LECTURE HANDOUTS

BME

III/V

Course Name with Code : BIO MEDICAL INSTRUMENTATION AND MEASUREMENTS
16BMD03
Course Teacher : Mrs.D.G.BeautlinVinola

Unit: I - Electrophysiology and Biopotential Electrodes   **Date of Lecture:**

Topic of Lecture: Origin of Bio-potential

Introduction :
- Bioelectric potentials are generated at a cellular level and the source of these potentials is ionic in nature.

- A cell consists of an ionic conductor separated from the outside environment by a semipermeable membrane which acts as a selective ionic filter to the ions. This means that some ions can pass through the membrane freely where as others cannot do so.

- All living matter icomposed of cells of different types. Human cells may vary from 1 micron to 100 microns in diameter, from 1 mm to 1 m in length, and have a typical membrane thickness of 0.01 micron.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics of action of living tissues

- Conduction of signals

Origin of Bio-potential
Bio-potential
The principal ions involved with the phenomena of producing cell potentials are sodium ($Na+$), potassium ($K+$) and chloride ($Cl–$). The membrane of excitable cells readily permits the entry of $K+$ and $Cl–$but impedes the flow of $Na+$ even though there may be a very high concentration gradiant of sodium across the cell membrane.
This results in the concentration of the sodium ion more on the outside of the cell membrane than on the inside. Since sodium is a positive ion, in its resting state, a cell has a negative charge along the inner surface of its membrane and a positive charge along the outer portion.
The unequal charge distribution is a result of certain electrochemical reactions and processes occurring within the living cell and the potential measured is called the resting potential. The cell in such a condition is said to be polarized. A decrease in this resting membrane potential difference is called depolarization.
The distribution of positively charged ions on the outer surface and negatively charged ions inside the cell membrane results in the difference of potential across it and the cell becomes, in effect, a tiny biological battery.
Experiments have shown that the internal resting potential within a cell is approximately –90 mV with reference to the outside of the cell.
**Depolarization**

When the cell is excited or stimulated, the outer side of the cell membrane becomes momentarily negative with respect to the interior. This process is called depolarization and the cell potential changes to approximately +20 mV.

Repolarization

Repolarization then takes place a short time later when the cell regains its normal state in which the inside of the membrane is again negative with respect to the outside.Repolarization is necessary in order to re-establish the resting potential. This discharging and recharging of the cell produces the voltage waveforms which can be recorded by suitable methods using microelectrodes.

Cell potential waveform
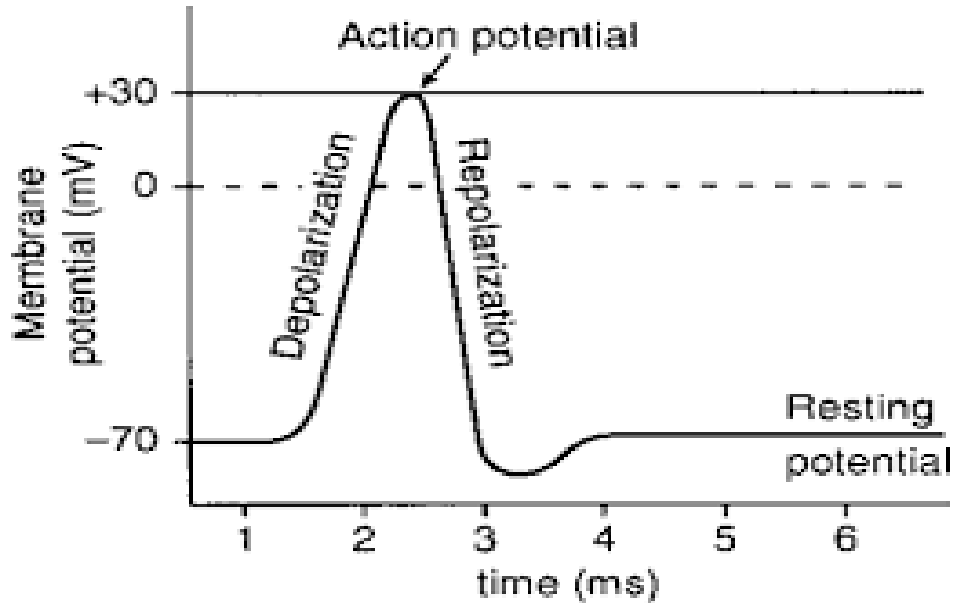
The wave of excitation while propagating in the muscle causes its contraction. The contraction wave always follows the excitation wave because of its lower velocity. This phenomenon is found with the skeletal muscles, the heart muscle and the smooth muscles.

Action potential

Every contraction(movement) of a muscle results in the production of an electric voltage. This voltage occurs in the muscle in such a way that the moving muscle section is always negative with respect to its surroundings. These voltages are called action potentials because they are generated by the action of the muscles.

After complete contraction, repolarization takes place resulting in the relaxation ofthe muscle and its returning to the original state.

Electrical Activity Associated with one contraction in a Muscle
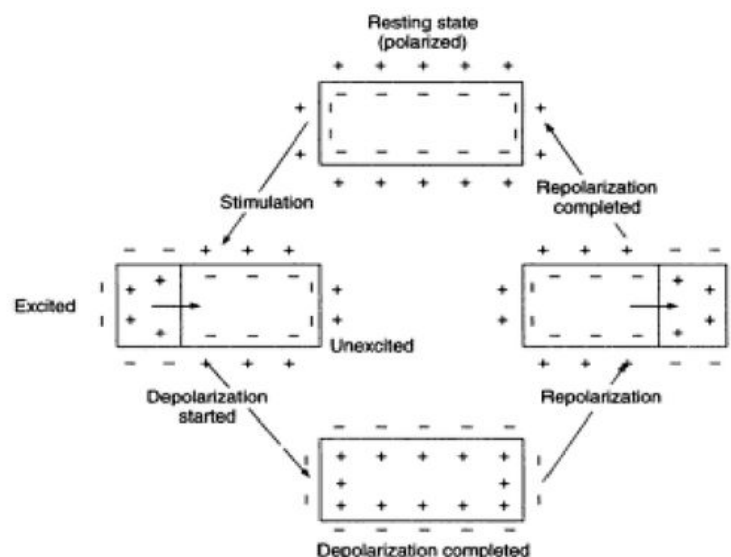
The currents involved in bioelectricity are unlike the currents involved in electronics. Bioelectric currents are due to positive and negative ion movement within a conductive fluid. The ions possess finite mass and encounter resistance to movement within the fluid for they have limited speeds. The cell action potential, therefore, shows a finite rise time and fall time. It may be noted that a cell may be caused to depolarize and then repolarize by subjecting the cell membrane to an ionic current.

Stimulus threshold

 Unless a stimulus above a certain minimum value is applied, the cell will not be depolarized and no action potential is generated. This value is known as the stimulus threshold.

Refractory period

        After a cell is stimulated, a finite period of time is required for the cell to return to its pre-stimulus state. This is because the energy associated with the action potential is developed from metabolic processes within the cell which take time for completion. This period is known as refractory period.

   The bioelectric signals of clinical interest, which are often recorded, are produced by the coordinated activity of large groups of cells.In this type of synchronized excitation of many cells, the charges tend to migrate through the body fluids towards the still unexcited cell areas. Such charge migration constitutes an electric current and hence sets up potential differences between various portions of the body, including its outer surface. Such potential differences can be conveniently picked up by placing conducting plates (electrodes) at any two points on the surface of the body and measured with the help of a sensitive instrument. These potentials are highly significant for diagnosis and therapy.

Video Content / Details of website for further learning (if any):

https://www.egr.msu.edu/classes/ece445/mason/Files/6-Biopotentials.pdf

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 32-35

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L2

LECTURE HANDOUTS

BME

III/V

Course Name with Code   : BIO MEDICAL INSTRUMENTATION AND MEASUREMENTS
                                            16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit : I - Electrophysiology and Biopotential Electrodes   Date of Lecture:

Topic of Lecture: Electrode-electrolyte interface

Introduction :
- Bioelectric events have to be picked up from the surface of the body before they can be put into the amplifier for subsequent record or display. This is done by using electrodes.

- Electrodes make a transfer from the ionic conduction in the tissue to the electronic conduction which is necessary for making measurements.

- Electrodes are also required when physiological parameters are measured by the impedance method and when irritable tissues are to be stimulated in electrotherapy

**Prerequisite knowledge for Complete understanding and learning of Topic:**
- Basic knowledge about Electrode

- Basics of Electrolyte

Electrode-electrolyte interface
Electrode –tissue Interface:
The most commonly used electrodes in patient monitoring and related studies are surface electrodes. The notable examples are when they are used for recording ECG, EEG and respiratory activity by impedance pneumography. In order to avoid movement artefacts and to obtain a clearly established contact (low contact impedance) an electrolyte or electrode paste is usually employed as an interface between the electrode and the surface of the source of the event.
Electrode-tissue interface for surface electrodes used with electrode jelly
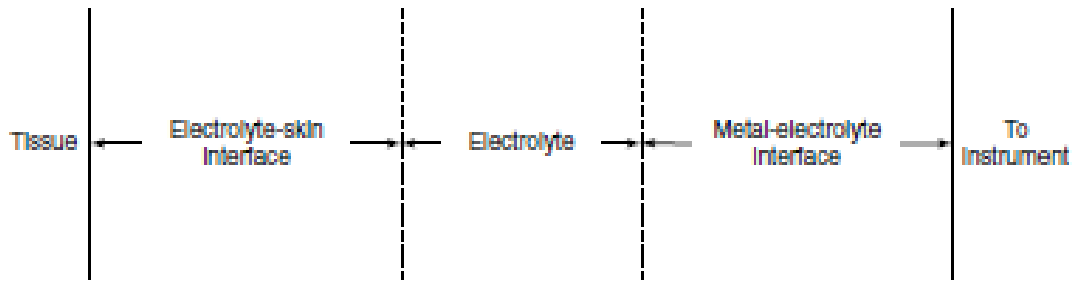
The characteristic of a surface electrode composed of a metal electrode and attached to the surface of the body through an electrolyte(electrode jelly) are dependent upon the conditions at the metal electrolyte interface, the electrolyte-skin interface and the quality of the electrolyte.

Electrode tissue interface circuit involves transfer of electrons from the metal phase to an ionic carrier in theelectrolyte, a charge double layer (capacitance) forms at the interface
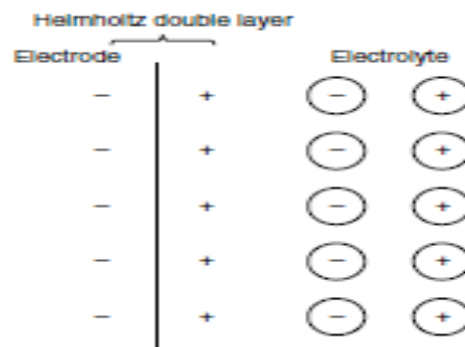
Metal-Electrolyte Interface:
At the metal-electrolyte transition, there is a tendency for each electrode to discharge ions into the solution and for ions in the electrolyte to combine with each electrode. The net result is the creation of a charge gradient (difference of potential) at each electrode, the spatial arrangement of which is called the electrical double layer. The double layer is known to be present in the region immediately adjacent to the electrode and can be represented, in its simplest form, as two parallel sheets of charge of opposite sign separated by a thin film of dielectric.
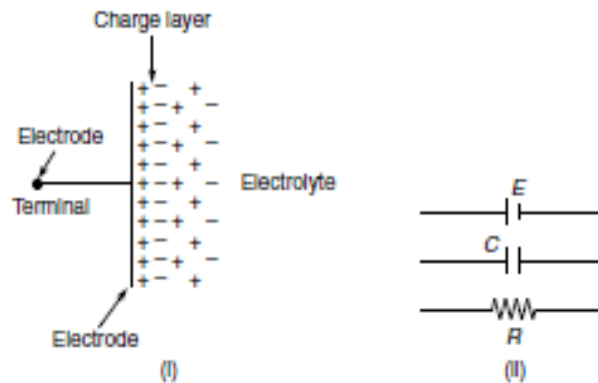
(i) Charge distribution at electrode-electrolyte interface
(ii) Three components representing the interface

Therefore, the metal- electrolyte interface appears to consist of a voltage source in series with a parallel combination of a capacitance and reaction resistance. The voltage developed is called the half-cell potential.To a first-order approximation, the half-cell potential is equal to the electrode potential of the metal, if the electrodes were used in a chemical measuring application.
All electrode potentials are measured with respect to a reference electrode, usually that of hydrogen absorbed on platinum black. This is an inconvenient electrode to make and, therefore, other alternative electrodes which may have fairly stable and repeatable potential (e.g. calomel electrode) are employed.The difference in half-cell potentials that exists between two electrodes is also called 'offset

potential'.

The differential amplifiers used to measure potentials between two electrodes are generally designed to cancel the electrode offset potential so that only the signals of interest are recorded. The electrode offset potential produced between electrodes may be unstable and unpredictable. The long-term change in this potential appears as baseline drift and short-term changes as noise on the recorded trace. If electrodes are used with ac-coupled amplifiers, the long term drift may be partially rejected by the low frequency characteristics of the amplifier. But it will depend upon the rate of change of electrode offset potential in relation to the ac-coupling time constant in the amplifier. For example, if the electrode offset potential drift rate is 1 mV/s,satisfactory results can only be obtained if the low frequency response of the amplifier is 1 Hz.

It has been observed that the Warburg series RC equivalent does not adequately represent the behaviour of an electrode/electrolyte interface as this equivalent does not truly account for the very low-frequency behaviour of the interface. It is well known that such an interface can pass direct current. Therefore, a resistance Rf placed in parallel with the Warburg equivalent is more appropriate.

Figure(b) shows this equivalent circuit in which Rf represents the Faradic leakage resistance. The value of Rf is high in the low-frequency region and is dependent on current density, increasing with a increase in current density.To complete the equivalent circuit of an electrode/electrolyte interface, it is necessary to add the half-cell potential E. This is the potential developed at the electrode/electrolyte interface. The value of E depends on the species of metal and the type of electrolyte, its concentration and temperature.(c) illustrates the complete equivalent circuit of a single electrode/electrolyte interface.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=yNSGVNFpjpY&ab_channel=ENGINEERINGTUTORIAL

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 40-43

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IQAC

LECTURE HANDOUTS	L3

BME	III/V

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03
Course Teacher : Mrs.D.G.BeautlinVinola

Unit : I - Electrophysiology and Biopotential Electrodes   **Date of Lecture:**

Topic of Lecture: Electrode–skin interface and half cell potential

Introduction :
Electrolyte-skin interface can be had by assuming that the skin acts as a diaphragm arranged between two solutions (electrolyte and body fluids) of different concentrations containing the same ions, which is bound to give potential differences.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic principles of Electrode
- Potential difference

Electrode–skin interface and half cell potential
Electrolyte-Skin Interface:
The simplest equivalent representation could then be described as a voltage source in series with a parallel combination of a capacitance and resistance. The capacitance represents the charge developed at the phase boundary whereas the resistance depends upon the conditions associated with ion-migration along the phase boundaries and inside the diaphragm. The above discussion shows that there is a possibility of the presence of voltages of non physiological origin. These voltages are called contact potentials.

The electrical equivalent circuit of the surface electrode suggests that the voltage presented to the measuring instrument from the electrode consists of two main components. One is the contact potential and the other is the biological signal of interest. The contact potential depends upon several factors and may produce an interference signal which exceeds several times the useful signal. The contact potential is found to be a function of the type of skin, skin preparation and composition of the electrolyte.

When bioelectric events are recorded, interference signals are produced by the potential differences of metal-electrolyte and the electrolyte-skin interface. Normally, these potential differences are connected in opposition during the recording procedure, and in the case of a truly reversible and
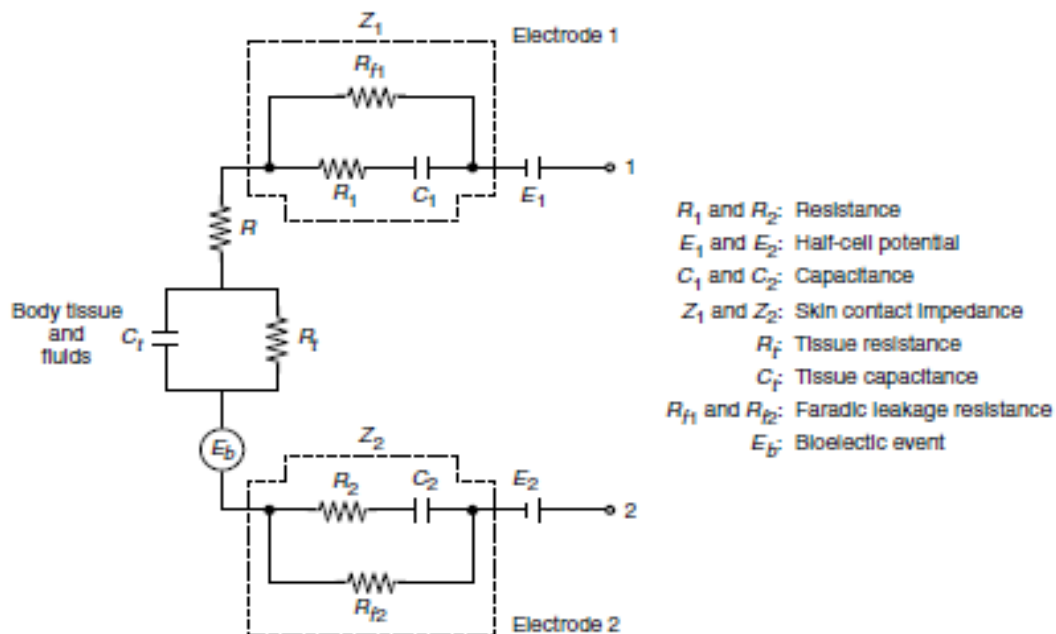
uniform electrode pair, their difference would be nil. However, in practice, a difference of potential—may be extremely small—is found to exist between electrodes produced even under conditions of utmost care during manufacture. Also, some of the elements in the equivalent circuit are time-dependent and are bound to show slow variations with time.

The main reason for this rate of change is due to a relative displacement affecting chiefly the potential of the metal-electrolyte transition. Other factors responsible for variations of potential difference with time can possibly be temperature variations, relative displacement of the components in the system and changes in the electrolyte concentration,.

If ac signals are to be recorded, the potential difference between the two electrodes will not interfere with the useful signals, provided that the contact potential difference between the electrodes is constant. However, if the rate of change with time of the contact potential falls within the frequency spectrum of the signal under test, an error will be produced.

The problem of difference of contact potentials becomes serious in case dc signals such as EOG are to be recorded. Any variation in the contact potential would greatly alter the character of the signal to be recorded which may itself be of extremely low amplitude—of the order of a few microvolts. Based on the above mentioned considerations, it is possible to construct the circuit in which a pair of electrodes is placed in electrolytic contact with a subject. The electrodes are used to measure a bioelectric event and are connected to a differential amplifier. Three potentials are found to exist in this circuit one is due to the bioelectric event (Eb) and the other two are non-physiologic and represent the half-cell potentials ($E1$ and $E2$) of the electrodes.

Equivalent circuit for a pair of electrodes (1,2) on a subject represented by R R$_t$, C$_t$. Embedded in the subject is a bioelectric generator E$_b$

R_1 and R_2: Resistance
E_1 and E_2: Half-cell potential
C_1 and C_2: Capacitance
Z_1 and Z_2: Skin contact impedance
R_t: Tissue resistance
C_t: Tissue capacitance
R_{f1} and R_{f2}: Faradic leakage resistance
E_b: Bioelectic event

$Z1$ and $Z2$ are the skin contact impedances of these electrodes and R is the tissue resistance or resistance of the bioelectric generator. This circuit shows that the impedance of the electrodes would be high in the lowfrequency region and it would decrease with increasing frequency. It is further clear that in the measurement of a bioelectric signal, it is essential to minimize potential drops across the electrode impedance. This is achieved by making the skin-contact impedance as low as possible and making the input impedance of the measuring device as high as possible.

Half Cell Potential
The metal- electrolyte interface appears to consist of a voltage source in series with a parallel combination of a capacitance and reaction resistance. The voltage developed is called the half-cell potential.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=yNSGVNFpjpY&ab_channel=ENGINEERINGTUTORIAL

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 43-45

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L4

LECTURE HANDOUTS

BME

III/V

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit : I - Electrophysiology and Biopotential Electrodes   Date of Lecture:

Topic of Lecture: Contact Impedance

Introduction :
- The bioelectrical events are usually recorded by means of metallic electrodes placed on the surface of the body.

- The electrical activity generated by various muscles and nerves within the body is conducted to the electrode sites through the body tissues, reaches the electrodes through the skin electrode transition and is then conducted by direct wire connection to the input circuit of the recording machine.

- Skin electrode impedance is known as the contact impedance and is of a value much greater than the electrical impedance of the body tissue as measured beneath the skin.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about Electrodes

- Electrical Activity of muscles

Contact Impedance
- The impedance at the electrode-skin junction comes in the overall circuitry of the recording machine and, therefore, has significant effect on the final record.

- Skin electrode impedance is known as the contact impedance and is of a value much greater than the electrical impedance of the body tissue as measured beneath the skin.

- The outer horny layer of the skin is responsible for the bulk of the skin contact impedance and, therefore, a careful skin preparation is essential in order to obtain best results.

Measurement of skin contact Impedance

This method has been suggested by Miller (1969).The three electrodes, A, B and C, have contact impedance respectively of Z_a, Z_b and Z_c. An oscillator provides a constant current in the frequency range of 0.1–100 Hz through the 47 kW series resistor. By suitably positioning the switch, a sensitive oscilloscope can be used to monitor either the voltage dropped across the 1 kW resistor or the voltage dropped across Z_b.

The voltage drop across Z_b can be neglected since the input impedance of the oscilloscope used with an input probe is usually high. From the voltage dropped across the 1 kW resistor it is possible to calculate the circuit current and thus to obtain a value for Z_c. Using this technique, the skin contact impedance of the following types of electrodes were measured by Hill and Khandpur .

- Plastic cup self-adhesive electrodes

- Metal plate limb electrodes used with conducting jelly

- Metal plate electrodes used with conducting plastic

Arrangement of Measurement Electrodes Skin Contact- Impedance for Surface Electrodes
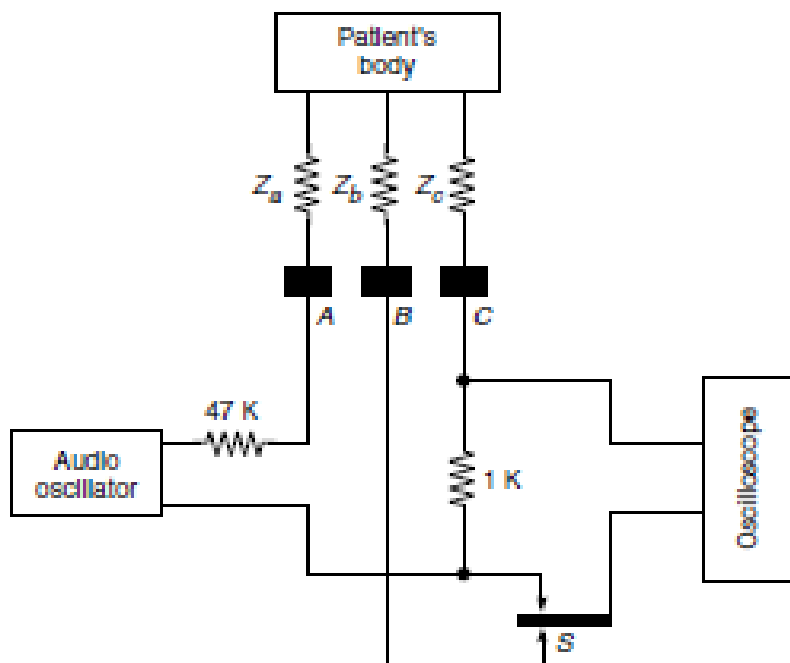
- Dry multi-point limb electrodes

- Dry multi-point suction chest electrodes

- Self-adhesive multi-point chest electrodes used with conducting jelly

- Self-adhesive gauze electrodes

- Self-adhesive dry multi-point chest electrodes

Representative plots of contact impedance versus frequency are shown down. Usually the contact impedance in respect of surface electrodes used for recording of ECG is measured at 10–20 Hz because most of the energy content of the ECG is concentrated below 30 Hz. Geddes and Baker (1968) used a synchronous rectifier with a phase sensitive detector to continuously measure the resistive and reactive components of the impedance.
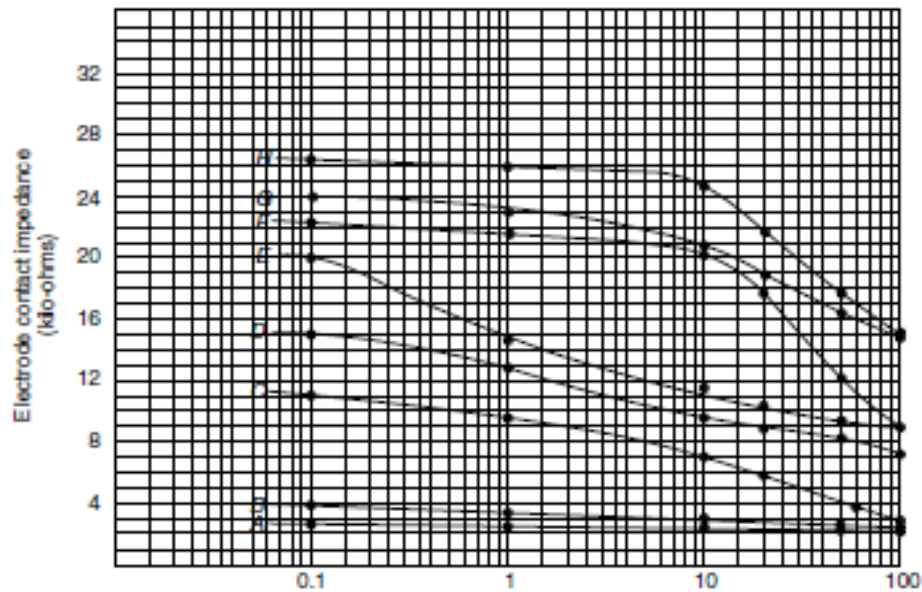
Video Content / Details of website for further learning (if any):

https://www.youtube.com/results?search_query=Electrode+skin+contact+impedance

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :46-47

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L5

LECTURE HANDOUTS

BME		III/V

Course Name with Code	:	BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS 16BMD03

Course Teacher : Mrs.D.G.BeautlinVinola

Unit : I - Electrophysiology and Biopotential Electrodes   Date of Lecture:

Topic of Lecture: polarization effects of electrode – non polarizable electrodes.

Introduction :
- In some metal/liquid interfaces, the electrical double layer gets temporarily disturbed by the externally applied voltage, and therefore, a very small current flows after the first surge, thus indicating a high resistance.

- This type of electrode will not permit the measurement of steady or slowly varying potentials in the tissues. They are said to, be polarized or non reversible.

- Non-polarizing electrodes on the other hand, are designed to rapidly dissipate any charge imbalance induced by powerful electrical discharges such as a defibrillation procedure.

- Rapid depolarization enables the immediate reappearance of bioelectric signals on the monitor after defibrillation.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic principles of Electrodes

- Defibrillation

Polarization effects of electrode – non polarizable electrodes

If a low voltage is applied to two electrodes placed in a solution, the electrical double layers are disturbed. Depending on the metals constituting the electrodes, a steady flow of current may or may not take place.

Polarizable Electrodes

In some metal/liquid interfaces, the electrical double layer gets temporarily disturbed by the externally applied voltage, and therefore, a very small current flows after the first surge, thus indicating a high resistance. This type of electrode will not permit the measurement of steady or slowly varying potentials in the tissues. They are said to, be polarized or non reversible.

Thus, the phenomenon of polarization affects the electro-chemical double layer on the electrode surface and manifests itself in changing the value of the impedance and voltage source representing the transition layer.

Non-polarizable Electrodes

Parsons (1964) stated that electrodes in which no net transfer of charge takes place across the metal-electrolyte interface can be termed as perfectly polarized. Those in which unhindered exchange of charge is possible are called non-polarizable or reversible electrodes. The ionic double layer in metals of these electrodes is such that they allow considerable current to flow when a small voltage is applied, thus offering a low resistance. Although polarizable electrodes are becoming less common, they are still in use. They usually employ stainless steel and are used for resting ECGs or other situations where there is small likelihood that the electrodes would be exposed to a large pulse of energy (such as a defibrillation discharge) in which case they would retain a residual charge, become polarized, and will no longer transmit the relatively small bioelectric signals, thus becoming useless.
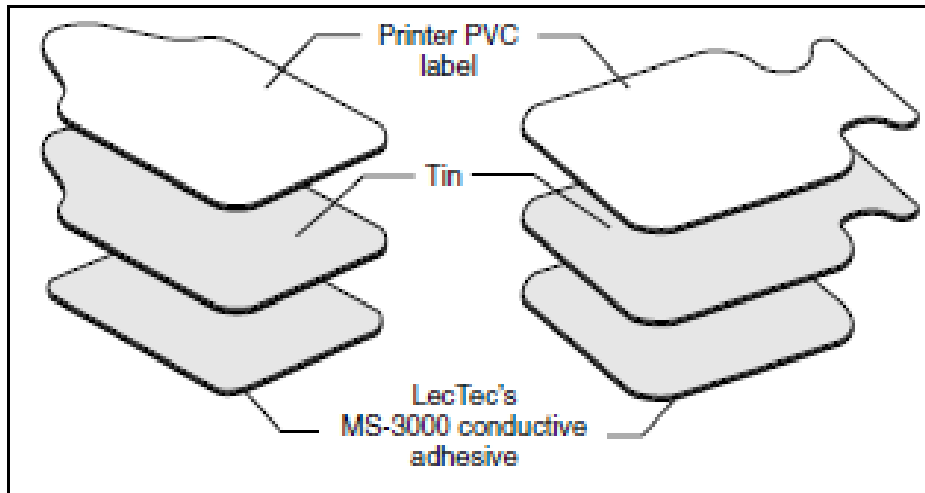
Non-polarizing electrodes on the other hand, are designed to rapidly dissipate any charge imbalance induced by powerful electrical discharges such as a defibrillation procedure. Rapid depolarization enables the immediate reappearance of bioelectric signals on the monitor after defibrillation.

For this reason, non-polarizing electrodes have become the electrodes of choice for monitoring in the intensive care units and stress testing procedures. Historically, these electrodes employ a conducting metal with a silver/silver-chloride (Ag/AgCl) surface in contact with the conducting gel.

The choice of metals for electrodes is not determined only by their susceptibility to polarization, but other factors such as mechanical properties, skin irritation or skin staining, etc. have also to be taken into consideration. A detailed comprehensive review of electrodes for measurement of bioelectronic events is given by Geddes and Baker (1975).

The LeeTec Corporation, USA has devised a tin-backed electrode, Tracets MP-3000 figure below which is non-polarizable and performs electrically as well as or better than similar electrodes employing silver/silver-chloride (Montecalvo and Rolf, 1990). U.S. Patent 4,674,512 describes the construction of this non-polarizing ECG electrode, which employs no silver. This represents a new era for electrocardiology where silver is no longer a critical electrode component for quality performance.

