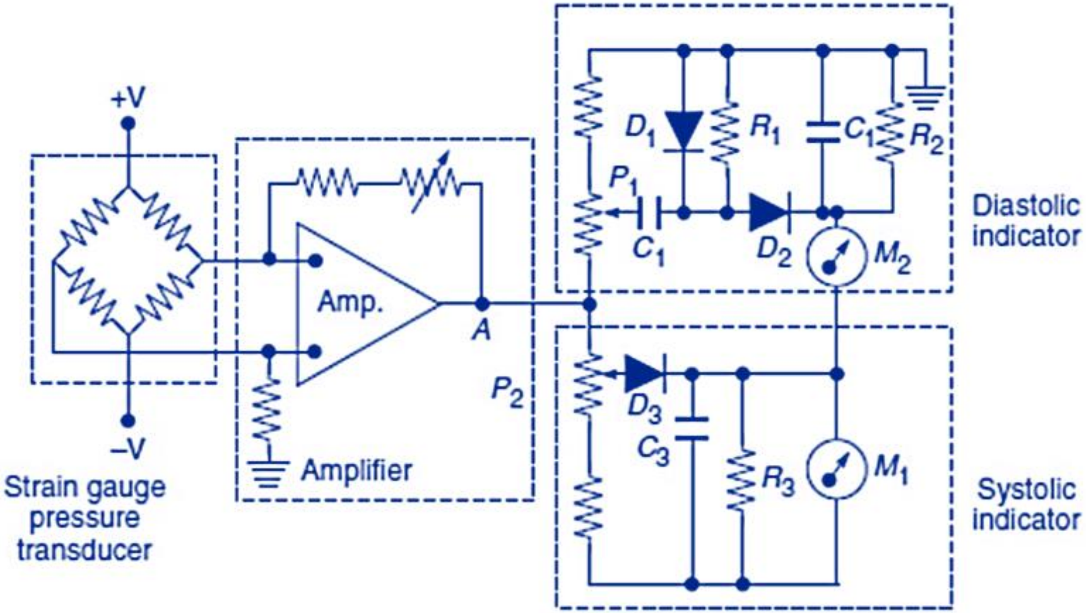


Typical set up of a pressure measuring system by direct method

- Pressure exerted on the tip is converted to the corresponding electrical signal in fluid filled catheter type.
- Pressure exerted on the fluid filled column is transmitted to external transducer.
- This transducer converts pressure in to electrical signal.
  - Here fluid filled catheter is used. Before inserting catheter into blood vessel, fluid filled system should be completely flushed out.
  - Usually sterile saline is used for this purpose.
  - Because blood clotting is avoided.
  - Blood taken from vessel using Cather tip probe.

BLOOD PRESSURE MEASUREMENT

Measurement of Systolic & Diastolic Blood Pressure



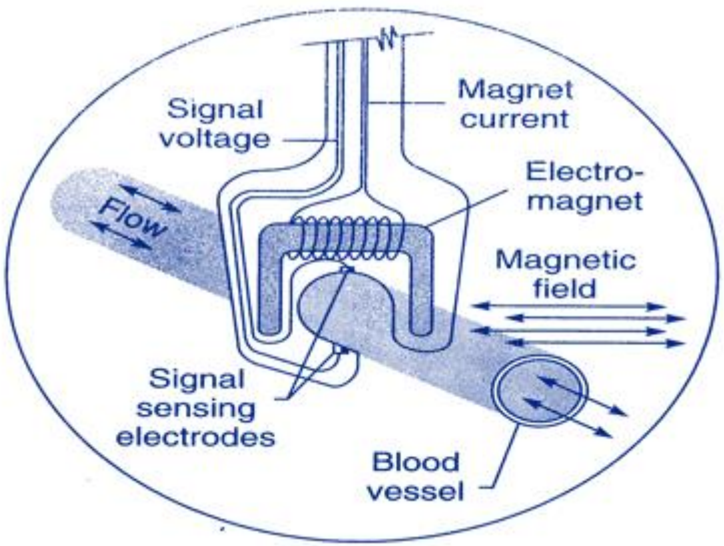
Circuit diagram for measurement of systolic and diastolic blood pressure

- ❖ Pressure exerted is transmitted to the pressure transducer.
- ❖ The output of transducer is given to pressure monitor. Because transducer converted into electrical signal.
- ❖ Strain gauge pressure transducer is used. The change in pressure is given to the amplifier circuit.
- ❖ Two indicators, systole, diastole display.
- ❖ If output of the amplifier is positive going pulse then D3 will be ON.
- ❖ In C3 charging up to peak value. R3 & C3 combination is used to set some time constant value, which is used to stable display.

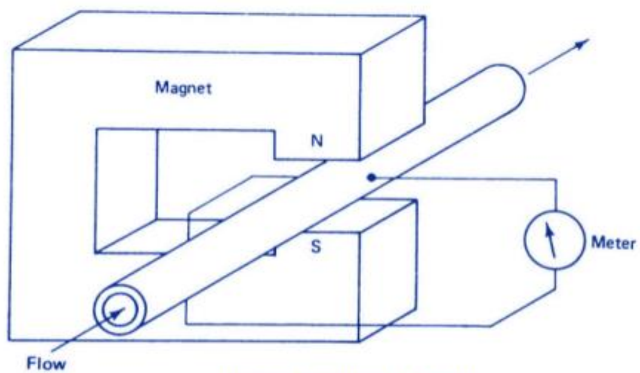
- ❖ Clamping circuit is available C1 & D1 used to develop voltage is equal to peak to peak value of the pressure pulse.
- ❖ This Voltage appeared across R1 resistance. D2 diode is ON so C2 charged up to the peak value.
- ❖ Diastolic pressure is displayed using the indicator M2

M2 reading = peak systolic value - peak to peak pressure value.

BLOOD FLOW METER



Electromagnetic Blood Flowmeter



Principle of EM blood flow meter.

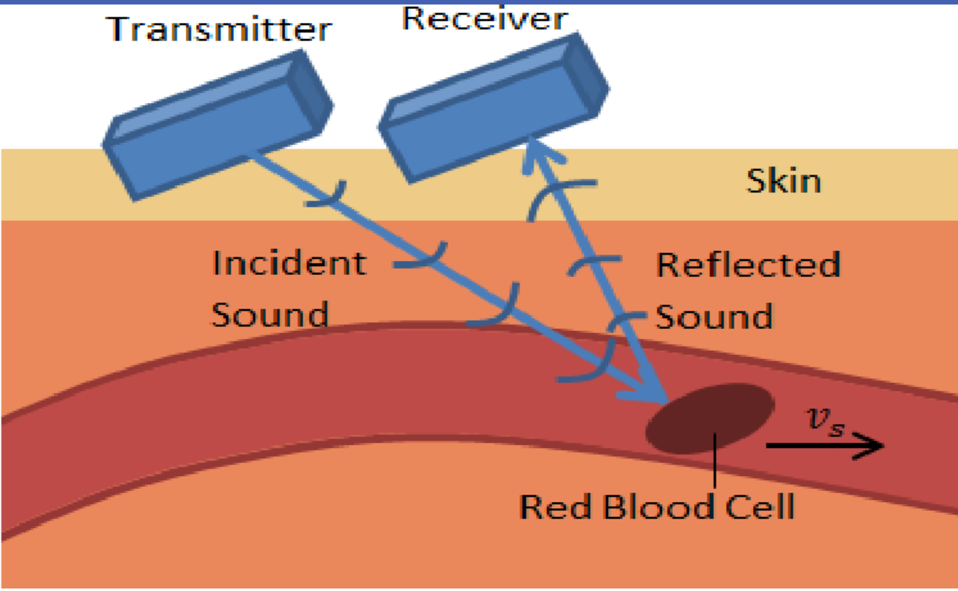
- Blood flow is the one of the important physiological parameter and the most difficult to measure accurately.
- The average velocities of blood flow vary over a wide range depending on diameter of blood vessel.

- There are many techniques for measuring the blood flow and velocity.
- They are categorized into

1. Invasive(surgical). 2. Non invasive(through the skin).

- ✓ Measures instantaneous pulsatile flow of blood.
- ✓ Works based on the principle of electromagnetic induction.
- ✓ The voltage induced in a conductor moving in a magnetic field is proportional to the velocity of the conductor.
- ✓ This method requires that the blood vessel be exposed so that the flow head or the measuring probe can be put across it.

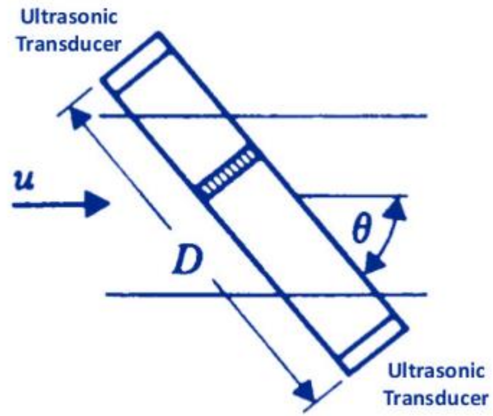
BLOOD FLOW METER



- ✓ A beam of ultrasonic energy is used to measure the velocity of flowing blood. .
- ✓ Lead zirconate titanate is a crystal that has the highest conversion efficiency.

Two types:

Transit time flow meters & Doppler type.

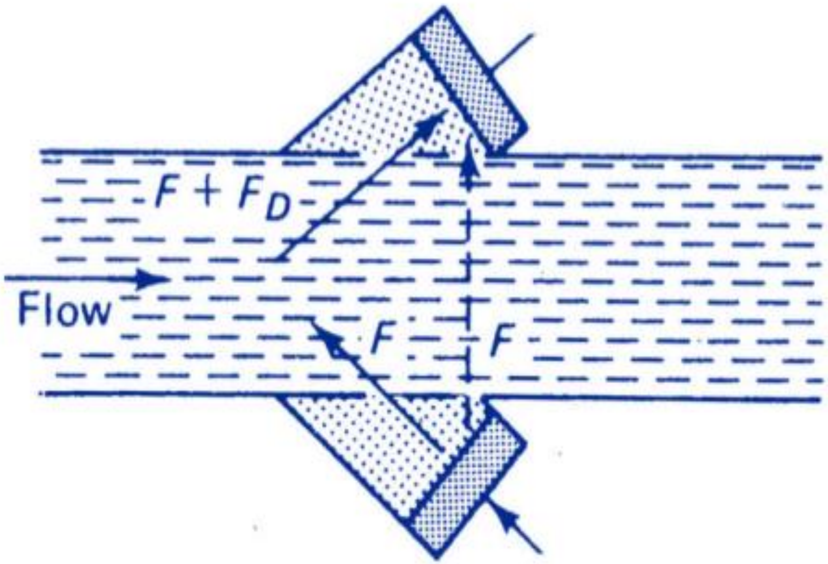


Transit-Time Ultrasonic Flow Meters

Ultrasonic blood flow meters:

- ❖ The pulsed beam is directed through a blood vessel at a shallow angle and its transit time is measured.
- ❖ The transit time is shortened when the blood flows in the same direction as the transmitted energy. The transit time is lengthened otherwise.

BLOOD FLOW METER

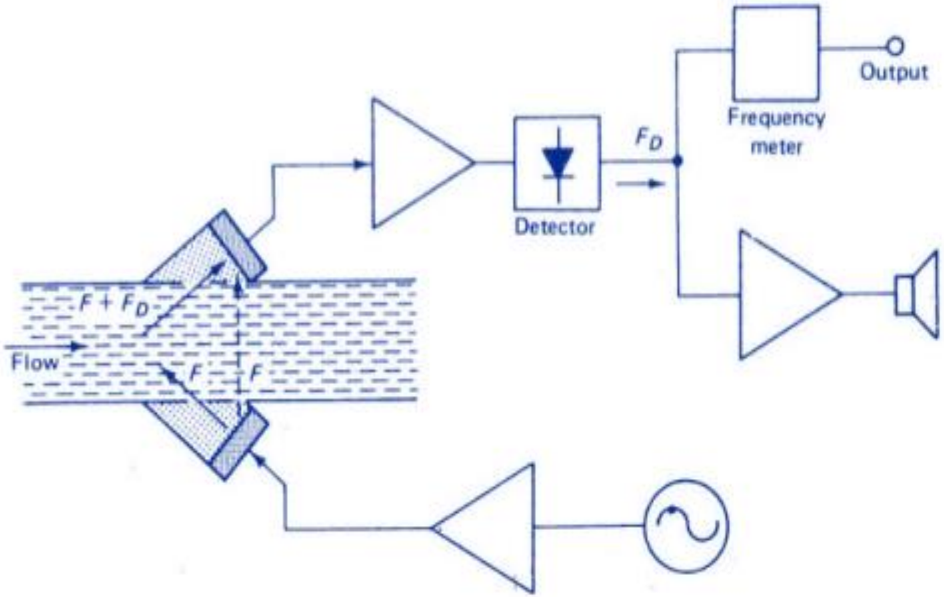


Doppler Type Ultrasonic Flow Meters

- After amplification of the composite signal, the Doppler frequency can be obtained at the output of the detector as the difference between the direct and the scattered signal components. For normal blood velocities, the Doppler signal is typically in the low audio frequency range.

- ✓ Based on the Doppler principle. A transducer sends an ultrasonic beam with a frequency F into the flowing blood.
- ✓ A small part of the transmitted energy is scattered back and is received by a second transducer arranged opposite the first one.
- ✓ The reflected signal has a different frequency F + FD or F – FD due to Doppler effect.
- ✓ The Doppler component FD is directly proportional to the velocity of the flowing blood.
- ✓ A fraction of the transmitted ultrasonic energy reaches the second transducer directly with the frequency being unchanged.

BLOOD FLOW METER



Doppler Type Ultrasonic Flow Meters

- After amplification of the composite signal, the Doppler frequency can be obtained at the output of the detector as the difference between the direct and the scattered signal components.

- For normal blood velocities, the Doppler signal is typically in the low audio frequency range.

