SKP Engineering College

Tiruvannamalai – 606611

A Course Material

on

Medical Electronics

By

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Quality Certificate

This is to Certify that the Electronic Study Material

Subject Code: EC6001

Subject Name: MEDICAL ELECTRONICS

Year/Sem:III/VI

Being prepared by me and it meets the knowledge requirement of the University curriculum.

Signature of the Author

Name: Dr.N.Nandhagopal

Designation: Associate Professor

This is to certify that the course material being prepared by Dr.N.Nandhagopal is of the adequate quality. He has referred more than five books and one among them is from abroad author.

Signature of HD

Name:

Seal:

Signature of the Principal

Name: Dr.V.Subramania Bharathi

Seal:

EC6001 MEDICAL ELECTRONICS L T P C 3 0 0 3

OBJECTIVES:

- To gain knowledge about the various physiological parameters both electrical and non electrical and the methods of recording and also the method of transmitting these parameters.
- To study about the various assist devices used in the hospitals.
- To gain knowledge about equipment used for physical medicine and the various recently developed diagnostic and therapeutic techniques.

UNIT I ELECTRO-PHYSIOLOGY AND BIO-POTENTIAL RECORDING 9

The origin of Bio-potentials; biopotential electrodes, biological amplifiers, ECG, EEG, EMG, PCG, lead systems and recording methods, typical waveforms and signal characteristics.

UNIT II BIO-CHEMICAL AND NON ELECTRICAL PARAMETER MEASUREMENT 9

pH, PO2, PCO2, colorimeter, Auto analyzer, Blood flow meter, cardiac output, respiratory measurement, Blood pressure, temperature, pulse, Blood Cell Counters.

UNIT III ASSIST DEVICES 9

Cardiac pacemakers, DC Defibrillator, Dialyser, Heart lung machine

UNIT IV PHYSICAL MEDICINE AND BIOTELEMETRY 9

Diathermies- Shortwave, ultrasonic and microwave type and their applications, Surgical Diathermy Telemetry principles, frequency selection, biotelemetry, radiopill, electrical safety

UNIT V RECENT TRENDS IN MEDICAL INSTRUMENTATION 9

Thermograph, endoscopy unit, Laser in medicine, cryogenic application, Introduction to telemedicine

TOTAL: 45 PERIODS

OUTCOMES: Upon completion of the course, students will be able to:

- Discuss the application of electronics in diagnostic and therapeutic area.
- Measure biochemical and various physiological information.
- Describe the working of units which will help to restore normal functioning.

TEXTBOOKS:

1. Leslie Cromwell, “Biomedical Instrumentation and Measurement”, Prentice Hall of India, New Delhi, 2007.

2. John G.Webster, “Medical Instrumentation Application and Design”, 3rd Edition, Wiley India Edition, 2007

CONTENTS

Unit - I

Electro-Physiology and Bio-Potential Recording

Part – A

1. The contraction of skeletal muscle is termed as what? Give its specifications. [CO1-L1-May/June 2014]

The contraction of skeletal muscle is termed as Electromyogram.Specification of Electromyogram**:** In voluntary contraction of the skeletal muscle, the muscle potentials range from 50 micro volts to 5 mill volts and the duration from 2 to 15 ms. The values vary with the anatomic position of the muscle and the size and location of the electrode.

2. What are the requirements of a biological amplifier?[Nov/Dec 2013] List the characteristics needed for Bio Amplifier [May/June 2013] List out the characteristics of Bio Amplifier.[CO1-L1- May/June 2012]