Resting ECG electrode Lec Tec MP-3000-a multipurpose monitoring and diagnostic non-polarizable electrode

Printer PVC label
Tin
LecTec's MS-3000 conductive adhesive

Video Content / Details of website for further learning (if any):
https://www.slideshare.net/jineshkj/polarizable-nonpolarizableelectrode

Important Books/Journals for further learning including the page nos.:
Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 45-46

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L6

LECTURE HANDOUTS

BME

III/V

Course Name with Code	**: BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS 16BMD03**
Course Teacher	**: Mrs.D.G.BeautlinVinola**

Unit : I - Electrophysiology and Biopotential Electrodes   **Date of Lecture:**

Topic of Lecture: Types of electrodes – surface electrodes

Introduction :

- The most common type of electrodes routinely used for recording ECG are rectangular or circular surface electrodes. The material used is german silver, nickel silver or nickel plated steel.

- They are applied to the surface of the body with electrode jelly. The typical value of the contact impedance of these electrodes, which are of normal size, is nearly 2 to 5 kW when measured at 10 Hz.

- The electrodes are held in position by elastic straps. They are also called limb electrodes as they are most suitable for application on the four limbs of the body.

- The size of the limb electrodes is usually 3 \ 5 cm and they are generally made of german silver, an alloy of zinc, copper and nickel. They are reusuable and last several years

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge about Electrodes

- Recording of ECG

Types of electrodes – surface electrodes

Limb Electrodes

The most common type of electrodes routinely used for recording ECG are rectangular or circular surface electrode.Limb electrodes are generally preferred for use during surgery because the patient's limbs arerelatively immobile. Moreover, chest electrodes cannot be used as they would interfere with the surgery.

Limb electrodes are not suitable for use in long-term patient monitoring because the long flowingleads are inconvenient to the patient. Also, the electromyographic voltages generated by the activity of the limb muscles makes them unsuitable for use when monitoring conscious and semi-conscious patients.

Suction-cup electrode is commonly used to record the unipolar chest leads. It has a high contact impedance as only the rim of the electrode is in contact with the skin. The electrode is popular for its practicality, being easily attachable to fleshy parts of the body. Electrode jelly forms the vacuum seal.

ECG plate electrode. The electrode is usually fastened to the arm or leg with a perforated rubber strap which keeps it in position during ECG recording

Rubber strap

Electrode

Arm
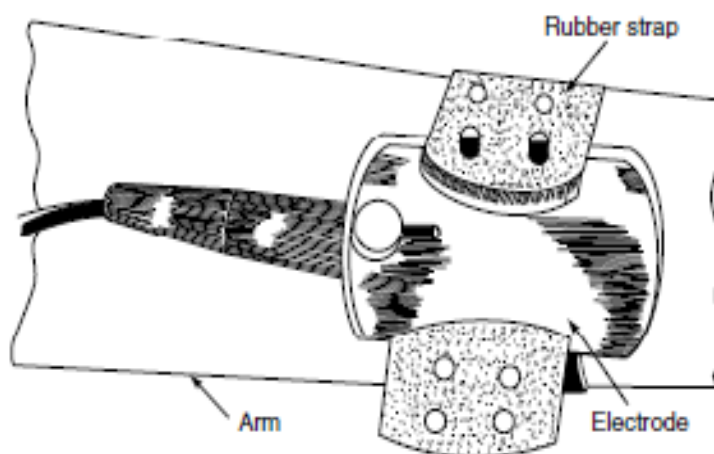
Floating Electrodes

Limb electrodes generally suffer from what is known as motion artefacts caused due to the relative motion at the interface between the metal electrode and the adjacent layer of electrode jelly,. The interface can be stabilized by the use of floating electrodes in which the metal electrode does not make direct contact with the skin.

The electrode in the figure below consists of a light-weight metalled screen or plate held away from the subject by a flat washer which is connected to the skin. Floating electrodes can be recharged, i.e. the jelly in the electrodes can be replenished if desired.

Light weight floating electrode with press stud for long-term monitoring of ECG
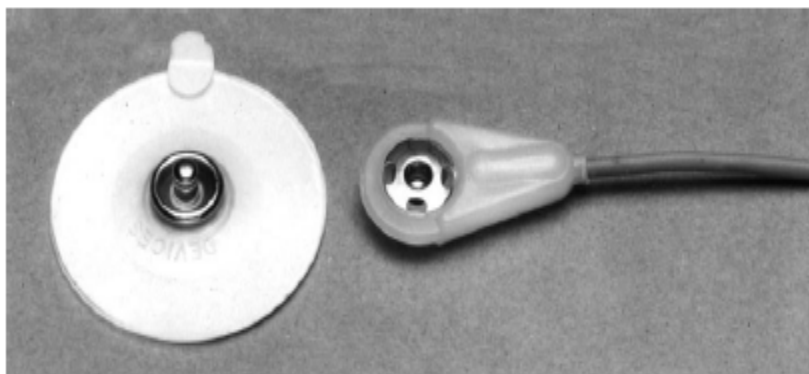
Connection with the instrument is established with silver-plated copper wires fixed in the conducting adhesive. The type of electrodes are extremely light-weight and donot make use of electrode jelly. This makes them ideal for use in monitoring the ECG of exercising subjects and aeroplane pilots as they give rise to minimal motion artefacts. The contact impedance shown by these electrodes is of the order of 50 kW.

Completely flexible ECG electrodes for the long-term monitoring of ECG during space flight are reported by Sandler *et al* (1973). These electrodes were made of silver-impregnated silastic rubber and were found to be comfortable to wear. They were also evaluated for use during exercise orprolonged monitoring as may be necessary in an intensive care or coronary care unit.

Pregelled Disposable Electrodes

Electrodes which are employed in stress testing or long term monitoring, present additional problems because of the severe stresses, perspiration and major body movement encountered in such studies. Both design considerations and application techniques of electrodes used in electrocardiography are necessary to prevent random noise on the baseline, baseline wandering and skin contact over extended periods causing a loss of signal.

To overcome problems due to prolonged application, special disposable electrodes have been developed. Fig(a)illustrates the principle of a pregelled electrode while Fig(b) shows a cross-section of

such an electrode.

The main design feature of these electrodes which helps in reducing the possibility of artefacts, drift and baseline wandering is the provision of a high-absorbancy buffer layer with isotonic electrolyte. This layer absorbs the effects of movement of the electrode in relationship to the skin, and attempts to maintain the polarization associated with the half-cell potential constant.Since perspiration is the most common cause of electrode displacement, the use of an additional porous overlay disc resists perspiration and ensures secure placement of the electrode on the skin even under stress conditions.
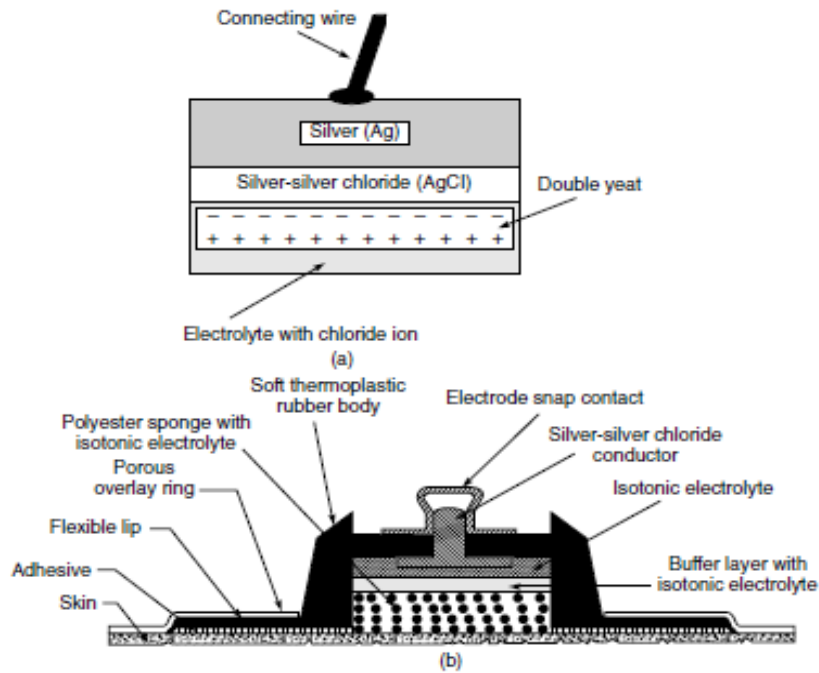
(a)Principle of pre-gelled ECG electrode made of silver-silver chloride. The electrode has electrolyte layers that are made of a firm gel which has adhesive properties. The firm gel minimizes the disturbance of the charge double layer

(b) Cross-section of a typical pre-gelled electrode

Disposable pre-gelled ECG electrode.
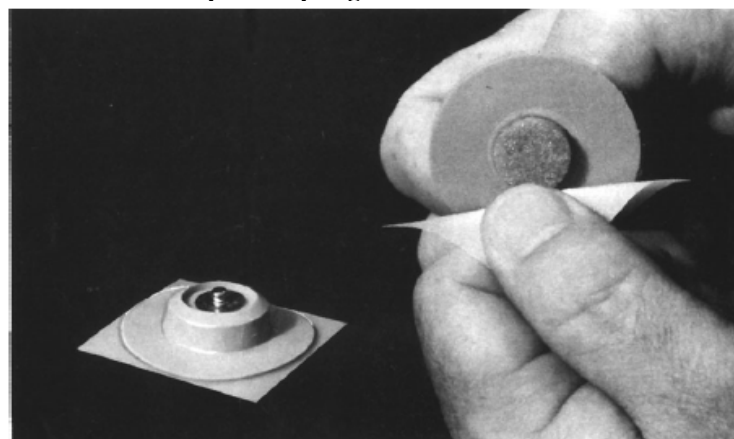
Pasteless Electrodes

Capacitive Electrodes:

A metal plate electrode in direct contact with the skin though makes a very high resistive contact and has a considerable capacitive contact too with the skin (Stevens, 1963).By using a very high input impedance amplifier, it is possible to record a signal through the tissueelectrode capacitance. Lopez and Richardson (1969) describe the construction of electrodes which can be capacitively coupled to the subject.

Schematic diagram of integrated electrode and amplifier arrangement for pasteless operation
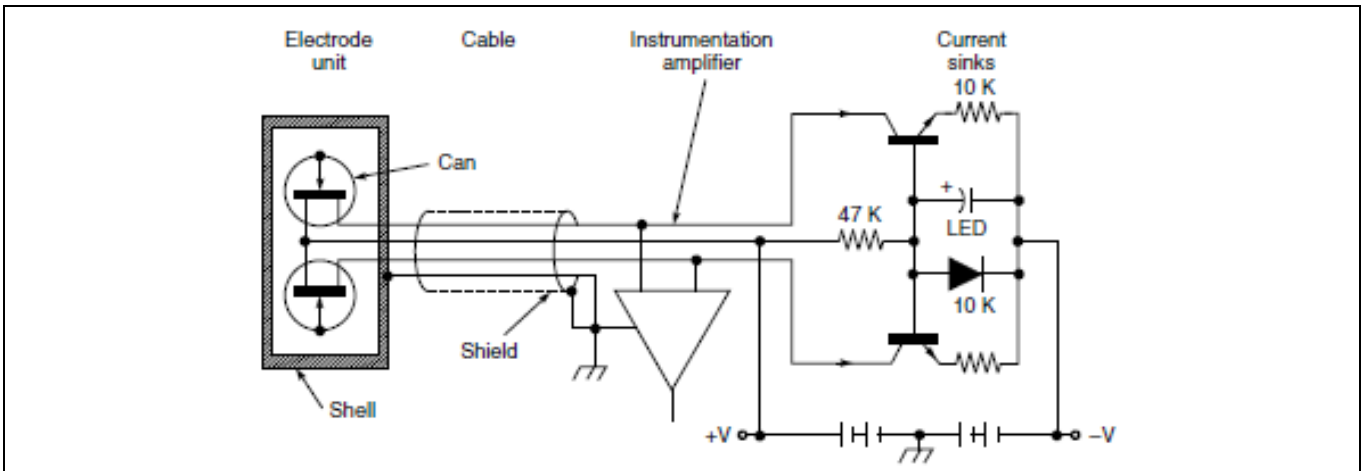
Electrode unit — Can, Shell, Shield
Cable
Instrumentation amplifier
Current sinks — 10 K, 47 K, LED, 10 K, +V, −V

Video Content / Details of website for further learning (if any):
https://www.slideshare.net/jineshkj/surface-electrode

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 50-55

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LECTURE HANDOUTS

L7

BME

III/V

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03

Course Teacher : Mrs.D.G.BeautlinVinola

Unit : I - Electrophysiology and Biopotential Electrodes   Date of Lecture:

Topic of Lecture :Types of Electrodes –Needle Electrodes

Introduction :
- Electrodes for electromyographic work are usually of the needle type.

- Needle electrodes are used in clinical electromyography, neurography and other electrophysiological investigations of the muscle tissues underneath the skin and in the deeper tissues.

- The material of the needle electrode is generally stainless steel. In spite of the fact that stainless steel is unfavourable electrode material from the point of view of noise, it is preferred in EMG work due to its mechanical solidity and low price.

- Needle electrodes are designed to be fully autoclavable and in any case they should be thoroughly sterilized before use.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about muscle tissues

- Principles of Electrodes

Needle Electrodes

Needle electrodes come in various forms. The monopolar needle electrode usually consists of a Teflon coated stainless steel wire which is bare only at the tip. It is found that after the needle has been used a number of times, the Teflon coating will recede, increasing the tip area.
    The needle must be discarded when this occurs. Bipolar (double coaxial) needle electrodes contain two insulated wires within a metal cannula. The two wires are bared at the tip and provide the contactsto the patient. The cannula acts as the ground. Bipolar electrodes are electrically symmetrical and have no polarity sense.
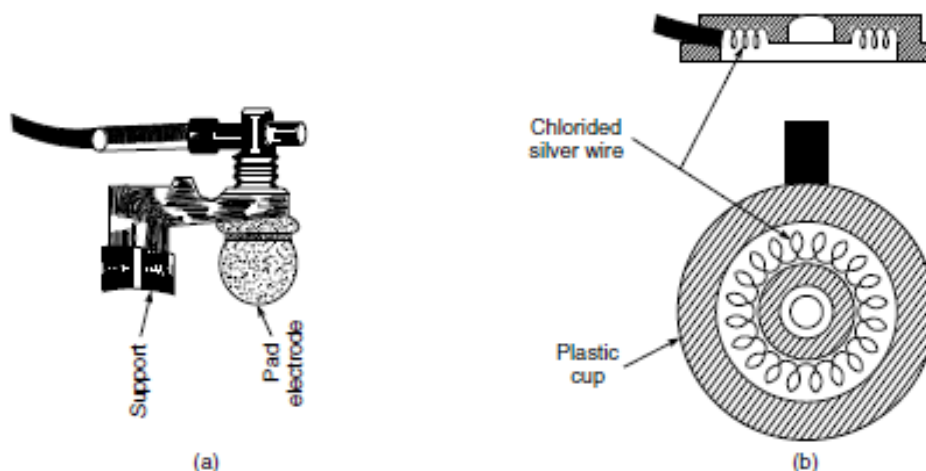

Support | Pad electrode

Chlorided silver wire

Plastic cup

(a)   (b)

A concentric (coaxial) core needle electrode contains both the active and reference electrode within the same structure. It consists of an insulated wire contained within a hypodermic needle. The inner wire is exposed at the tip and this forms one electrode. The concentric needle is very convenient to use and has very stable electrical characteristics. Care should be taken to maintain the surface electrode in good condition in order to avoid artefacts.

Concentric needle electrodes are made by moulding a fine platinum wire into a hypodermic needle having an outside diameter less than 0.6 mm. One end of the needle is bevelled to expose the end of the wire and to provide easy penetration when the needle is inserted. The surface area of the exposed tip of the wire may be less than 0.0005 mm2.

(a)   (b)
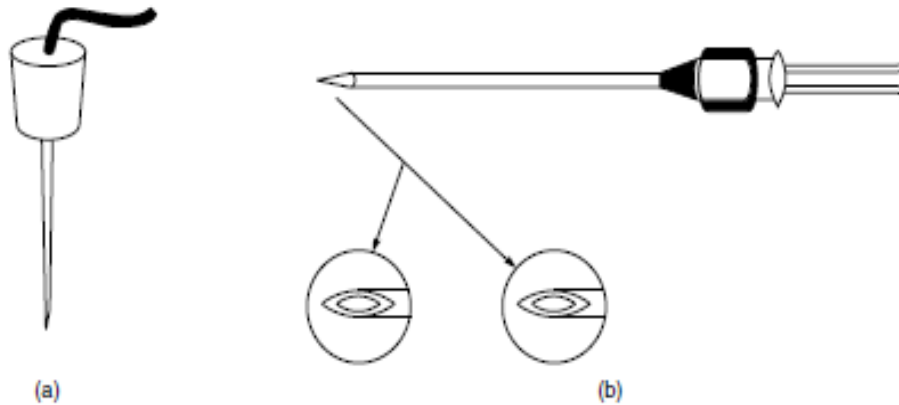
(a)Needle type EMG electrode
(b) Hypodermic needle type EMG electrode

Multi-element needle electrodes are used to pick up the signals from individual fibres of muscle tissue. Special needles are available using 25-micron diameter electrode surfaces and having up to 14 pick up surfaces down the side of one needle.

From the point of view of construction, needle electrodes are the simplest. However, edging of the needle point to the suitable angle, providing a proper plastic coating, making them resistant against thermal and chemical stresses and ensuring histological suitability is a difficult manufacturing process.

For the measurement of potentials from a specific part of the brain, longer needles are actually inserted into the brain. The needles are precisely located by means of a map or atlas of the brain. Generally, a special instrument called a stereotaxic instrument is used to hold the subject's head and guide the placement of electrodes. Often, these electrodes are implanted to permit repeated measurements over an extended period of time.

The ground electrode for EMG studies usually consists of a conducting strip which is inserted into a saline soaked strap and wrapped around the patient's limb. The ground electrode is usually positioned over bony structures rather than over large muscle masses, in the vicinity of the recording and stimulating electrodes, and where possible, equidistant from them. Surface electrodes are employed for recording gross electrical activity from a particular group of underlying muscles in nerve-conduction velocity measurements.

A single surface electrode may also be used as the reference (indifferent) electrode with monopolar needle electrodes. Surface electrodes can be easily and quickly attached and are generally comfortable to wear over long periods. Surface electrodes usually consist of square or circular metal (chlorided silver) plates with leadoff wires attached. They are held in place by straps or adhesive tapes. To reduce electrical resistance between the skin and the electrode, the use of saline soaked felt pads or a small amount of electrode gel between the electrode surface and the skin is recommended. Disposable, adhesive type electrodes are also used for EMG work.

Schematic diagram of the electrode configuration to study myoelectric signals
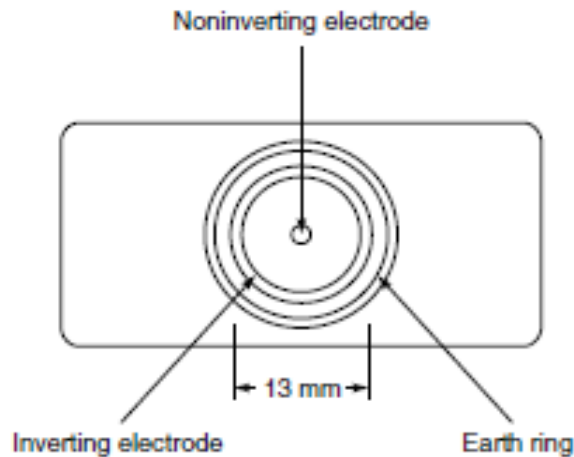
Bhullar *et al* (1990) describe the design and construction of a selective non-invasive surface electrode to study myoelectric signals. The electrode recording surfaces are two concentric steel rings. A third ring attached to the casing of the electrode is the earth contact. The rings are separated from each other by Teflon, the insulating material. The small surface area of the electrode plates, the small physical size and the concentric arrangement produce the effect of recording signals mainly from fibres near to the axis of the electrode and thereby make the electrode much more selective.

The concentric ring instead of the normal passive electrode configuration also obviates the problem of electrode alignment relative to the direction of the muscle fibres. The results of tests undertaken with these electrodes showed that it was able to pick up individual motor unit action potentials at moderate force levels. Crenner *et al* (1989) constructed a special electrode which allows recording of electrical signals from their muscular layers, specifically to collect electromyographic signals of the gastrointestinal tract. The active electrode is surrounded by a ring which avoids the recording of interfering signal.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=1XOSiOHO7sw&ab_channel=YOdotCOM

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :59-61

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LECTURE HANDOUTS

L8

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03

Course Teacher : Mrs.D.G.BeautlinVinola

Unit : I - Electrophysiology and Biopotential Electrodes   **Date of Lecture:**

Topic of Lecture: Types of Electrodes –Micro -Electrodes

Introduction :
- To study the electrical activity of individual cells, microelectrodes are employed.

- This type of electrode is small enough with respect to the size of the cell in which it is inserted so that penetration by the electrode does not damage the cell.

- The size of an intracellular microelectrode is dictated by the size of the cell and the ability of its enveloping membrane to tolerate penetration by the microelectrode tip.

- Single-living cells are rarely larger than 0.5 mm (500 microns) and are usually less than one-tenth of this size.

**Prerequisite knowledge for Complete understanding and learning of Topic:**
- Basic concepts of Electrical activity of Individual cell

- Basic principles of Electrodes

Micro Electrodes
Typical microelectrodes have tip dimensions ranging from 0.5 to 5 microns. The tips of these electrodes have to be sufficiently strong to be introduced through layers of tissues without breaking.
     Two types of microelectrodes are generally used metallic and glass micro capillaries. Metallic electrodes are formed from a fine needle of a suitable metal drawn to a fine tip. On the other hand, glass electrodes are drawn from Pyrex glass of special grade. These micro capillaries are usually filled with an electrolyte. The metal microelectrodes are used in direct contact with the biological tissue and, therefore, have a lower resistance.
     However, they polarize with smaller amplifier input currents. Hence, they tend to develop unstable electrode offset potentials and are therefore not preferred for steady state potential measurements. On the other hand, in case of glass microelectrodes, improved stability can be obtained by properly choosing the metal and the electrolyte so that the small current passing through their junction may not be able to modify the electrical properties of the electrodes. Also, the glass microelectrode has a substantial current carrying capacity because of the large surface contact area between the metal and the electrolyte.
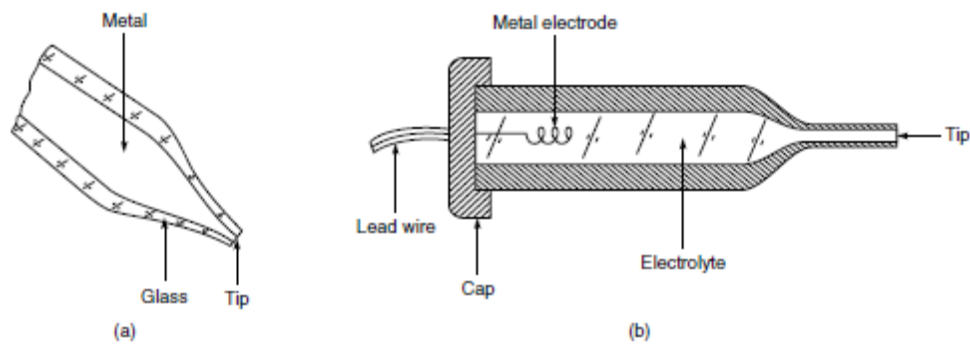
(a)Microelectrodes—metal microelectrodes

(b) Microelectrodes—micropipette or micro capillaries electrode

The microelectrodes have a very high impedance as compared to conventional electrodes used for recording ECG, EEG, etc. The high impedance of a metal microelectrode is due to the characteristics of the small area metal-electrolyte interface.

Similarly, a micropipet tip is filled with an electrolyte which substitutes an electrolytic conductor of small cross-sectional area, which gives a micropipet its high resistance. Because with extremely high input impedances are required to avoid loading the circuit and to minimize the effects of small changes in interface impedance.

Glass Microcapillary Electrodes

Several methods exist for producing microelectrodes of wide variety and shapes. For drawing electrodes of uniform and accurate diameter, it is essential to maintain constant timing, temperature, strength and direction of pull. These factors are difficult to control when the electrodes are drawn manually.

The mechanical method employs gravitational force for extension and the electrodes which are drawn in one or more stages can readily produce capillary tubes between 3–30 mm diameter, but great difficulty is encountered in producing electrodes of less than 1 mm.

The most commonly used method for making small tip micropipet consists of the circumferential application of heat to a small area of glass tubing which is placed under some initial tension. When the glass softens, the tension is increased very rapidly and the heat is turned off. Proper timing, controlled adjustment of the amount of heat as well as the initial and final tensions and cooling result in the production of microcapillaries with controlled dimensions.

Metal MicroElectrodes

Metal electrodes with very fine tips used for recording from single cells have the advantage over glass micropipetes of being relatively robust. Steel microelectrodes can be made from ordinary darning needles but preferably they should be of good stainless steel wire.

They can be easily made up to 10 mm diameter but great care has to be taken for diameters as small as 1 mm. These very small tips are not very satisfactory as they are extremely brittle and have very high input impedance.

Hubel (1957) described a method to make tungsten microelectrodes with a tip diameter of 0.4 mm. He used electropointing technique which consists in etching a metal rod while the metal rod is slowly withdrawn from the etching solution, thus forming a tapered tip on the end of the rod. The etched metal is then dipped into an insulating solution for placing insulation on all but the tip.
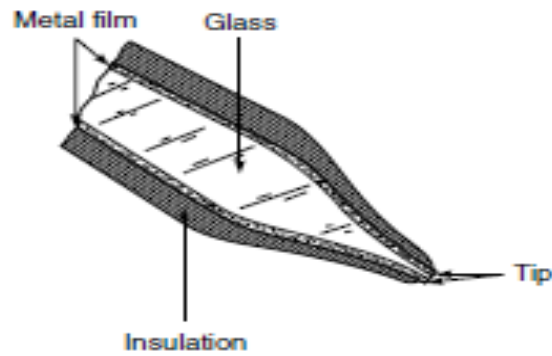
Figure shows the cross-section of a metal microelectrode. In this electrode, a thin film of precious metal is bonded to the outside of a drawn glass microelectrode. This arrangement offers lower impedance than the microcapillary electrode, infinite shelf life and reproduciable performance, with ease of cleaning and maintenance.

The metal—electrolyte interface is between the metal film and the electrolyte of the cell. Skrzypek and Keller (1975) illustrated a new method of manufacturing tungsten microelectrode permitting close control of microelectrode parameters. In this technique, the tips are dc electro etched to diameters below 500° A and completely covered of high impedance of microelectrodes, amplifiers

Video Content / Details of website for further learning (if any):

https://www.brainlatam.com/products/microelectrodes

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 63-64

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LECTURE HANDOUTS	

BME	**III/V**

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03
Course Teacher : Mrs.D.G.BeautlinVinola

Unit : I - Electrophysiology and Biopotential Electrodes   **Date of Lecture:**

Topic of Lecture: Recording problems - measurement with two electrodes.

Introduction :
- Motion artefact is a problem in biopotential measurements.

- The problem is greatest in cardiac stress laboratories where the exercise ECG is recorded.

- The problem is also serious in coronary care units where patients are monitored for relatively long periods.

- Motion of the subject under measurement creates artefacts which may even mask the desired signal or cause an abrupt shift in the baseline

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics of biopotential measurements

- Basics of ECG

Recording problems - measurement with two electrodes

 Motion of the subject under measurement creates artefacts which may even mask the desired signal or cause an abrupt shift in the baseline. These artefacts may result in a display being unreadable, a recording instrument exceeding its range, a computer yielding incorrect output or a false alarm being triggered by the monitoring device.

    Tam and Webster (1977) concluded that the skin-electrolytic paste interface is the major source of motion artefact. When a metal electrode contacts an electrolytic paste, a halfcell potential is generated at the electrode-paste interface. Kahn (1965) demonstrated that when polarizable metal-plate electrodes are used, the electrode-paste interface can be a source of motion artefact. When the paste is agitated, the half-cell potential varies because of the altered metallic ion gradient at the interface. He recorded a 1 mV offset potential change from a silver-silver chloride electrode exposed to a flowing stream of saline solution, as contrasted to 30 mV change for some silver electrodes.

    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 large currents flow through metallic electrodes, migration of some ions into the skin can cause irritation.

    However, silver-silver chloride electrodes do not cause much problem since silver chloride is almost insoluble in a chloride containing solution. Therefore, when these electrodes are used, the skin irritation is mostly caused by the paste and or the adhesive.

Most commercial pastes produce about the same irritation when used on unprepared skin. They cause itching due to restricted perspiration, and reddening of the skin directly under the electrodes appears in 2–4 days. Thakor and Webster (1985) studied the sources
of artefacts, means of reducing them using skin preparations, the electrode designs and their placement on the chest for long-term ambulatory ECG.

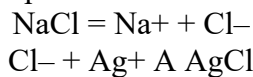**Silver-Silver Chloride Electrodes**

One of the important desirable characteristics of the electrodes designed to pick up signals from biological objects is that they should not polarize. This means that the electrode potential must not vary considerably even when current is passed through them. Electrodes made of silver-silver chloride have been found to yield acceptable standards of performance.

By properly preparing and selecting the electrodes, pairs have been produced with potential differences between them of only fractions of a millivolt (Feder, 1963). Standing voltage of not more than 0.1 mV with a drift over 30 min. of about 0.5 mV was achieved in properly selected silver-silver chloride electrodes by Venables and Sayer (1963).

Silver-silver chloride electrodes are also nontoxic and are preferred over other electrodes like zinc-zinc sulphate, which also produce low offset potential characteristics, but are highly toxic to exposed tissues. Silver-silver chloride electrodes meet the demands of medical practice with their highly reproducible parameters and superior properties with regard to long-term stability.

Production of Silver-Silver Chloride Electrodes:

Silver-silver chloride electrodes are normally prepared by electrolysis. Two silver discs are suspended in a saline solution. The positive pole of a dc supply is connected to the disc to be chlorided and the negative pole goes to the other disc. A current at the rate of 1 mA/cm2 of surface area is passed through the electrode for several minutes.A layer of silver chloride is thus deposited on the surface of the anode. The chemical changes that take place at the anode and cathode respectively are:

$$NaCl = Na+ + Cl–$$
$$Cl– + Ag+ \text{ A } AgCl$$

The positively charged sodium ions generate hydrogen when they reach the cathode surface.
2Na+ + 2H2O + 2 electrons A 2NaOH + H2.To prepare silver-silver chloride electrodes of good quality, only pure silver should be used and the saline solution should be made from analar grade sodium chloride. Before chloriding, silver must be cleaned—preferably by the electrolytic method.

Geddes *et al*. (1969) investigated the effect of the chloride deposit on the impedance-frequency characteristics of the silver-silver chloride electrodes. They demonstrated that the impedance was different for different layers of chloride and that there is an optimum chloriding, which gives the lowest impedance. They concluded that the lowest electrode-electrolyte impedance in the frequency range of 10 Hz to 10 kHz was found to occur with a chloride deposit ranging between 100 and 500 mAs/cm2 of electrode area.

To achieve this deposit by manipulation of current and time, the minimum constant chloriding current density should be 5 mA/cm2 of electrode area. Higher values may be used with a corresponding reduction in time to achieve the 100–500mAs/cm2 chloride deposit. With this chloride deposit, the electrode electrolyte impedance was found to be resistive.