CARDIAC OUTPUT MEASUREMENT

Cardiac output is the term that describes the amount of blood your heart pumps each minute. Doctors think about cardiac output in terms of the following equation:

$$\boxed{\text{Cardiac output} = \text{stroke volume} \times \text{heart rate.}}$$

Cardiac output is calculated by multiplying stroke volume with heart rate.

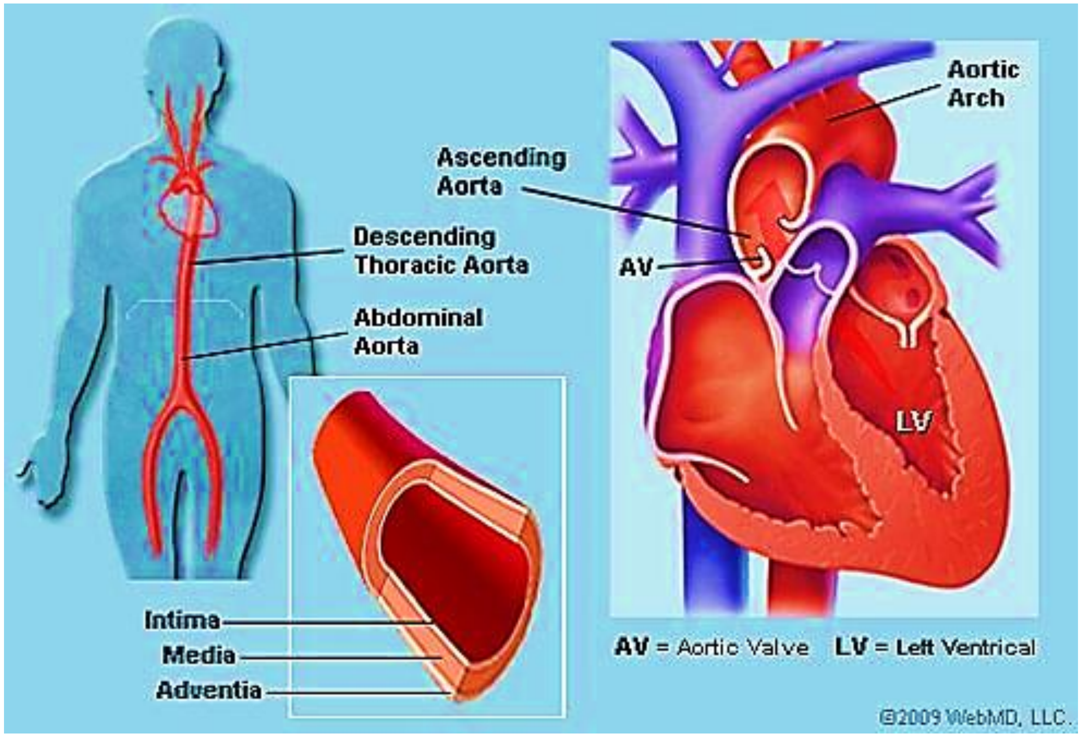


Fig: Picture of Aorta

- ❖ The aorta is the main artery that carries blood away from your heart to the rest of your body.
- ❖ The aorta is the large artery that carries oxygen-rich blood from the left ventricle of the heart to other parts of the body.
- ❖ The blood leaves the heart through the aortic valve.
- ❖ Then it travels through the aorta, making a cane-shaped curve that allows other major arteries to deliver oxygen-rich blood to the brain, muscles and other cells.

❖ The aorta is the largest blood vessel in the body. This artery is responsible for transporting oxygen rich blood from your heart to the rest of your body.

Determination of Cardiac output Methods

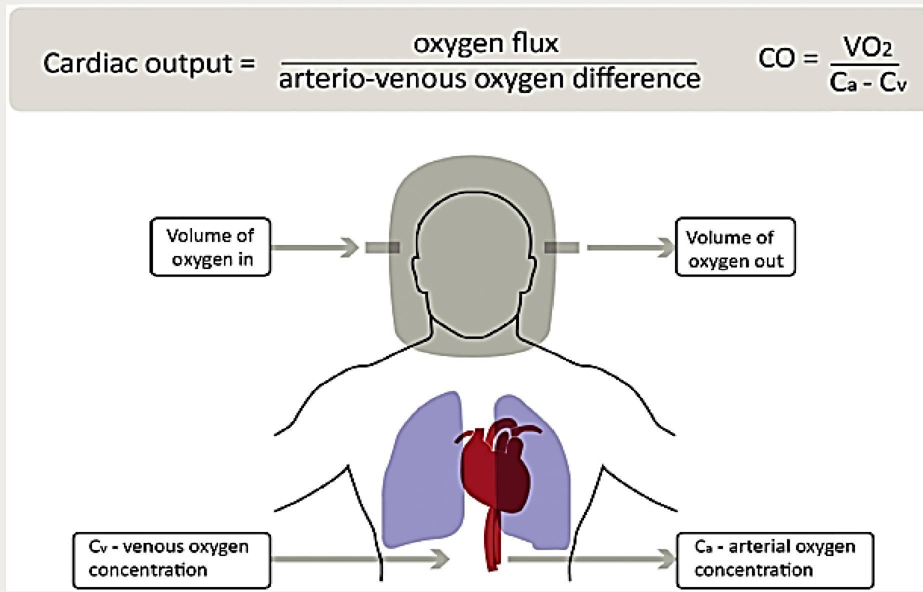
❖ Direct Methods:

1) Electromagnetic flow meter
2) Doppler with Echocardiography

❖ Indirect Methods:

1) Direct Fick's Principle
2) Indirect Fick's Priciple
3) Indicator Dilution Method
4) Thermo dilution method
5) Echo cardiography
6) Roentgenographic (X Ray) Method

The Fick Principle



Cardiac output can be determined by this method using oxygen as a marker of uptake. This can be achieved by either measurement of respiratory gases in a closed system, or by measurement of the partial pressure of dissolved oxygen in arterial and mixed venous blood.

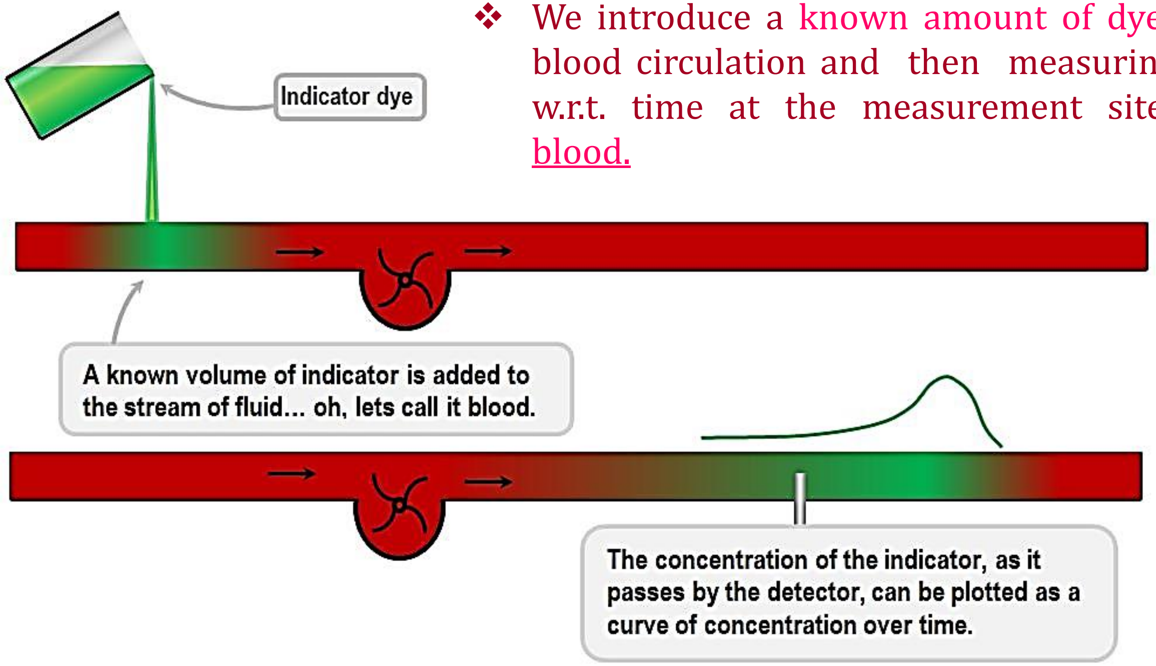
Indicator Dilution Method

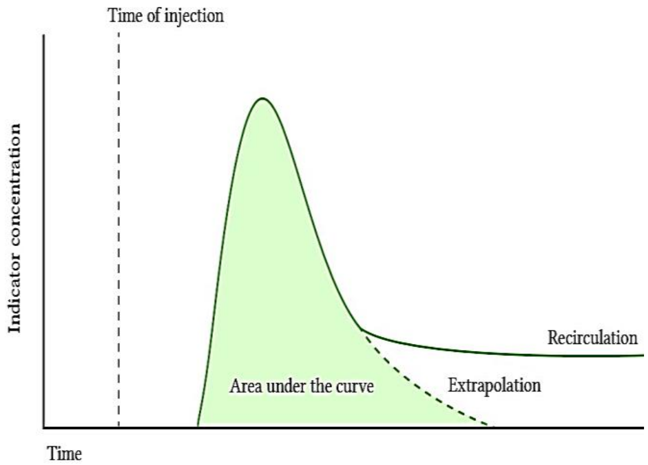
- ❖ Cardiac output measurement by indicator dilution method is an invasive technique that measures the amount of blood ejected by the heart every minute for peripheral circulation in the whole body.

The principle of indicator dilution cardiac output measurement

- ❖ At a basic level, the indicator dilution technique determines the rate of flow from the rate of change in the concentration of substance after a known amount of it has been added to the bloodstream.

- ❖ We introduce a known amount of dye or radio isotope as an indicator in the blood circulation and then measuring the concentration of the indicator w.r.t. time at the measurement site, we can estimate the volume of the blood.





Indicator Dilution Method

1. Let M mg of an indicator injected in to the large vein (right Heart itself).
2. After passing through the right heart, lungs and left heart the indicator appears in the arterial circulation.
3. The presence of indicator in the artery is detected by detector.

- ✓ The O/P of the detector is directly proportional to the concentration of the indicator.
- ✓ The detector is displayed on a chart recorder w.r.t. time.

- ❖ Indicator dilution techniques utilize the principle that if a substance is injected into the circulatory system, its change in concentration over time is related to the rate of flow in the system.
- ❖ If a known indicator is introduced into the system and is measured by a detector, a curve of indicator change over time can be plotted.
- ❖ Flow or cardiac output can be found by the amount of indicator, divided by the integral, of the area under this curve. For a fixed amount of indicator, the cardiac output is inversely proportional to the area under the curve.
- ❖ Values for cardiac output can be gained in this way using the modified Stewart - Hamilton equation

The Stewart-Hamilton equation

$$\dot{Q} = \frac{V \times (Tb - Ti)\, K1 \times K2}{Tb(t)\, dt}$$

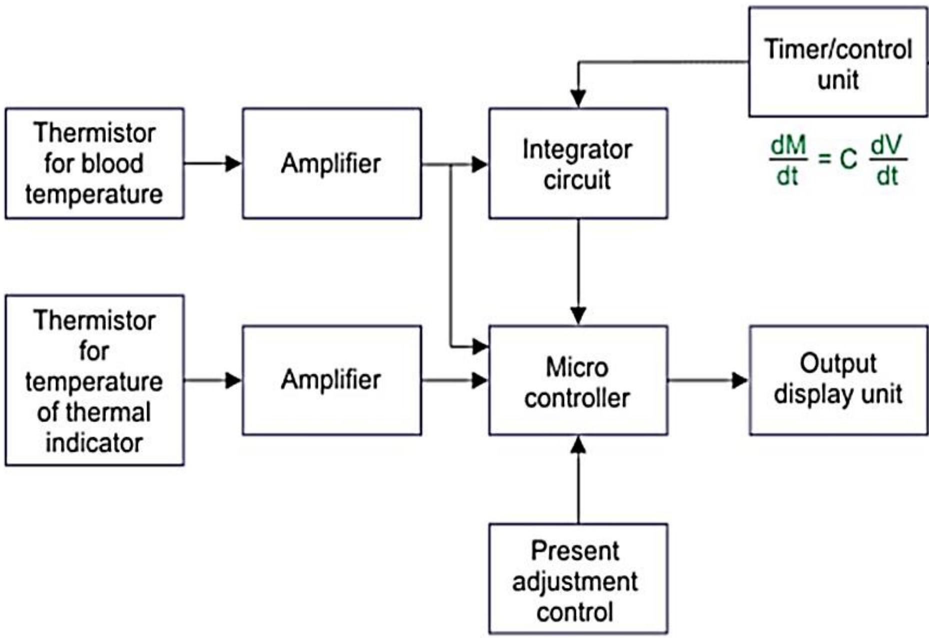
Q = cardiac output
V = injected volume
Tb = blood temperature
Ti = injectate temperature
K1 and K2 = corrections for specific heat and density of the injectate and for blood and dead space volume
Tb(t)dt = change in blood temperature as a function of time

Thermal Dilution Method

Principle:

- Thermal indicator of known volume introduced in to either right or left atrium will produce a resultant temperature change in the pulmonary artery or in the Aorta respectively.
- The integral of which is inversely proportional to the Cardiac output.

$$\textit{Cardiac output} = \frac{a\ constant\ X\ (blood\ temperature\ -\ Injectate\ Temp)}{Area\ under\ the\ dilution\ curve}$$



Procedure:

❖ 10 milliliters of 5% dextrose in water at room temperature is injected as a thermal indicator in to the right atrium.

❖ After mixing it is detected in the pulmonary artery by a thermistor, placed at the tip of a miniature catheter probe.