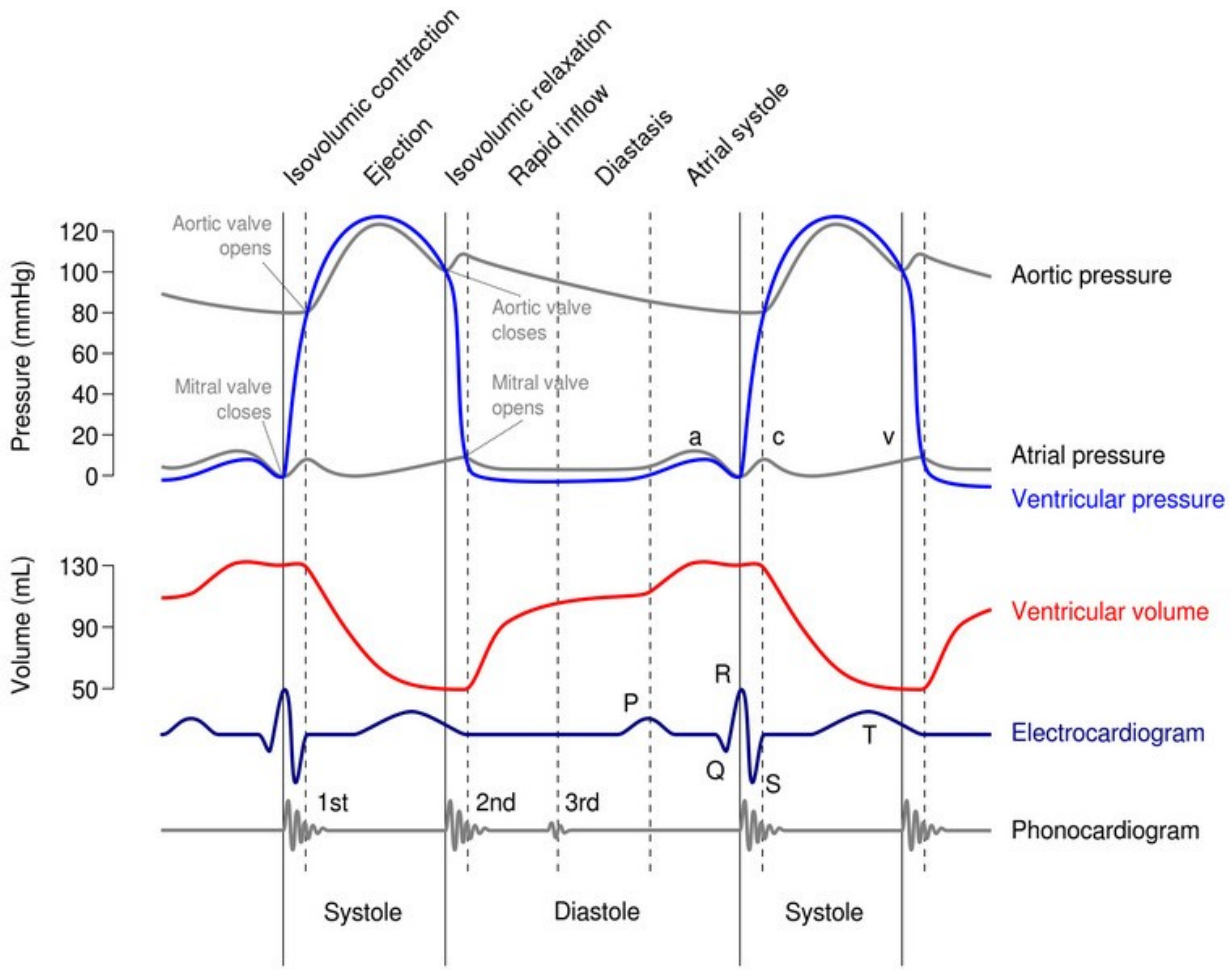
The basic requirements that a biological amplifier has to satisfy are:

- the physiological process to be monitored should not be influenced in any way by the amplifier
- the measured signal should not be distorted
- the amplifier should provide the best possible separation of signal and interferences
- the amplifier has to offer protection of the patient from any hazard of electrical shock
- the amplifier itself has to be protected against damages that might result from high input voltages as they occur during the application of defibrillators or electrosurgical instrumentation Bio amplifiers must have

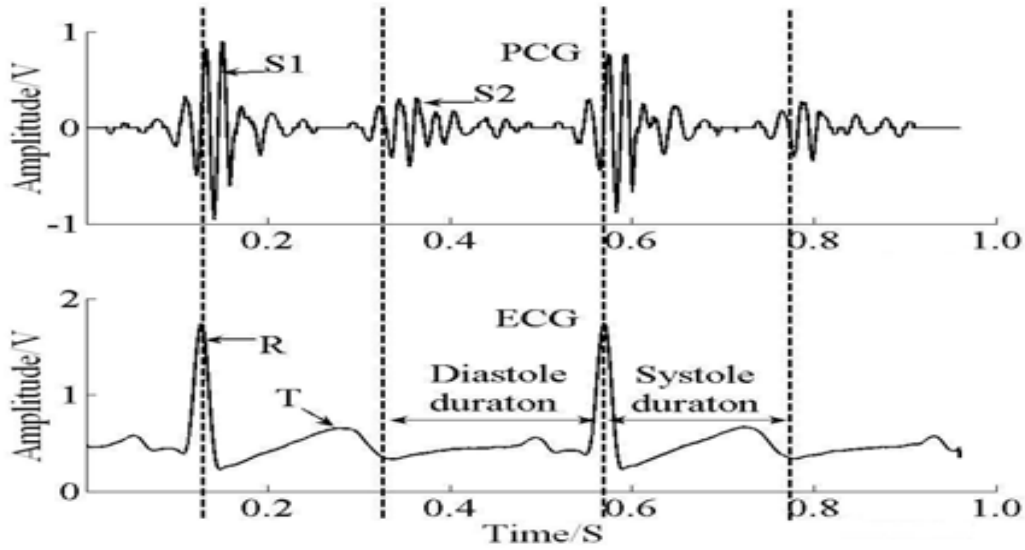
a) High input impedance
b) Isolation and protection circuit
c) High voltage gain
d) Constant gain throughout required bandwidth
e) Low output impedance

f) High CMRR

3. Draw the waveform of a typical PCG signal and label its components.[CO1-L1-Nov/Dec 2013].



4. Compare the signal characteristics of ECG and PCG. [CO1-L2-May/June 2013][Nov/Dec 2011]



5. Name the electrodes used for recording EMG and ECG. [CO1-L1-Nov/Dec 2012]

EMG : Surface Electrode, Needle Electrode ECG : Limb Electrode, Floating Electrode, Pregelled Disposable Electrode, Pasteless electrodes

6. What is PCG? [CO1-L1-Nov/Dec 2012]

Phonocardiogram or PCG is a technique to measure the sounds/murmurs generated by the heart during opening and closing of heart valves with the help of the machine called phonocardiograph.