The use of a chloride deposit in excess of this range did not alter the resistive nature of the electrode-electrolyte impedance although it increased its magnitude. Cole and Kishimoto (1962), however found that the chloride deposit for achieving the lowest impedance is 2000 mAs/cm2. Geddes (1972) confirmed that an optimal coating of silver chloride applied to a silver electrode minimizes the electrical impedance.

This is supported by Getzel and Webster(1976) who concluded that silver chloride may be applied to cleaned silver electrodes in the amount of 1050–1350 mA s/cm2 in order to reduce the impedance of the electrodes. However, to further reduce the impedance of the electrodes, they should be coated with at least 2000 mAs/cm2of silver chloride followed by immersion in a photographic developer for 3 minutes.

A second layer of silver chloride, however, did not result in any further reduction in impedance. Grubbs and Worley (1983) obtained a lower and more stable impedance electrode by placing a heavier initial chloride coat on an etched silver electrode, and then electrolytically removing a portion of that coat.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=A34ci8BdBFY&ab_channel=Aleesha

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 47-49

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| L1 |

LECTURE HANDOUTS

| BME |

| III/V |

Course Name with Code :BIO MEDICAL INSTRUMENTATION AND MEASUREMENTS
                                16BMD03
Course Teacher   :Mrs.D.G.BeautlinVinola

Unit: II - Bio-Potential Measurement of Parameters   Date of Lecture:

Topic of Lecture: Bio signals characteristics – frequency and amplitude ranges

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Introduction :
- Accurate knowledge of different signals from the brain and other body parts are very important in understanding neural substrates of many physiological and pathological functions of the brain and the body parts.

- This quest for knowledge on the human neural makeup and bio signals has created the needs for better signal processing techniques

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Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics principles of Bioelectric signals

- Physiological parameters

Bio signals characteristics – frequency and amplitude ranges

 Over the years, different signals from the human body have been studied and characterized.These signals include electroencephalogram (EEG**),** electroencephalogram (EEG), electrooculography (EOG), electrocardiography (ECG), and electromyography (EMG), among others. Under different experimental conditions and measurement techniques, many of the parameters obtained have not been consistent, which continues to pose major challenges to electronics designers developing neural systems to manipulate and process these signals.

However, while these measurements results have varied primarily due to the environmental conditions (e.g. characteristics and positioning of electrodes, nature and characteristics of equipment, anatomical minor differences, presence of glands and blood vessels, different tissue fat levels, etc) under which they are obtained, there are commonalities among them.

 Our focus here is primarily on the electrical properties of the signals that are useful to circuit designers. Accordingly, we do not cover the clinical and physiological components of these signals.

Furthermore, where reported, we present the power consumption, quantization resolution and the noise figures for the published biosignal acquisition systems. It is important to clarify that some of the reported data are from discrete systems while some are from monolithic integrated systems.

Bioelectrical signals

Some of the most important bioelectrical signals are electroencephalogram (EEG), electrooculography (EOG), electrocardiography (ECG), electromyography (EMG), and neural recordings.

(a) Electroencephalography (EEG)

EEG is the measurement of electrical activity produced by the brain as recorded from electrodes placed on the surface of the scalp. When these EEG signals are analyzed, they are used in clinical setting as a diagnostic tool to detect pathologies associated with aberrant electrical behavior or stimulus-directed behavior.

(b) Neural Recordings

A method similar to the EEG is intracranial EEG (icEEG), also described as subdural EEG (sdEEG) and electrocorticography (ECoG). This signal refers to the recording of activity from the surface of the brain (rather than the scalp), i.e., the electrodes, typically an array of spikes, are inserted into the brain tissues.

While many literatures lump EEG and icEEG together, we break them apart since the techniques and the environments upon which the data are obtained make the signals to be different. Our Neural Recordings include this icEEG, neural spikes and local field potentials (LFPs).

(c) Electrooculography (EOG)

Electrooculography is a technique for measuring the resting potential of the retina with the resulting signal called the electrooculogram. This involves a record of the difference in electrical charge between the front and back of the eye that is correlated with eyeball movement and obtained by electrodes placed on the skin near the eye.

It has many applications in ophthalmological diagnosis, recording eye movements and general human-computer interface.

(d) *Electrocardiography (ECG)*

ECG is a graphic produced by an electrocardiograph, which records the electrical activity of the heart over time. When electrical waves which cause the heart muscle to pump pass through the body, they can be measured at electrodes attached to the skin thereby providing the activities of the heart muscle**.**

Using an ECG, the voltage between pairs of these attached electrodes, and the muscle activity that they measure, from different directions are displayed.

(e) *Electromyography (EMG)*

This is a method for evaluating and recording physiologic properties of resting and contracting muscles. It is used to detect the electrical potential generated by these muscle cells when they contract as well as when they are at rest.

This procedure is done with the aid of equipment named electromyograph, to produce a result called an electromyogram. An electromyograph detects the electrical potential generated by muscle cells when these cells contract, and also when the cells are at rest. Recorded measured external EMG potentials range from about 100μV to 100 mV, depending on the muscle under observation. Typically, measured

frequency range from 14Hz to 8 kHz, again based on the muscular activity under consideration.

For internal EMG, the signal amplitude ranges from 1μV to 5 mV while the frequency range is about from DC to 15 KHz.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=0uhG11LZBFs

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 32-38

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L2

LECTURE HANDOUTS

BME

III/V

Course Name with Code   : BIO MEDICAL INSTRUMENTATION AND MEASUREMENTS
                                          16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit : II - Bio-Potential Measurement of Parameters   Date of Lecture:

Topic of Lecture: ECG – Einthoven's triangle

Introduction :
- The electrocardiograph (ECG) is an instrument, which records the electrical activity of the heart.

- Electrical signals from the heart characteristically precede the normal mechanical function and

  monitoring of these signals has great clinical significance.

- ECG provides valuable information about a wide range of cardiac disorders such as the presence of an inactive part (infarction) or an enlargement (cardiac hypertrophy) of the heart muscle.

- Electrocardiographs are used in catheterization laboratories, coronary care units and for routine diagnostic applications in cardiology.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about Electric signals

- Diagnostic applications

**ECG – Einthoven's triangle :**
Block Diagram
The potentials picked up by the patient electrodes are taken to the lead selector switch. In the lead selector, the electrodes are selected two by two according to the lead program. By means of capacitive coupling, the signal is connected symmetrically to the long-tail pair differential preamplifier.

The preamplifier is usually a three or four stage differential amplifier having a sufficiently large negative current feedback,from the end stage to the first stage, which gives a stabilizing effect. The amplified output signal is picked up single-ended and is given to the power amplifier. The power amplifier is generally of the push-pull differential type.

The base of one input transistor of this amplifier is driven by the preamplified unsymmetrical signal. The base of the other transistor is driven by the feedback signal resulting from the pen position and connected via frequency selective network. The output of the power amplifier is single-ended and is fed to the pen motor, which deflects the writing arm on the paper.

A direct writing recorder is usually adequate since the ECG signal of interest has limited bandwidth.

Frequency selective network is an *R–C* network, which provides necessary damping of the pen motor and is preset by the manufacturer. The auxiliary circuits provide a 1 mV calibration signal and automatic blocking of the amplifier during a change in the position of the lead switch. It may include a speed control circuit for the chart drive motor.
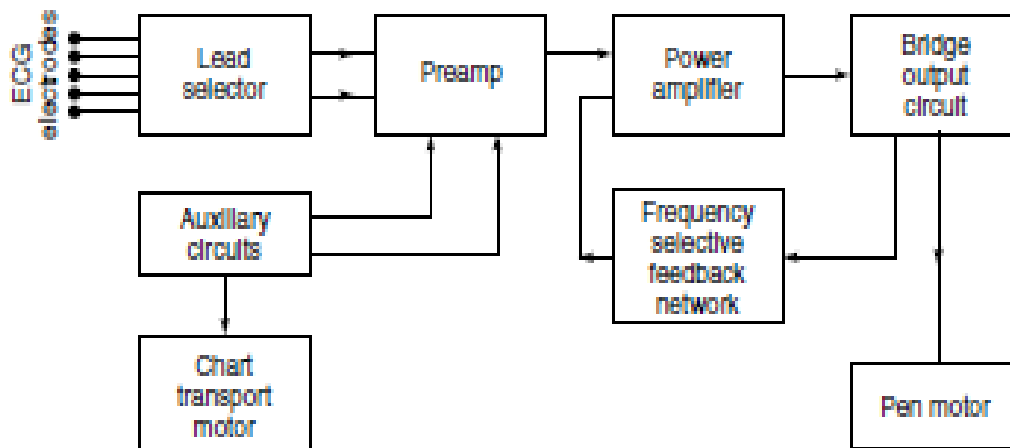
A 'stand by' mode of operation is generally provided on the electrocardiograph. In this mode, the stylus moves in response to input signals, but the paper is stationary. This mode allows the operator to adjust the gain and baseline position controls without wasting paper.

Electrocardiograms are almost invariably recorded on graph paper with horizontal and vertical lines at 1 mm intervals with a thicker line at 5 mm intervals.

Time measurements and heart rate measurements are made horizontally on the electrocardiogram. For routine work, the paper recording speed is 25 mm/s. Amplitude measurements are made vertically in millivolts. The sensitivity of an electrocardiograph is typically set at 10 mm/mV

Einthoven's Triangle
Two electrodes placed over different areas of the heart and connected to the galvanometer will pick up the electrical currents resulting from the potential difference between them.

For example, if under one electrode a wave of 1 mV and under the second electrode a wave of 0.2 mV occur at the same time, then the two electrodes will record the difference between them, i.e. a wave of 0.8 mV. The resulting tracing of voltage difference at any two sites due to electrical activity of the heart is called a "LEAD".

Bipolar Leads
In bipolar leads, ECG is recorded by using two electrodes such that the final trace corresponds to the difference of electrical potentials existing between them. They are called standard leads and have been universally adopted. They are sometimes also referred to as Einthoven leads.

In standard lead I, the electrodes are placed on the right and the left arm (RA and LA). In lead II, the electrodes are placed on the right arm and the left leg and in lead Ill, they are placed on the left arm and the left leg.
In all lead connections, the difference of potential measured between two electrodes is always with reference to a third point on the body. This reference point is conventionally taken as the "right leg". The records are, therefore, made by using three electrodes at a time, the right leg connection being always present.

In defining the bipolar leads, Einthoven postulated that at any given instant of the cardiac cycle, the electrical axis of the heart can be represented as a two dimensional vector. The ECG measured from any of the three basic limb leads is a time-variant single-dimensional component of the vector.

He proposed that the electric field of the heart could be represented diagrammatically as a triangle, with the heart ideally located at the centre. The triangle, known as the *"Einthoven triangle"*
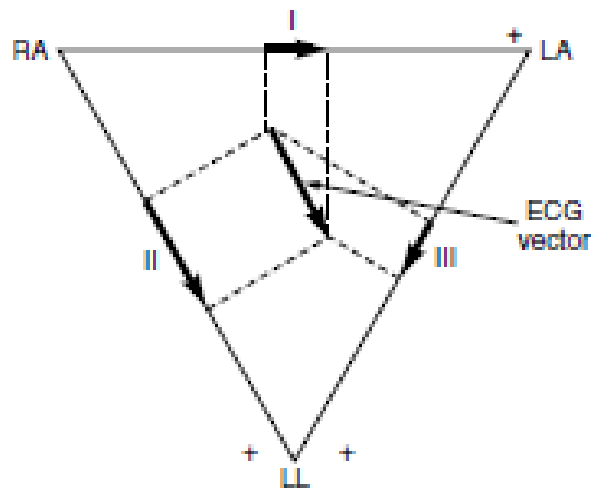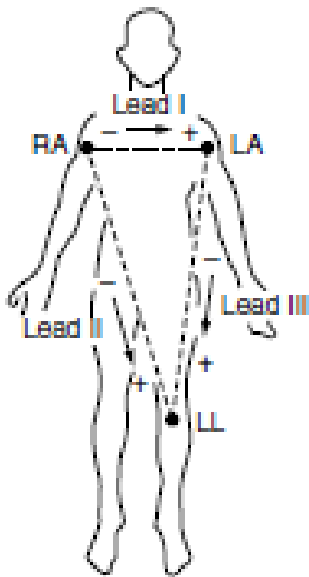
Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=BKJfB9KyQxc

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LECTURE HANDOUTS	L3

BME	III/V

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03
Course Teacher   : Mrs.D.G.BeautlinVinola

Unit : II - Bio-Potential Measurement of Parameters   Date of Lecture:

Topic of Lecture: ECG - standard 12 lead system

Introduction :
- Two electrodes placed over different areas of the heart and connected to the galvanometer will pick up the electrical currents resulting from the potential difference between them.

- For example,if under one electrode a wave of 1 mV and under the second electrode a wave of 0.2 mV occur at the same time, then the two electrodes will record the difference between them, i.e. a wave of 0.8 mV.

- The resulting tracing of voltage difference at any two sites due to electrical activity of the heart is called a "LEAD"

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic principles of Electrode

- Potential difference

ECG - standard 12 lead system
Bipolar Leads
In bipolar leads, ECG is recorded by using two electrodes such that the final trace corresponds to the difference of electrical potentials existing between them. They are called standard leads and have been universally adopted. They are sometimes also referred to as Einthoven leads.

In standard lead I, the electrodes are placed on the right and the left arm (RA and LA). In lead II, the electrodes are placed on the right arm and the left leg and in lead Ill, they are placed on the left arm and the left leg.
 In all lead connections, the difference of potential measured between two electrodes is always with reference to a third point on the body. This reference point is conventionally taken as the "right leg". The records are, therefore, made by using three electrodes at a time, the right leg connection being always present

In defining the bipolar leads, Einthoven postulated that at any given instant of the cardiac cycle, the electrical axis of the heart can be represented as a two dimensional vector. The ECG measured from any of the three basic limb leads is a time-variant single-dimensional component of the vector.

He proposed that the electric field of the heart could be represented diagrammatically
as a triangle, with the heart ideally located at the centre.The sides of the triangle represent the lines
along which the three projections of the ECG vector are measured. It was shown that the instantaneous
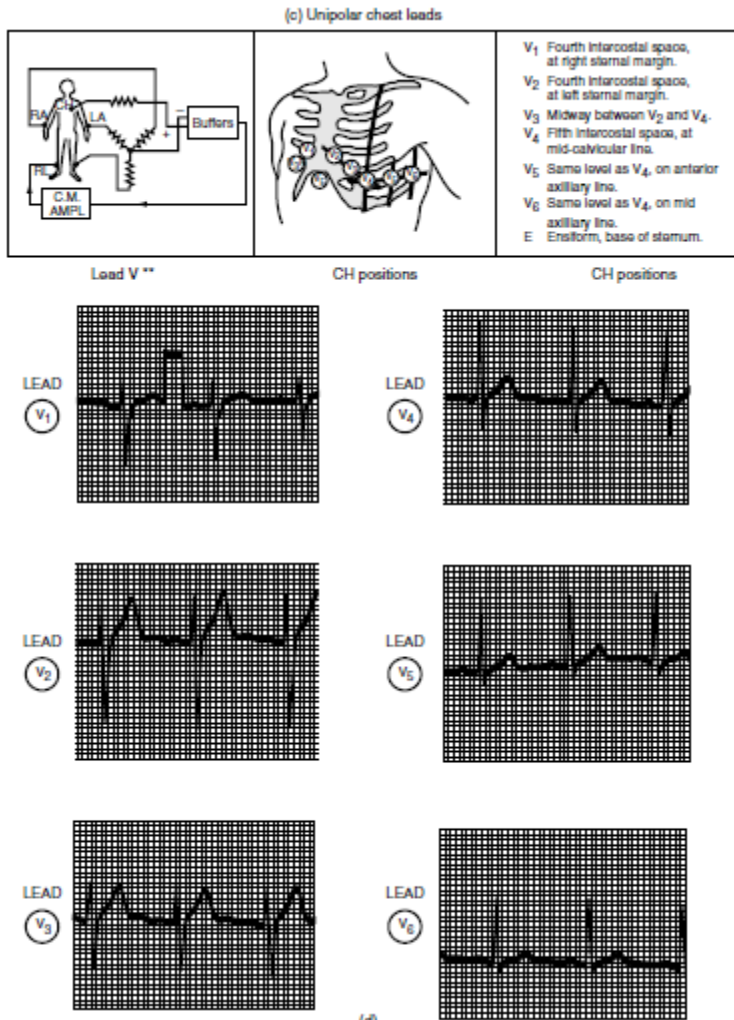voltage measured
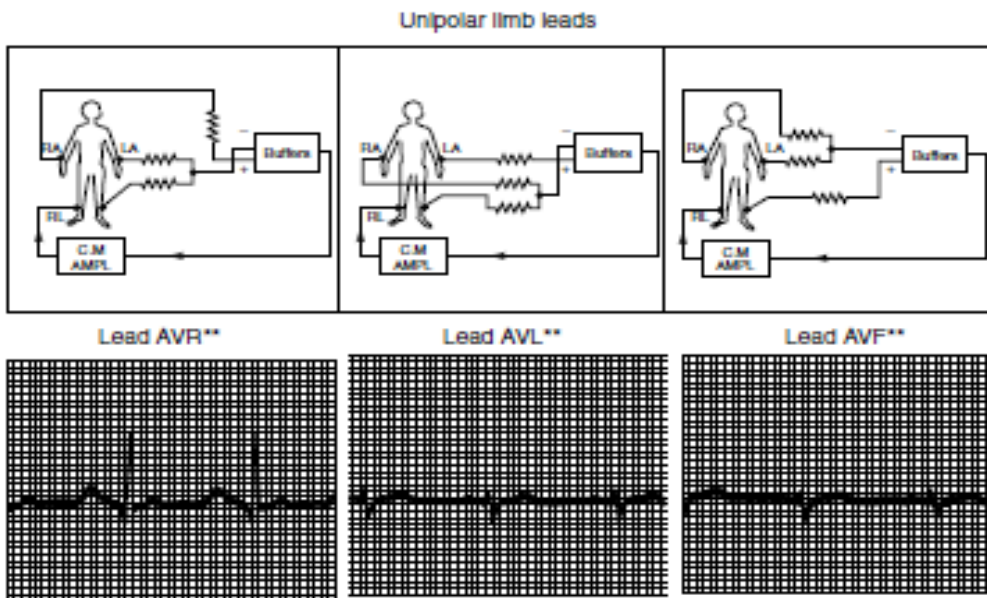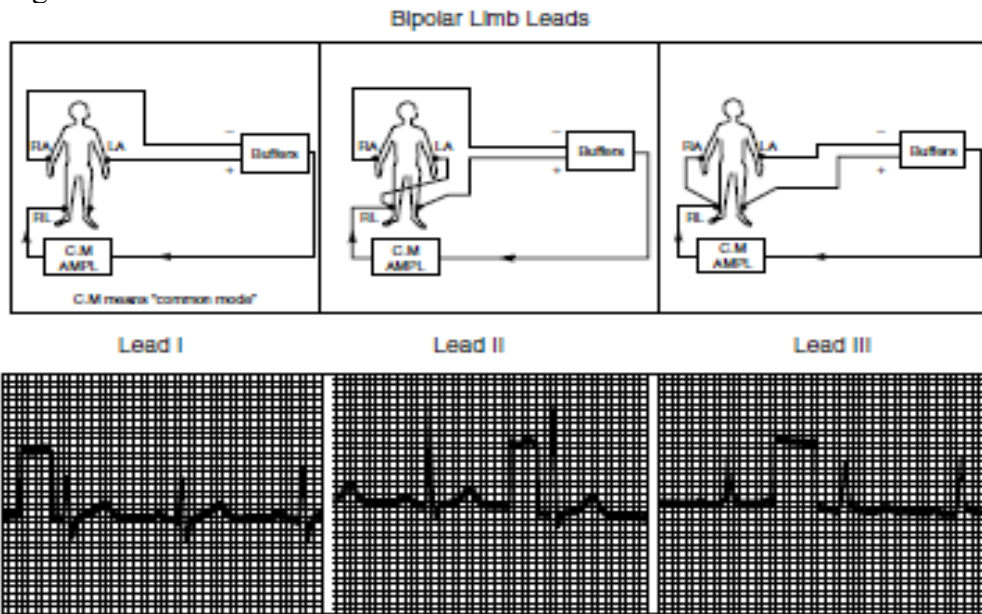
(a) bipolar limb leads
(b) unipolar limb leads

from any one of the three limb lead positions is approximately equal to the algebraic sum of the
other two or that the vector sum of the projections on all three lines is equal to zero.
In all the bipolar lead positions, *QRS* of a normal heart is such that the *R* wave is positive and
is greatest in lead II

(c) position of the chest lead in unipolar precordial lead recording
(d) C leads

Unipolar Leads (V Leads)
The standard leads record the difference in electrical potential between two points on the body produced by the heart's action. Quite often, this voltage will show smaller changes than either of the potentials and so better sensitivity an be obtained if the potential of a single electrode is recorded. Moreover, if the electrode is placed on the chest close to the heart, higher potentials can be detected than normally available at the limbs.

This lead to the development of unipolar leads introduced by Wilson in 1894. In this arrangement, the electrocardiogram is recorded between a single exploratory electrode and the central terminal, which has a potential corresponding to the centre of the body.
In practice, the reference electrode or central terminal is obtained by a combination of several electrodes tied together at one point. Two types of unipolar leads are employed which are: (i) limb leads, and (ii) precordial leads.

(i) Limb leads
In unipolar limb leads two of the limb leads are tied together and recorded with respect to the third limb. In the lead identified as AVR, the right arm is recorded with respect to a reference established by joining the left arm and left leg electrodes.

In the AVL lead, the left arm is recorded with respect to the common junction of the right arm and left leg. In the AVF lead, the left leg is recorded with respect to the two arm electrodes tied together. They are also called augmented leads or 'averaging leads'. The resistances inserted between the electrodes-machine connections are known as 'averaging resistances'.

(ii) Precordial leads

The second type of unipolar lead is a precordial lead. It employs an exploring electrode to record the potential of the heart action on the chest at six different positions. These leads are designated by the capital letter 'V' followed by a subscript numeral, which represents the position of the electrode on the pericardium.

Video content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=BKJfB9KyQxc

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 157-161

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Estd. 2000

IQAC

L4

LECTURE HANDOUTS

BME

III/V

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03

Course Teacher : Mrs.D.G.BeautlinVinola

Unit : II - Bio-Potential Measurement of Parameters   Date of Lecture:

Topic of Lecture: Principles of vector cardiography
Introduction : • Vector cardiography is the technique of analysing the electrical activity of heart by obtaining ECG along three axis. The display is know as vector cardiogram. • This gives the representation of distribution of electrical potential generated by the heart and produces loop type patterns on the CRT screen.
Prerequisite knowledge for Complete understanding and learning of Topic: • Basic knowledge about Cardiography • Basics of Electric Potential
Principles of vector cardiography Vectorcardiography is the technique of analyzing the electrical activity of the heart by obtaining ECG's along three axes at right angles to one another and displaying any two of these ECGs as a vector display on an X-Y oscilloscope. The display is known as a vectorcardiogram (VCG). In contrast, the electrocardiogram which displays the electrical potential in any one single axis, the vectorcardiogram displays the same electrical events simultaneously in two perpendicular axes. This gives a vectorial representation of the distribution of electrical potentials generated by the heart, and produces loop type patterns on the CRT screen. Usually a photograph is taken of each cardiac cycle. From such pictures, the magnitude and orientation of the P, Q, R, S and T vector loops are determined. Vectorcardiogram [QRS T]
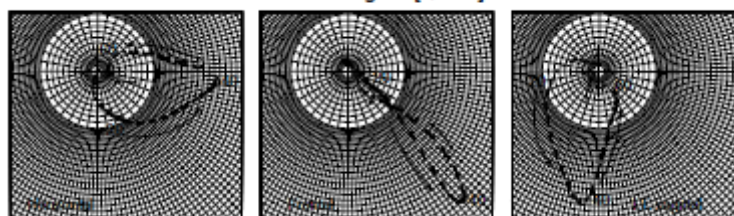
VCG illustrates the phase differences between the voltages and also the various leads from which it is derived. The major information that it provides is the direction of depolarization and repolarization of the atria and the ventricles. Each vectorcardiogram exhibits three loops, showing the vector orientation of the *P* wave, the *QRS*axis and the *T* wave. Because of the high amplitude associated with *QRS,* loops from the *QRS* complex predominate.

An increase in horizontal and vertical deflection sensitivities is normally required to adequately display the loops resultingfrom the *P* wave and *T* wave. Bourne describes circuit details of an automated vector ECG recording system.

The VCG has been demonstrated to be superior to the standard 12-lead scalar electrocardiogram in the recognition of undetected atrial and ventricular hypertrophy, sensitivity in identification of myocardial infarction and capability for diagnosis of multiple infarctions in the presence of fascicular and bundle branch blocks.

Video Content / Details of website for further learning (if any):

https://www.bem.fi/book/16/16.htm

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :166-167

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L5

LECTURE HANDOUTS

BME

III/V

Course Name with Code	: BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS 16BMD03
Course Teacher	: Mrs.D.G.BeautlinVinola

Unit : II - Bio-Potential Measurement of Parameters   **Date of Lecture:**

Topic of Lecture: EEG – 10-20 electrode system

Introduction :
- Electroencephalograph is an instrument for recording the electrical activity of the brain, by suitably

  placing surface electrodes on the scalp.

- EEG, describing the general function of the brain activity,is the superimposed wave of neuron potentials operating in a non-synchronized manner in the physical sense.

- Its stochastic nature originates just from this, and the prominent signal groups can

  be empirically connected to diagnostic conclusions

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic principles of Electrodes

- Neuron potentials

EEG – 10-20 electrode system

Block Diagram Description of EEG

Montages: A pattern of electrodes on the head and the channels they are connected to is called a montage. Montages are always symmetrical. The reference electrode is generally placed on a nonactive site such as the forehead or earlobe. EEG electrodes are arranged on the scalp according to a standard known as the 10/20 system, adopted by the American EEG Society.

Traditionally, there are 21 electrode locations in the 10/20 system. This system involves placement of electrodes at distances of 10% and 20% of measured coronal, sagittal and circumferential arcs between landmarks on the cranium.

 Electrodes are identified according to their position on the head: **Fp**for frontal-polar, **F** for frontal, **C** for central, **P** for parietal, **T** for temporal and **O** for occipital. Odd numbers refer to electrodes on the

left side of the head and even numbers rep placed at a relatively neutral site on the head, usually the midline forehead.

A new montage convention has recently been introduced in which electrodes are spaced at 5% distances along the cranium. These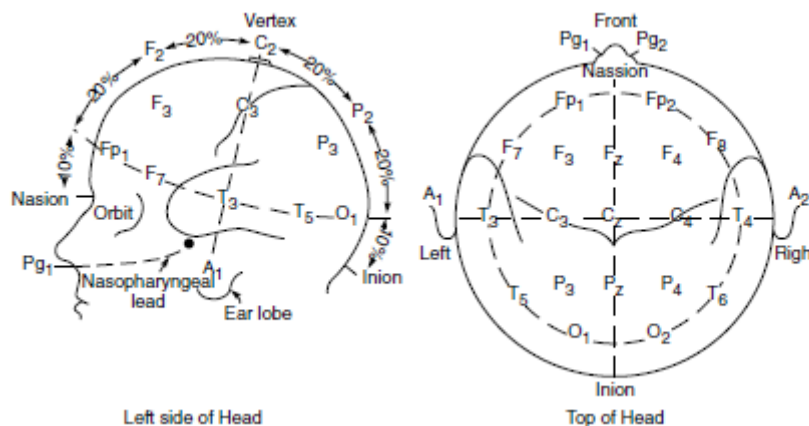 electrodes are called closely spaced electrodes and have their own naming conventionresentthose on the right while **Z** denotes midline electrodes.
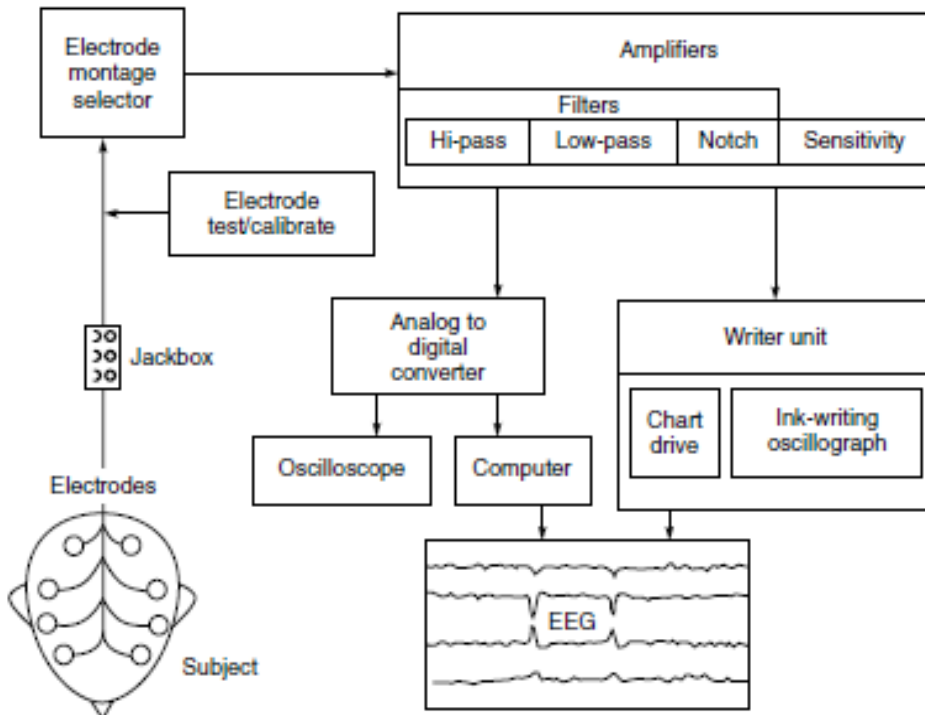
Schematic diagram of an EEG machine

Left side of Head   Top of Head

10-20 system of placement of electrodes

Electrode Montage Selector

EEG signals are transmitted from the electrodes to the head box,which is labelled according to the 10–20 system, and then to the montage selector. The montage selector on analog EEG machine is a large panel containing switches that allow the user to select which electrode pair will have signals subtracted from each other to create an array of channels of output called a montage
.

 Each channel is created in the form of the input from one electrode minus the input from a second electrode.Montages are either bipolar (made by the subtraction of signals from adjacent electrode pairs) or referential (made by subtracting the potential of a common reference electrode from each electrode on the head).

In order to minimize noise, a separate reference is often chosen for each side of the head e.g. the ipsilateral ear. Bipolar and referential montages contain the same basic information that is transformable into either format by simple substration as long as all the electrodes, including reference,

are included in both montages and linked to one common reference.

Many modern digital EEG machines record information referentially, allowing easy conversion to several different bipolar montages. The advantage of recording EEG in several montages is that each montage displays different spatial characteristics of the same data.

Preamplifier

Every channel has an individual, multistage, ac coupled, very sensitive amplifier with differential input and adjustable gain in a wide range. Its frequency response can be selected by single-stage passive filters.

A calibrating signal is used for controlling and documenting the sensitivity of the amplifier channels. This supplies a voltage step of ad **Sensitivity Control:** The overall sensitivity of an EEG machine is the gain of the amplifier multiplied by the sensitivity of the writer. Thus, if the writer sensitivity is 1 cm/V, the amplifier must have an overall gain of 20,000 for a 50 mV signal. The various stages are capacitor coupled.