❖ The temperature difference between the inject ate temperature and the circulating blood temperature in the pulmonary artery is measured. The reduction in temperature is integrated with respect to time. It is displayed in the output unit. After applying corrections, the cardiac output is displayed in liters per minute. Amplifier block is used to remove the non-linearity of the thermistor.

Thermal Dilution Method

Principle:

- The thermodilution method involves injection of a definite amount of heat into the bloodstream, and the corresponding downstream temperature change is recorded.
- A cold fluid is often used as an indicator in the thermodilution method, because cold fluid is less harmful to the blood and tissue than a hot fluid.

The thermodilution method has several advantages; that is, the indicator has no toxicity, and so measurements can be performed repeatedly, the dilution curve can be easily recorded by a thermistor placed in the vessel, and the recirculation component is sufficiently small that integration of the dilution curve can be performed accurately.

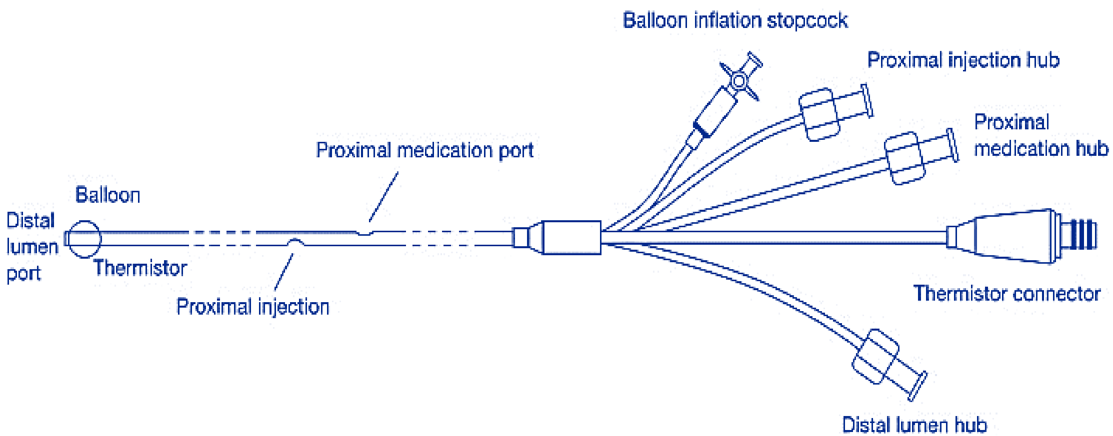


Figure: Swan–Ganz thermodilution catheter.

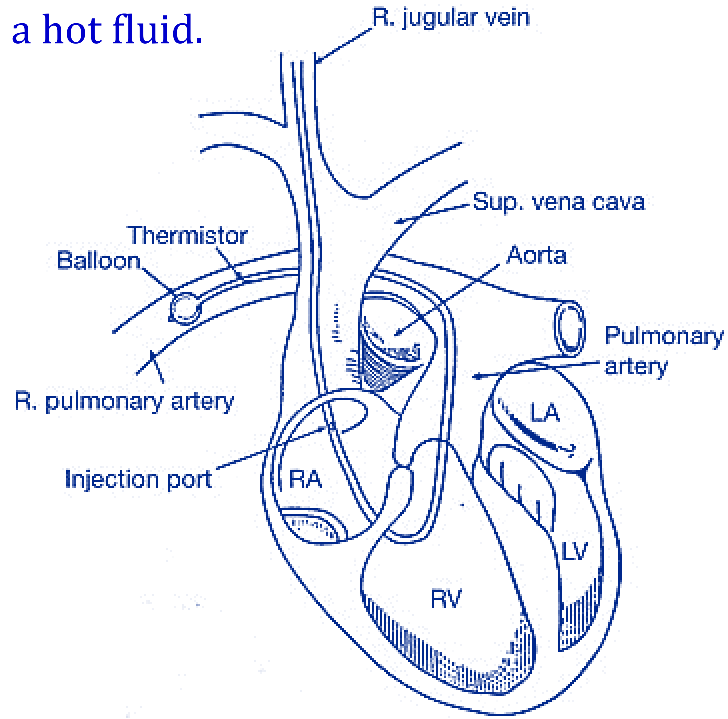


Figure: Thermodilution method for monitoring of cardiac output.

Dye Dilution Method

<u>What is dye dilution method?</u>

The dye dilution method for measuring cardiac output is based on injecting rapidly a known quantity of a dye at one site into the circulatory system, and withdrawing blood at a distal site for determination of a concentration curve of the dye.

Distal refers to **sites located away from a specific area**

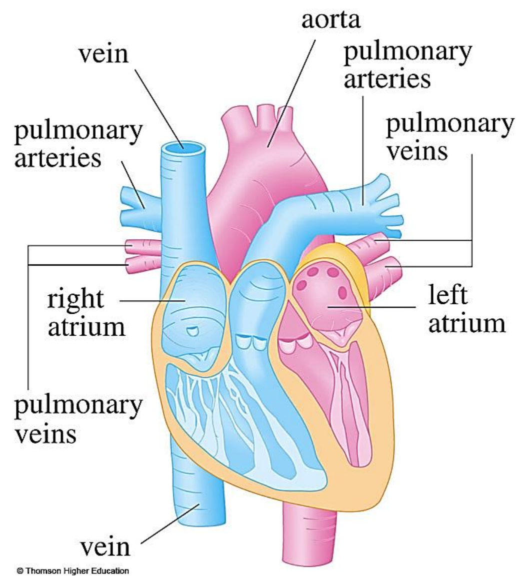
- ✓ The dye dilution method is used to measure the cardiac output.
- ✓ Dye is injected into the right atrium and flows through the heart into the aorta.

❖ A probe inserted into the aorta measures the concentration of the dye leaving the heart at equally spaced times over a time interval [0, T] until the dye has cleared.

Dye dilution method

- A known amount of dye is injected into an arm vein
- Serial concentration of dye are calculated from an artery and cardiac output is calculated as

$$\text{Cardiac output (ml/min)} = \frac{\text{Milligrams of dye injected} \times 60}{\left(\begin{array}{c}\text{Average concentration of dye}\\ \text{in each milliliter of blood}\\ \text{for the duration of the curve}\end{array}\right) \times \left(\begin{array}{c}\text{Duration of}\\ \text{the curve}\\ \text{in seconds}\end{array}\right)}$$



Dye Dilution Method

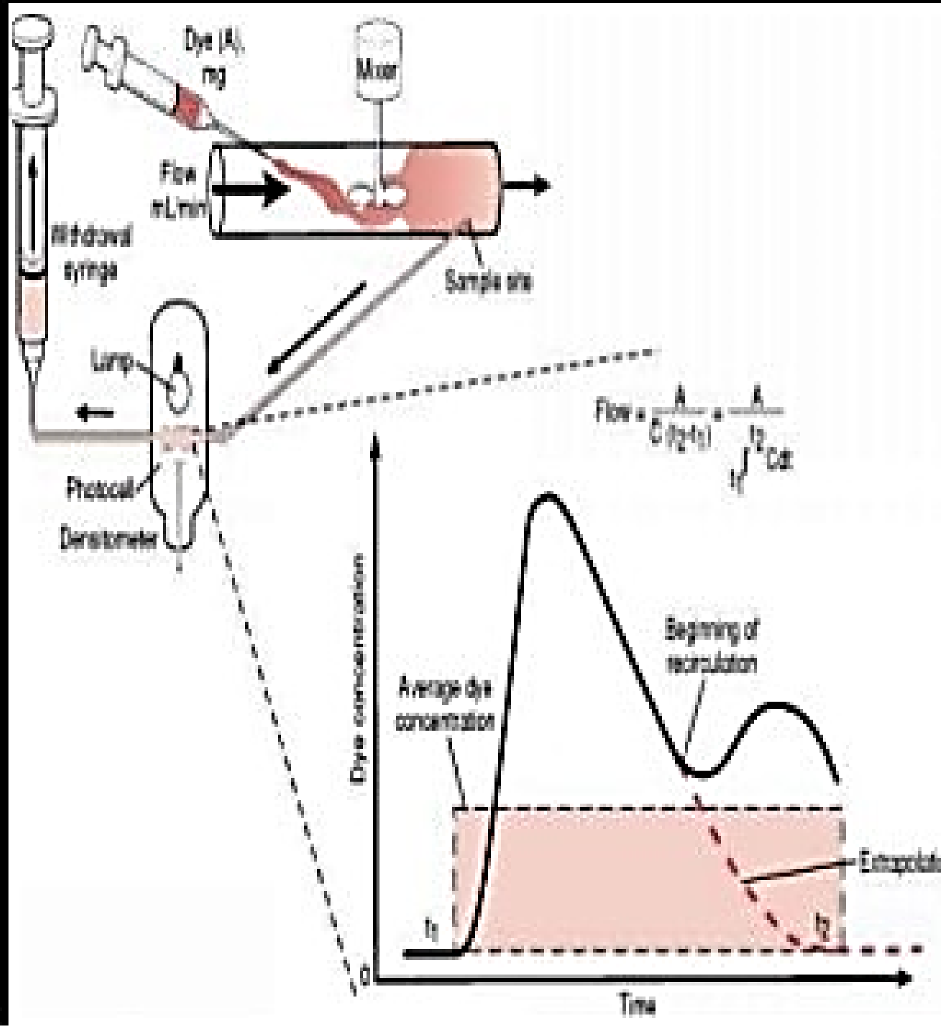
INDICATOR OR DYE DILUTION METHOD.

- **Principle** – Known amount of dye injected into Rt atrium & mean concentration of its first passage through an artery is determined.
- **Blood flow (F)= Q/Ct**

- F = blood flow in L/min.
- Q= quantity of dye injected.
- C = Mean Conc. of dye.
- T = Time duration in sec of first passage of dye.

Dye Dilution Method : Procedure

- 5 mg of Evan's blue dye mixed with venous blood.
- Duration of first passage of dye(t) & mean conc of dye (C) in arterial blood estimated.
- CO= Q/ct × 60 = 5/1.5L ×40 × 60 = 5 L/min




THANK YOU

MEDICAL ELECTRONICS

BIO-CHEMICAL MEASUREMENT

Dr.M.Sivakumar,

BIO-CHEMICAL MEASUREMENT

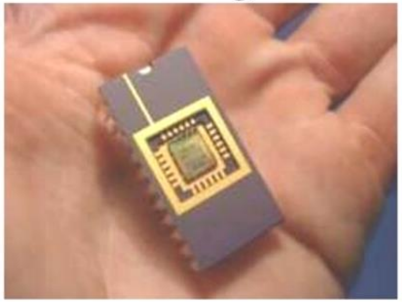
Contents

- Biochemical sensors : pH, pCO2 and, pO2
- Ion Selective Field Effect Transistor (ISFET)
- Immunologically Sensitive FET (IMFET)
- Blood glucose sensors
- Blood gas analyzers
- Colorimeter
- Flame photometer
- Spectrophotometer
- Blood cell counter,
- Auto analyzer (simplified schematic description).

Introduction : Biomedical sensors

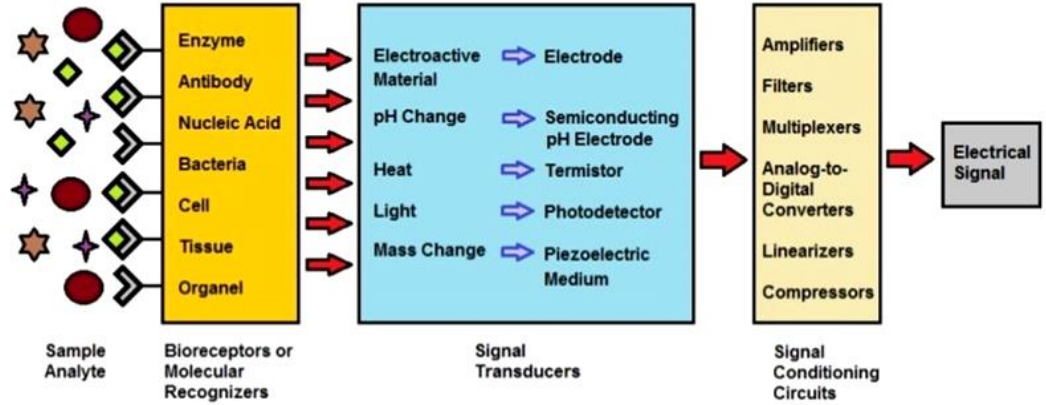
WHAT IS BIOSENSOR?

A biosensor is an analytical device which converts the biological signal into a measurable electrical signal.

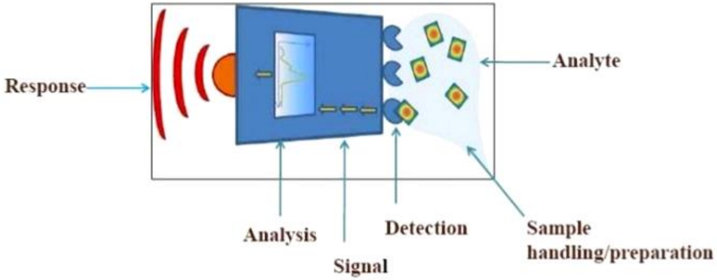


Parts of biosensor

Bio receptor | Transducer | Signal processor



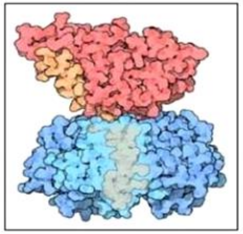
Biosensor



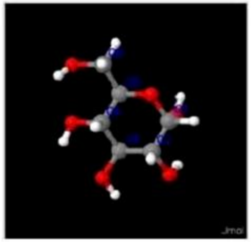
THE ANALYTE
(What do you want to detect?)

- Molecule

(Protein, toxin, peptide, vitamin, sugar, metal ion)



Cholera toxin



Glucose

Bio Sensors

pH sensors

- ✓ pH sensors measure the level of pH in sample solutions by measuring the activity of the hydrogen ions in the solutions.
- ✓ This activity is compared to pure water (a neutral solution) using a pH scale of 0 to 14 to determine the acidity or alkalinity of the sample solutions.