An EEG machine has two types of gain controls. One is continuously variable and it is used to equalize the sensitivities of all channels. The other control operates in steps and is meant to increase or reduce the sensitivity of a channel by known amounts.

This control is usually calibrated in decibels. The gain of amplifiers is normally set so that signals of about 200 mV deflect the pens over their full linear range. Artefacts, several times greater than this, can cause excessive deflections of the pen by charging the coupling capacitors to large voltages.

This will make the system unusable over a period depending upon the value of the coupling capacitors. To overcome this problem, most modern EEG machines have de-blocking circuits similar to those used in ECG machines.

Filters

Just like in an ECG when recorded by surface electrodes, an EEG may also contain muscle artefacts due to contraction of the scalp and neck muscles, which overlie the brain and skull. The artefacts are large and sharp, in contrast to the ECG, causing great difficulty in both clinical and automated EEG interpretation.

The most effective way to eliminate muscle artefact is to advise the subject to relax, but it is not always successful. These artefacts are generally removed using lowpass filters. This filter on an EEG machine has several selectable positions, which are usually labelled in terms of a time constant. A typical set of time constant values for the low-frequency control are 0.03, 0.1, 0.3

Video Content / Details of website for further learning (if any):

https://www.slideshare.net/mohibullahfazli/10-and-20-electrode-placement

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 171-174

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L6

LECTURE HANDOUTS

BME		**III/V**

Course Name with Code   **: BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS**
                                           16BMD03

Course Teacher   **: Mrs.D.G.BeautlinVinola**

Unit : II - Bio-Potential Measurement of Parameters   **Date of Lecture:**

Topic of Lecture: EEG -unipolar, bipolar and average mode

Introduction :
- Electroencephalograph is an instrument for recording the electrical activity of the brain, by suitably placing surface electrodes on the scalp.

- EEG, describing the general function of the brain activity,is the superimposed wave of neuron potentials operating in a non-synchronized manner in the physical sense.

- Its stochastic nature originates just from this, and the prominent signal groups can be empirically connected to diagnostic conclusions

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic principles of Electrodes

- Neuron potentials

EEG -unipolar, bipolar and average mode

Monitoring the electroencephalogram has proven to be an effective method of diagnosing many neurological illnesses and diseases, such as epilepsy, tumour, cerebrovascular lesions, ischemia and problems associated with trauma.

It is also effectively used in the operating room to facilitate anaesthetics and to establish the integrity of the anaesthetized patient's nervous system. This has become possible with the advent of small, computer-based EEG analyzers. Consequently, routine EEG monitoring in the operating room and intensive care units is becoming popular.

EEG electrodes are smaller in size than ECG electrodes. They may be applied separately to the scalp or may be mounted in special bands, which can be placed on the patient's head. In either case, electrode jelly or paste is used to improve the electrical contact. If the electrodes are intended to be used under the skin of the scalp, needle electrodes are used.

They offer the advantage of reducing movement artefacts. EEG electrodes give high skin contact impedance as compared to ECG electrodes. Good electrode impedance should be generally below 5

kilohms. Impedance between a pair of electrodes must also be balanced or the difference between them should be less than 2 kilohms.

EEG preamplifiers are generally designed to have a very high value of input iEEG may be recorded by picking up the voltage difference between an active electrode on the scalp with respect to a reference electrode on the ear lobe or any other part of the body.

This type of recording is called 'monopolar' recording. However, 'bipolar' recording is more popular wherein the voltage difference between two scalp electrodes is recorded. Such recordings are done with multi-channel electroencephalographs.

EEG signals picked up by the surface electrodes are usually small as compared with the ECG signals. They may be several hundred microvolts, but 50 microvolts peak-to-peak is the most typical.
The brain waves, unlike the electrical activity of the heart, do not represent the same pattern over and over again. Therefore, brain recordings are made over a much longer interval of time in order to be able to detect any kind of abnormalities.mpedance to take care of high electrode impedance

Bipolar

In a bipolar measurement, the potential difference between a pair of electrodes is amplified by one amplifier channel.

Unipolar

In a unipolar measurement the output signals are formed by several input electrodes that are all amplified against one so called reference. This reference can be an electrode (the common reference electrode), or a calculated internal reference potential consisting of two or more electrode signals. This is never done by one amplifier channel, but always in a multichannel set-up (with a minimum of two channels).

This type of recording is often used when measuring EEG or multichannel ECG. A new field of unipolar measurements is the high density surface EMG, where for instance 128 channels are measured using so called grid electrodes.

As a result of the above, two types of unipolar amplifier principles can be distinguished:

- The common reference amplifier
- The average reference amplifier

The common reference amplifier amplifies the signal of each unipolar electrode against the signal from one common electrode, which is thus present in each of the outputs. In EEG, a variant of this is sometimes used by amplifying each unipolar electrode against the mean of the two ear-electrodes, the so called 'linked-ears'.

In the average reference amplifier there is no electrode that acts as the reference for the measurement system. Instead, each of the unipolar electrodes is amplified against the average of all the connected unipolar electrodes.

The average reference principle has several advantages over the common reference principle. The first one is very obvious: if the reference electrode is bad (or worse yet, falls off entirely), it does not invalidate the entire recording. Also, from an amplifier-technical point of view, it is beneficial not to have one electrode 'distributed' over all input channels. The average-reference principle, as employed by TMSi, can be seen as the multi-channel counterpart of the well know instrumentation amplifier that has been used in electrophysiology for decades.

It should be stressed, that the way in which signals are recorded and the way they are analyzed are two

different things: as long as electrodes are included in the measurement set-up, they can always be 're-montaged' in software. Thus, common mode montages can be derived from average reference recordings and vice versa. Also, special montages like the so-called Wilson Central Terminal in ECG can easily be derived.

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Video Content / Details of website for further learning (if any):

https://www.tmsi.com/blog/measurement-principles/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 171-174

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L7

LECTURE HANDOUTS

BME

III/V

Course Name with Code   : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit : II - Bio-Potential Measurement of Parameters   Date of Lecture:

Topic of Lecture : Electromyograph

Introduction :
- Electromyograph is an instrument used for recording the electrical activity of the muscles to

  determine whether the muscle is contracting or not; or for displaying on the CRO and loudspeaker the action potentials spontaneously present in a muscle or those induced by voluntary contractions as a means of detecting the nature and location of motor unit lesions; or for recording the electrical activity evoked in a muscle by the stimulation of its nerve.

- The instrument is useful for making a study of several aspects of neuromuscular function, neuromuscular condition, extent of nerve lesion, reflex responses, etc.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about electrical activity of muscles

- Basics of neuromuscular function

Electromyograph

EMG measurements are also important for the myoelectric control of prosthetic devices (artificial limbs). This use involves picking up EMG signals from the muscles at the terminated nerve endings of the remaining limb and using the signals to activate a mechanical arm.

This is the most demanding requirement from an EMG since on it depends the working of the prosthetic device.EMG is usually recorded by using surface electrodes or more often by using needle electrodes,which are inserted directly into the muscle. The surface electrodes may be disposable, adhesive types or the ones which can be used repeatedly. A ground electrode is necessary for providing a common reference for measurement.

These electrodes pick up the potentials produced by the contracting muscle fibres. The signal can then be amplified and displayed on the screen of a cathode ray tube. It is also applied to an audioamplifier connected to a loudspeaker. A trained EMG interpreter can diagnose various muscular disorders by listening to the sounds producedwhen the muscle potentials are fed to the loudspeaker. oscilloscopedisplays EMG waveforms.

The tape recorder is included in the system to facilitate playback and study of the EMG sound waveforms at a later convenient time. The waveform can also be photographed from the CRT screen by using a synchronized camera. The amplitude of the EMG signals depends upon various factors, e.g. the type and placement of electrodes used and the degree of muscular exertions.

The needle electrode in contact with a single muscle fibre will pick up spike type voltages whereas a surface electrode picks up many overlapping spikes and therefore produces an average voltage effect. A typical EMG signal rangesfrom 0.1 to 0.5 mV.

They may contain frequency components extending up to 10 kHz. Such high frequency signals cannot be recorded on the conventional pen recorders and therefore, they are usually displayed on the CRT screen. Modern EMG machines are PC based available both in console as well as laptop models.

**PC based digital EMG recording and reviewing system for 2 to 4 channels**

Preamplifier

The preamplifiers used for EMG are generally of differential type with a good bandwidth. The input impedance of the amplifier must be greater than 2 \ 50 MW. Present day electronic devices easily provide input impedances of the order of 1012 ohms in parallel with 5 picofarads.

It is preferable to mount the preamplifiers very near the subject using very small electrode leads, in order to avoid the undesirable effects of stray capacitance between connecting cables and the earth. Also, any movement of the cable from the output of the electrode will not generate significant noise signals in the cable, which feeds into the subsequent amplifier.

The preamplifier provides an output with low impedance and, therefore, the high frequencies do not get attenuated even if long cables are used to connect the preamplifier and the rest of the machine. The common-mode rejection should be greater than 90 dB up to 5 kHz.

A calibrating square wave signal of 100 mV (peak-to-peak) at a frequency of 100 Hz is usually available. The main amplifier has controls for gain adjustment from 5 mV/div to 10 mV/div for selecting the sensitivity most appropriate to the incoming signal from the patient.
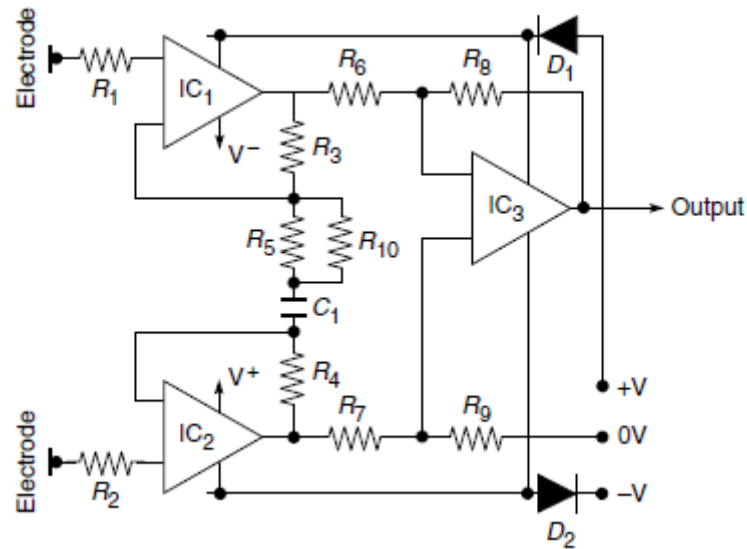
Pre-amplifier circuit for an EMG machine

Video Content / Details of website for further learning (if any):

https://www.healthline.com/health/electromyography

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :178-180

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	L8
LECTURE HANDOUTS	

BME	**III/V**

Course Name with Code   : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
        16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit : II - Bio-Potential Measurement of Parameters   Date of Lecture:

Topic of Lecture: EMG – unipolar and bipolar mode

Introduction :

- Electromyograph is an instrument used for recording the electrical activity of the muscles to

  determine whether the muscle is contracting or not; or for displaying on the CRO and loudspeaker the action potentials spontaneously present in a muscle or those induced by voluntary contractions as a means of detecting the nature and location of motor unit lesions; or for recording the electrical activity evoked in a muscle by the stimulation of its nerve.

- The instrument is useful for making a study of several aspects of neuromuscular function, neuromuscular condition, extent of nerve lesion, reflex responses, etc.

Prerequisite knowledge for Complete understanding and learning of Topic:
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- Basics of neuromuscular function

EMG – unipolar and bipolar mode

EMG measurements are also important for the myoelectric control of prosthetic devices (artificial limbs). This use involves picking up EMG signals from the muscles at the terminated nerve endings of the remaining limb and using the signals to activate a mechanical arm.

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The surface electrodes may be disposable, adhesive types or the ones which can be used repeatedly. A ground electrode is necessary for providing a common reference for measurement.

In a bipolar measurement, the potential difference between a pair of electrodes is amplified by one amplifier channel. In a unipolar measurement the output signals are formed by several input electrodes that are all amplified against one so called reference.

This reference can be an electrode (the common reference electrode), or a calculated internal reference potential consisting of two or more electrode signals. This is never done by one amplifier channel, but always in a multichannel set-up (with a minimum of two channels). This type of recording is often

used when measuring EEG or multichannel ECG. A new field of unipolar measurements is the high density surface EMG, where for instance 128 channels are measured using so called grid electrodes.

As a result of the above, two types of unipolar amplifier principles can be distinguished:

- The common reference amplifier
- The average reference amplifier

The common reference amplifier amplifies the signal of each unipolar electrode against the signal from one common electrode, which is thus present in each of the outputs. In EEG, a variant of this is sometimes used by amplifying each unipolar electrode against the mean of the two ear-electrodes, the so called 'linked-ears'.

In the average reference amplifier there is no electrode that acts as the reference for the measurement system. Instead, each of the unipolar electrodes is amplified against the average of all the connected unipolar electrodes.

The average reference principle has several advantages over the common reference principle. The first one is very obvious: if the reference electrode is bad (or worse yet, falls off entirely), it does not invalidate the entire recording. Also, from an amplifier-technical point of view, it is beneficial not to have one electrode 'distributed' over all input channels.

The average-reference principle, as employed by TMSi, can be seen as the multi-channel counterpart of the well know instrumentation amplifier that has been used in electrophysiology for decades.

It should be stressed, that the way in which signals are recorded and the way they are analyzed are two different things: as long as electrodes are included in the measurement set-up, they can always be 're-montaged' in software.

Thus, common mode montages can be derived from average reference recordings and vice versa. Also, special montages like the so-called Wilson Central Terminal in ECG can easily be derived.

Video Content / Details of website for further learning (if any):
https://www.tmsi.com/blog/measurement

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :180

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IQAC

| L9 |

| **LECTURE HANDOUTS** |

| **BME** |

| **III/V** |

Course Name with Code   : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
                          16BMD03
Course Teacher   :Mrs.D.G.BeautlinVinola

Unit : II - Bio-Potential Measurement of Parameters   Date of Lecture:

Topic of Lecture: Recording of ERG& EOG.

Introduction :
- The electroretinogram (ERG) is a diagnostic test that measures the electrical activity of the retina in response to a light stimulus.

- Electrooculography (EOG) is a technique for measuring the corneo-retinal standing potential that exists between the front and the back of the human eye.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics of electrical activity of retina

- Basics of potential difference

Recording of ERG& EOG.

Recording of ERG

It is found that an electrical potential exists between the cornea and the back of the eye. This potential changes when the eye is illuminated. The process of recording the change in potential when light falls on the eye is called electroretinography.

ERG potentials can be recorded with a pair of electrodes. One of the electrodes is mounted on a contact lens and is in direct contact withthe cornea. The other electrode is placed on the skin adjacent to the outer corner of the eye.

A reference electrode may be placed on the forehead. A general purpose direct writing recorder may be used for recording electroretinograms. The magnitude of the ERG voltage depends upon the intensity and duration of the light falling on the eye. It may be typically about 500 mV Preparation of patient

        Avoid fundus photography, fundus autofluorescence, fluorescein angiography, and other intense illumination before ERG recording. If this is unavoidable, allow at least 30 min recovery time in ordinary room illumination.
        Maximally dilate the pupils (note pupil size before testing).There is no need to correct

refractive error.

       Before dark-adapted protocols: 20 min of dark-adaptation.
       Before light-adapted protocols: 10 min of light-adaptation.

       If corneal contact lens electrodes are inserted after dark-adaptation, this should be performed under dim red light. Allow 5 min of extra dark adaptation after insertion of contact lens electrodes.
       Present low strength flashes before stronger flashes to avoid partial light adaptation from strong flashes.
       Request the patient to fixate steadily and not move his/her eyes. Ocular movements introduce large electrical artifacts, change electrode position, and may cause blockage of light by the eyelids/electrode.

Recording electrodes: in contact with cornea, bulbar conjunctiva, or skin below lower eyelid

       Protect corneal surface with non-irritating ionic conductive solution (artificial tears or contact lens solutions containing sodium chloride and no more viscous than 0.5% methyl cellulose). Improper installation of contact lens electrodes can cause corneal abrasions.Topical anesthesia is used for contact lens electrodes, but may not be necessary for DTL electrodes.

Types of Recording Electrodes

       Burian-Allen (BA): consists of an annular ring of stainless steel surrounding a polymethylmethacrylate (PMMA) contact-lens core. BA electrodes incorporate a lid speculum, which helps to minimize eye blinks/closure. BA lenses are reusable and are available in sizes ranging from pediatric to adult.

       Dawson-Trick-Litzkow (DTL): Low-mass conductive silver/nylon thread. DTL electrodes are disposable and are typically more comfortable for the patients, as compared to other corneal electrodes.

       Jet: disposable plastic lens with a gold-plated peripheral circumference.

       Skin Electrode: may be used as a replacement for corneal electrodes by placing an electrode on the skin over the infraorbital ridge near lower eyelid. ERG amplitudes tend to be small and noisy, but skin electrodes are better-tolerated in pediatric populations.

       Mylar Electrode: aluminized or gold-coated Mylar (not in common use).

       Cotton-Wick: Burian-Allen electrode shell fitted with a cotton wick, which is useful for minimizing light-induced artifacts (not in common use).

       Hawlina-Konec Electrode: Teflon-insulated thin metal wire (silver, gold, platinum) with three central windows, 3 mm in length, molded to fit into the lower conjunctival sac (not in common use).

       Recording of EOG

Electrooculography (EOG) is a technique for measuring the corneo-retinal standing potential that exists between the front and the back of the human eye. The resulting signal is called the electrooculogram. Primary applications are in ophthalmological diagnosis and in recording eye movements. Unlike the electroretinogram, the EOG does not measure response to individual visual stimuli.

To measure eye movement, pairs of electrodes are typically placed either above and below the eye or to the left and right of the eye. If the eye moves from center position toward one of the two electrodes, this electrode "sees" the positive side of the retina and the opposite electrode "sees" the negative side of the retina. Consequently, a potential difference occurs between the electrodes. Assuming that the resting potential is constant, the recorded potential is a measure of the eye's position

Video Content / Details of website for further learning (if any):

https://www.medicine.mcgill.ca/physio/vlab/Other_exps/EOG/eogintro_n.htm
https://webvision.med.utah.edu/book/electrophysiology/the-electroretinogram-erg/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No :183

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LECTURE HANDOUTS	L1

BME	III/V

Course Name with Code :BIO MEDICAL INSTRUMENTATION AND MEASUREMENTS
16BMD03
Course Teacher **:Mrs.D.G.BeautlinVinola**

Unit: III - Bio Amplifier and Signal Conditioning Circuits **Date of Lecture:**

Topic of Lecture: Need for bio-amplifier - single ended bio-amplifier

Introduction :
- A Bioamplifier 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

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics principles of Amplifier

- Placement of Electrodes

Need for bio-amplifier - single ended bio-amplifier

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

Every bio-amplifier should consist of isolation and protection circuits, to prevent the patients from electrical shocks.

For biophysical measurements, the amplifiers employed include:

(i) ac/dc universal amplifier with special features such as capacity neutralization, current injection, low leakage current and low dc drift suitable for intracellular measurements through high resistance fluid-filled electrodes or to make extracellular recordings through metal microelectrodes for EMG, EEG, EOG, etc.
 (ii) an ECG amplifier with full 12 lead selection and patient isolation
(iii) a transducer amplifier suited for bridge measurements on strain gauges, strain gauge based blood pressure transducers, force transducers, resistance temperature devices and direct low level dc input signals
(iv) a dc amplifier used in conjunction with standard thermistor probes for the accurate measurement of temperature within the range of medical applications

Basic Requirements for Biological Amplifiers

1. 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.

2. When electrodes pick up biopotentials from the human body, the input circuit should be protected. Every bio-amplifier should consist of isolation and protection circuits, to prevent the patients from electrical shocks.

3. Since the output of a bioelectric signal is in millivolts or microvolt range, the voltage gain value of the amplifier should be higher than 100dB.

4. Throughout the entire bandwidth range, a constant gain should be maintained.

5. A bio-amplifier should have a small output impedance.

6. A good bio-amplifier should be free from drift and noise.

7. Common Mode Rejection Ratio (CMRR) value of amplifier should be greater than 80dB to reduce the interference from common mode signal.

8. The gain of the bio-amplifier should be calibrated for each measurement.

Single- Ended Amplifier

Single ended amplifier, amplifies the difference between its single input and ground.There are however problems with this method of cabling and transporting signals.The main problem is that ground is not a constant 0V

With a connection between two quite different grounds, the difference in these levels can cause large currents to flow, these are commonly known as earth or ground loops.

Single ended inputs can suffer from noise injection.Noise can be injected into signals because the wire that carries the signals can act as an aerial and thus pick up all manner of electrical background noise.Once this noise has been introduced into the signal this way there is no way to remove it.

General amplifier circuit symbol
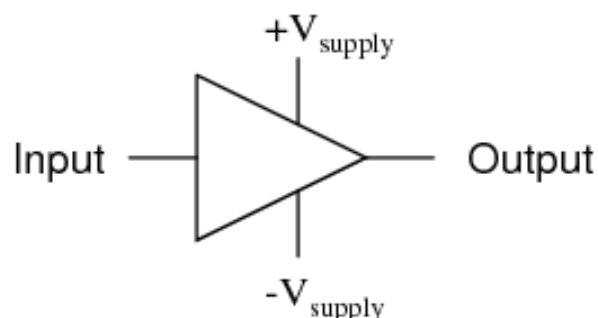
Video Content / Details of website for further learning (if any):

https://www.electrical4u.com/biological-amplifiers/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 114 -115

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L2

LECTURE HANDOUTS

BME		III/V

Course Name with Code : BIO MEDICAL INSTRUMENTATION AND MEASUREMENTS
16BMD03

Course Teacher : Mrs.D.G.BeautlinVinola

Unit: III - Bio Amplifier and Signal Conditioning Circuits   **Date of Lecture:**

Topic of Lecture: Differential bio-amplifier

Introduction :
- Medical amplifiers designed for use in the input stage (preamplifiers) are mostly of the differential type.

- These type have three input terminals out of which one is arranged at the reference potential and the other two are live terminals.

- The differential amplifier is employed when it is necessary to measure the voltage difference between two points, both of them varying in amplitude at different rates and in different patterns

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Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about Amplifier

- Basics of potential difference

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Differential bio-amplifier

Heart-generated voltages picked up by means of electrodes on the arms and legs, and brain-generated voltages picked up by the electrodes on the scalp are typical examples of signals whose measurement requires the use of differential amplifiers.

The differential amplifier is an excellent device for use in the recording systems. Its excellence lies in its ability to reject common-mode interference signals which are invariably picked up by electrodes from the body along with the useful bioelectric signals. Also, 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 a good many applications, e.g.applications requiring floating inputs and outputs or for applications where grounded inputs and/or outputs are desirable.

The working of a differential amplifier can be explained with the help of Fig. 4.2 where the two

transistors with their respective collector resistances ($R1$ and $R2$) form a bridge circuit. If the two resistors and the characteristics of the two transistors are identical, the bridge is perfectly balanced and the potential difference across the output terminals is zero.
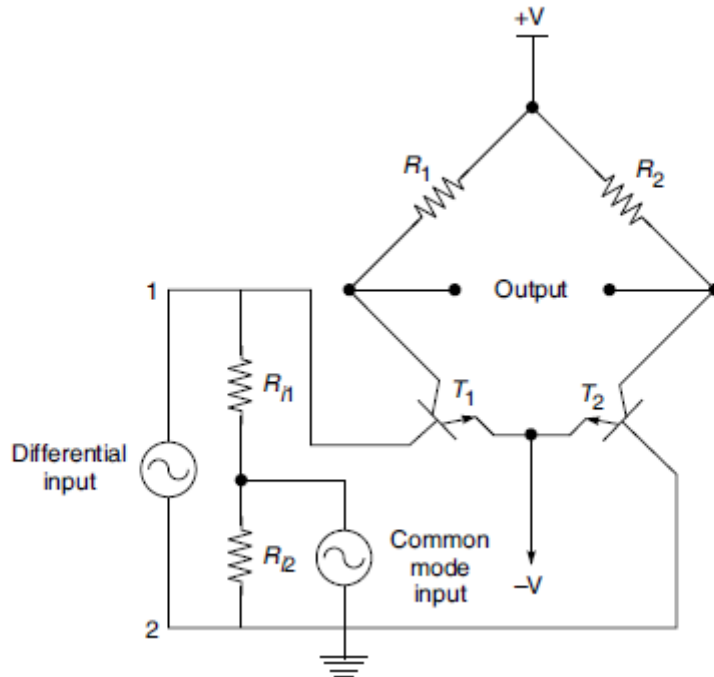
**Typical differential amplifier configuration**

no output at all for common-mode signals. Resistances $Ri1$ and $Ri2$ are current limiting resistances for common-mode signals.The ability of the amplifier to reject these common voltages on its two input leads is known as common-mode rejection and is specified as the ratio of common-mode input to differential input to elicit the same response. It is abbreviated as CMRR (Common-mode rejection ratio).
 CMRR is animportant specification referred to the differential amplifier and is normally expressed as decibels.CMRR of the preamplifiers should be as high as possible so that only the wanted signals find away through the amplifier and all unwanted signals get rejected in the preamplifier stage.

A highrejection ratio is usually achieved by the use of a matched pair of transistors in the input stage of the preamplifier and a large 'tail' resistance in the long-tailed pair to provide maximum negative feedback for inphase signals.

The technique of long-tailing (a technique used to current drive an active device) improves the CMRR in differential amplifiers without upsetting the gain for the desired signal. Very high CMRR can be achieved with the use of an active long-tail.

In order to be able to minimize the effects of changes occurring in the electrode impedances, it is necessary to employ a preamplifier having a high input impedance. It has been found that a low value of input impedance gives rise to a considerable distortion of the recordings.
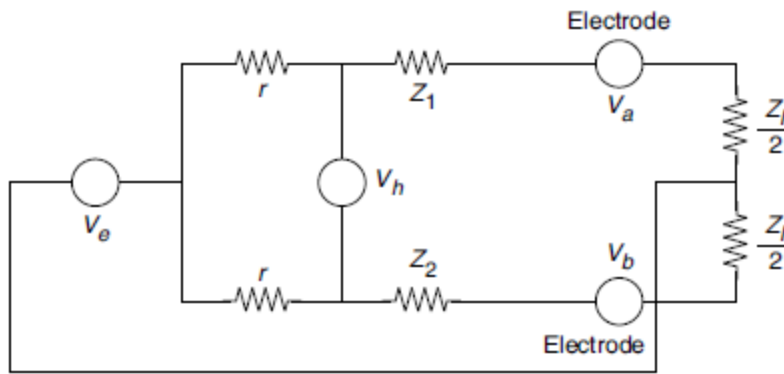
Equivalent circuit for the input of an ECG amplifier

The design of a good differential amplifier essentially implies the use of closely matched components which has been best achieved in the integrated circuit form. High gain integrated dc amplifiers, with differential input connections and a provision for external feedback have been given the name operational amplifiers because of their ability to perform mathematical operations.

These amplifiers are applied for the construction of ac or dc amplifiers, active filters, phase inverters, multi-cvibrators and comparators, etc. by suitable feedback arrangement, and therefore find a large number of applications in the medical field.

Gain $= R_2/R_1$

Output $V_0 = (V_1 - V_2)\dfrac{R_2}{R_1}$
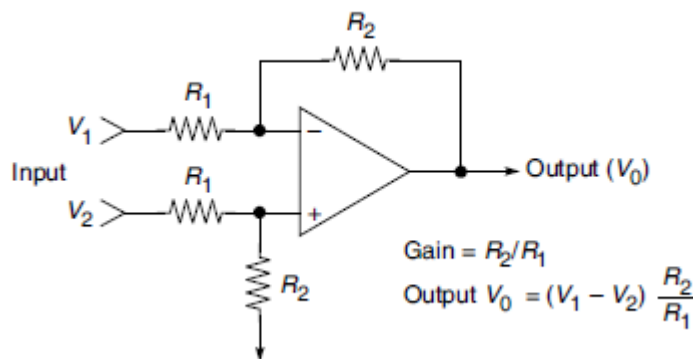
A single op-amp in a differential configuration

Video Content / Details of website for further learning (if any):

https://www.electronics-tutorials.ws/opamp/opamp_5.html

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 115-117

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L3

LECTURE HANDOUTS

BME

III/V

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
                                              16BMD03
Course Teacher   : Mrs.D.G.BeautlinVinola

Unit: III - Bio Amplifier and Signal Conditioning Circuits   Date of Lecture:

Topic of Lecture: ECG -   Impedance matching circuit

Introduction :
- The amplifier has a limited input impedance and therefore, draws some current from the

- signal source and loads them to some extent.

- The CMRR of the amplifier may not exceed 60 dB in most of the cases, which is usually inadequate in modern biomedical instrumentation systems.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic principle of an amplifier

- Basics of Biomedical Instrumentation

Impedance matching circuit
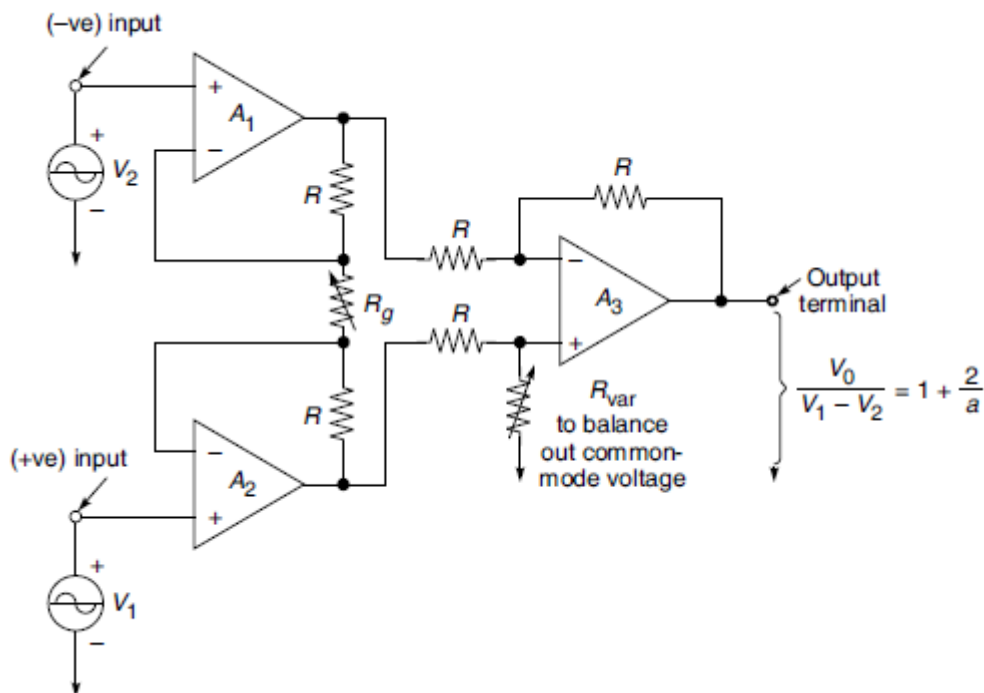**Instrumentation Amplifier**
The differential amplifier is well suited for most of the applications in biomedical measurements. However, it has the following limitations:

• The amplifier has a limited input impedance and therefore, draws some current from the signal source and loads them to some extent.

• The CMRR of the amplifier may not exceed 60 dB in most of the cases, which is usually inadequate in modern biomedical instrumentation systems.

These limitations have been overcome with the availability of an improved version of the differential amplifier.

An instrumentation amplifier is a precision differential voltage gain device that is optimized for operation in an environment hostile to precision measurement. It basically consists of three op-amps and seven resistors.

Basically,connecting a buffered amplifier to a basic differential amplifier makes an instrumentation amplifier.

The equation shown in the figure:
$$\frac{V_0}{V_1 - V_2} = 1 + \frac{2}{a}$$

Schematic diagram of an instrumentation amplifier

In the figure shown above, op-amp $A3$ and its four equal resistors R form a differential amplifier with a gain of 1. Only $A3$ resistors have to be matched. The variable resistance Rvar is varied to balance out any common-mode voltage. Another resistor Rg, is used to set the gain using the formula

If the inputs are prone to high voltage spikes or fast swings, which the op-amps cannot cope with, they may be protected using back-to-back connected diodes at their inputs. However, this reduces the input impedance value substantially and also limits the bandwidth.

The instrumentation amplifier offers the following advantages for its applications in the biomedical field:
• Extremely high input impedance
• Low bias and offset currents
• Less performance deterioration if source impedance changes
• Possibility of independent reference levels for source and amplifier
• Very high CMRR
• High slew rate
• Low power consumption

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L4

LECTURE HANDOUTS

BME

III/V

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16MDD03/16BMD03

Course Teacher   : **Mrs.D.G.BeautlinVinola**

Unit: III - Bio Amplifier and Signal Conditioning Circuits   **Date of Lecture:**

Topic of Lecture: Isolation amplifiers – transformer and optical isolation

Introduction :
- Isolation amplifiers are commonly used for providing protection against leakage currents. They break the ohmic continuity of electric signals between the input and output of the amplifier.

- The isolation includes different supply voltage sources and different grounds on each side of the isolation barrier.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about Amplifiers

- Basics of leakage current

Isolation amplifiers – transformer and optical isolation
Isolation amplifiers
Three methods are used in the design of isolation amplifiers:
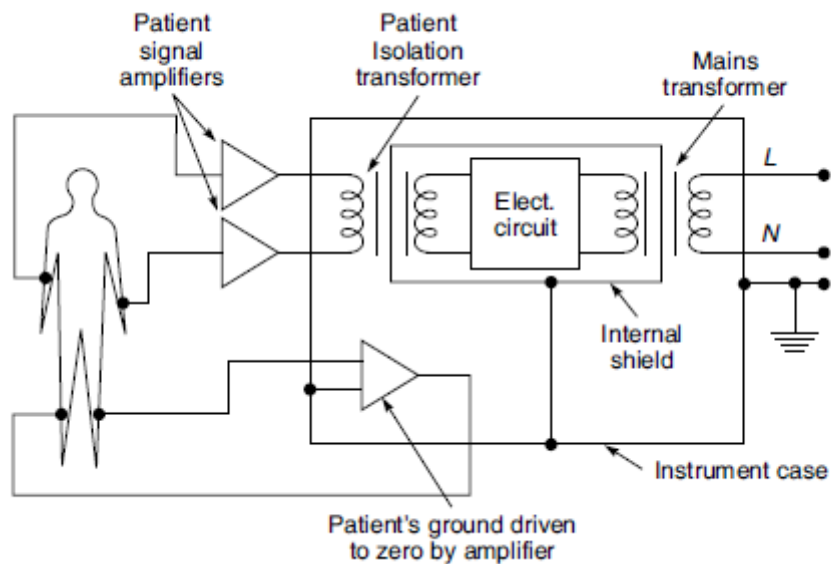 (i) transformer isolation
(ii) optical isolation
It uses either a frequency-modulated or a pulsewidth- modulated carrier signal with small signal bandwidths up to 30 kHz to carry the signal. It uses an internal dc–to-dc converter comprising of a 20 kHz oscillator, transformer, rectifier and filter to supply isolated power.

Isolation 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 ,having its original frequency, amplitude and linearity. No modulator/demodulator is needed because the signal is transmitted optically all the way.

The capacitive method 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.

Isolation amplifier (transformer type)
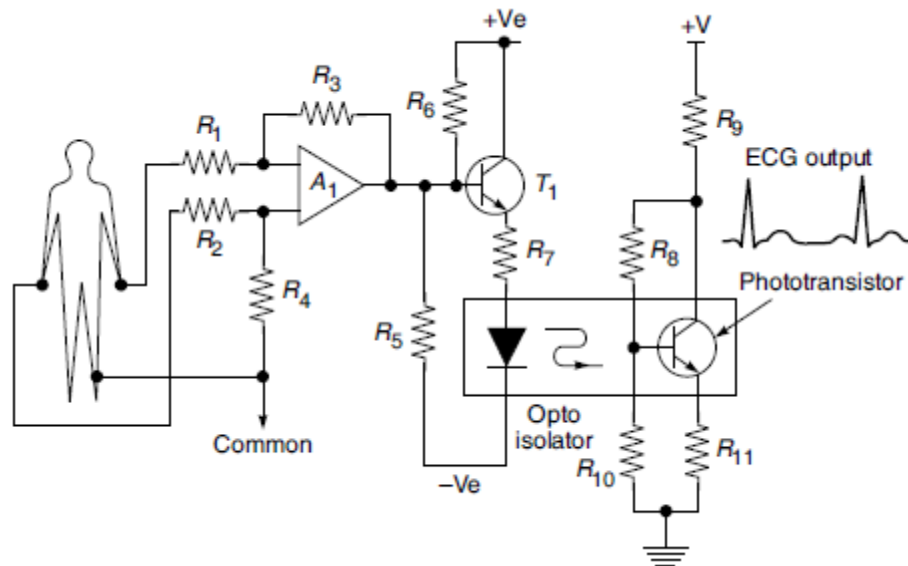
Optically isolated isolation amplifier

The relative merits of the three types of isolation techniques are:
• All three types are in common use, though the transformer isolation amplifier is more popular.
• Opto-coupled amplifier uses a minimum number of components and is cost effective, followed by the transformer coupled amplifier. The capacitor coupled amplifier is the most expensive.
• Opto-isolated amplifiers offer the lowest isolation voltage (800 V continuous) between input and output; transformer coupled 1200 V and capacitance coupled 2200 V.
• Isolation resistance levels are of the order of 1010, 1012 and 1012 ohms for transformer coupled, opto-coupled and capacitance coupled amplifiers respectively

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Video Content / Details of website for further learning (if any):
https://www.analog.com/en/products/amplifiers/isolation-amplifiers.html

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Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :123 -124

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LECTURE HANDOUTS

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III/V

Course Name with Code   :   **BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS**
                                         16MDD03/16BMD03

Course Teacher   : **Mrs.D.G.BeautlinVinola**

Unit: III - **Bio Amplifier and Signal Conditioning Circuits**   Date of Lecture:

Topic of Lecture: **Isolated DC amplifier and AC carrier amplifier**

Introduction :
- To obtain zero frequency response of the dc amplifier and the inherent stability of the capacitance coupled amplifier, a carrier type of amplifier is generally used.

- The carrier amplifier consists of an oscillator and a capacitance coupled amplifier. The oscillator is used to energize the transducer with an alternating carrier voltage.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics of an amplifier

- Basics of transducer

Isolated DC amplifier and AC carrier amplifier

The transducers, which require ac excitation, are those whose impedance is not purely resistive. Example can be of a capacitance based pressure transducer whose impedance is mainly capacitative with a small resistive component.

The frequency of the excitation voltage is usually around 2.5 kHz. The transducer shall change the amplitude of the carrier voltage in relation to the changes in the physiological variable being measured.

The output of the transducer therefore, would be an amplitude modulated (AM) signal (Fig. 4.6). The modulated ac signal can then be fed to a multi-stage capacitance coupled amplifier. The first stage produces amplification of the AM signal.

The second stage is so constructed that it can respond only to signal frequency of the carrier. It can be further amplified in the following stage. After amplification, the signal is demodulated in a phase-sensitive demodulator circuit.

This helps to extract amplified signal voltage after the filter circuit. The voltage produced by the demodulator can then be applied to the driver stage of the writing system.

Carrier amplifiers can be used with a resistance strain gauge transducer such as a semi Conductor strain gauge. When use enables direct measurements of the blood pressure from the calibrated graphic recorder.

Lock-in amplifier is a useful version of the carrier technique designed for the measurement of low-level signals buried in noise. This type of amplifier, by having an extremely narrow-width output band in which the signal is carried, reduces wideband noise and increases the signal-to noise ratio.

Thus, the difference between carrier amplifier and lock-in amplifier is that the former is a general purpose instrument amplifier while the latter is designed to measure signals in a noisy background.

In principle, the lock-in amplifier works by synchronizing on a single frequency, called the reference frequency. This frequency is made to contain the signal of interest.

The signal is modulated by the reference frequency in such a way that all the desired data is at the single reference frequency whereas the inevitable noise, being broadband, is at all frequencies. This permits the signal to be recovered from its noisy background.
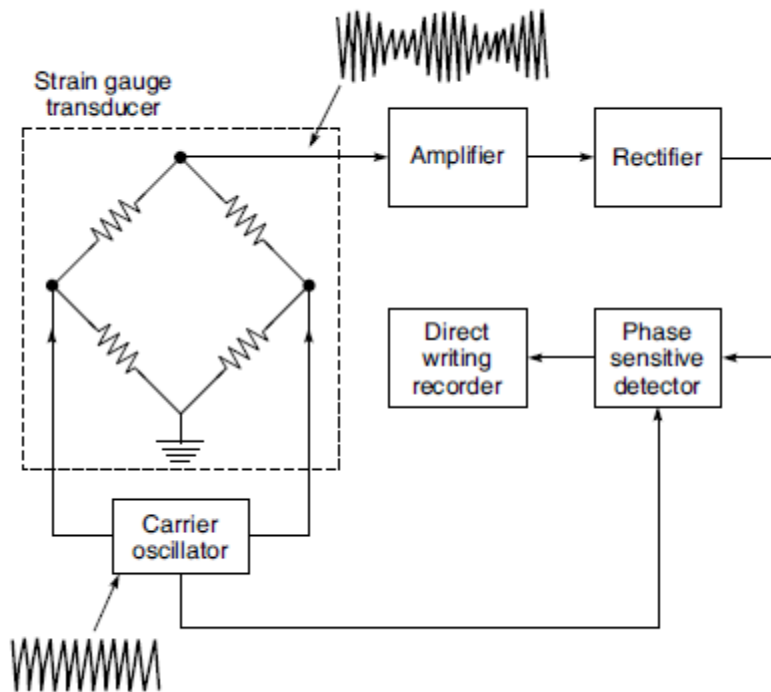
Block diagram of carrier amplifier

Video Content / Details of website for further learning (if any):

https://encyclopedia2.thefreedictionary.com/carrier+amplifier

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 120-121

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LECTURE HANDOUTS

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III/V

Course Name with Code	: BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS 16BMD03
Course Teacher	: Mrs.D.G.BeautlinVinola

Unit: III - Bio Amplifier and Signal Conditioning Circuits   Date of Lecture:

Topic of Lecture: Chopper amplifier

Introduction :
The chopper amplifier is a useful device in the field of medical electronics as it gives another solution to the problem of achieving adequate low frequency response while avoiding the drift problem inherent in direct coupled amplifiers.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about amplifier

- Basics about Electronics

Chopper amplifier

This type of amplifier makes use of a chopping device, which converts a slowly varying direct current to an alternating form with amplitude proportional to the input direct current and with phase dependent on the polarity of the original signal.

The alternating voltage is then amplified by a conventional ac amplifier whose output is rectified back to get an amplified direct current. A chopper amplifier is an excellent device for signals of narrow bandwidth and reduces the drift problem.

The amplifier achieves its ultra low dc offset voltage and bias current by chopping the low frequency components of the input signal, amplifying this chopped signal in an ac amplifier ($A1$) and then demodulating the output of the ac amplifier.

The low frequency components are derived from the input signal by passing it through the low-pass filter, consisting of $R2$, $C2$ and $R2$. The chopping signal is generated by the oscillator. The filtered output is then further amplified in a second stage of dc amplification ($A2$). High frequency signals, which are filtered out at the input of the chopper channel, are coupled directly into the second stage amplifier.

 The result of this technique is to reduce the dc offsets and drift of the second amplifier by a factor equal to the gain of the chopper channel. The ac amplifier introduces no offsets. Minor offsets and bias currents exist due to imperfect chopping, but these are extremely small.

The amplifier modules contain the chopper channel, including switches and switch-driving oscillator built on the module; only the dc power is supplied externally
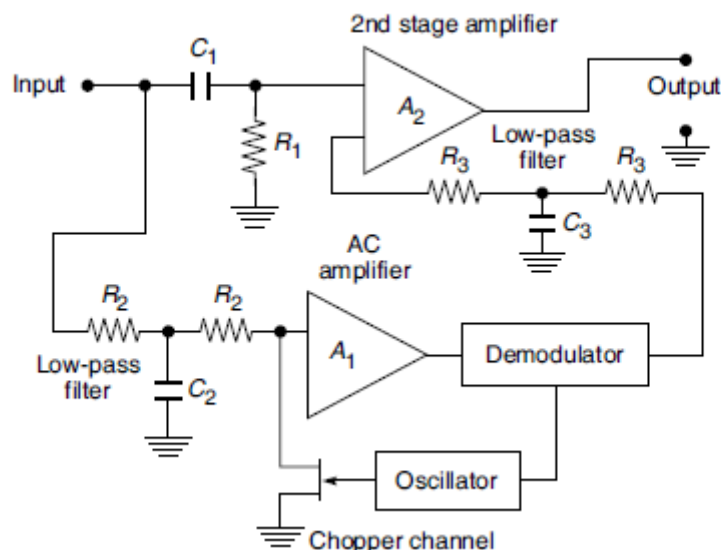
Simplified block diagram of a single ended chopper amplifier

Due to the extremely low dc offset and dc drift associated with the chopper-stabilized amplifier, the signal resolution is limited only by the noise present in the circuit. Thus, it is desirable to design the feedback networks and external wiring to minimize the total circuit noise.

When the full bandwidth of the amplifier is not required, it is advisable that a feedback capacitor beused to limit the overall bandwidth and eliminate as much high frequency noise as possible. Shielding of feedback components is desirable in chopper amplifiers. It is particularly necessary in electrically noisy environments.

Use of shielded wire for summing junction leads is also recommended.Typical voltage drift in chopper-stabilised amplifiers is 0.1 mV/0C and current drift as 0.5 pA/°C .The great strength of the chopper-stabilized amplifier is its insensitivity to component changes due to ageing, temperature change, power supply variation or other environmental factors.

Thus,it is usually the best choice where both offset voltage and bias current must be small over long periods of time or when there are significant environmental changes. Both bias current and offset voltage can be externally nulled.

Chopper amplifiers are available in both single-ended as well as differential input configurations. Chopper amplifiers find applications in the medical field in amplification of small dc signals of a few microvolts. Such order of amplitudes are obtainable from transducers such as strain gauge pressure transducers, temperature sensors such as thermistors and strain gauge myographs, when they are used as arms of a dc Wheatstone bridge. A chopper amplifier is also suitable for use with a thermocouple

Video Content / Details of website for further learning (if any):

https://www.electrical4u.com/chopper-amplifier/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :121 -123

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LECTURE HANDOUTS

BME

III/V

Course Name with Code   : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit: III - Bio Amplifier and Signal Conditioning Circuits   Date of Lecture:

Topic of Lecture : Power line interference

Introduction :
The power line interference of 50/60 Hz is the source of interference and it corrupt the recordings of Electrocardiogram (ECG) which are extremely important for the diagnosis of patients.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about interference

- Importance of diagnosis

Power line interference

The interference is caused by: a. Electromagnetic interference by power line b. electromagnetic field (EMF) by the machinery which is placed nearby.

The harmonics frequency is integral multiple of fundamental frequency such as 50Hz. c. Stray effect of the alternating current fields due to loops in the cables .

Improper grounding of ECG machine or the patient.Electrical equipments such as air conditioner, elevators and X-ray units draw heavy power line current, which induce 50 Hz signals in the input .

The noise from electric power system is a major source of noise during the recording or monitoring of ECG. Different noises have different frequencies. The noise with low frequency is being problem with ECG signal as well as some time high frequency noises also interfere ECG like mobile phone.

If the physical or mathematical variable changes rapidly then it can be high frequency and if it changes slowly then it would be low frequency. If the variable does not change at all then it is said that it has zero frequency. Most of the electronic devices such as ECG, transmitter, receiver, computer etc get power from power line.

The 50 Hz alternative current (AC) is reduced in voltage, rectified and then filter to obtain low voltage direct current (DC). This is used to give power to those electronic devicircuits of the ECG machine.

This noise occurs at the time of muscle activity during an ECG recording especially in a stress test. This artifact consist of maximum frequency of 10 KHz

Data Collecting Device Noise: This noise is mainly due to signal processing hardware

Patient–Electrode Motion Artifacts: It is the movement of the electrode away from the contact area on the skin that leads to variations in the impedance between the electrode and skin causing potential variations in the ECG

Baseline Wandering : Baseline wander is a low-frequency component present in the ECG system. This is due to offset voltages in the electrodes, respiration, and body movement. Baseline wander have frequency greater than 1Hz

Contact Noise: This noise is caused by the loss of contact between the electrode and the skin, which effectively disconnects the measurement system and generates large artifacts since the ECG signal is usually capacitively coupled to the system. The characteristics of this noise signal include the amplitude of the initial transition, the amplitude of the 60 Hz component and the constant time of the decay.

Electrosurgical Noise: Electrosurgical noise is generated by other medical equipment present in the patient care environment at frequencies between 100 KHz and 1 MHz .This noise remains

approximately for 1 to 10 seconds.

Channel Noise: Poor channel conditions can also introduce noise to the ECG when ECG is transmitted. It is mainly like white Gaussian noise which contains all frequency component

Video Content / Details of website for further learning (if any):

https://biomedical-engineering-online.biomedcentral.com/articles/10.1186/1475-925X-4-50

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :125 -126

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LECTURE HANDOUTS

BME

III/V

Course Name with Code   : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
                         16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit: III - Bio Amplifier and Signal Conditioning Circuits   Date of Lecture:

Topic of Lecture: Right leg driven ECG amplifier

Introduction :
Right leg driven ECG amplifier is an electronic circuit that is often added to biological signal amplifiers to reduce common mode Interference.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic concepts of an amplifier

- Basics of circuitry

Right leg driven ECG amplifier

A **driven right leg circuit** or **DRL** circuit is an electric circuit that is often added to biological signal amplifiers to reduce common-mode interference.

Biological signal amplifiers such as ECG (electrocardiogram) EEG (electroencephalogram) or EMG circuits measure very small electrical signals emitted by the body, often as small as several micro-volts (millionths of a volt).

Unfortunately, the patient's body can also act as an antenna which picks up electromagnetic interference, especially 50/60 Hz noise from electrical power lines.

This interference can obscure the biological signals, making them very hard to measure. Right leg driver circuitry is used to eliminate interference noise by actively cancelling the interference.

A Driven Right Leg Circuit or DRL circuit is an electric circuit that is often added to biological signal amplifiers to reduce Common-mode interference. Biological signal amplifiers such as ECG (Electrocardiogram) EEG (Electroencephalogram) or EMG circuits measure very small electrical signals emitted by the body, often as small as several micro-volts (millionths of a volt).

Unfortunately, the patient's body can also act as an antenna which picks up electromagnetic interference, especially 50/60 Hz noise from electrical power lines. This interference can obscure the biological signals, making them very hard to measure. Right Leg Driver circuitry is used to eliminate interference noise by actively cancelling the interference.

Objective:
➢ Reduce interference in amplifier
➢ Improve patient safety

Approach:
➢ Patient right leg tied to output of an auxiliary amp rather than ground.
➢ Common mode voltage on body sensed by averaging resistors, Ra's & R_F fed back to right leg.
➢ Provides negative feedback to reduce common mode voltage.
➢ If high voltage appears between patient and ground, auxiliary Op-amp effectively un-grounds the patient to stop current flow.
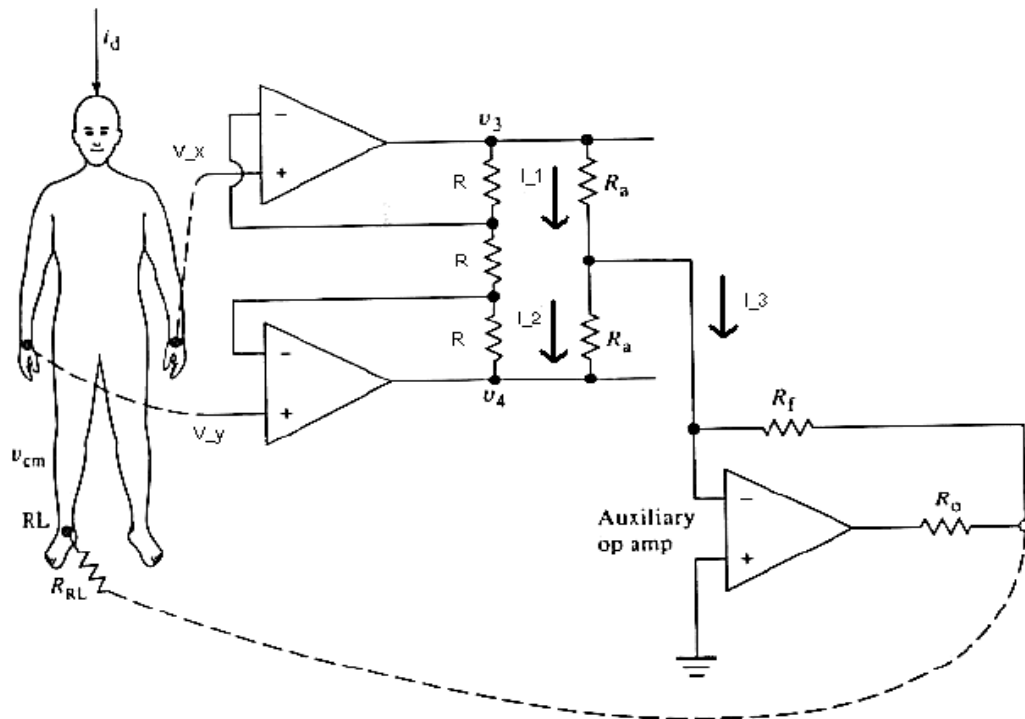
Diagram for right leg driven ECG Amplifier

Video Content / Details of website for further learning (if any):

http://pnrsolution.org/Datacenter/Vol3/Issue4/142.pdf

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :116 -117

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

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IQAC

LECTURE HANDOUTS	**L9**

BME	**III/V**

Course Name with Code	: BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS 16BMD03
Course Teacher	:Mrs.D.G.BeautlinVinola

Unit: III - Bio Amplifier and Signal Conditioning Circuits   **Date of Lecture:**

Topic of Lecture: Band pass filtering

Introduction :

A band pass filter (also known as a BPF or pass band filter) is defined as a device that allows frequencies within a specific frequency range and rejects (attenuates) frequencies outside that range.

Band pass filtering

The low pass filter is used to isolate the signals which have frequencies higher than the cutoff frequency. Similarly, the high pass filter is used to isolate the signals which have frequencies lower than the cutoff frequency.

By the cascade connection of high pass and low pass filter makes another filter, which allows the signal with specific frequency range or band and attenuate the signals which frequencies are outside of this band. This type of filter is known as Band Pass Filter.The Band Pass Filter has two cutoff frequencies. The first cutoff frequency is from a high pass filter.

This will decide the higher frequency limit of a band that is known as the higher cutoff frequency (fc-high). The second cutoff frequency is from the low pass filter. This will decide the lower frequency limit of the band and that is known as lower cutoff frequency (fc-low).

Band Pass Filter Circuit

The band pass filter is a combination of low pass and high pass filters. Therefore, the circuit diagram contains the circuit of high pass and low pass filters. The circuit diagram of the passive RC band pass filter is as s The first half of the circuit diagram is a passive RC high pass filter.

This filter will allow the signals which have frequencies higher than the lower cutoff frequency (fc-low). And attenuate the signals which have frequencies lower than (fc-low).
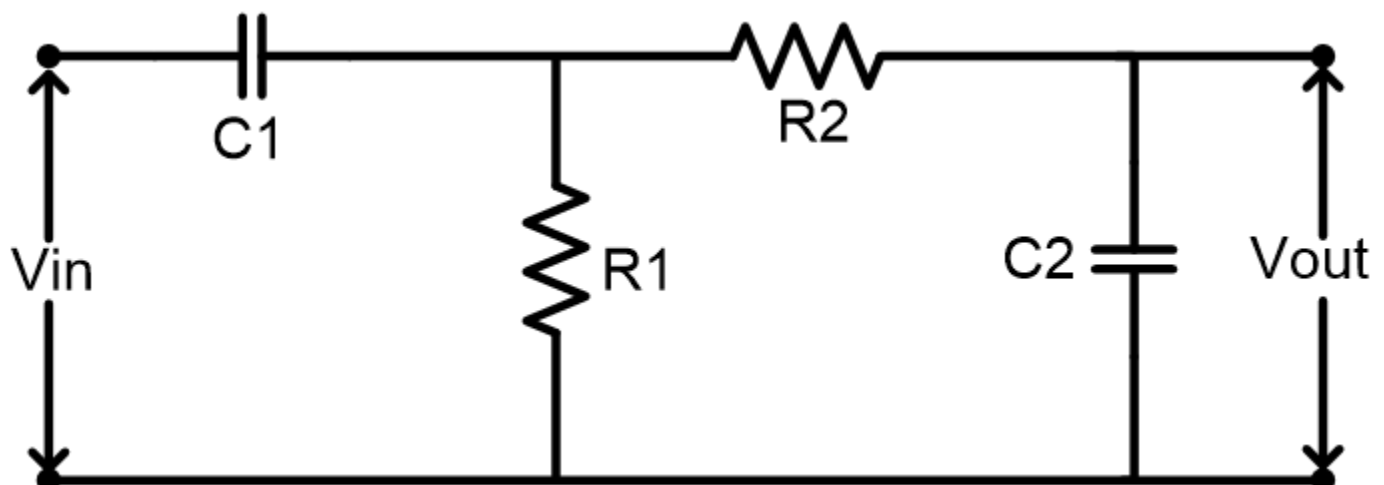
$$F_{clow} = \frac{1}{2\pi R_1 C_1}$$

The second half of the circuit diagram is a passive RC low pass filter. This filter will allow the signals which have frequencies lower than the higher cutoff frequency (fc-high). And it will attenuate the signals which have frequencies higher than (fc-high).

$$F_{chigh} = \frac{1}{2\pi R_2 C_2}$$

The band or region of frequency in which the band pass filter allows the signal to pass that is known as Bandwidth. The bandwidth is a difference between the higher and lower value of cutoff frequency.

Band pass filter circuit

Video Content / Details of website for further learning (if any):

https://www.allaboutcircuits.com/textbook/alternating-current/chpt-8/band-pass-filters/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 115

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L1

LECTURE HANDOUTS

BME

III/V

Course Name with Code :BIO MEDICAL INSTRUMENTATION AND MEASUREMENTS
16BMD03
Course Teacher   :Mrs.D.G.BeautlinVinola

Unit: IV- Measurement of Non- Electrical Parameters   Date of Lecture:

Topic of Lecture: Temperature, respiration rate and pulse rate measurements

Introduction :
- Temperature is the quantity measured by a thermometer. Temperature is related to the average kinetic energy of atoms and molecules in a system

- The respiration rate is the number of breaths a person takes per minute

- A normal resting heart rate for adults ranges from 60 to 100 beats per minute.

- Generally, a lower heart rate at rest implies more efficient heart function and better cardiovascular fitness. For example, a well-trained athlete might have a normal resting heart rate closer to 40 beats per minute.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics about temperature

- Basics about respiration and pulse

Temperature, respiration rate and pulse rate measurements
Temperature Measurement

The transducer normally used for temperature measurement in a patient monitoring system is a thermistor. Changes in resistance of the thermistor with changes in temperature are measured in a bridge circuit and indicated on a calibrated meter.

The measuring range is 30–42°C.

In a patient monitoring system, provision for two channel temperature measurements are usually made. Similar to ECG monitoring, the output circuits are isolated through opto-couplers. Provision for inoperate conditions are also included in such type of monitoring equipment.

Respiration Measurement

The primary functions of the respiratory system are to supply oxygen and remove carbon dioxide from the tissues. The action of breathing is controlled by a muscular action causing the volume of

the lung to increase and decrease to effect a precise and sensitive control of the tension of carbon dioxide in the arterial blood.

Under normal circumstances, this is rhythmic action with the result that the respiration rate provides a fairly good idea about the relative respiratory activity.

Several techniques have been developed for the measurement of the respiration rate. The choice of a particular method depends mostly upon the ease of application of the transducer and their acceptance by the subject under test.

Pulse Rate Measurement

Each time the heart muscle contracts, blood is ejected from the ventricles and a pulse of pressure is transmitted through the circulatory system. This pressure pulse when travelling through the vessels, causes vessel-wall displacement, which is measurable at various points of the peripheral circulatory system.

The pulse can be felt by placing the finger tip over the radial artery in the wrist or some other location where an artery seems just below the skin. The timing and wave shape of the pressure pulse are diagnostically important as they provide valuable information.

The pulse pressure and waveform are indicators for blood pressure and flow. Instruments used to detect the arterial pulse and pulse pressure waveforms in the extremities are called plethysmographs. Most plethysmograph techniques respond to a change in the volume of blood as a measure of blood pressure.

The pulse gives a measure of pulse wave velocity and can be recorded and compared with the ECG signal (Fig. 6.14). The pulse wave travels at 5 to 15 m/s, depending on the size and rigidity of the arterial walls. The larger and more rigid the artery walls, the greater the velocity. The velocity is 10–15 times faster than blood flow, and is relatively independent of it.

The methods used for the detection of volume (pulse) changes due to blood flow are:
• Electrical impedance changes
• Strain gauge or microphone (mechanical)
• Optical changes (changes in density)

An electric impedance method measures the impedance change between two electrodes causedby the change in blood volume between them. The change in impedance (0.1 ohm) may be small ascompared to the total impedance (several hundred ohms).

The impedance is measured by applying an alternating current between electrodes attached to the body. An alternating signal (10–100kHz) is used (rather than dc) in order to prevent polarization of the electrodes.

Video Content / Details of website for further learning (if any):

https://www.urmc.rochester.edu/encyclopedia/content.aspx?ContentTypeID=85&ContentID=P00866

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :232,204

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LECTURE HANDOUTS	**L2**

BME	**III/V**

Course Name with Code : BIO MEDICAL INSTRUMENTATION AND MEASUREMENTS
16BMD03

Course Teacher : Mrs.D.G.BeautlinVinola

Unit: IV- Measurement of Non- Electrical Parameters   **Date of Lecture:**

Topic of Lecture: Blood Pressure: indirect methods - auscultatory method

Introduction :
- The classical method of making an indirect measurement of blood pressure is by the use of a cuff over the limb containing the artery.

- This technique was introduced by Riva-Rocci for the determination of systolic and diastolic pressures. Initially, the pressure in the cuff is raised to a level well above the systolic pressure so that the flow of blood is completely terminated. Pressure in the cuff is then released at a particular rate.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about blood pressure

- Basics of indirect measurement

Blood Pressure: indirect methods - auscultatory method

The problem here finally reduces to determining the exact instant at which the artery just opens and when it is fully opened. The method given by Korotkoff and based on the sounds produced by flow changes is the one normally used in the conventional sphygmomanometers.