Clark electrode oxygen sensor

- ➢ The Clarke electrode is a type of electrochemical oxygen sensor.
- ➢ It measures oxygen levels in liquid using a cathode and an anode submerged in an electrolyte.

Infrared oxygen sensor

- ➢ Infrared pulse oximeters, commonly called fingertip oximeters or finger pulse oximeters, are oxygen sensors that measure the amount of oxygen in the blood by light.

Based on the type of transducer the Biosensor are classified as

- Calorimetric/Thermal Detection Biosensors.
- Optical Biosensors.
- Resonant Biosensors.
- Piezoelectric Biosensors.
- Ion Sensitive Biosensors.
- Electrochemical Biosensors.
  - Conductometric Sensors.
  - Amperometric Sensors.
  - Potentiometric Sensors.

Introduction : Classifications of biomedical sensors

❖A wide variety of chemical sensors are classified in many ways.

Class of sensor	Biomedical sensor
Physical sensors	
	Geometric
	Mechanical
	Thermal
	Hydraulic
	Electric
	Optical
Chemical sensors	
	Gas
	Electrochemical
	Photometric
	Other physical chemical methods
Biopotential electrodes	
	Body surface biopotential electrode
	Metal plate
	Intracavitary and intratissue electrode
	Microelectrode
Bioanalytic (or biosensor)	
	Enzyme
	Protein
	Antigen
	Antibody
	Ligand
	Cell
	DNA

❖Chemical sensors are used to detect chemical components being measured and chemical composition measured in the gas phase.

❖Electrochemical sensors are utilized to measure chemical concentration, or more precisely, activities based on chemical reactions that interact with electrical systems.

❖Photometric chemical sensors are optical devices that detect chemical concentrations based on changes in light transmission, reflection or color.

❖Other types of physical chemical sensors such as the mass spectrometer utilize various physical methods to detect and quantify chemicals associated with biologic systems.

A biochemical sensor is **a device which is capable of**. **converting a chemical (or biological) quantity into an electrical**. **signal**.

Electrodes Principle operation

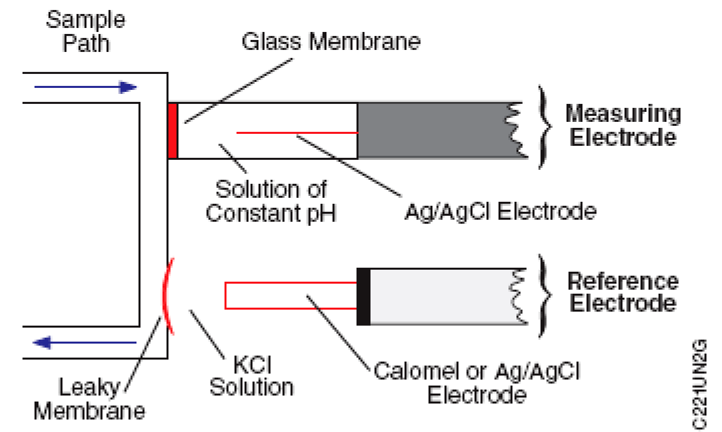


Figure 1. pH electrode system

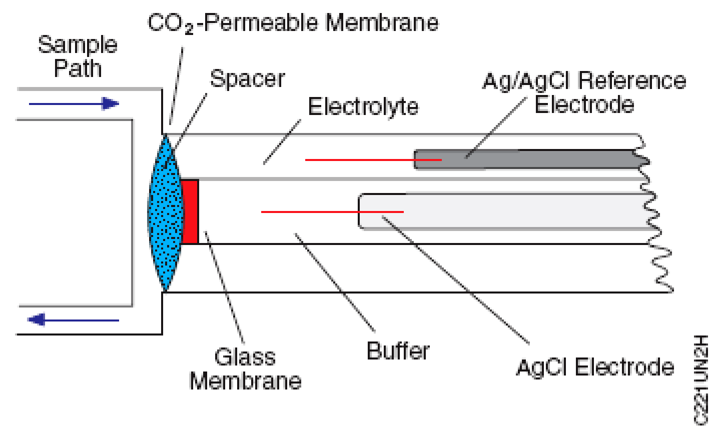


Figure 2. PCO_2 electrode system

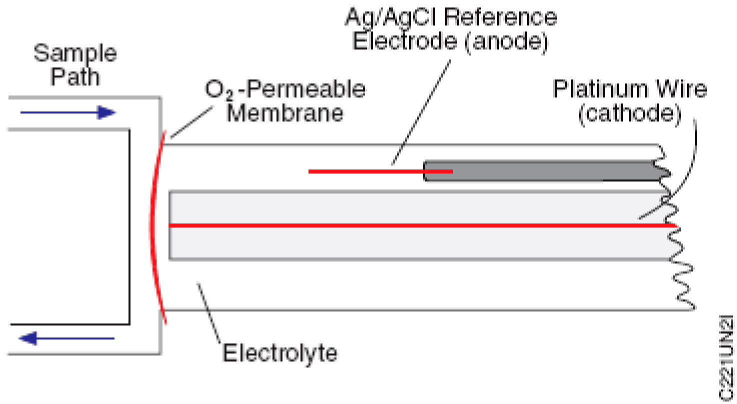
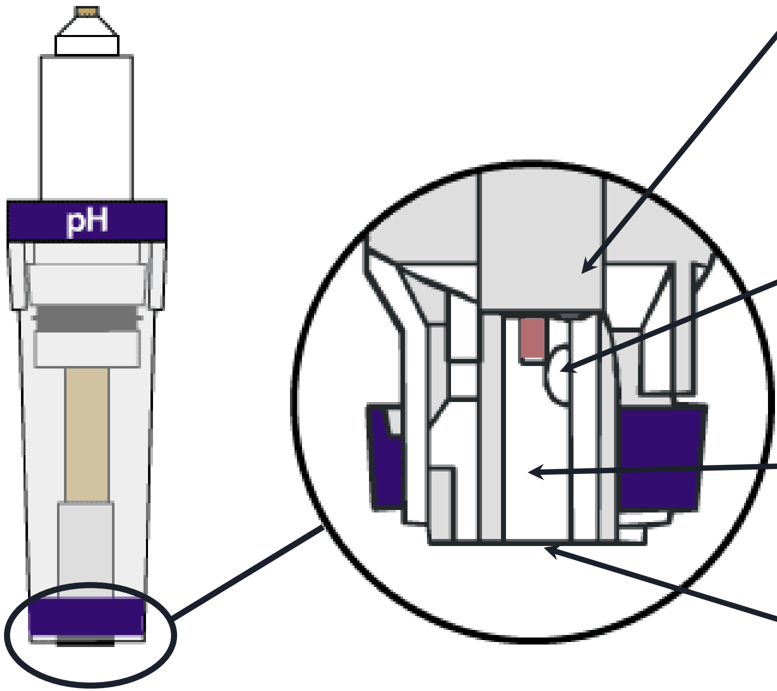


Figure 3. PO_2 electrode system

pH electrode

❖ pH electrode is constructed of two half cells, which develop an electrical potential when connected together



Ag rod coated with AgCl

- provides electrical contact to inner buffer solution
- Ag/AgCl equilibrium maintains a stable potential

Air bubble

- allows expansion of solution at 37 °C

Inner buffer solution

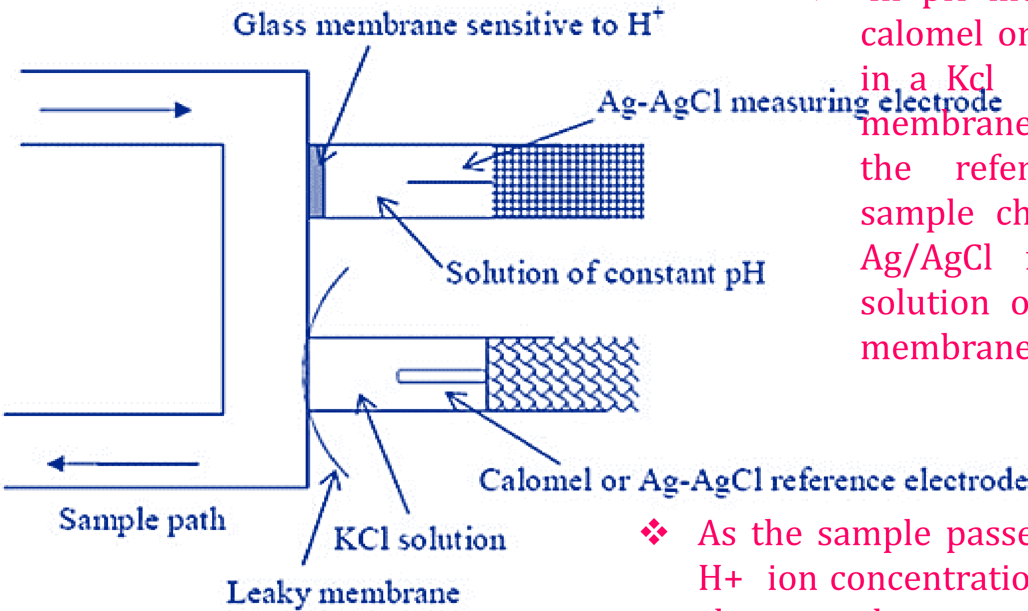
- has a constant and known pH

pH-sensitive glass membrane

- changes in potential only due to changes in pH of sample

pH Measurement

pH measurement:



pH value is a measure of H^+ ion concentration.

$pH = \log_{10}[1/(H^+)] = -\log_{10}(H^+)$

❖ The pH equation is given as

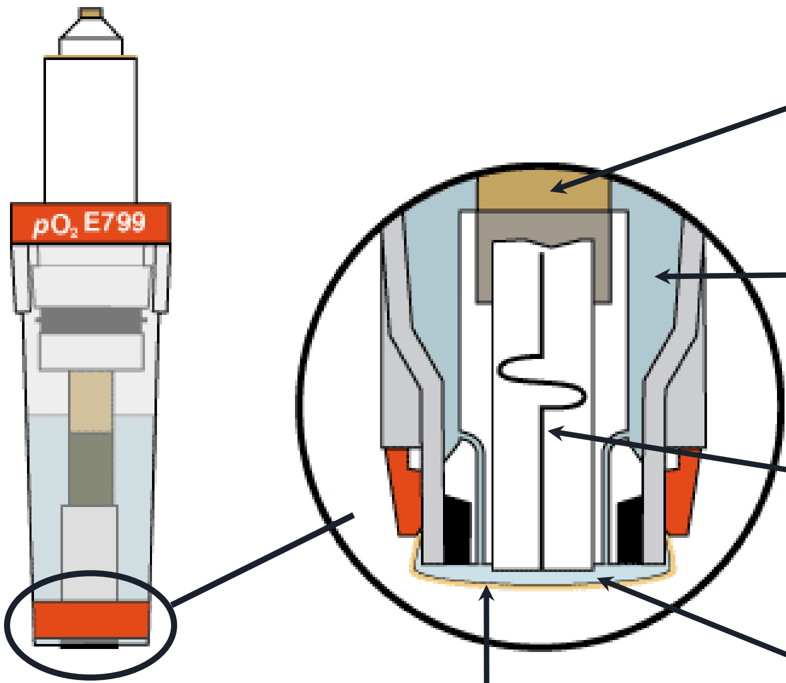
pH = - log10[H+] = log10 x 1/[H+]

pH is the acid base balance in a fluid.

- ❖ In pH measurement two electrodes are used a calomel or Ag/AgCl reference electrode immersed in a Kcl solution and closed by a leaky membrane that permits a current flow from the reference electrode via the sample in the sample chamber to the measuring electrode and a Ag/AgCl measuring electrode immersed in a solution of constant pH and closed by a glass membrane that is sensitive to H+.
- ❖ As the sample passes through the chamber, the difference in H+ ion concentration on either side of the glass membrane changes the potential at the measuring electrode.
- ❖ The reference electrode produces a constant potential irrespective of H+ concentration in the sample.
- ❖ The change in the potential at the measuring electrode is detected by a voltmeter, which has been calibrated in pH units.
- ❖ So the pH is defined as logarithmic of the reciprocal value of H+ ion concentration.

pO2 electrode

The pO_2 electrode is designed to measure the current produced during an electrochemical reaction



Anode (+) – Ag rod coated with AgCl
- oxidation of Ag

Electrolyte solution
- provides electrical contact between anode and cathode

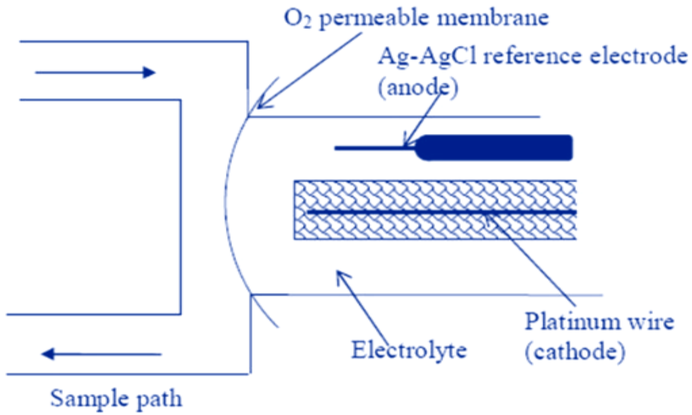
Cathode (–) – Pt wire encased in glass
- reduction of O_2

Platinum black catalyst (thin black layer)
- conversion of H_2O_2 to H_2O and O_2

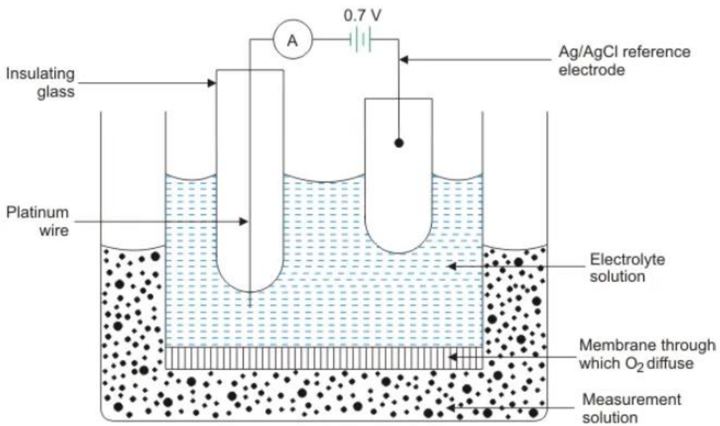
Polypropylene membrane
- permeable to O_2

pO2 Measurement

pO_2 measurement:



$$4Ag \rightarrow 2Ag^+ + 4e^-$$
$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$



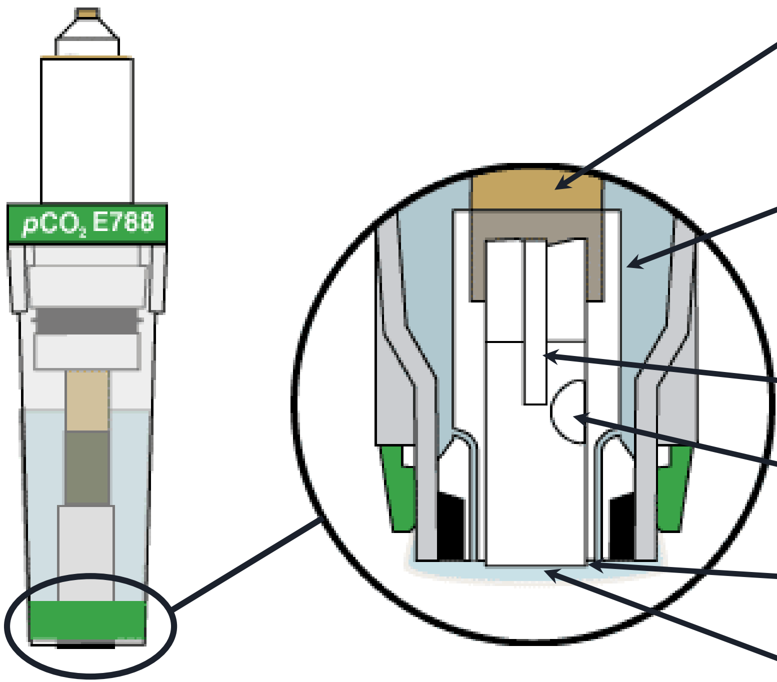
pO_2 Electrode

- ❖ A polar graphic electrode system consisting of a Ag/Agcl reference electrode (anode) and a thin platinum wire (cathode) both immersed in an electrolyte (H2O) and separated from the sample by a O2 permeable membrane.
- ❖ A potential of 0.7V is applied between these electrodes.
- ❖ The current generated by the system is the measure of pO2 in that sample.
- ❖ The partial pressure of a gas is proportional to the quantity of that gas present in that blood.
- ❖ There are two types Vitro – Blood sample is taken for measurement & Vivo – Measurement is done while the blood is flowing
  - ❖The pO2 equation is given as

$$4Ag \rightarrow 2Ag^+ + 4e^-$$
$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

pCO2 electrode

Consists of a pH electrode and an internal reference electrode in one complete unit



Reference electrode – Ag/AgCl

Electrolyte solution

- The bicarbonate electrolyte solution also contains glycerol to prevent collection of air bubbles in the jacket, thus improving electrode stability

pH electrode – Ag/AgCl

- Inner solution with known and constant pH

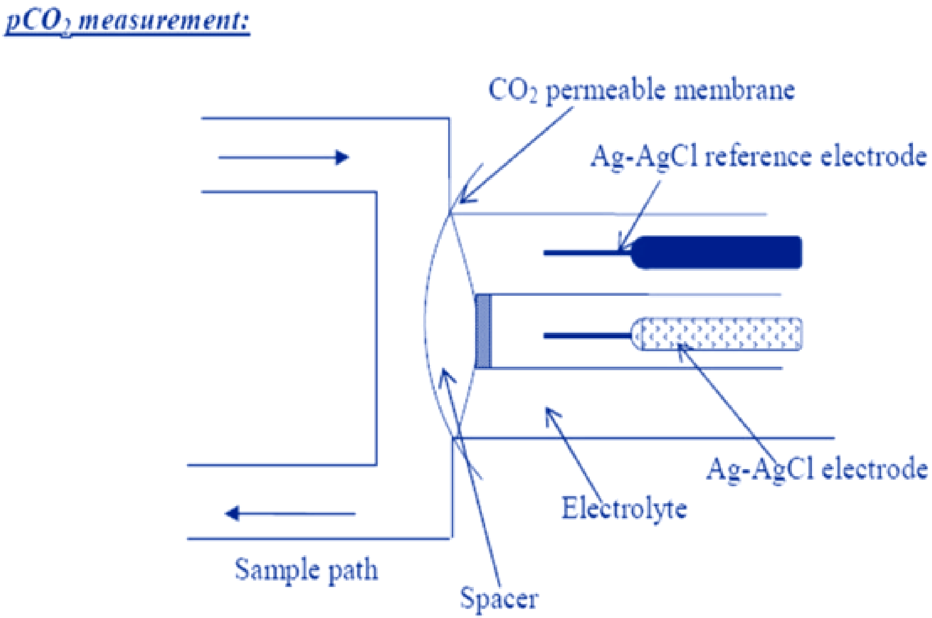
Air bubble

pH-sensitive glass membrane

Silicone membrane on nylon net

- Silicone is permeable to CO_2
- Nylon net traps electrolyte solution

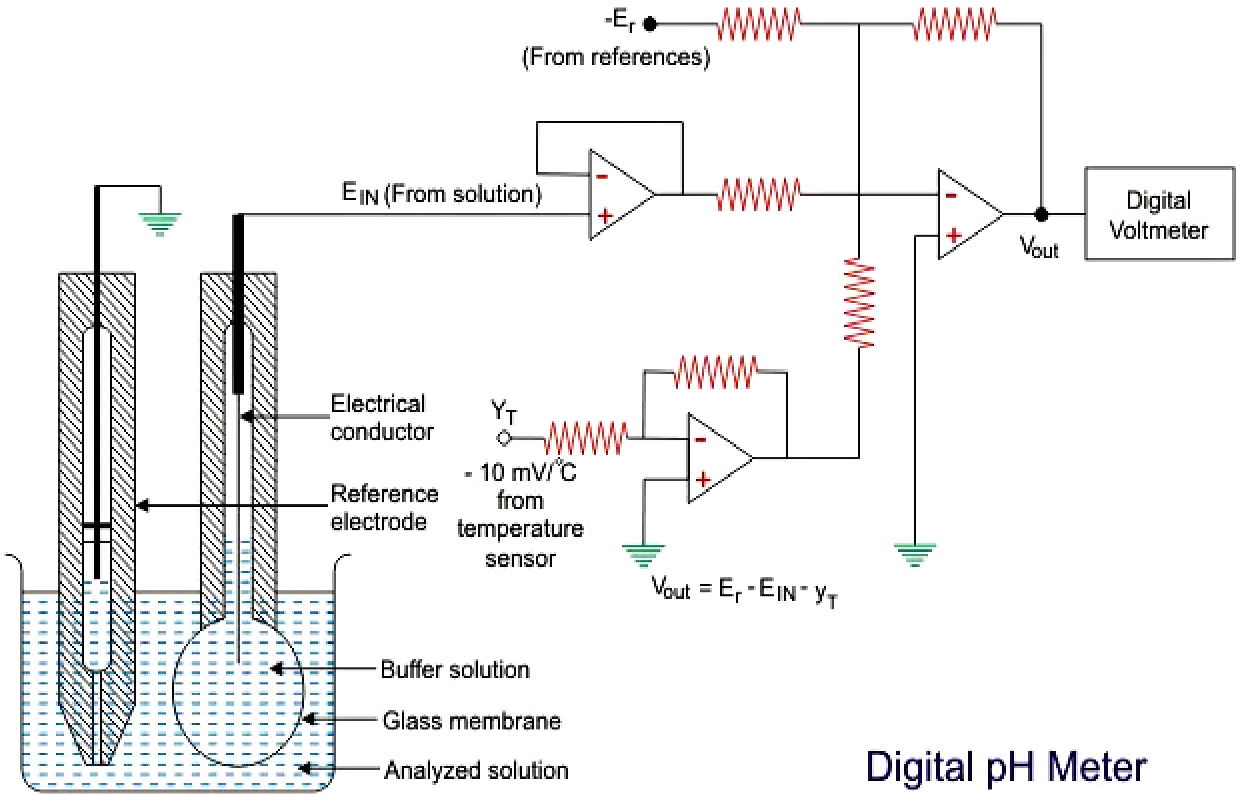
pCO2 Measurement



- A Severing Hans pCO2 electrode consisting of a Ag/Agcl reference electrode and a glass pH electrode both immersed in an electrolyte and separated from the sample by a CO2 permeable membrane and a spacer which acts as a support for the aqueous HCO3 layer.
- Diffusion of CO2 alters the pH of the electrolyte thereby changing potential output of this modified pH electrode.
- This gives the pCO2 in the sample.

$$H_2O + CO_2 ® H+ + HCO_3$$

pO_2 and pCO Measurement



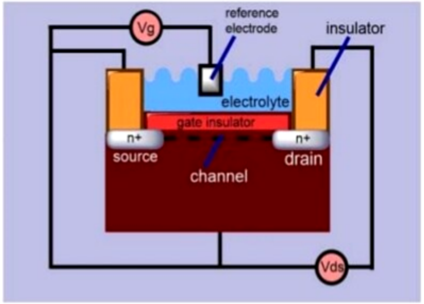
Digital pH Meter

- Partial pressure for oxygen and carbon dioxide are denoted as pO2 and pCO2 and they are important physiological chemical measurement.
- pO2 and pCO2 are analyzed for functioning of respiratory and cardiovascular system.
- The partial pressure of gas is directly related to the quantity of gas present in the blood.

Introduction : Ion Selective Field Effect Transistor (ISFET)

ION-SENSITIVE BIOSENSORS

- An ISFET is an **ion-sensitive field-effect transistor**, that is a field-effect transistor(FET) used for **measuring ion concentrations in solution**; when the **ion** concentration (such as H^+, see pH scale) changes, the current through the transistor will change accordingly.



- This type of biosensors has a **semiconducting device** called **field effect transistor(FET).** FET consists of **silicon crystals**. It has **high electrical resistance** unless the electric field is modified.
- When **an analyte** is kept in **contact with FET**. Some ions in the **analyte adsorbed onto the silicon crystal** and create an electrical charge. This **electrical charge** switches on the **FET to conduct** the electric charge to the transducer. From the transducer, **electric signals are amplified**, read out and recorded.

ION-SENSITIVE BIOSENSORS

- Are semiconductor FETs(field effect transistor) with ion-sensitive surface.
- Surface Electrical Potential changes when the ions &semiconductors interact.
- Measures the Change in Potential.

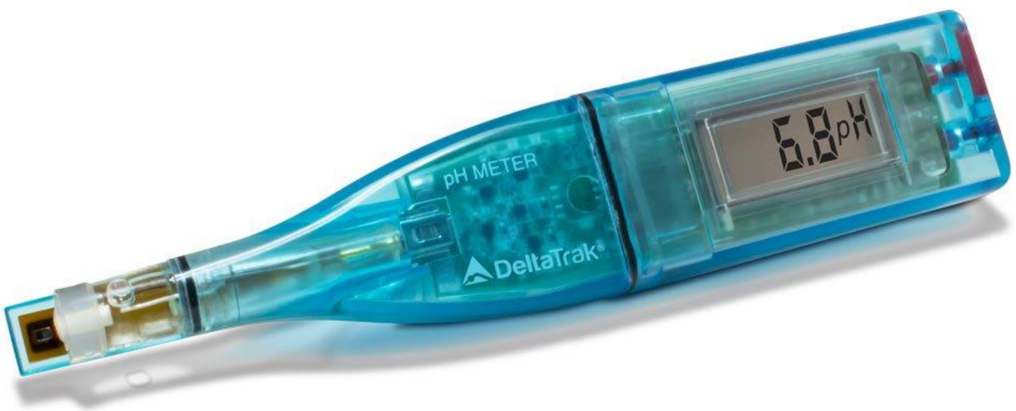
Uses:

- pH Detection.

- A **glucose biosensor** coupled with a **minipump** containing **insulin**, is used to **detect blood glucose level** directly and to deliver the accurate amount of insulin required by the diabetic. **Usually enzyme electrode** is used for this purpose.
- Biosensors are used to **detect mutagenic substances** (**eg**. **Mitomycin**) in the body fluid.
- A few biosensors are employed to detect **toxic substances** and **heavy metals** in **blood samples**.

ISFET Based pH Sensor

- pH meter with ISFET sensor produced by ISFETCOM (Japan) enables pH measurements in small sample volumes (50 µl).
- One-digit precision, temperature reading (Celsius degrees).
- One-point or two-point calibration.
- The sample is placed dropwise between ISFET sensor and reference electrode tip or the sensor part can be immersed into solution.
- Gel-filled reference electrode lifetime is typically 2–3 years, it may be regenerated or replaced.