The sounds first appear when the cuff pressure falls to just below the systolic pressure. They are produced by the brief turbulent flow terminated by a sharp collapse of the vessel and persist as the cuff pressure continues to fall. The sounds disappear or change in character at just below diastolic pressure when the flow is no longer interrupted.

These sounds are picked up by using a microphone placed over an artery distal to the cuff. The sphygmomanometric technique is an ausculatory method; it depends upon the operator recognizing the occurrence and disappearance of the Korotkoff sounds with variations in cuff pressure.

A number of automated blood pressure measuring instruments have been designed which make use of the Riva-Rocci method. They operate in a manner analogous to that employed by a human operator, but differ in the method of detecting the pulsations of blood flow at the systolic and diastolic levels.

Frequency bands that best discriminate the Korotkoff sounds at systole and diastole from the sounds immediately preceding these events must be defined for achieving a high

degree of reliability in the automatic electronic blood pressure instruments. Golden *et al* (1974) carried out a special analysis of seven Korotkoff sounds centred about the systolic and diastolic ausculatory events and found that a maximum increase in amplitude at the systolic transition occurred in the 18–26 Hz band.
 Similarly, a maximum decrease in spectral energy of diastolic Korotkoff sounds, at ausculatory cessation, was observed within a 40–60 Hz passband

Auscultatory method

The "differential auscultatory technique" is a non-invasive method for accurately measuring blood pressure. A special cuff-mounted sensor consisting of a pair of pressure sensitive elements, isolates the signal created each time the artery is forced open
.
As long as the cuff pressure exceeds the pressure in the artery,the artery is held closed, and no pulse is generated. However, as soon as the intra-arterial pressure rises to a value, which momentarily exceeds the cuff pressure, the artery "snaps" open; and a pulse is created. Once the artery is open, blood flows through it giving rise to the low frequency pressure
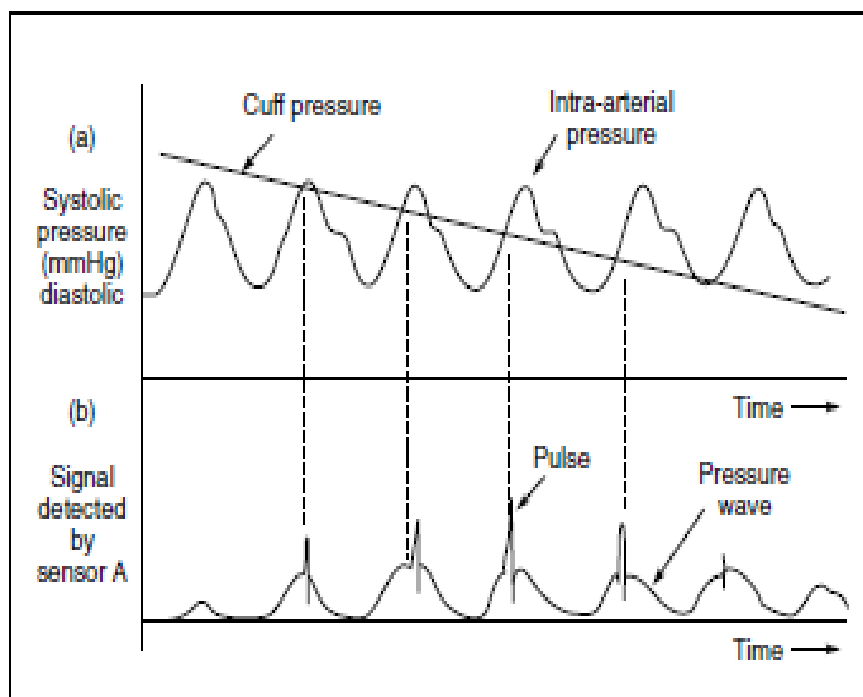
(a)Diagram showing the relationship between cuff pressure and
intra-arterial pressure
(b) Signal created by the relative pressure changes

wave signal, which lasts until the arterial pressure again drops below the cuff pressure. This process is repeated until the cuff pressure drops to a value below the diastolic.

Note that this signal consists of a slowly rising, low frequency component (in the frequency range of 0.5–5 Hz) with a fast "pulse"(frequencies approximately 10–80 Hz) superimposed on it. This signal is denoted by the arrows marked A transmitted from the artery to both the sensor and the air bag in the cuff.
Due to the air bag characteristics, the high frequency component is highly attenuated, leaving only the low-frequency signal,.Therefore, only the low frequency signal is transmitted to the side of the sensor facing the air bag, as denoted by the arrows marked B . Since most artefact signals (unwanted signals due to motion, etc.) fall in a frequency range below 10 Hz, they are also transmitted to both sides of the sensor.

The systolic pressure is determined as the pressure at which the first opening of the artery occurs, as shown by the first pulse , because this pulse is created the first time the artery is forced open by intra-arterial pressure. Similarly, diastolic value is determined as the

pressure at which the differential signal essentially disappears, because this corresponds to the last time the artery is forced open.

The differential sensor subtracts the side "B" signal from the side "A" signal, thereby cancelling out the pressure wave component and the motion artefact signals, and the higher frequency Korotkoff signals are isolated

Video Content / Details of website for further learning (if any):
https://www.medicine.mcgill.ca/physio/vlab/cardio/auscul.htm

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :222 -223

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L3

LECTURE HANDOUTS

BME

III/V

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
                                              16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit: IV- Measurement of Non- Electrical Parameters   Date of Lecture:

Topic of Lecture: Blood Pressure: indirect methods -Oscillometric Method

Introduction :
- The classical method of making an indirect measurement of blood pressure is by the use of a cuff over the limb containing the artery.

- This technique was introduced by Riva-Rocci for the determination of systolic and diastolic pressures. Initially, the pressure in the cuff is raised to a level well above the systolic pressure so that the flow of blood is completely terminated. Pressure in the cuff is then released at a particular rate

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about blood pressure

- Basics of indirect measurement

Blood Pressure: indirect methods -Oscillometric Method

The automated oscillometric method of non-invasive blood pressure measurement has distinct advantages over the auscultatory method. Since sound is not used to measure blood pressure in the oscillometric technique, high environmental noise levels such as those found in a busy clinical or emergency room do not hamper the measurement.

 In addition, because this technique does not require a microphone or transducer in the cuff, placement of the cuff is not as critical as it is with the auscultatory or Doppler methods. The oscillometric method works without a significant loss in accuracy even when the cuff is placed over a light shirt sleeve. The appropriate size cuff can be used on the forearm, thigh, or calf as well as in the traditional location of the upper arm.

 A disadvantage of the oscillometric method, as well as the auscultatory method, is that excessive movement or vibration during the measurement can cause inaccurate readings or failure to obtain any reading at all.

The oscillometric technique operates on the principle that as an occluding cuff deflates from a level above the systolic pressure, the artery walls begin to vibrate or oscillate as the blood flows turbulently through the partially occluded artery and these vibrations will be sensed in the transducer system monitoring cuff pressure.

As the pressure in the cuff further decrease, the oscillations increase to a maximum amplitude and then decrease until the cuff fully deflates and blood flow returns to normal.

The cuff pressure at the point of maximum oscillations usually corresponds to the mean arterial pressure.. These correlations have been derived and proven empirically but are not yet well explained by any physiologic theory.

The actual determination of blood pressure by an oscillometric device is performed by a proprietary algorithm developed by the manufacturer of the device.

The oscillometric method is based on oscillometric pulses (pressure pulses) generated in the cuff during inflation or deflation. Blood pressure values are usually determined by the application of mathematical criteria to the locus or envelope formed by plotting a certain characteristic, called the oscillometric pulse index, of the oscillometric pulses against the baseline cuff pressure.

The baseline-to-peak amplitude, peak-to-peak amplitude, or a quantity based on the partial or full time-integral of the oscillometric pulse can be used as the oscillometric pulse index.The baseline cuff pressure at which the envelope peaks (maximum height) is generally regarded as the MAP (mean arterial pressure). Height-based and slope-based criteria have been used to determine systolic and diastolic pressures.

An envelope that has been normalized with respect to the peak index can also be used for the determination of the oscillometric blood pressure. The ECG-gating technique has been used to assist in the identification of oscillometric pulse signals.

Measurement sites for oscillometric blood pressure measurement include the upper arm, forearm, wrist, finger and thigh.Most of the patient monitoring systems are based on the oscillometric measuring principle.An air pump is used to automatically inflate the patient cuff. The pump is of a membrane type and is enclosed in a foam rubber filled casing to attenuate noise.

The pneumatic unit includes damping chambers to (i) prevent a rapid increase of pressure caused by the pump, (ii) slow down the pressure change in the measurement of infant and (iii) smooth down rapid pressure pulses caused by the bleed valve. A safety valve prevents accidental cuff over-pressurization and operates nominally at 330 mmHg. A bleed valve is incorporated to release the cuff pressure. The opening of
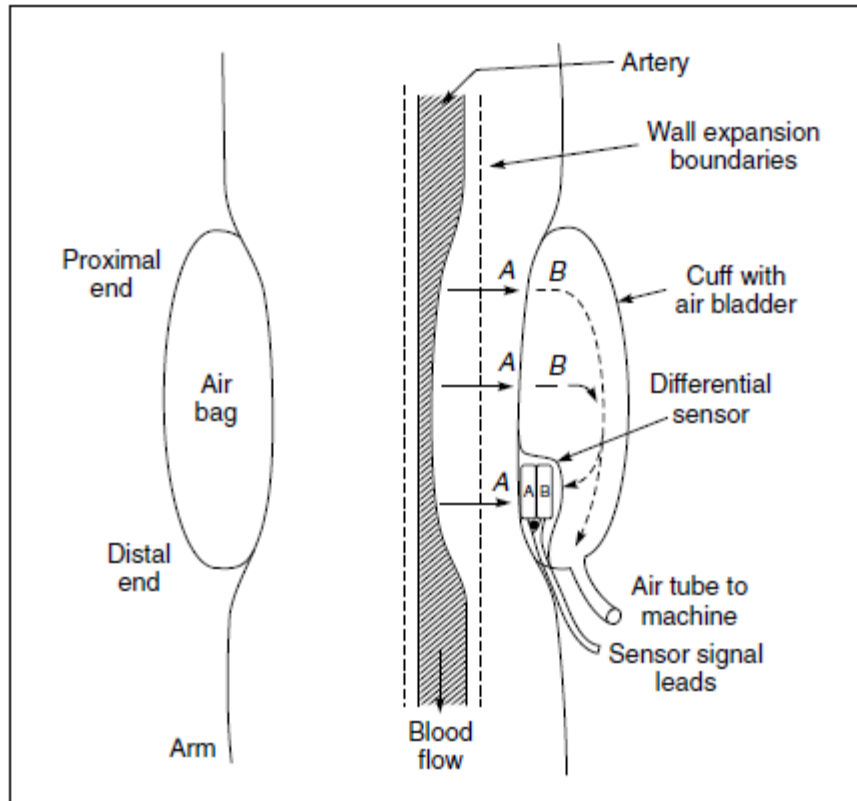
Cut-away view showing signal detection

Video content / Details of website for further learning (if any):

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3541069/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 223 -224

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| **L4** |

| **LECTURE HANDOUTS** |

| **BME** | | **III/V** |

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
                                       16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit: IV- Measurement of Non- Electrical Parameters   **Date of Lecture:**

Topic of Lecture: Direct methods: Electronic manometer

Introduction :
- Direct monitoring requires the placement of a catheter into a peripheral artery, most commonly the dorsal metatarsal or femoral artery in smaller patients, although any accessible artery could be used.

- The catheter is connected to a pressure transducer with non-compliant tubing filled with heparinized saline to allow continuous measurement, which can be observed on a monitoring device. Most devices give continuous values and a pressure waveform can be observed.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about Arteries

- Principle of Transducer

Direct methods: Electronic manometer
Manometer

Manometers are precision instruments that are used to measure pressure, which is the force exerted by a gas or liquid per unit surface area owing to the effects of the weight of that gas or liquid from gravity. Depending on the type and how they are configured, manometers can be set-up to provide a measurement of different pressure values. A common type of manometer with which most people are familiar is the one that physicians and medical professionals use to measure and monitor a patient's blood pressure. This type of manometer is called a sphygmomanometer.

Pressure Definitions

It is useful to review a few basic principles that relate to pressure. Pressure is a measure of the amount of force (F) that is exerted per unit area (A):

$$P = \frac{F}{A}$$

The unit of measure for pressure is, therefore, a force value divided by a squared distance value. In metric units, the unit a measure for pressure is Newtons/(meter)^2, known as a Pascal (Pa). Other common pressure units of measure include pounds per square inch (psi), millibars, atmospheres (atm), millimeters of mercury (mm Hg), and inches of water (in H_2O).

Pressure can be represented in terms of three specific categories:

- Absolute pressure
- Gauge pressure
- Differential pressure

Absolute pressure measures the value of pressure that is exerted relative to the absolute zero pressure of a vacuum. Gauge pressure is presenting the difference between the measured value of pressure and the local atmospheric pressure (think in terms of a tire pressure gauge). Differential pressure is used to describe making a measurement that is the difference between two (unknown) pressure levels, where there is not a reference pressure being specified, but measuring the amount of pressure by which the two differ is still important.

Digital Manometers and How They Work

Digital manometers, also known as electronic manometers, do not rely on Hydrostatic Balance of fluids to determine pressure. Instead, they contain a pressure transducer, a device that can convert an observed pressure level into an electrical signal whose characteristic value is proportional to, or a proxy for, the magnitude of the pressure. The elastic portion of the transducer deflects under pressure and that deflection is then converted to a value of an electrical parameter which can be detected and calibrated to a pressure reading. Pressure transducers typically make use of one of three types of electrical parameters – resistive, capacitive, or inductive.

1. Resistive transducers result in the deformation changing the electrical resistance of a strain gauge.
2. Capacitive transducers rely on changes to the value of capacitance observed resulting from the deformation changing the relative position of the two plates of a capacitor.
3. Inductive transducers use the deformation of the elastic portion to alter the linear motion of an attached ferromagnetic core within a coil or inductor. This movement varies the induced emf

and AC current generated in the coil.

To perform measurements on very low pressures, there are additional types of pressure transducer styles used, including a Pirani gauge, thermocouple type transducer, and ionization gauge. Low-pressure manometers are also called micromanometers.

Digital manometers some advantages over analog models. Digital manometers:

- Are portable in size, weigh less, and feature easy to read displays.
- Can interface with a computer or programmable logic controller (PLC).
- Do not rely on the use of manometric fluids, some of which (mercury, for example) can be toxic.
- Are not subject to issues relating to fluid properties that can impact the accuracy of measurements.
- Can correct for deviations from standard conditions via software programming.

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Video Content / Details of website for further learning (if any):

https://www.thomasnet.com/articles/instruments-controls/all-about-manometers-what-they-are-and-how-they-work/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :208 -209

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LECTURE HANDOUTS	L5

BME	III/V

Course Name with Code : **BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS**
16BMD03

Course Teacher : **Mrs.D.G.BeautlinVinola**

Unit: IV- Measurement of Non- Electrical Parameters   Date of Lecture:

Topic of Lecture: Pressure amplifiers,Systolic, diastolic, mean detector circuit

Introduction :
- The direct method of pressure measurement is used when the highest degree of absolute accuracy,dynamic response and continuous monitoring is required.

- The method is also used to measure the pressure in deep regions inaccessible by indirect means. For direct measurement, a catheter or a needle type probe is inserted through a vein or artery to the area of interest.

- Two types of probes can be used. One type is the catheter tip probe in which the sensor is mounted on the tip of the probe and the pressures exerted on it are converted to the proportional electrical signals.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic principles of Electrodes

- Defibrillation

**Pressure amplifiers,Systolic, diastolic, mean detector circuit**

Figure below shows a simplified circuit diagram commonly used for processing the electrical signals received from the pressure transducer for the measurement of arterial pressure. The transducer is excited with a 5 V dc excitation.

The electrical signals corresponding to the arterial pressure are amplified in an operational amplifier or a carrier amplifier. The modern preamplifier for processing pressure signals are of the isolated type and therefore comprise of floating and grounded circuits similar to ECG amplifiers.

The excitation for the transducer comes from an amplitude controlled bridge oscillator through an isolating transformer, which provides an interconnection between the floating and grounded circuits. An additional secondary winding in the transformer is used to obtain isolated power supply for the floating circuits.

The input stage is a differential circuit, which amplifies pressure change, which is sensed in the patient connected circuit. The gain of the amplifier can be adjusted depending upon the sensitivity of the transducer.After RF filtering, the signal is transformer-coupled to a synchronized demodulator for removing the carrier frequency from the pressure signal.

For the measurement of systolic pressure, a conventional peak reading type voltmeter is used. When a positive going pressure pulse appears at A, diode $D3$ conducts and charges $C3$ to the peak
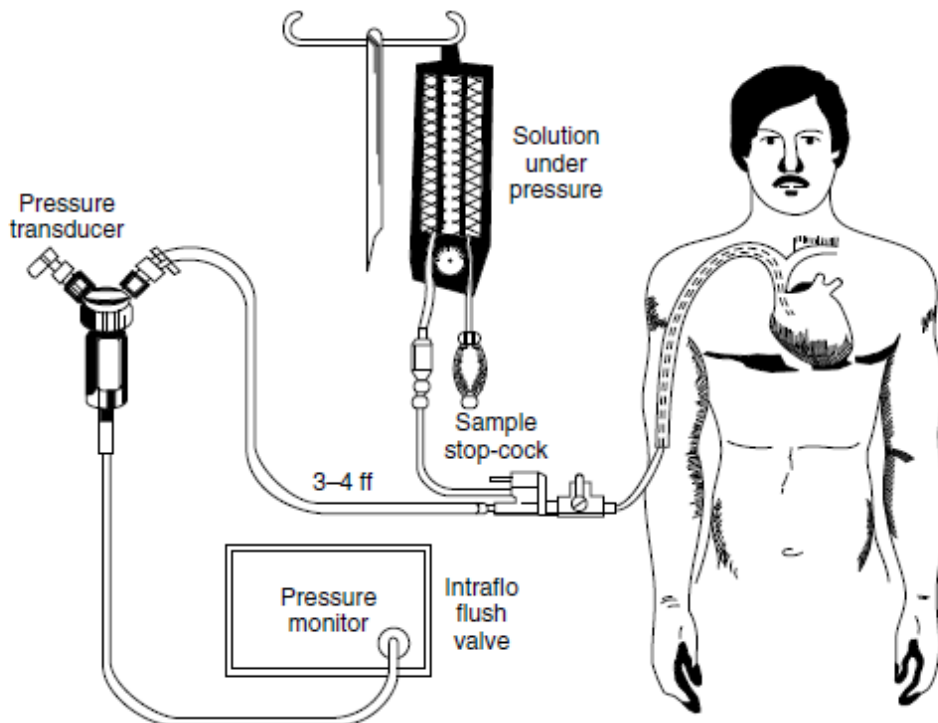
Typical set up of a pressure measuring system by direct method
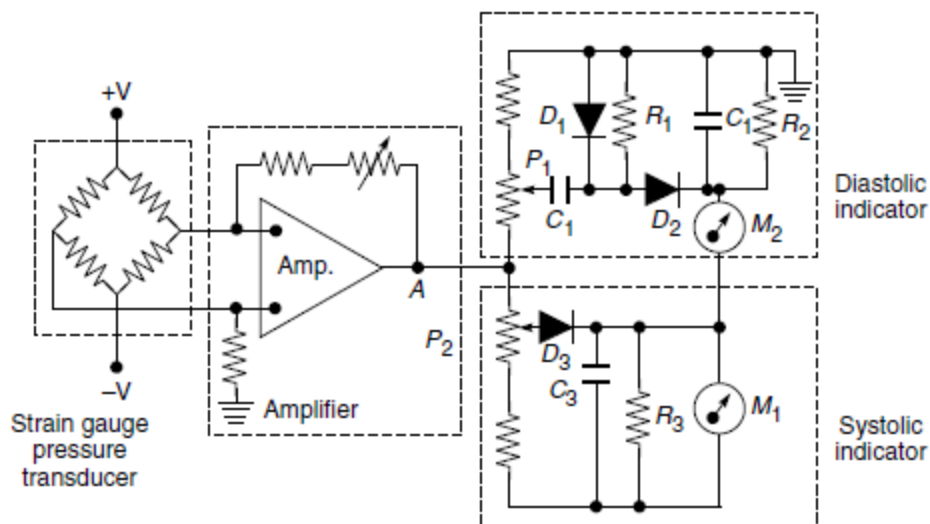
Circuit diagram for measurement of systolic and diastolic blood pressure

value of the input signal, which corresponds to the systolic value. Time constant $R3C3$ is chosen in such a way that it gives a steady output to the indicating meter.

The value of diastolic pressure is derived in an indirect way. A clamping circuit consisting of $C1$ and $D1$ is used to develop a voltage equal to the peak-to-peak value of the pulse pressure. This voltage appears across $R1$.

Diode $D2$ would then conduct and charge capacitor $C2$ to the peak value of the pulse signal. The diastolic pressure is indicated by a second meter $M2$ which shows the Central venous pressure (CVP) measurements made with needle cannulation techniques prove extremely useful in the management of acute circulatory failure and in the maintenance of blood volume in difficult fluid balance problems.

Simple water manometers are still the most common measuring device in use, although highly sensitive pressure transducers are preferred when accurate measurements are required. However, the transducers cannot be conveniently mounted at the catheter tip and small positional changes cause large errors in venous pressure.

Infusingintravenous fluids while measuring pressure through the same catheter is another problem encountered in these measurements. Central venous pressure is usually measured from a catheter located in the superior vena cava.

The CVP reflects the pressure of the right atrium and is sometimes referred to as right atrial pressure. The catheter can even be located in the right atrium. Major peripheral veins used as entry sites for CVP monitoring are the brachial, subclavian and jugular veins

Video Content / Details of website for further learning (if any):

https://www.nxp.com/docs/en/application-note/AN4328.pdf e

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :210 -212

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| LECTURE HANDOUTS | L6 |

| BME | III/V |

Course Name with Code   : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit: IV- Measurement of Non- Electrical Parameters   **Date of Lecture:**

Topic of Lecture: Blood flow and cardiac output measurement: Indicator dilution

Introduction :

- Indicator dilution principle states that if we introduce into or remove from a stream of fluid a known amount of indicator and measure the concentration difference upstream and downstream of the injection (or withdrawal) site, we can estimate the volume flow of the fluid.

- The method employs several different types of indicators.

- Two methods are generally employed for introducing the indicator in the blood stream, viz: it may be injected at a constant rate or as a bolus.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic knowledge about dilution principle

- Basics of Indicators

Blood flow and cardiac output measurement: Indicator dilution

The method of continuous infusion suffers from the disadvantage that most indicators recirculate, and this prevents a maxima from being achieved.

In the bolus injection method, a small but known quantity of an indicator such as a dye or radioisotope is administered into the circulation. It is injected into a large vein or preferably into the right heart itself.

After passing through the right heart, lungs and the left heart, the indicator appears in the arterial circulation.
The presence of an indicator in the peripheral artery is detected by a suitable (photoelectric) transducer and is displayed on a chart recorder.

This way we get the cardiac output curve shown in Figure below. This is also called the dilution curve.

The run of the dilution curve is self-explanatory. During the first circulation period, the indicator would mix up with the blood and will dilute just a bit.
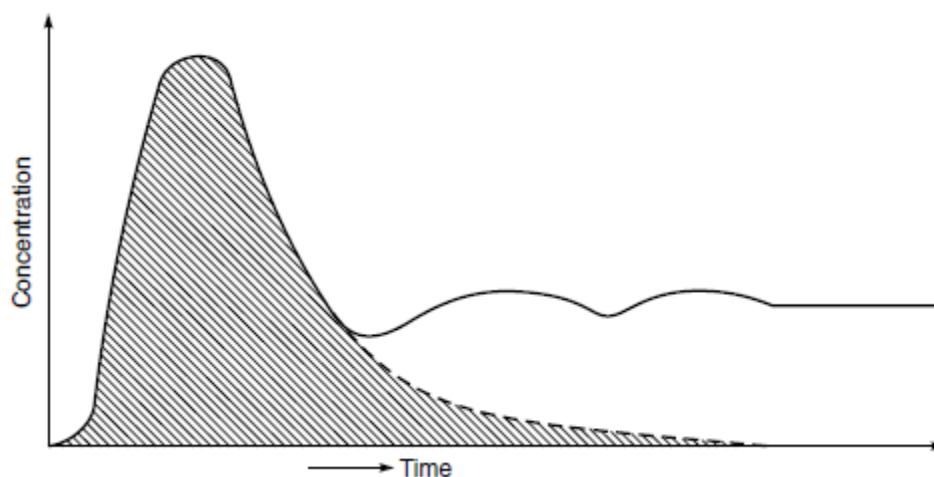
The run of the dilution curve

When passing before the transducer, it would reveal a big and rapid change of concentration. This is shown by the rising portion of the dilution curve.

Had the circulation system been an open one, the maximum concentration would have been followed by an exponentially decreasing portion so as to cut the time axis as shown by the dotted line.

The circulation system being a closed one, a fraction of the injected indicator would once again pass

through the heart and enter the arterial circulation. A second peak would then appear.

When the indicator is completely mixed up with blood, the curve becomes parallel with the time axis. The amplitude of this portion depends upon the quantity of the injected indicator and on the total quantity of the circulating blood.

For calculating the cardiac output from the dilution curve, assume that
$$M = \text{quantity of the injected indicator in mg}$$
$$Q = \text{cardiac output}$$
$$\text{then } Q = M$$
Suppose that 10 mg of the indicator was injected and the average concentration as calculated from the curve was 5 mg/l for a curve duration of 20 s; then Q = 6 I/min.

The area under the primary curve obtained by the prolongation of the down slope exponential curve to cut the time axis, encloses an area showing the time concentration relationship of the indicator on its first passage round the circulation and does not include any of the subsequent recirculations.

It demands a considerable time to perform the exponential extrapolation for calculating the area. The evaluation of the dilution curve is simplified by replotting the curve on a semilogarithmic scale paper. The indicator concentration (Y-axis) is plotted on a logarithmic scale and the time (X-axis) on a linear scale.

The decreasing exponential portion of the curve appears as a straight line, which is projected downwards to cut the time axis. The area under the replotted primary dilution curve is then measured either with a mechanical planimeter or by counting the square units under the curve.

 It can be approximated by summing the indicator concentration occurring at one second intervals from the start to the end of the curve.

Video Content / Details of website for further learning (if any):

https://www.slideshare.net/jineshkj/indicator-dilution-method-blood-flow-meters

Important Books/Journals for further learning including the page nos.:
Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :344 -346

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L7

LECTURE HANDOUTS

BME

III/V

Course Name with Code   : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
                                        16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit: IV- Measurement of Non- Electrical Parameters   Date of Lecture:

Topic of Lecture : Blood flow and cardiac output measurement - Thermal dilution

Introduction :
- Thermodilution is an indicator-dilution method of measuring blood flow. This method is based on the premise that when an indicator substance is added to circulating blood, the rate of blood flow is inversely proportional to the change in concentration of the indicator over time.

- The indicator substance can be a dye (dye-dilution method) or a fluid with a different temperature than blood (thermodilution method).

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about dilution technique

- Principles of an Indicator

Blood flow and cardiac output measurement - Thermal dilution

A thermal indicator of known volume introduced into either the 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.

Cardiac output = "a constant" (blood tem - injectate temp.)/ area under dilution curve

Although first reported by Fegler (1954), thermal dilution as a technique did not gain clinical acceptance until Branthwaite and Bradley (1968) published their work showing a good correlation between Fick and thermal measurement of cardiac output in man.

However, the technique of cannulation of the internal jugular vein and the difficulty of floating small catheters into the pulmonary artery prevented a rapid clinical acceptance of the technique.

In 1972, a report appeared in the American Heart Journal describing a multi-lumen thermistor catheter, known today as the Swan-Ganz triple lumen balloon catheter (Ganz and Swan, 1972). The balloon, located at or near the tip, is inflated during catheter insertion to carry the tip through the heart and into the pulmonary artery.

One lumen terminates at the tip and is used to measure the pressure during catheter insertion. Later, it measures pulmonary artery pressure and intermittently, pulmonary–capillary wedge pressure. A second lumen typically terminates in the right atrium and is used to the monitor right atrial pressure (central venous pressure) and to inject the cold solutions for thermal dilution. A third lumen is used to inflate the balloon. For use with thermal dilution, the pulmonary-artery catheter carries a thermistor proximal to (before) the balloon.

The thermistor is encapsulated in glass and coated with epoxy to insulate it electrically from the blood. This catheter simplified the technique of cardiac cannulation making it feasible to do measurements not only in
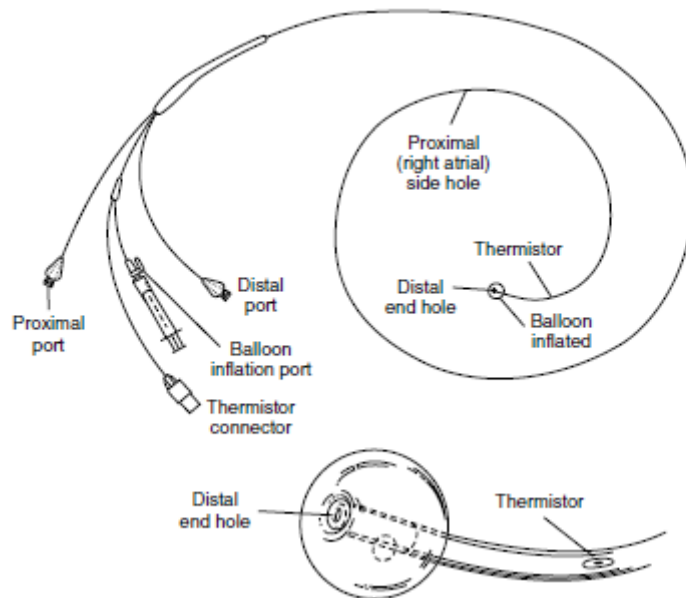
Swan-Ganz Catheter - A 4-lumen catheter

This catheter simplified the technique of cardiac cannulation making it feasible to do measurements not only in A solution of 5% Dextrose in water at room temperature is injected as a thermal indicator into the right atrium.

It mixes in the right ventricle, and is detected in the pulmonary artery by means of a thermistor mounted at the tip of a miniature catheter probe. The injectate temperature is also sensed by a thermistor and the temperature difference between the injectate and the blood circulating in the pulmonary artery is measured.

The reduction in temperature in the pulmonary artery (due to the passage of the Dextrose) is integrated with respect to time and the blood flow in the pulmonary artery is then computed electronically by an analog computer which also applies correction factors. A meter provides a direct reading of cardiac output after being muted until integration is complete so as to avoid spurious indications during a determination
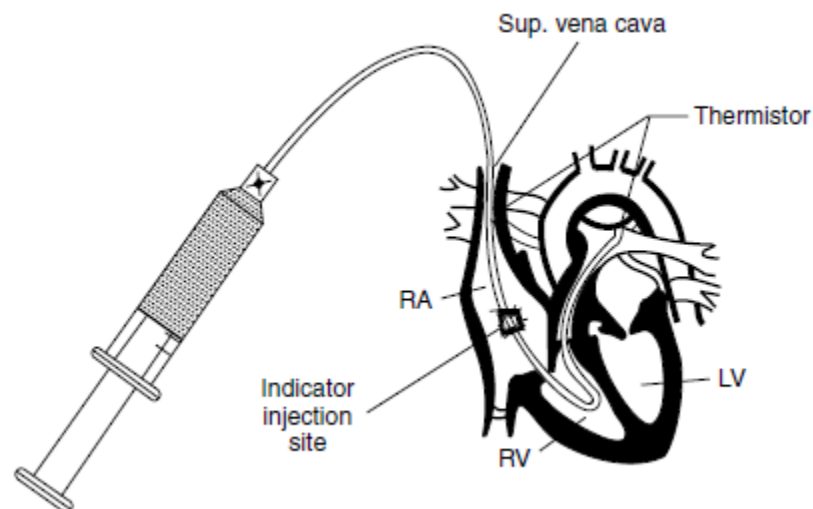
Cardiac output thermal-dilution set-up

The electronic computation is relatively simple, because there is no significant recirculation of the indicator in man. The calculation rests upon the integral of the inscribed curve, the resting temperature in the pulmonary artery, the temperature of the injectate, and a number of constants.

Absence of the need to subtract that part of the area under the curve due to recirculation, and the ease with which an unsatisfactory curve can be detected by failure to return to the original baseline

value of temperature, contribute to the internal consistency of the results.

Video Content / Details of website for further learning (if any):

https://medical-dictionary.thefreedictionary.com/thermodilution

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :347 -349

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LECTURE HANDOUTS

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03

Course Teacher : Mrs.D.G.BeautlinVinola

Unit: IV- Measurement of Non- Electrical Parameters **Date of Lecture:**

Topic of Lecture: Blood flow and cardiac output measurement - dye dilution method

Introduction :

   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.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about dilution technique

- Principles of an Indicator

Blood flow and cardiac output measurement - dye dilution method

The procedure consists in injecting the dye into the right atrium by means of a venous catheter. Usually 5 mg of cardiogreen dye is injected in a 1 ml volume. The quantity used may be 2.5 mg in the case of children.

A motor driven syringe constantly draws blood from the radial or femoral artery through a cuvette. The curve is traced by a recorder attached to the densitometer. After the curve is drawn, an injection of saline is given to flush out the dye from the circulating blood.

There are problems relating to the use of the indicator indocyanine green. It has been experimentally determined that above a dye concentration of approximately 20 mg/ml of blood, the optical density rises less with an increase in dye concentration than below this level (Chamberlain,1975).

Thus for optimum accuracy, the amount of dye chosen for injection should result in dye curves whose peak concentration is less than 20 mg/ml.The photometric part consists of a source of radiation and a photocell and an arrangement for holding the disposable polyethylene tube constituting the cuvette.

 An interference filter with a peak transmission of 805 nm is used to permit only infrared radiation to be transmitted. This wavelength is the isobestic wavelength for haemoglobin (Jarlov and Holmkjer, 1972) at various levels of oxygen saturation.

 In order to avoid the formation of bubbles, the cuvette tubing should be flushed with a solution of silicone in ether. A flow rate of 40 ml/min is preferred in order to get as short a response time as possible for the sampling catheter. The sampling syringe has a volume of 50 mi/min. The output of the photocell is connected to a low drift amplifier. It has a high input impedance and low output impedance. The amplification is directly proportional to the resistance value of the potentiometer R. A potentiometric recorder records the amplifier signal on a 200 mm wide recording paper and a paper speed of 10 mm/s.
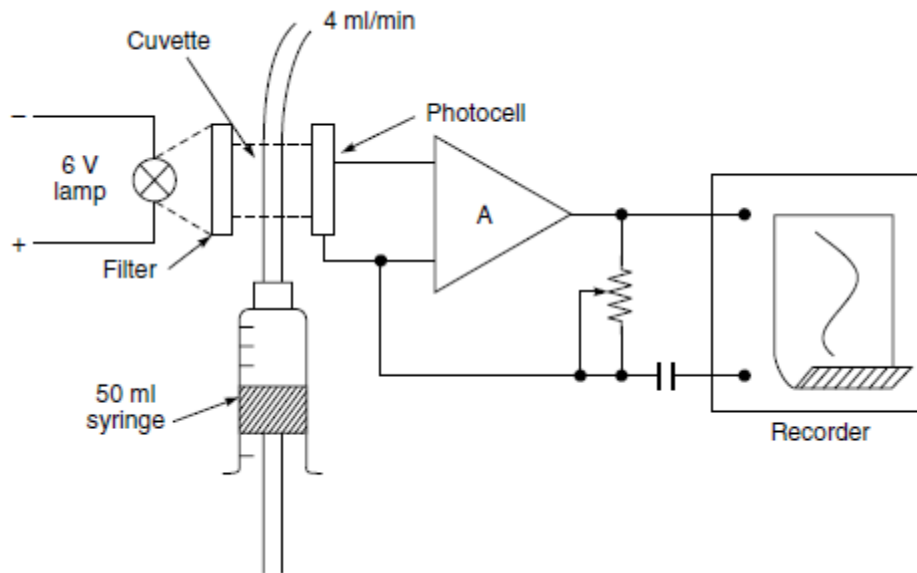
Diagrammatic representation of a densitometer for quantitative measurement of dye concentration

In the recording of dye dilution curves, it is generally necessary that the densitometer be at some point removed from the site of interest. A catheter is used to transport the blood containing dye from the sampling site, inside the cardiovascular system, to the densitometer located outside the body.

Sampling through the catheter densitometer system distorts the concentration time curve.First, the velocity of flow within the catheter is not uniform, which causes the dye to mix within the tube as it travels downstream.

The mixing is a function of the flow rate and the volume of the sampling system, the viscosity of the sampled fluid and the shape of the configuration of the sampling tube.

The second source of distortion is the measuring instrument itself, which may not have response characteristics fast enough to record instantaneous dye concentration as it actually occurs in the lumen.

Distortion is very important when the indicator dilution method is used to measure volume since it is the measurement of the mean transit time of an indicator from the point of injection to the point of sampling, which is of interest. To reduce distortion, computer softwarebased corrections have been devised.

Video Content / Details of website for further learning (if any):

https://pubmed.ncbi.nlm.nih.gov/2092991/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :346 -347

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LECTURE HANDOUTS	L9

| BME | III/V |

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
                                 16BMD03
Course Teacher :Mrs.D.G.BeautlinVinola

Unit: IV- Measurement of Non- Electrical Parameters   **Date of Lecture:**

Topic of Lecture: Electromagnetic and ultrasound blood flow measurement.

Introduction :
- The most commonly used instrument for the measurement of blood flow is of the electromagnetic type. With this type of instrument, blood flow can be measured in intact blood vessels without cannulation and under conditions which would otherwise be impossible.

- Most of the recent efforts have been concentrated on the development of Doppler-shift instruments,which are now available for the measurement of blood velocity, volume flow, flow direction, flow profile and to visualize the internal lumen of a blood vessel.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics of Electromagnetic field

- Basics of blood velocity

Electromagnetic and ultrasound blood flow measurement.
Electromagnetic blood flow measurement.

The operating principle underlying all electromagnetic type flowmeters is based upon Faraday's law of electromagnetic induction which states that when a conductor is moved at right angles through a magnetic field in a direction at right angles both to the magnetic field and its length, an emf is induced in the conductor.

In the flowmeter, an electromagnetic assembly provides the magnetic field placed at right angles to the blood vessel in which the flow is to be measured. The blood stream, which is a conductor, cuts the magnetic field and voltage is induced in the blood stream.

This induced voltage is picked up by two electrodes incorporated in the magnetic assembly. The magnitude of the voltage picked up is directly proportional to the strength of the magnetic field, the diameter of the blood vessel and the velocity of blood flow, i.e
$$e = CHVd$$
where e = induced voltage
H = strength of the magnetic field
V = velocity of blood flow
d = diameter of the blood vessel
C = constant of proportionality
If the strength of the magnetic field and the diameter of the blood vessel remain unchanged,
then the induced voltage will be a linear function of the blood flow velocity. Therefore, $e = C_1 V$
whereC_1 is a constant and equal to CHd.
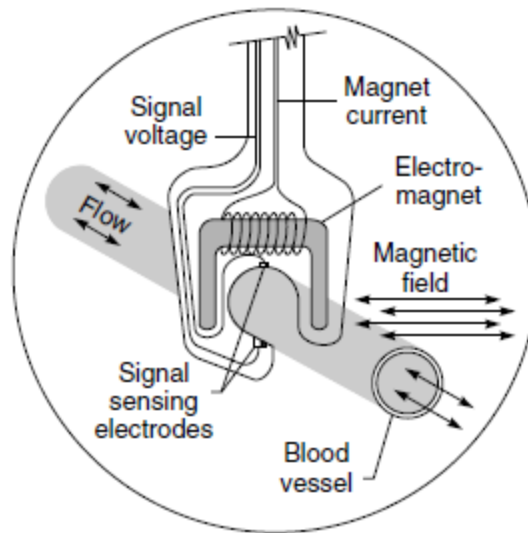Further, the flow rate Q through a tube is given by
$$Q = VA$$
therefore,
$$V = Q/A$$
whereA is the area of cross-section of the tube, hence
$$e = C_1 \backslash Q/A = C_2 \backslash Q$$

Principle of electromagnetic flowmeter

Design of the Flow Transducer

In actual practice, the electromagnetic flowmeter transducer(Wyatt, 1984) is a tube of non-magnetic material to ensure that the magnetic flux does not bypass the flowing liquid and go into the walls of the tube.

The tube is made of a conducting material and generally has an insulating lining to prevent short circuiting of the induced emf. The induced emf is picked up by point electrodes made from stainless steel or platinum.

The flow head contains a slot through which the intact blood vessel can be inserted to make a snug fit. Several probes of different sizes must therefore accompany the flowmeter to match the full range of sizes of the blood vessels which have various diameters. It is naturally more difficult to construct flow

Ultrasound blood flow measurement

There are basically two types of ultrasonic blood flow-velocity meters. The first type is the transittime velocity meter and the second is the Doppler-shift type. For routine clinical measurements, the transcutaneous Doppler instrument has, by far, superseded the transit-time type.

Therefore, most of the recent efforts have been concentrated on the development of Doppler-shift instruments,which are now available for the measurement of blood velocity, volume flow, flow direction, flow profile and to visualize the internal lumen of a blood vessel.

Doppler Shift Flow Velocity Meters

It is a non-invasive technique to measure blood velocity in a particular vessel from the surface of the body. It is based on the analysis of echo signals from the erythrocytes in the vascular structures. Because of the Doppler effect, the frequency of these echo signals changes relative to the frequency which the probe transmits. The Doppler frequency shift is a measure of the size and direction of the flow velocity.
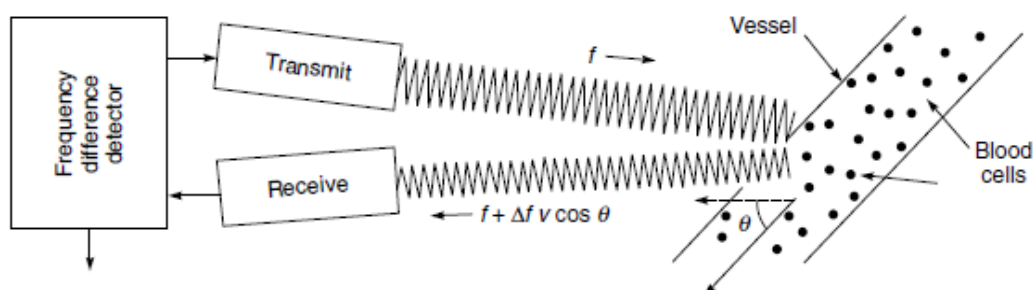
Principle of ultrasonic Doppler-shift flow velocity meter

$$f1 = (C \ v \cos)C - q$$

where f = transmitted frequency
C = velocity of sound in blood
q = angle of inclination of the incident wave to the direction of blood flow
v = velocity of blood cells

The piezo-electric crystal A is electrically excited to generate ultrasonic waves, which enter the blood. Ultrasound scattered from the moving blood cells excites the receiver crystal. The electrical signal received at **B** consists of a large amplitude excitation frequency component, which is directly coupled from the transmitter to the receiver, plus a very small amplitude Doppler-shifted component scattered from the blood cells.

The detector produces a sum of the difference of the frequencies at **D**. The low-pass filter selects the difference frequency, resulting in audio frequencies at **E**. Each time the audio wave crosses the zero axis, a pulse appears at **G**. The filtered output level at **H** will be proportional to the blood velocity.

The following two pitfalls are encountered in Doppler ultrasonic blood flowmeters. High frequency response is usually inadequate which introduces a non-linearity into the input-output calibration curve.
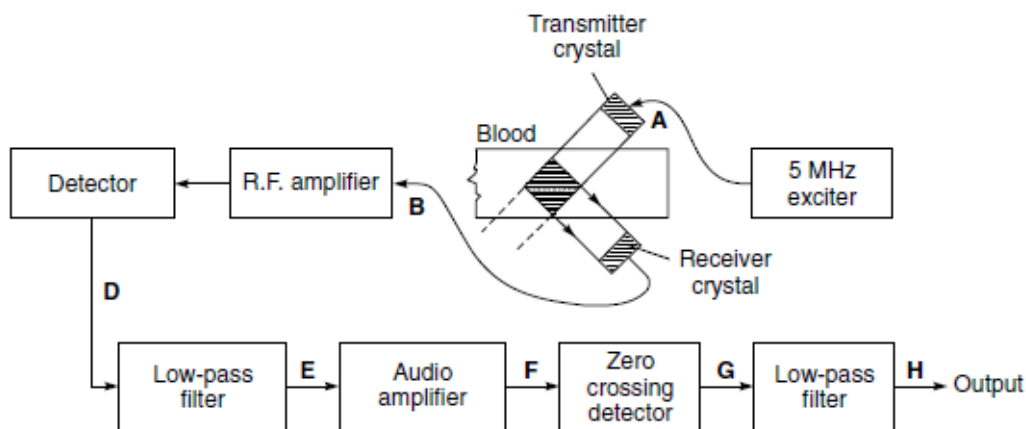
Block diagram of Doppler shift blood flowmeter

Video Content / Details of website for further learning (if any):

https://www.elprocus.com/what-is-an-ultrasonic-flow-meter-types-and-its-applications/

https://www.researchgate.net/publication/315767379_Electromagnetic_Blood_Flow_meter_Review

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 331 - 333

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LECTURE HANDOUTS

BME		III/V

Course Name with Code :BIO MEDICAL INSTRUMENTATION AND MEASUREMENTS
                                16BMD03
Course Teacher   :Mrs.D.G.BeautlinVinola

Unit: V- Bio –Chemical Measurement   **Date of Lecture:**

Topic of Lecture: Biochemical sensors - pH, pO2 and pCO2

Introduction :
- Today's blood gas sensors are the result of many years of gradual improvements and optimizations. The operating principles behind sensor technology have largely remained unchanged, even though the size of analyzers and thus of sensors has decreased remarkably.

- However, miniaturization has created a new challenge: to fit sensor technology into the limits set by the basic sensor design requirements.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics of sensors

- Basic knowledge about Analyzers

Biochemical sensors - pH, pO2 and pCO2

The pH electrode

This electrode was developed, or rather discovered, in the beginning of the previous century, when it was found that a thin glass membrane separating two solutions differing in pH could develop a small difference in electrical potential.

In the beginning it was very difficult to measure this potential, but with improvements in electronics it became practically feasible and instruments that could measure pH were built.

The pCO2 sensor

Much later, actually more than half a century later, the discovery of the pH electrode enabled the development of the pCO2 sensor by American scientists Stow and Severinghaus. Stow used a glass pH electrode, which was covered by a plastic membrane.

A Ag/AgCl reference electrode was placed under the membrane as well. J. W. Severinghaus improved this design by adding a source of bicarbonate ions to the electrolyte solution.

By doing this, the pH of the inner solution became linked to the partial pressure of pCO2 outside the membrane by a simple mathematical equation, now commonly known as the Henderson-Hasselbalch

equation glass membrane separating two solutions.

The pO₂ sensor

The pO₂ sensor was finally added by L. C. Clark and shortly thereafter built into a combined instrument by J. W. Severinghaus. This instrument is now commonly referred to as the first blood gas analyzer in the world.

The pO₂ sensor was designed as a membrane-covered electrode. It had a very thin platinum wire melted into a glass rod. The covering plastic film reduced the flux of oxygen molecules to the platinum surface, so when the electrode was polarized appropriately, the oxygen reduction current was proportional to the partial pressure of oxygen.

This idea of reducing the flux of molecules to the electrode surface by the application of a plastic membrane has later been used in many other sensors, for instance the ubiquitous glucose sensortions differing in pH could develop a small difference in electrical potential.
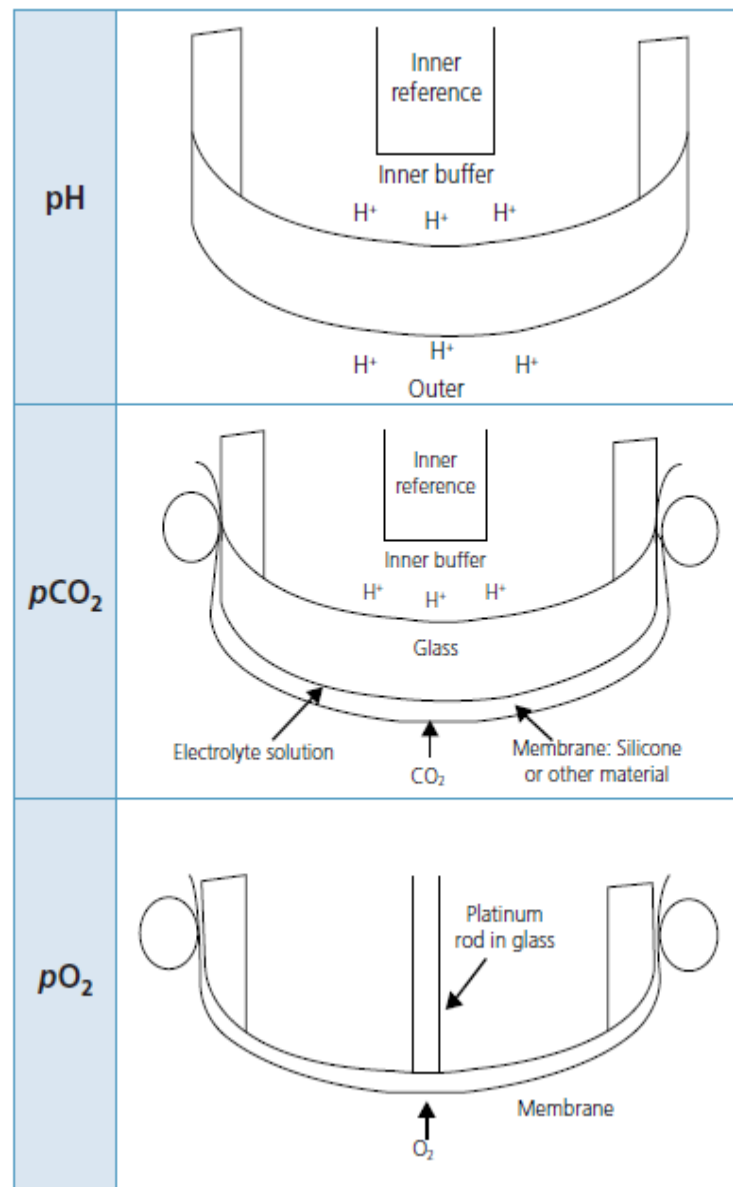
working principles of these sensors

Scientific challenges to designers of today

Today's challenge when dealing with these well-known sensors is hence to provide:
   • Intimate understanding of the basic physical chemistry and electrochemistry of the sensor

• Selection of optimal materials that provide the desired sensor function(s)
• Physical characterization methods that allow monitoring of material properties of the sensors. This could be surface roughness, chemical impurities, etc.

The job is even more important today because of the ongoing miniaturization trend. The hope is, of course, that smaller sensors will lead to "*better*" analyzers, as mentioned in the introduction, but it may not necessarily be straightforward.

When the scientific principles of the sensor are well understood, it often becomes clear that the design issues remain the same as in traditional sensors. As an example of this, some considerations on what determines the response time of the Severinghaus pCO2 sensor is presented in **Example 1**.

On the chemical side it is also the same fundamental (electro)chemical laws that govern small sensors as well as conventional sensors. These laws impose restrictions on the sensors, and this is illustrated by an example involving the oxygen sensors.

The reaction in question is comprised of a series of simpler reactions that in combination lead to the electrochemical reduction of oxygen. If one of the simpler reactions is not as fast as it is supposed to be, it has become "rate limiting", and some of the electrical current may be "*lost*", at least temporarily, if ignored.

Video Content / Details of website for further learning (if any):
https://link.springer.com/chapter/10.1007/978-94-011-0161-5_18

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :106 -108

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L2

LECTURE HANDOUTS

BME

III/V

Course Name with Code   : BIO MEDICAL INSTRUMENTATION AND MEASUREMENTS
                                                  16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit: V- Bio –Chemical Measurement   Date of Lecture:

Topic of Lecture: Ion selective Field effect Transistor (ISFET)

Introduction :

- An ion-sensitive field-effect transistor (ISFET) is a field-effect transistor 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.

- Here, the solution is used as the gate electrode. A voltage between substrate and oxide surfaces arises due to an ion sheath. It is a special type of MOSFET (metal-oxide-semiconductor field-effect transistor)

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basics knowledge about transistor

- Basic principles of Electrode

**Ion selective Field effect Transistor (ISFET)**

An ISFET is an ion-sensitive field effect transistor 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. Here, the solution is used as the gate electrode. A voltage between substrate and oxide surfaces arises due to an ion sheath..

For mass production of this sensor type, nearly all the highly developed technological arsenal of microelectronics could be used.On the other hand, all the achievements of potentiometry with ISEs also became usable for ISFET sensor

To ensure accurate measurement, instruments which work with ISEs must have a high input impedance. As a rule of thumb, their input resistance should be ca. 100 times higher than the internal resistance of the cell containing the ISE.

Since several ISEs (e.g. the glass electrode) have resistances in the range of megaohms, a good pH meter should have at least an input resistance of gigaohms. Even low-cost pocket pH meters fulfil this requirement today

ISE with MOSFET and low impedance connection to measuring instrument (left). Measuring set-up with ISFET (right)
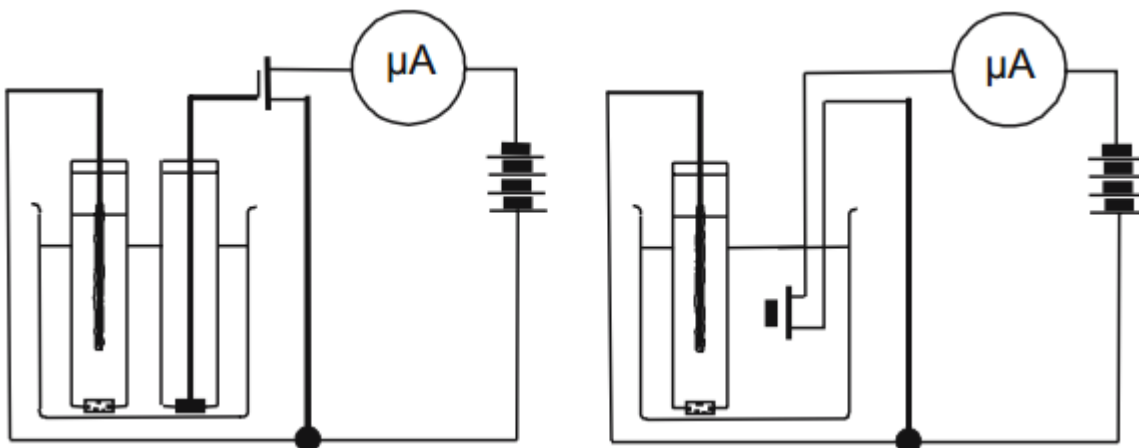
The below ISFET structure is identical to that of the MOSFET. Commonly, two n-type zones are incorporated in a substrate of p-doped silicon. The substrate is covered by an insulating layer formed normally by silicon dioxide. Sometimes silicon nitride Si3N4 is used. A component made with such a composition would more accurately be called not MOSFET, but IGFET (isolated gate FET). Both oxides and nitrides are good insulators. The metallic gate layer is plated on top of the insulating layer.

.
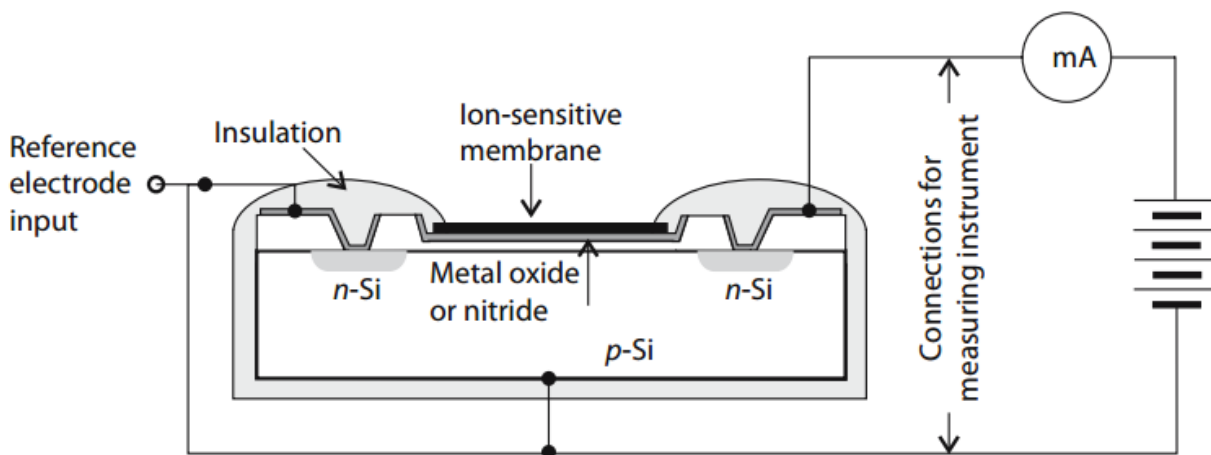
Finally, the ion-selective film is applied on top of the gate. The emf appearing between the reference electrode in solution and ion-selective membrane appears as a voltage between the gate and source electrodes of the MOSFET, as shown in figure.

This gate-source voltage acts as an input voltage of the amplifier circuit and will bring about a linear current increase, which is measurable at the output of the circuit. Alternatively, an amplifier circuit with constant drain current can be used.

All the ion-selective membrane materials mentioned in connection with solid- and liquid-membrane ISEs can be used with ISFETs. The most common are pH-sensitive ISFETs. They do not suffer from the traditional drawbacks of glass electrodes, namely high price, fragility and extremely high impedance.

Even the insulation layers of SiO_2 and Si_3N_4 exhibit some pH sensitivity. More common pH-sensitive layers are liquid membranes (polymers with solvent) containing ion exchangers, e.g. amines attached with a hydrophobic alkyl chain at the opposite end. pH-sensitive glass has also been tested, in an adaptation of enamel electrodes. pH-sensitive ISFETs are commercially available, but they are still

unable to replace the classic glass electrode

Two problems have accompanied the development of the ISFET from the very beginning.

- ✓ The first one is the problem of direct contact for making contact with the sensitive membrane, which is inherent in ISEs.
- ✓ The second problem is encapsulation of the humidity-sensitive regions of the MOSFET substrate in such a way that only the gate (including the ion-selective layer) is exposed to solution.

  The technological progress achieved by the introduction of ISFETs is somewhat diminished by the fact that an external reference electrode is still necessary for measurement.

An alternative solution, where silicon technology is used throughout, is depicted in figure(Smith and Scott 1986). In this example, the basis is a pH-sensitive ISFET on an n-type silicon chip. A groove is formed by 'anisotropic etching'.

The following technological steps (formation of p-doped zones by diffusion, generation of an isolating nitride film, metallizing with aluminium etc.) result in the formation of a MOS structure. Finally, by etching with hydrofluoric acid, a porous silicon layer is generated inside the groove.

The latter acts as a diaphragm, which establishes the liquid–liquid junction to the AgCl pellet added later. The described process retains some advantages of microelectronics technology but suffers from some additional elaborate steps.
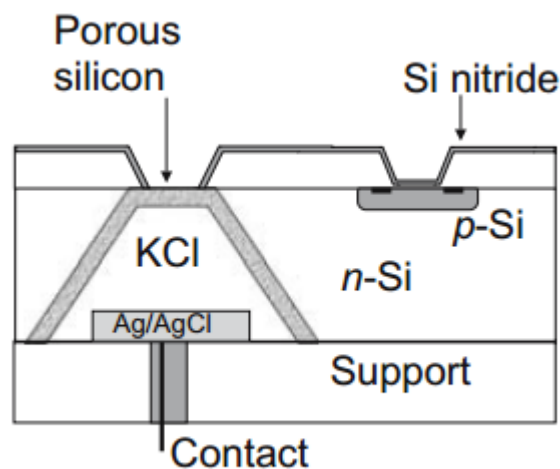
ISFET in silicon technology with integrated microreference electrode.

Video Content / Details of website for further learning (if any):

https://www.elprocus.com/ion-sensitive-field-effect-transistor-isfet-working-principle/

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :222 -223

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	L3
LECTURE HANDOUTS	

BME	**III/V**

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
                                            16BMD03

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit: V- Bio –Chemical Measurement   **Date of Lecture:**

Topic of Lecture: Immunologically sensitive FET (IMFET)

Introduction :

- Diagnostics as a whole represent a large, well-established, and continually expanding market. Methods for the selective determination of analytes in biological fluids, such as blood and urine, are important.

- When a foreign substance (antigen) invades the human body, the immune system produces antibodies that interact with the antigen.

- Such a recognizing process involves the formation of an immunocomplex based on interactions between the immunospecies.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basic knowledge about analytes

- Basics of diagnostics

Immunologically sensitive FET (IMFET)

In order to understand the operation of the IMFET, one must trace its origins back to the ISFET or ChemFET (Fig.1). The latter devices have been described in depth elsewhere (20–22). ISFETs and ChemFETs have, in turn, evolved from the Metal Oxide Semiconductor Field Effect Transistor (MOSFET), currently the most popular active device in the entire semiconductor industry. It is a unipolar device, where the current is given by the flow of majority carriers, either holes in PMOS type or electrons in NMOS type.

The operation of the MOSFET can be considered as a resistor controlled by the status of a gate region, so-called MIS structure. It is a sandwich consisting of a stacked-gate metal layer, an insulator (typically silicon oxide), and a semiconductor.

Assume a low-level doped p-type (NMOS device). Three different states of charge distribution can occur, depending on the voltage V_g , applied between the metal and a semiconductor. A negative value of V_g causes positive holes to accumulate at the semiconductorinsulator interface.

A positive value of V_g of a low magnitude leads to the ''depletion'' condition in which mobile holes

are driven away from the interface, resulting in a negative charge of low density due to the presence of immobile acceptor atoms.

 Finally, if the Vg exceeds a certain threshold voltage (Vth), electrons accumulate at the semiconductor-insulator interface at a density greater that the hole density, a situation opposite to that normally found with p-type semiconductors. This depletion of mobile charge carriers followed by surface inversion is known as the ''field effect.''

It forms an electrically conductive channel between two other terminals, a source and a drain.The drain current Id through the transistor is a functions of drain and gate voltage.

Without surface inversion (i.e., Vg < Vth,) the drain current is negligible, because the drain-to-substrate PN junction is reverse biased. The MOSFET and its descendants are charge-controlled devices.

In analytical applications (e.g., ISFETs, Chem-FETs, and IMFETs), the change in charge density is brought about by adsorption of one or more species present in the solution onto the FET structure.