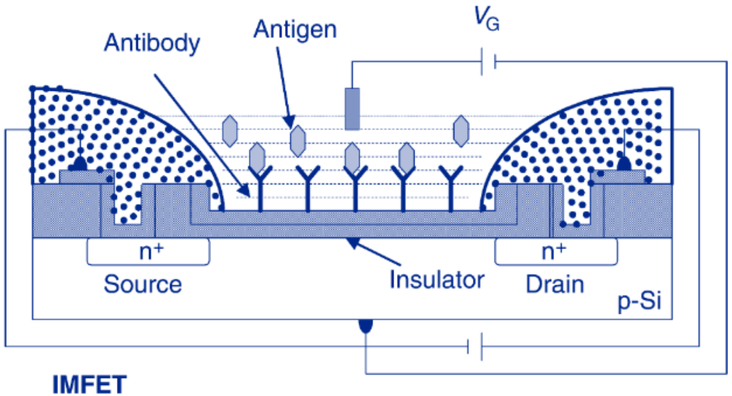


- The pH meter is rated IP67 waterproof and is ideal in applications involving food and beverage, medical, pharmaceutical, agriculture, and environmental studies.
- Model 24006 is a low-cost non-glass Pocket ISFET (Ion-Sensitive Field Effect Transistor) pH Meter featuring a virtually unbreakable silicon chip sensor that gives stable readings in seconds.

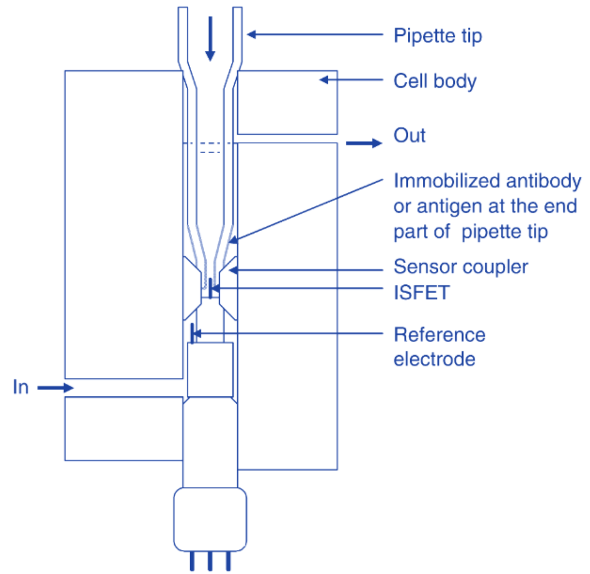
Introduction : Immunologically Sensitive FET (IMFET)

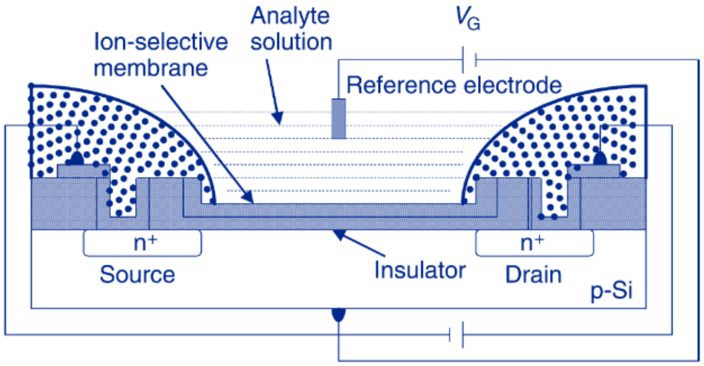
- IMFET is similar in structure to the ISFET except that the solution membrane intertface is polarized rather than unpolarized that is charged species cannot pass through the membrane.
- ISFET interacts through an ion exchange mechanism with the chemical analyte that is being measured where as IMFET operation is based on antigen – antibody reaction.
- An antibody is immobilized on the membrane that is attached to the insulator of a FET.
- In this way the device is used as an antigen sensor

- An antibody could be detected in a similar way by immobilizing an antigen on the membrane.
- IMFET measures charge, so in order to be sensed, the absorbing species on the membrane must possess a net electric charge.



IMFET



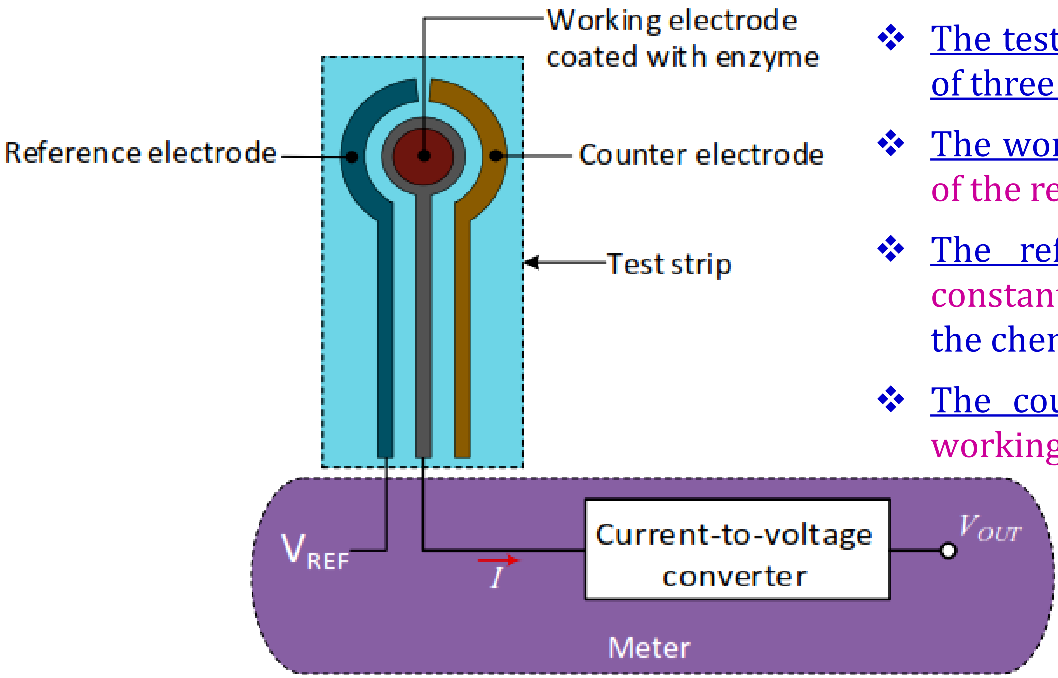


ISFET

Introduction : Blood Glucose Monitoring Sensors

- A glucose monitoring sensor is used to measure the concentration of blood glucose and is a crucial home glucose monitoring device for people living with diabetes.

Block diagram of the device for glucose measurement with finger-pricking method.



- The test strip contains the enzyme and an arrangement of three electrodes
- The working electrode, which senses the actual current of the reaction;
- The reference electrode, holding a voltage always constant respect to the working electrode to aid with the chemical reaction; and
- The counter electrode, supplying the current to the working electrode

BLOOD GAS ANALYZERS

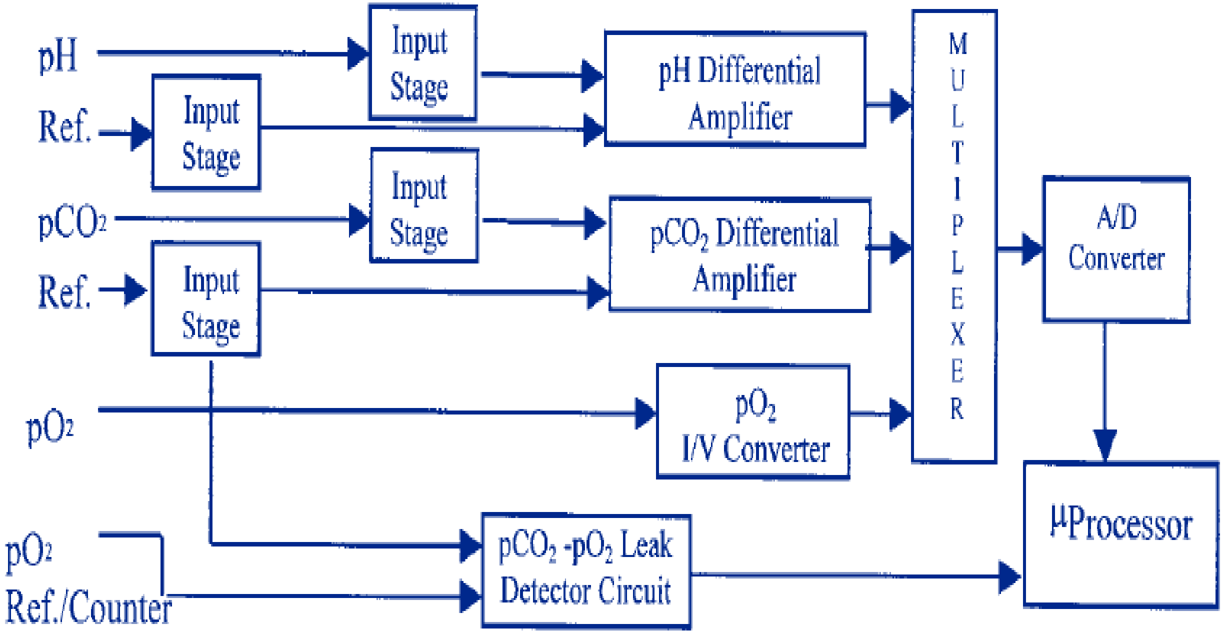


Fig: Block Diagram of Complete Blood Gas Analyzer

- The blood gas analyzer consists of three types of electrode systems for the measurement of pH, p02 and pCO2 respectively and a sample chamber.
- The electrode systems and the sample chamber are located inside a temperature-controlled block maintained at 37^0 C(human body temperature).
- The blood sample is first injected into the sample chamber where it undergoes a temperature equilibration before measurement.

✓ Blood gas analyzers are mainly used to measure partial pressure of hydrogen , carbon di oxide, oxygen present in human blood.

- BGA are used to measure the pH, Partial pressure of carbon dioxide (pCO2) and Partial pressure of Oxygen (p02) of the body fluids with special reference to the human blood.

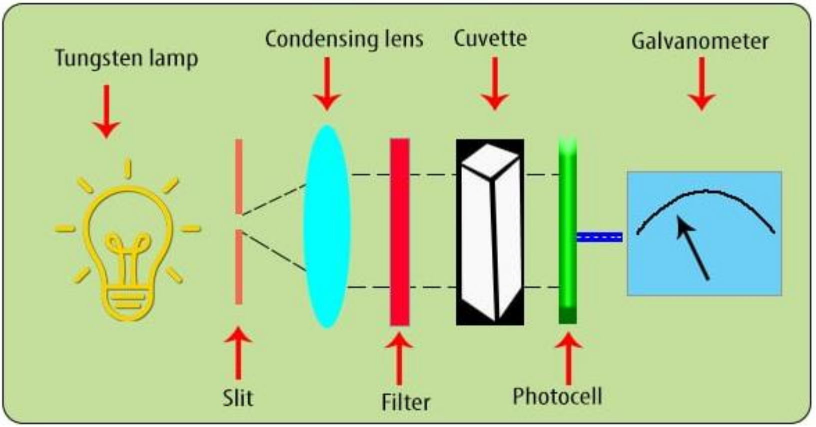
Introduction :Colorimeter

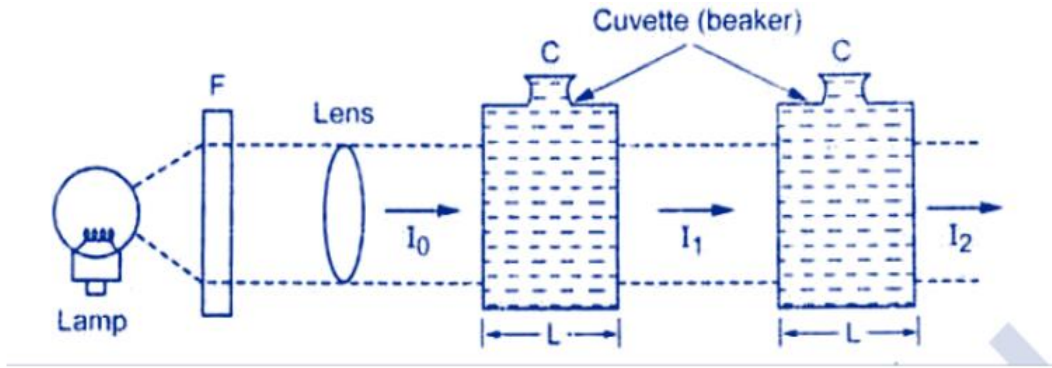
- A colorimeter is an electrically powered instrument which measures the concentration of analytes in colored solutions.
- The colorimeter is used for clinical chemistry, namely for determining haemoglobin concentrations.
- It is a simple version of a photometer. Colorimeters may be manual or semi-automated. Therefore colorimeter is a device that measures the absorbance of particular wavelengths of light by a specific solution.
- In a colorimeter, the sample is normally a liquid.
- The sample compartment of a colorimeter is provided with a holder to contain the cuvette, in which the liquid is examined.
- Usually this holder is mounted on a slide with positions for at least two cuvettes, so that sample and reference cuvettes are measured first and a shutter is moved into or out of the light beam until the micrometer gives a full-scale deflection (100% T-scale reading).
- The sample is then moved into the beam and the light passing through it is measured as a percentage to the reference value.

APPLICATIONS OF COLORIMETER

- Colorimeters are widely used to monitor the growth of a bacterial or yeast culture by providing reliable and highly accurate results when used for the assessment of color in bird plumage.
- They are used to measure and monitor the color in various foods and beverages, including vegetable products and sugar.
- Colorimeters are used for basic research in chemistry laboratories.
- Colorimeters have many practical applications such as testing water quality by screening chemicals such as chlorine, fluoride, cyanide, dissolved oxygen, iron, molybdenum, zinc and hydrazine.
- Also they are used to determine the concentrations of plant nutrients such as ammonia, nitrate and phosphorus in soil or hemoglobin in blood.

COMPONENTS OF COLORIMETER



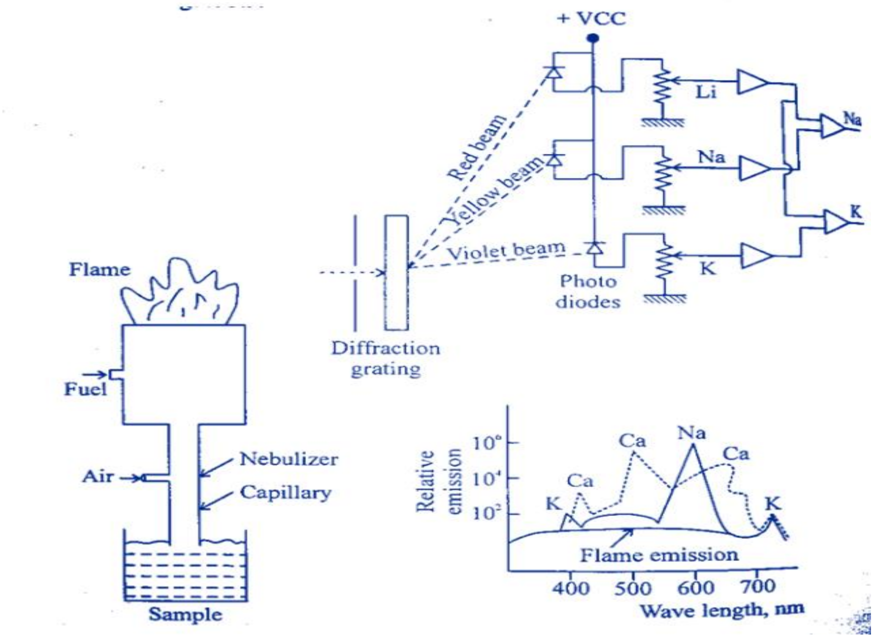


The three main components of a colorimeter are a light source, a cuvette containing the sample solution and a photocell for detecting the light passed through the solution.

The essential parts of a colorimeter which including the following:

- Light source (Low-voltage filament lamp)
- Filters (optics filters are used in the colorimeter to select the wavelength of light which the solute absorbs the most). The usual wavelength range is from 400 to 700 nanometers (nm).
- Cuvettes: this is a simple part of colorimeter that hold the sample to be analyzerd
- Output: this can be analogue or digital meter which final output. the output may be a chart recorder, OR data logger.

FLAME PHOTOMETER

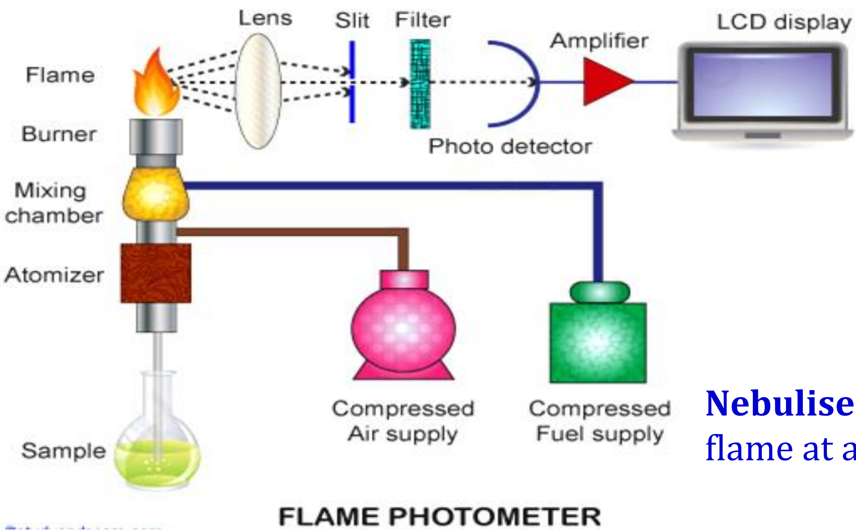


- A photoelectric flame photometer is a device used in inorganic chemical analysis to determine the concentration of certain metal ions, among them sodium, potassium, lithium, and calcium.

- Group 1 and Group 2 metals are quite sensitive to Flame Photometry due to their low excitation energies.

- A flame photometer is used to determine the concentration of potassium(K), Sodium(Na), Calcium (Ca) and Lithium.
- It is used in the analysis of blood or urine. Here lithium is used as a calibration substance in the analysis of other 3 chemical substances.
- A colorimeter flame appears yellow for sodium and violet for potassium when their solutions are aspirated into the flame.
- This characteristics is used in flame photometer.
- In this method fine droplets of the sample is aspirated into a glass flame that burns in a chimney.
- A known amount of lithium salt is added to the sample as reference.
- As a result red light is emitted by lithium and yellow and violet beam are emitted due to sodium and potassium respectively.

FLAME PHOTOMETER



A simple flame photometer consists of the following basic components:

Source of flame: A Burner in the flame photometer is the source of flame. It can be maintained in at a constant temperature. The temperature of the flame is one of the critical factors in flame photometry.

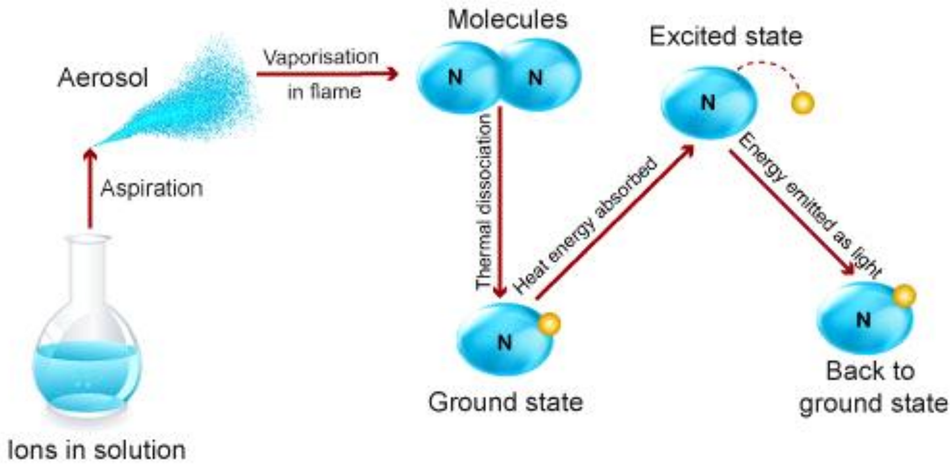
Nebuliser: Nebuliser is used to send homogeneous solution into the flame at a balanced rate.

Optical system: The optical system consists of convex mirror and convex lens. The convex mirror transmits the light emitted from the atoms. Convex mirror also helps to focus the emissions to the lens. The lens helps to focus the light on a point or slit.

Simple colour filters: The reflections from the mirror pass through the slit and reach the filters. Filters will isolate the wavelength to be measured from that of irrelevant emissions.

Photo-detector: The intensity of radiation emitted by the flame is measured by photo detector. Here the emitted radiation is converted to an electrical signal with the help of photo detector. These electrical signals are directly proportional to the intensity of light.

FLAME PHOTOMETER



OVERVIEW OF FLAME PHOTOMETRY

Scheibe-Lomakin equation describes intensity of light emitted with the help of following formula:

$$I = k \times c^n$$

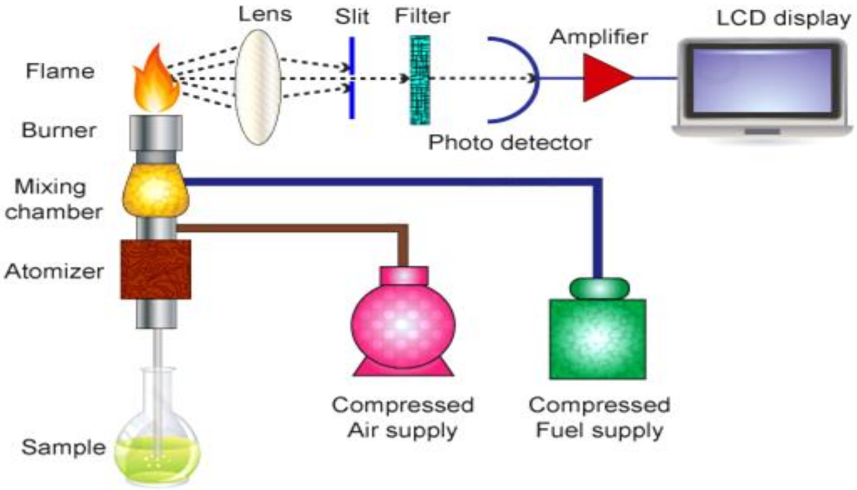
Where:

I = Intensity of emitted light
c = Concentration of the element
k = Proportionality constant

At the linear part of the calibration curve n~1, then I = k × c. In other words, the intensity of emitted light is directly related to the concentration of the sample.

- The solvent is first aspirated to obtain fine solid particles.
- These molecules in the solid particles are moved towards the flame to produce gaseous atoms and ions.
- These ions absorb the energy from the flame get excited to high energy levels from the ground state.
- But as these ions are unstable, they return back to ground state. While returning they emit characteristic radiation.
- The intensity of emitted light is proportional to the concentration of the element.

FLAME PHOTOMETER



FLAME PHOTOMETER

Element	Emitted wavelength	Flame colour
Potassium (K)	766 nm	Violet
Lithium (Li)	670 nm	Red
Calcium (Ca)	622 nm	Orange
Sodium (Na)	589 nm	Yellow
Barium (Ba)	554 nm	Lime green

Emitted wavelength and flame colors of various alkali and alkaline earth metals

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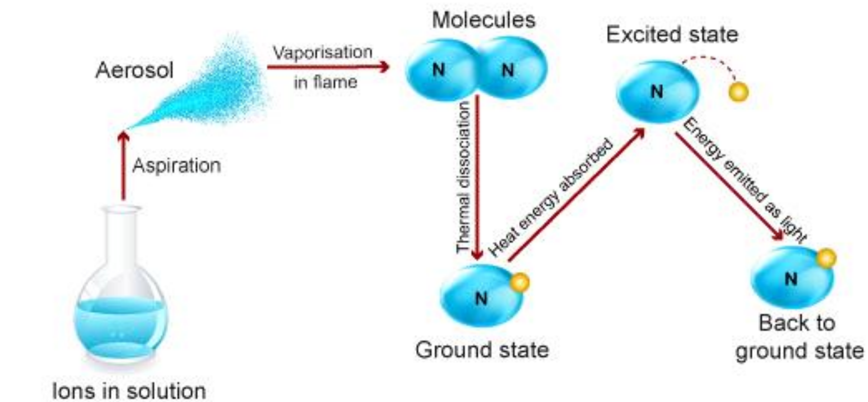
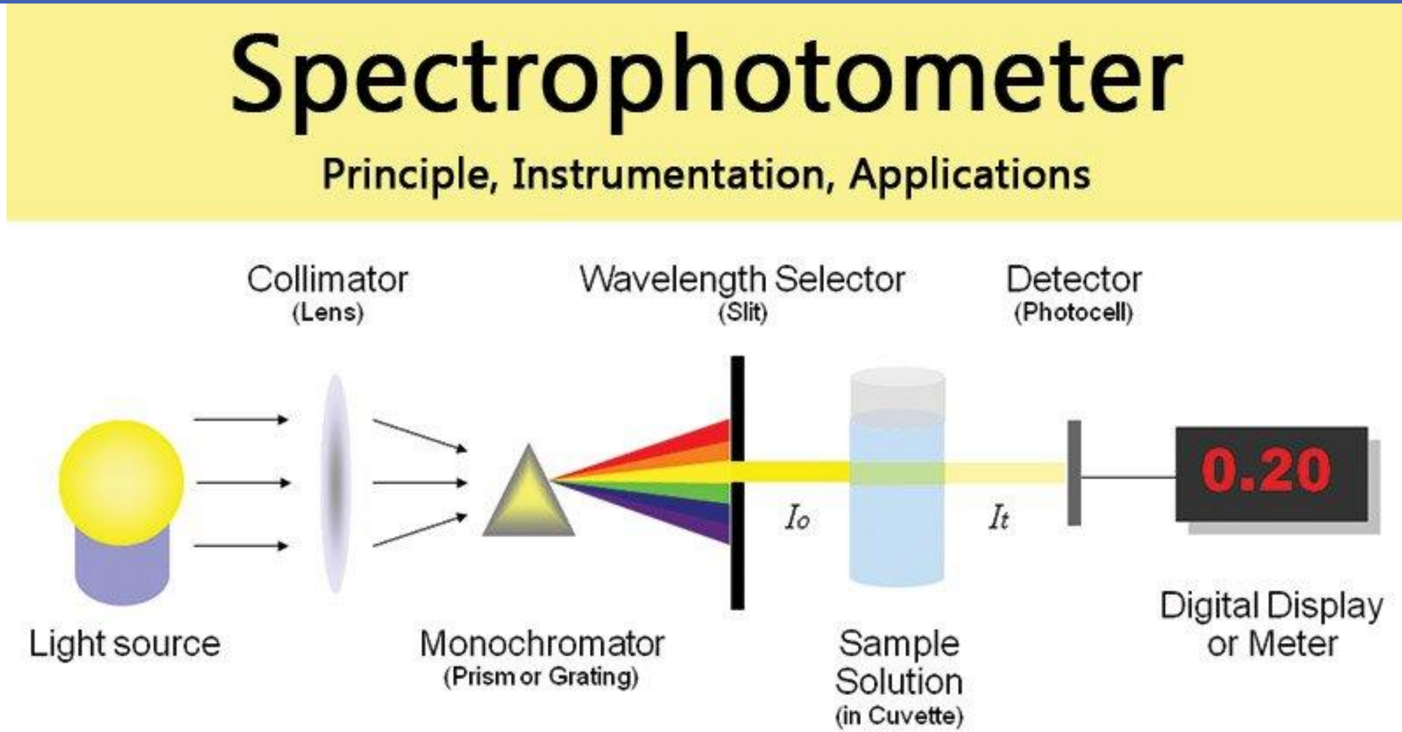


OVERVIEW OF FLAME PHOTOMETRY

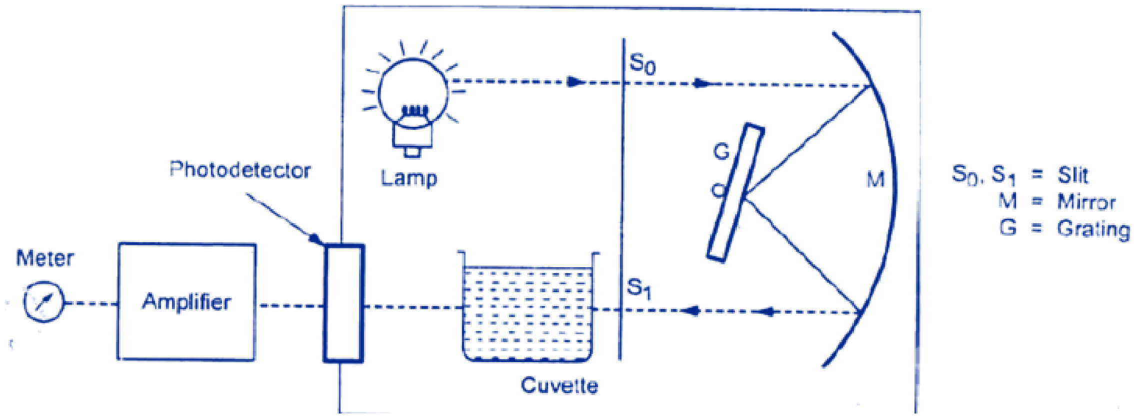
- Flame photometer can be used to determine the concentration of certain metal ions like sodium, potassium, lithium, calcium and cesium etc.
- In flame photometer spectra the metal ions are used in the form of atoms.