In the ISFET, the gate metal is replaced with a conventional reference electrode(Ag/AgCl or Hg/Hg2Cl2), a solution containing an ionic species of interest, and an electroactive material(membrane) capable of selective ion exchange with the analyte, which is an example of a nonpolarizable interface, that is, reversible charge transfer occurs between the solution and the membrane.

The analyte generates a Nernst potential at the membrane-solution interface, which then modulates the drain current analogous to the manner in which changing the externally applied voltage does for the MOSFET.
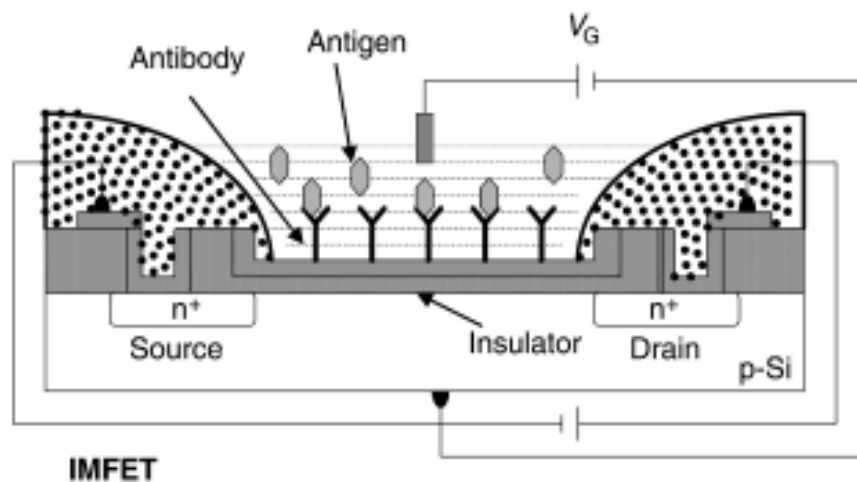
IMFET

The structure of the direct-acting IMFET is similar to that of the ISFET, except that the solution-membrane interface is polarized rather than unpolarized.

 If the solution-membrane interface of the ISFET is ideally polarized (i.e.,charge cannot cross the interface), then the ISFET can measure the adsorption of charged species at the interface as shown below.

As antibodies, antigens, and proteins are generally electrically charged molecules, the polarized ISFET could be used to monitor their nonspecific adsorption at the solution-membrane interface.

To render the polarized ISFET selective for a given antigen and thus create the so-called IMFET, the specific antibody for that antigen has to be immobilized on the surface of the ISFET.

The adsorption of this antigen would then be specifically enhanced over other molecules in the solution

and the signal measured by the ISFET would be mostly due to the adsorption of that particular antigen.

 The ISFET interacts with the analyte through an ion-exchange mechanism, whereas the IMFET interaction is based on the antigen-antibody reaction.

Video content / Details of website for further learning (if any):
https://www.researchgate.net/publication/229595686_Immunologically_Sensitive_Field-Effect_Transistors

Important Books/Journals for further learning including the page nos.:

Immunologically Sensitive Field-Effect Transistors, EMMANUEL S. ZACHARIAH ,University of New Jersey New Brunswick, Page No : 98 -100

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	L4
LECTURE HANDOUTS	

BME	**III/V**

**Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03**

Course Teacher   : Mrs.D.G.BeautlinVinola

Unit: V- Bio –Chemical Measurement   **Date of Lecture:**

Topic of Lecture: Blood glucose sensors

Introduction :
- A biosensor is an analytical device which is used to determine the presence and concentration of a specific substance in a biological analyte.

- There are a wide variety of applications for biosensors, and they are used most commonly in healthcare settings. Because of their ability to be highly selective, sensitive, and relatively easy to use, biosensors can rapidly recognize and measure key biometrics in bodily fluids to aid in health monitoring

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics of Analytes

- Basics of sensors

Blood glucose sensors

Blood glucose meters are one of the oldest and most common methods for testing glucose. These devices use enzyme-coated test strips that are manufactured with a precise amount of specific enzymes that can only react to one blood sample.

Because of this, test strips are intended for single use and cannot be reused. When inserted into the blood glucose meter and after receiving a blood sample, the test strip communicates with the glucose meter which calculates the amount of glucose in the blood and displays the result on the meter's screen.

The cost of blood glucose meters and test strips is typically more affordable than continuous glucose monitoring devices. Meters also provide more discrete and intermittent testing, since they don't need to be worn on your body

Continuous Glucose Sensors

A continuous glucose monitor (CGM) uses a filament coated in glucose sensing enzymes to detect glucose in the interstitial fluid (the fluid between your cells). As a wearable sensor, a CGM automatically detects and measures glucose levels 24 hours a day.

A CGM sensor can be used continuously for several days or weeks — the exact duration will vary by manufacturer. Implantable CGM sensor options offer months-long wear, as they are embedded below the skin in a larger capsule, versus the thinner filament in other CGM sensors.

The sensor then works with a transmitter that sits above the skin to send data to a receiver or smart device. The transmitter allows you to wirelessly view your current glucose level and trends, or you can be notified when it's time to replace the sensor.

How Does a Glucose Sensor Work?

Glucose testing tools — like glucose meter test strips and wearable sensors — are glucose biosensors. These compact devices are comprised of several crucial components for the detection and measurement of glucose.

The National Center for Biotechnology Information (NCBI) features an exhaustive explanation of the parts of a biosensor.

For a glucose biosensor, the following components are used:

Analyte: A substance with chemical constituents that are being identified and measured. In this instance, glucose is the analyte that the biosensor is designed to detect.

Bioreceptor: This is a molecule that specifically recognizes the analyte. For the detection of glucose, specific enzymes are used, which are proteins that facilitate a chemical reaction. For example, the test strip for a blood glucose test contains the enzyme that interacts with the analyte in the drop of blood.

Transducer: This part of the biosensor converts one form of energy into another. Specifically, it converts the recognition of the bioreceptor into a measurable signal. Most modern-day glucose meters and continuous glucose monitors measure electrical signals, although earlier generations of glucose meters used a colorimetric process (color change) that was measured optically.

Electronics and display: These components process the transduced signal and prepare it for display. The processed signals are then quantified and shown on either the glucose meter's display or the receiver for a continuous glucose monitor (or compatible app).

Video Content / Details of website for further learning (if any):
https://agamatrix.com/blog/glucose-sensors/

Important Books/Journals for further learning including the page nos.:

Heidi E. Koschwanez, William M. Reichert, in Biomaterials Science (Third Edition), 2013,page no: 9-13

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LECTURE HANDOUTS

BME

III/V

Course Name with Code : **BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS 16BMD03**

Course Teacher : **Mrs.D.G.BeautlinVinola**

Unit: V- Bio –Chemical Measurement   Date of Lecture:

Topic of Lecture: Blood gas analyzers - colorimeter

Introduction :

- Electronics designers and medical practitioners have been working together to develop instruments to aid in diagnosis of medical conditions and in therapy. This has given rise to the field of biomedical electronics.

- The field of biomedical electronics has given new solutions for diagnosis and health care.

- The use of sensors to measure the vital parameters of the body is not new; the electrocardiogram has been aiding the medical practitioners to give them a view of the workings of the human heart. It is used to note any abnormalities in its functioning

Prerequisite knowledge for Complete understanding and learning of Topic:

- Basic principle of analyzer

- Basics about blood gas

Blood gas analyzers – colorimeter

Colours are an important aspect of life and are necessary information needed for the brain to process the visual data received. Colours describe the property of an object and also describe the characteristics of the light being reflected from an object.

Colours also define the brains interpretation of the specific manner in which the light is perceived by the eye. Colorimetry is the technique to measure and describe the human colour perception[57]. The Human eye is composed of photoreceptors which are called as cones and rods which act as the sensors to produce an image in the brain.

The rods and cones act in different ways, the rods are monochromatic and are used at low light conditions. The cones are the receptors which are responsible for the colour image and work in bright light conditions.

There are three types of cones and each one is sensitive to a different wavelength of light spectrum.The three wavelengths fall in the red, green and blue regions of the spectrum and are referred as the long, medium and short wavelength regions.

The light entering in the eye is reduced to the three colour components and the three cones generate signals based on the energy of the spectra falling on them and the values are known as the tristimulus values.

The tristimulus values of a colour are the amounts of the three primary colours needed to reproduce the original colour using a three component additive colour model. The tristimulus colorimetric model based on the RGB colour model measures the colour in the three basic colours red, blue and green and it is called as the RGB colour space.

Zero intensity for each of the colour components results in the darkest colour black which means there is no light and the full intensity of all the colour components gives the colour white.When one of the components has the highest intensity then the colour is closer to that primary colour for example if the intensity of the component green is the highest then the colour will be greenish.

A secondary colour is formed when two out of the three components have a stronger intensity than the third; high intensity in green and blue result in a colour cyan, magenta is the result when red and blue have high intensity and yellow is a result of red and green having higher intensity than blue.

Experiment Setup

The change in colour of an indicator to change in pH is explained in the previous sections. The measurement of colour in terms of the primary colours from a digital image has also been discussed. To determine the pH from the colour of the indicator a mathematical relation is needed. A test bed was setup to explore the relation between the colour of the indicator and the pH.
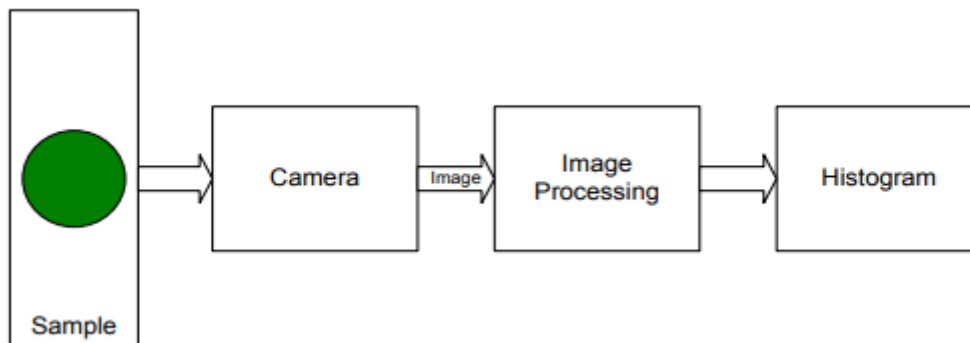
A block diagram of the test setup is shown in figure 3.6. It consists of the pH sample mixed with the indicator bromothymol blue, the camera to record the image and the image processing software to record the histogram of the colour from the samples.

The pH samples were prepared in the range of 6.1 to 7.9 in units of 0.1 and the indicator bromothymol blue of concentration 0.1 Molar (M). The indicator Bromothymol Blue was mixed with pH samples of known values. The samples were backlit with a white light source.

The samples were then imaged using a 1.3 MP CCD camera. The camera used for the experiment is a µEye UI-2240SE-C-HQ from IDS Imaging Development Systems. The CCD camera was used as it provides more sensitivity to colour than the CMOS camera.

The resolution of the camera does not influence the accuracy of the analyser due to the fact that the camera used is of very high resolution. The camera was controlled using a Lab-VIEW Virtual Instrument (VI).Laboratory Virtual Instrumentation Engineering Workbench (Lab-VIEW) is a graphical programming.

Environment used to develop sophisticated measurement, test and control systems. It uses graphical icons and wires and the flow of logic resembles a flowchart.

The program through the use of drivers and interface cards allows the user to interface with different instruments and input devices. It provides a seamless approach to integrate the camera with the

software and control its operations.

Video Content / Details of website for further learning (if any):
http://vuir.vu.edu.au/19422/1/Jaideep_Chandran.pdf

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No : 420 -422

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| L6 |

| **LECTURE HANDOUTS** |

| **BME** |

| **III/V** |

Course Name with Code   : **BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS 16BMD03**

Course Teacher   : **Mrs.D.G.BeautlinVinola**

Unit: V- Bio –Chemical Measurement   **Date of Lecture:**

| **Topic of Lecture: Blood gas analyzers - Sodium Potassium Analyzer** |

Introduction :

Electrolytes play multiple roles in the maintenance of body functions such as sustaining proper body Ph, regulating function of the heart and other muscles, and participating in enzymatic functions. Electrolytic imbalances can result in congestive heart failure, diabetes insipidus, and kidney diseases.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics of Electrolytes

- Basics of Analyzer

Sodium Potassium Analyzer

Electrolytes play multiple roles in the maintenance of body functions such as sustaining proper body Ph, regulating function of the heart and other muscles, and participating in enzymatic functions. Electrolytic imbalances can result in congestive heart failure, diabetes insipidus, and kidney diseases.

For these reasons electrolytic analysis is a key factor in patient diagnosis and treatment. Electrolyte analyzers measure electrolytes in serum, plasma and urine. Major components of an electrolyte analyzer are - reagents, electrode module, peristaltic pump, and sample probe. Automated systems feature comprehensive test menu, a high throughput as well as STAT testing.

The most common methods of analysis are - Flame Emission Photometry (FEP) and Ion Selective Electrode (ISE). Flame Photometry can be used to measure Na+, K+ and Li+.

It provides an indirect measurement, while ISE methods offer direct measurements. Most analyzers use ISE technology to make electrolyte measurements.

Four models of Medica's EasyLyte electrolyte analyzers that use ISE technology are:

- EasyLyte Na+/K+

- EasyLyte PLUS Na+/K+/Cl-

- EasyLyte Lithium Na+/K+/Li+

- EasyLyte Calcium Na+/K+/Ca++/pH

When it comes to the AVL 9180 analyzer model, this is a fully automatic system that measures sodium, potassium and chloride. Yes/ No keys in the device can perform all functions, including sample measurement data input, programming and quality control testing.

The measuring chamber consists of the movable left locking device that holds the electrode in place. Three different electrodes used are sodium, potassium, chloride and a reference electrode.

Laboratories should make sure to choose an analyzer that suits their setting's present and future testing requirements and performance needs.

Also consider the degree of linearity, stability, precision and specificity of the device. Purchasing the device from a reliable laboratory equipment supplier will ensure efficient post-sales support including installation, repair and maintenance.

Sodium Potassium Analyzer

Video Content / Details of website for further learning (if any):
https://www.slideshare.net/guesteda25a3/electrolyte-analyzerpptx-autosaved

Important Books/Journals for further learning including the page nos.:
Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :433

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L7

LECTURE HANDOUTS

BME	III/V

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS 16BMD03

Course Teacher : Mrs.D.G.BeautlinVinola

Unit: V- Bio –Chemical Measurement   **Date of Lecture:**

Topic of Lecture : Blood gas analyzers - spectrophotometer

Introduction :
- Spectrophotometry is a method to measure how much a chemical substance absorbs light by measuring the intensity of light as a beam of light passes through sample solution.

- The basic principle is that each compound absorbs or transmits light over a certain range of wavelength. This measurement can also be used to measure the amount of a known chemical substance.

- Spectrophotometry is one of the most useful methods of quantitative analysis in various fields such as chemistry, physics, biochemistry, material and chemical engineering and clinical applications.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics of photometry

- Basics of quantitative analysis

Blood gas analyzers – spectrophotometer

A spectrophotometer is an instrument that measures the amount of photons (the intensity of light) absorbed after it passes through sample solution. With the spectrophotometer, the amount of a known chemical substance (concentrations) can also be determined by measuring the intensity of light detected. Depending on the range of wavelength of light source, it can be classified into two different types:

- UV-visible spectrophotometer: uses light over the ultraviolet range (185 - 400 nm) and visible

range (400 - 700 nm) of electromagnetic radiation spectrum.

- IR spectrophotometer: uses light over the infrared range (700 - 15000 nm) of electromagnetic radiation spectrum.

In visible spectrophotometry, the absorption or the transmission of a certain substance can be determined by the observed color. For instance, a solution sample that absorbs light over all visible ranges (i.e., transmits none of visible wavelengths) appears black in theory. On the other hand, if all visible wavelengths are transmitted (i.e., absorbs nothing), the solution sample appears white. If a solution sample absorbs red light (~700 nm), it appears green because green is the complementary color of red. Visible spectrophotometers, in practice, use a prism to narrow down a certain range of wavelength (to filter out other wavelengths) so that the particular beam of light is passed through a solution sample.

Devices and mechanism

Figure 1 illustrates the basic structure of spectrophotometers. It consists of a light source, a collimator, a monochromator, a wavelength selector, a cuvette for sample solution, a photoelectric detector, and a digital display or a meter. Detailed mechanism is described below. Figure 2 shows a sample spectrophotometer (Model: Spectronic 20D).
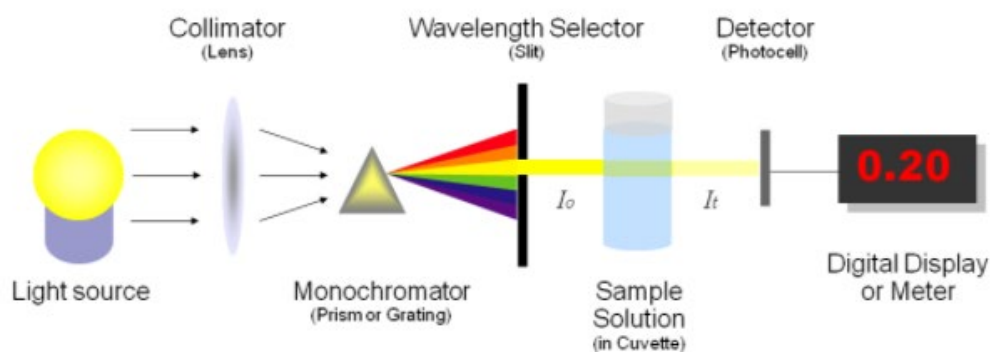
Basic structure of spectrophotometers

A spectrophotometer, in general, consists of two devices; a spectrometer and a photometer. A spectrometer is a device that produces, typically disperses and measures light. A photometer indicates the photoelectric detector that measures the intensity of light.

- Spectrometer: It produces a desired range of wavelength of light. First a collimator (lens) transmits a straight beam of light (photons) that passes through a monochromator (prism) to split it into several component wavelengths (spectrum). Then a wavelength selector (slit) transmits only the desired wavelengths, as shown in Figure 1.
- Photometer: After the desired range of wavelength of light passes through the solution of a sample in cuvette, the photometer detects the amount of photons that is absorbed and then sends a signal to a galvanometer or a digital display, as illustrated in Figure 1.

Beer-Lambert Law

Beer-Lambert Law (also known as Beer's Law) states that there is a linear relationship between the absorbance and the concentration of a sample. For this reason, Beer's Law can *only* be applied when there is a linear relationship. Beer's Law is written as:

$$A = \epsilon l c A = \epsilon l c$$

where

- A is the measure of absorbance (no units),
- ϵ is the molar extinction coefficient or molar absorptivity (or absorption coefficient),
- l is the path length, and
- c is the concentration.

A single wavelenth spectrophotometer

Video Content / Details of website for further learning (if any):

https://www.sciencedirect.com/topics/chemistry/spectrophotometry

Important Books/Journals for further learning including the page nos.:

Accurate Measurement of Optical Properties of Materials**,** Spectrophotometry, Volume 46,1st Edition
by Thomas Germer ,Page No :560 -562

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| | **L8** |

LECTURE HANDOUTS

BME | **III/V**

Course Name with Code : **BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS 16BMD03**

Course Teacher : **Mrs.D.G.BeautlinVinola**

Unit: V- **Bio –Chemical Measurement**   Date of Lecture:

Topic of Lecture: Blood cell counter

Introduction :

- Changes in the normal functioning of an organism are often accompanied by changes in the bloodcell count. Therefore, the determination of the number and size of blood cells per unit volume often provides valuable information for accurate diagnosis.

- The blood constitutes 5–10% of the total body weight and in the average adult, it amounts to 5–6 l. Blood consists of corpuscles suspended in a fluid called plasma in the proportion of 45 parts of corpuscles (cells) to 55 parts of plasma.

- The percentage of cells in the blood is called the haematocrit value or packed cell volume (PCV). The majority of the corpuscles in blood are red blood cells (erythrocytes), others being white blood cells(leucocytes) and platelets (thrombocytes).

Prerequisite knowledge for Complete understanding and learning of Topic:
- Basics of blood cell

- Basics of plasma

Blood cell counter

Erythrocytes (Red Blood Cells): Red blood cells have the form of a bi-concave disc with a mean diameter of about 7.5 m and thickness of about 1.7 m. The mean surface area of the cell is about 134mm2.

There are about 5.5 million of them in every cubic millimetre of blood in men and nearly 5 million in women. In the whole body, there are about 25 billion erythrocytes and they are constantly being destroyed and replaced at a rate of about 9000 million per hour.

The normal red cell lasts approximately 120 days before it is destroyed.The erythrocytes have no nucleus. They are responsible for carrying oxygen from the lungs to the tissues and carbon dioxide from the tissues to the lungs.

Anaemia (reduction in the oxygen carrying capacity of blood) can develop from a change in the

number, volume or Hb concentration of erythrocytes, caused by bone marrow dysfunction resulting in the poor production rate of RBCs.

Since these changes are specific, the measurement of packed cell volume (PCV), the number of RBCs and the haemoglobin (Hb) are very important.

Leucocytes (White Blood Cells):

Leucocytes are spherical cells having a nucleus. There are normally 5000–10,000 white cells per cubic mm of blood but their number varies during the day. They live for seven to fourteen days and there is a rapid turn over, with constant destruction and replacement.

Leucocytes form the defence mechanism of the body against infection. They are of two main types: the neutrophils and the lymphocytes. Neutrophils ingest bacteria and lymphocytes are concerned with immunological response.

The number and proportion of these types of leucocytes may vary widely in response to various disease conditions. For thus reason, it is important to know the total leucocyte count. The change, however, is often so small that the WBC count remains within normal limits and only the differential count would indicate any abnormality.

Neutrophils are nearly twice as big as the red cells and contain both a nucleus divided into several lobes and granules in their protoplasm. Lymphocytes are of the same size as the red cells but contain a large density staining nucleus and no granules.

Monocytes are another type of leucocytes,which are twice as big as the neutrophils. They have a single large nucleus and no granules.

Thrombocytes (Platelets):

Platelets are usually tiny, round, oblong or irregularly shaped cells of the blood with an average diameter of approximately 2 m. They play an important role in the blood coagulation process. There are usually 250,000–750,000 platelets in every cubic mm of blood.

Coulter counter wide range of particle counting instruments designed to meet a wide variety of needs in the haemotology laboratory are being commercially produced. These instruments range from the small counters used primarily for red and white cell counts in very small hospitals and clinics, to the multi-parameter microprocessor controlled instrument featuring fully automatic diluting of samples and printing of results.

Figure 16.4 shows a block diagram showing the principle of a Coulter counter. A platinum electrode is placed inside the orifice tube and a second electrode is submerged into the beaker containing the cell dilution, creating an electrical circuit between the two electrodes.

Current will flow from one electrode to the other through the orifice. When the cell suspension is drawn through the orifice, cells will displace their own volume of electrolyte and cause a resistance change, which is converted to a voltage change, and is amplified and displayed.
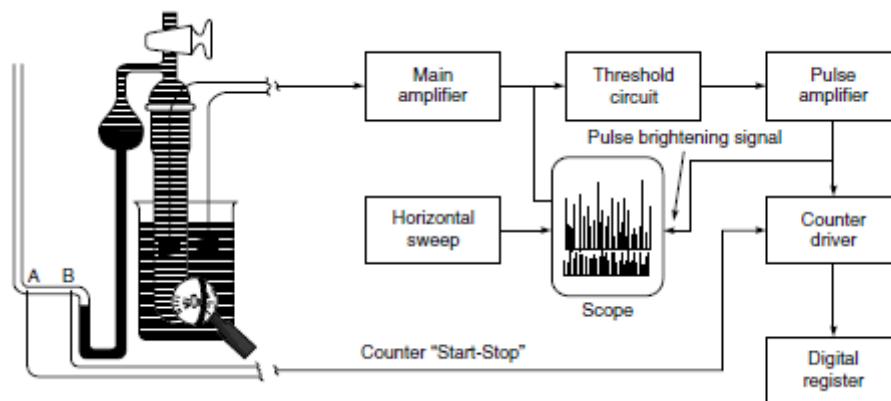
Principle of Coulter counter

In practice, the cell suspension is drawn through the orifice by means of a mercury manometer. This manometer includes two platinum wire contacts (A and B) set through the glass walls. Contact A will start the count and contact B will stop it when precisely 0.5 ml of the dilution has passed through the orifice tube.

Thus, it provides a count of the number of particles in a fixed volume of suspension. Figure 16.5 shows the sequence of building up the pulse in terms of increase in resistance at different positions of the cell with respect to the orifice.

To enable the instrument to count only those pulses, which fall within certain preset size limits, the threshold facility is required. The threshold is also necessary to enable the instrument to ignore any electronic noise, which may be present in the system.

The lower threshold sets an overall voltage level, which must be exceeded by a pulse before it can be counted. The upper threshold willnot allow pulses to be counted which exceed its preset level.The Coulter counters are usually provided with an oscilloscope monitor to display the pulse information, which has passed through the amplifier, and acts as a visible check on the counting process indicating instantaneously any malfunctions such as a blocked orifice.

In particular, it provides information regarding (i) relative cell size, (ii) relative cell size distribution, (iii) settings of the threshold level control, and (iv) means to check the performance of the instrument for reliability of counts. The voltage pulses produced each time a cell passes through the orifice are displayed on the oscilloscope screen as a pattern of vertical spikes.

Video Content / Details of website for further learning (if any):

https://www.sciencedirect.com/topics/chemistry/spectrophotometry

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, Second Edition by R.S.Khandpur Page No :444 -450

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L9

LECTURE HANDOUTS

BME

III/V

Course Name with Code : BIOMEDICALINSTRUMENTATIONANDMEASUREMENTS
16BMD03
Course Teacher   :Mrs.D.G.BeautlinVinola

Unit: V- Bio –Chemical Measurement   **Date of Lecture:**

Topic of Lecture: Auto analyzer
Introduction : It is an automated analyzer using a flow technique called continuous flow analysis (CFA),The first applications were for clinical analysis,but methods for industrial analysis soon followed.The design is based on separating a continuously flowing stream with air bubbles.
Prerequisite knowledge for Complete understanding and learning of Topic: • Basics of analyzer • Basics of machine physics
Auto Analyzer It is an automated analyzer using a flow technique called continuous flow analysis (CFA),The first applications were for clinical analysis,but methods for industrial analysis soon followed.The design is based on separating a continuously flowing stream with air bubbles. **Operating principle** In continuous flow analysis (CFA) a continuous stream of material is divided by air bubbles into discrete segments in which chemical reactions occur,The continuous stream of liquid samples and reagents are combined and transported in tubing and mixing coils,

The tubing passes the samples from one apparatus to the other with each apparatus performing different functions,such as distillation,dialysis,extraction,ion exchange,heating,incubation,and subsequent recording of a signal,An essential principle of the system is the introduction of air bubbles,The air bubbles segment each sample into discrete packets and act as a barrier between packets to prevent cross contamination as they travel down the length of the tubing,The air bubbles also assist mixing by creating turbulent flow (bolus flow),and provide operators with a quick and easy check of the flow characteristics of the liquid,Samples and standards are treated in an exactly identical manner as they travel the length of the tubing,eliminating the necessity of a steady state signal,however,since the presence of bubbles create an almost square wave profile,bringing the system to steady state does not significantly decrease throughput (third generation CFA analyzers average 90 or more samples per hour) and is desirable in that steady state signals (chemical equilibrium) are more accurate and reproducible.A continuous flow analyzer (CFA) consists of different modules including a sampler,pump,mixing coils,optional sample treatments (dialysis,distillation,heating,etc.),a detector,and data generator,Most continuous flow analyzers depend on color reactions using a flow through photometer,however,also methods have been developed that use ISE,flame photometry,ICAP,fluorometry,and so forth.

Flow injection analyzer
Flow injection analysis (FIA),was introduced in 1975 by Ruzicka and Hansen,The first generation of FIA technology,termed flow injection (FI),was inspired by the AutoAnalyzer technique invented by Skeggs in early 1950s.[citation needed] While Skeggs' AutoAnalyzer uses air segmentation to separate a flowing stream into numerous discrete segments to establish a long train of individual samples moving through a flow channel,FIA systems separate each sample from subsequent sample with a carrier reagent,While the AutoAnalyzer mixes sample homogeneously with reagents,in all FIA techniques sample and reagents are merged to form a concentration gradient that yields analysis results.

FIA methods can be used for both fast reactions as well as slow reactions,For slow reactions,a heater is often utilized,The reaction does not need to reach completion since all samples and standards are given the same period to react,For typical assays commonly measured with FIA (e.g.,nitrite,nitrate,ammonia,phosphate) it is not uncommon to have a throughput of 60–120 samples per hour.

FIA methods are limited by the amount of time necessary to obtain a measurable signal since travel time through the tubing tends to broaden peaks to the point where samples can merge with each other,As a general rule,FIA methods should not be used if an adequate signal cannot be obtained within two minutes,and preferably less than one.[citation needed] Reactions that need longer reaction times should be segmented,However,considering the number of FIA publications and wide variety of uses of FIA for serial assays,the "one minute" time limitation does not seem to be a serious limitation for most real life assays.[citation needed] Yet,assays based on slow chemical reactions have to be carried either in stopped flow mode (SIA) or by segmenting the flow.

OI Analytical,in its gas diffusion amperometric total cyanide method,uses a segmented flow injection analysis technique that allows reaction times of up to 10 minutes by flow injection analysis.

Technicon experimented with FIA long before it was championed by Ruzicka and Hansen,Andres Ferrari reported that analysis was possible without bubbles if flow rates were increased and tubing diameters decreased.In fact,Skegg's first attempts at the auto analyzer did not segment,Technicon chose to not pursue FIA because it increased reagent consumption and the cost of analysis.

The second generation of the FIA technique,called sequential injection analysis (SIA),was conceived in 1990 by Ruzicka and Marshal,and has been further developed and miniaturized over the course of the

following decade.[citation needed] It uses flow programming instead of the continuous flow regime (as used by CFA and FIA),that allows the flow rate and flow direction to be tailored to the need of individual steps of analytical protocol,Reactants are mixed by flow reversals and a measurement is carried out while the reaction mixture is arrested within the detector by stepping the flow,Microminiaturized chromatography is carried out on microcolumns that are automatically renewed by microfluidic manipulations,The discrete pumping and metering of microliter sample and reagent volumes used in SI only generates waste per each sample injection,The enormous volume of FI and SI literature documents the versatility of FI and SI and their usefulness for routine assays (in soil,water,environmental,biochemical and biotechnological assays) has demonstrated their potential to be used as a versatile research tool.

Dialyzer module
In medical testing applications and industrial samples with high concentrations or interfering material,there is often a dialyzer module in the instrument in which the analyte permeates through a dialysis membrane into a separate flow path going on to further analysis,The purpose of a dialyzer is to separate the analyte from interfering substances such as protein,whose large molecules do not go through the dialysis membrane but go to a separate waste stream,The reagents,sample and reagent volumes,flow rates,and other aspects of the instrument analysis depend on which analyte is being measured,The autoanalyzer is also a very small machine

Video Content / Details of website for further learning (if any):

https://dir.indiamart.com/impcat/semi-auto-biochemistry-analyzer.html

Important Books/Journals for further learning including the page nos.:

Hand Book of Bio-Medical instrumentation, Tata McGraw Hill Publishing Co Ltd, 2004 by R.S.Khandpur Page No : 101-104

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Verified by HOD