SPECTROPHOTOMETER



- The spectrophotometer technique is to measure light intensity as a function of wavelength.
- It does this by diffracting the light beam into a spectrum of wavelengths, detecting the intensities with a charge-coupled device, and displaying the results as a graph on the detector and then on the display device.
- Respiratory gas analysis in hospitals

SPECTROPHOTOMETER



- ➢ Spectrophotometer is an instrument which isolates monochromatic radiation in a more efficient and vessalile manner.
- ➢ In these instruments Light from the source is made into a parallel beam and passed to a prism or diffraction graling ,where light of different wavelengths is dispersed at different angles.

- ❖ In this selection filter of the colorimeter is replaced by Monochromator. Monochromator uses a diffraction grating G or a prism to disperse light from the lamp.
- ❖ Light falls through the slit S0 into the spectral components Slit S1 is used for selecting a narrow band of the spectrum which is used to measure the absorption of a sample in the cuvette.
- ❖ The light from the cuvette is given to photo detector. It converts lights into electrical signal.
- ❖ The electrical signal is amplified by using an amplifier.
- ❖ The output from the amplifier is given to meter which shows absorbance.
- ❖ Light absorption is varied when the wavelength is varied. Mirror M is used to reduce the size of the instrument.

Colorimeter vs Spectrophotometer

Like colorimeters, spectrophotometers are used to measure the color absorbing properties of a substance.

The key difference between the two is that the spectrophotometer measures the transmittance and reflectance as a function of wavelength, whereas the colorimeter measures the absorbance of specific colors.

Spectrophotometers measure the transmittance and reflectance for all colors of light and show how they vary as the color is changed.

Colorimeters operate only in the visible portion of the electromagnetic spectrum whereas spectrophotometers work with infrared as well as visible light. Spectrophotometers will produce valid results for Beer's law and can effectively be used as colorimeters but are much higher in cost and complexity.

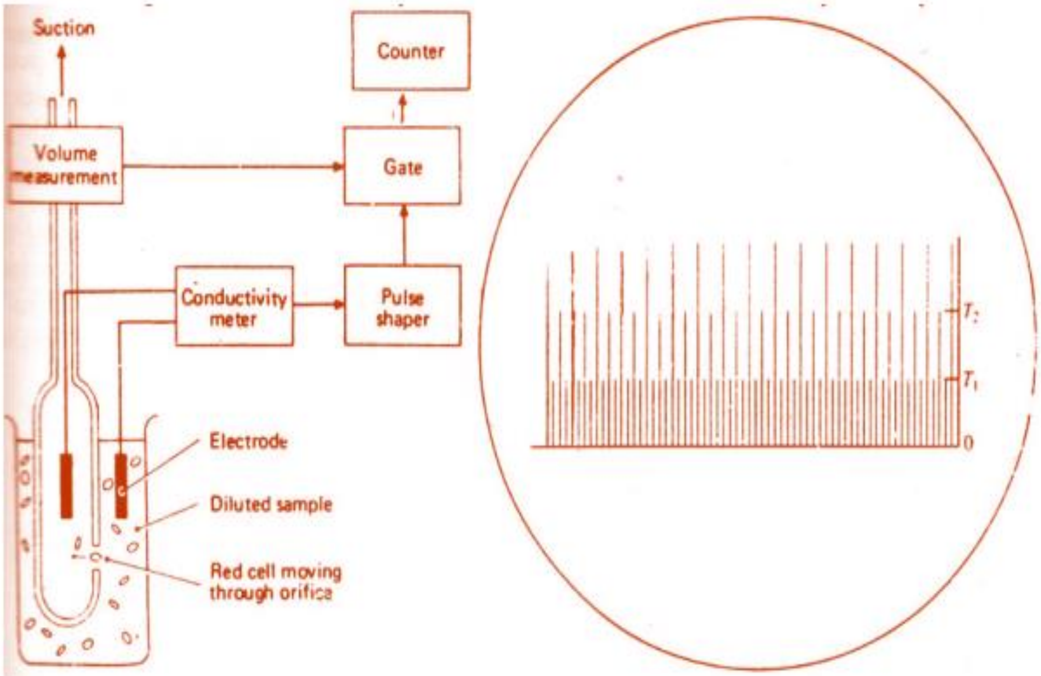
BLOOD CELL COUNTER

- A complete blood count (CBC), also known as a complete blood cell count, full blood count (FBC), or full blood exam (FBE), is a blood panel requested by a doctor or other medical professional that gives information about the cells in a patient's blood, such as the cell count for each blood cell type and the concentrations of hemoglobin.
- A scientist or lab technician performs the requested testing and provides the requesting medical professional with the results of the CBC.

The blood cell counter count the number of RBC or WBC per unit of volume of blood using either of two method:

- Electrical method called aperture impedance change
- Optical method called flow cytometry

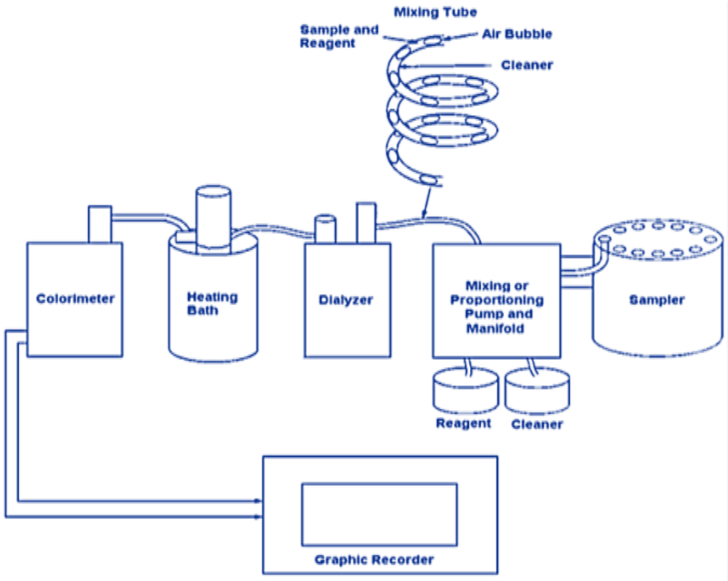
Automatic Red Blood Cell Counter



- ❖ This method us based on the fact that red cells have a higher electrical resistivity than the saline solution in which they are suspended.
- ❖ Fig shows the automatic blood cell counter using electronic circuitry.
- ❖ A diluted blood sample is drawn through a small orifice by means of a section pump.
- ❖ The electrodes are placed such that one in the surrounding sample chamber and other in the suctioned blood.

- ❖ The electrodes are attached with the conductivity bridge such that their resistance forms one arm of bridge. Before suctioning, the resistance of the electrode arm is equal to R.
- ❖ The threshold is first set to zero and the counter output is given by the total number of particles (WBCs + RBCS + platelets) per litre.
- ❖ Then the threshold is set to T1 and the counter gives the total number RBCS and WBCS per litre.
- ❖ After that the threshold is set to T2 and the counter reads the total number of WBCS per litre.

AUTO ANALYZER



The system includes the following elements.

- Sampler - aspirates samples, standards, and wash solutions to the autoanalyzer system.
- Proportioning pump and manifold - introduces (mixes) samples with reagents to effect the proper chemical color reaction to be read by the colorimeter. It also pumps fluids at precise flow rates to other modules, as proper color development depends on reaction time and temperature.
- Dialyzer - separates interfacing substances from the sample material by permitting selective passage of sample components through a semipermeable membrane.
- Heating bath - heats fluids continuously to exact temperature (typically 37°C incubation, equivalent to body temperature). Temperature is critical to color development.
- Colorimeter - monitors the changes in optical density of the fluid stream flowing through a tubular flow cell. Color intensities (optical densities) proportional to substance concentrations are converted to equivalent electrical voltages
- Recorder – Converts optical density electrical signal from the colorimeter into a graphic display on a moving chart.

The heart of the auto analyzer system is the proportioning pump. This consists of a peristaltic pump. Air segmentation in the mixing tube separates the sample / reagent mixture from the cleaning fluid and other samples. As these air-separated fluids traverse the coil of the mixing tube, effective mixing action is achieved. One problem with automatic analyzer is certain identification of samples. Patient data can be intermixed with that of other patients if care is not taken. Sterilization is also needed for samples, glassware and equipment parts that are contaminated with disease. Diseases such as hepatitis or other communicable infections can be spread to equipment operators.

- ❖ The auto analyzer sequentially measures blood chemistry and displays this on a graphic readout.
- ❖ As shown in Figure above, this is accomplished by mixing, reagent reaction, and colorimetric measurement in a continuous stream.

Some Basic Questions

Why Is Arterial Blood Gas done?

- An arterial blood gas (ABG) test measures the acidity (pH) and the levels of oxygen and carbon dioxide in the blood from an artery.
- This test is used to check how well your lungs are able to move oxygen into the blood and remove carbon dioxide from the blood.

What do blood gases tell us?

- Blood gases are a group of tests that are performed together to measure the pH and the amount of oxygen (O2) and carbon dioxide (CO2) present in a sample of blood, usually from an artery, in order to evaluate lung function and help detect an acid-base imbalance that could indicate a respiratory, metabolic or kidney .

What is a normal arterial blood gas?

According to the National Institute of Health, typical normal values are:

- ✓ pH: 7.35-7.45.
- ✓ Partial pressure of oxygen (PaO2): 75 to 100 mmHg.
- ✓ Partial pressure of carbon dioxide (PaCO2): 35-45 mmHg.

What is the name of the Po2 electrode?

- ✓ Severinghaus electrode
- ✓ The Severinghaus electrode is an electrode that measures carbon dioxide (CO2).

Some Basic Questions

What is normal pO2?

- Most healthy adults have a PaO2 within the normal range of **80–100 mmHg**.
- If a PaO2 level is lower than 80 mmHg, it means that a person is not getting enough oxygen .

What does PCO2 stand for?

- The partial pressure of carbon dioxide (PCO2) is the measure of carbon dioxide within arterial or venous blood.
- It often serves as a marker of sufficient alveolar ventilation within the lungs.
- Generally, under normal physiologic conditions, the value of PCO2 ranges between 35 to 45 mmHg, or 4.7 to 6.0 kPa.

What causes blood pH?

- ✓ This analysis has revealed three independent variables that regulate pH in blood plasma.
- ✓ These variables are carbon dioxide, relative electrolyte concentrations, and total weak acid concentrations.
- ✓ All changes in blood pH, in health and in disease, occur through changes in these three variables.

Some Basic Questions

What is the pH of blood?

- ✓ The acidity or alkalinity of any solution, including blood, is indicated on the pH scale.
- ✓ The pH scale, ranges from 0 (strongly acidic) to 14 (strongly basic or alkaline).
- ✓ A pH of 7.0, in the middle of this scale, is neutral.
- ✓ Blood is normally slightly basic, with a normal pH range of **about 7.35 to 7.45**.

- ❖ **pH** is a measurement of the acidity of the blood, reflecting the number of hydrogen ions present.
- ❖ Lower numbers mean more acidity; higher numbers mean more alkalinity.

Arterial blood gas analysis typically measures:

- ❖ pH (acidity)
- ❖ pCO_2 (partial pressure of carbon dioxide)
- ❖ pO_2 (partial pressure of oxygen)
- ❖ CO_2 (carbon dioxide content)
- ❖ Base excess (the loss of buffer base to neutralize acid)

Some Basic Concepts

pCO2 (partial pressure of carbon dioxide) reflects the the amount of carbon dioxide gas dissolved in the blood.

Indirectly, the pCO2 reflects the exchange of this gas through the lungs to the outside air. Two factors each have a significant impact on the pCO2. The first is how rapidly and deeply the individual is breathing:

- ❖ Someone who is hyperventilating will "blow off" more CO2, leading to lower pCO2 levels
- ❖ Someone who is holding their breath will retain CO2, leading to increased pCO2 levels

The second is the lungs capacity for freely exchanging CO2 across the alveolar membrane:

- With pulmonary edema, there is an extra layer of fluid in the alveoli that interferes with the lungs' ability to get rid of CO2. This leads to a rise in pCO2.
- With an acute asthmatic attack, even though the alveoli are functioning normally, there may be enough upper and middle airway obstruction to block alveolar ventilation, leading to CO2 retention.

- ❖ PO2 (partial pressure of oxygen) reflects the amount of oxygen gas dissolved in the blood. It primarily measures the effectiveness of the lungs in pulling oxygen into the blood stream from the atmosphere.


THANK YOU