PCG is a graphic display of the sounds generated by the heart and picked up by a microphone at the surface of the body. Frequency response required is 5 to 2000 Hz. It is measured by special transducer or microphone.

7. What are the peak amplitude and frequency response for ECG, EEG and EMG. [CO1-L1].

Bioelectric potentia	Function	Peak amplitude	Frequency response	Observation
ElectroCardioGram (ECG)	Records electrical activity of heart	0.1 to 4mV	0.05 to 120 Hz	Used to measure heart rate, arrhythmia and abnormalities
ElectroEncephaloGram (EEG)	Records electrical activity of brain	2 to 200μV	0.1 to 100 Hz	Used to analysis evoked potential, certain patterns, frequency response
ElectroMyoGram (EMG)	Records muscle potential	50μV to 1mV	5 to 2000 Hz	Used as indicator of muscle action for measuring fatigue

8. What is ECG? [CO1-L1-Nov/Dec 2011]

The recording of electrical activity associated with the functioning of heart is called Electrocardiogram(ECG).

9. What is half-cell potential? [CO1-L1-April/May 2011]

A characteristic potential difference established by electrode and its surrounding electrolyte which depends on the metal, concentration of ions in solution and temperature is called Half-cell potential.

11.Give the EMG signal characteristics. [CO1-L1-April/May 2011]

Mention the normal amplitude and frequency of EMG signal.[Nov/Dec 2010]

EMG signal ranges from 0.1mV to 0.5mV.The frequency components of EMG signal vary from 20Hz to 200Hz for clinical purpose using a low pass filter.

12. What are the different types of bio-potential electrodes? [CO1-L1-Nov/Dec 2010]

The different types of bio-potential electrode are

a) Micro electrode
b) Depth and needle electrode
c) Surface electrode

13. Mention the importance of biological amplifiers.[**CO1-L1-April/May 2010]**

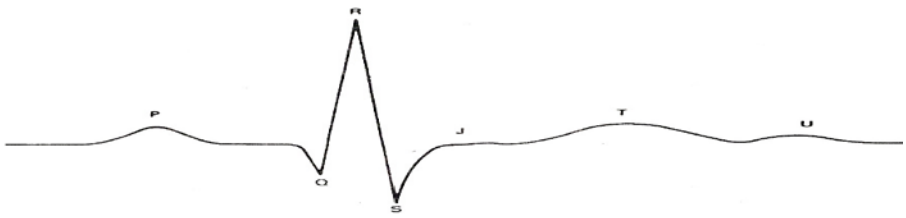
Bio signals such as ECG, EMG, EEG, EOG have low amplitude and low frequency. So, amplifier is used to boost the amplitude level of bio signals.

14. Mention the various lead systems used in ECG recording. [**CO1-L1-Apr/May 2010]**

The lead systems used in ECG recording are

a) Bipolar Limb leads or Standard leads
b) Augmented unipolar limb leads
c) Chest leads or precordial leads

15. Draw a typical ECG waveform. [CO1-L1-Nov/Dec 2009]



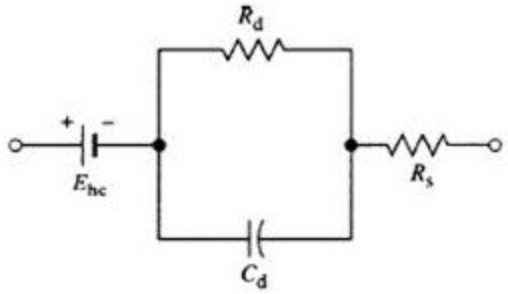
16. Define the term Conduction Velocity[CO1-L1-Apr/May 2008, Nov/Dec 2009, May /June 2007]

Conduction velocity is defined as the rate at which an action potential moves down a fiber or is propagated from cell to cell. It is also called as Nerve conduction rate.
Conduction velocity is defined as the ratio of difference in distance between stimulation point and sensing electrode to the difference in latency.

17. What are the important bands of frequencies in EEG and state their importance[CO1-L1].

Waves	Frequency (Hz)	Observation
Delta(δ)	0.5 – 4	These waves occur in deep sleep in premature babies and in very serious organic brain disease.
Theta(θ)	4 – 8	These waves occurs during emotional stress in some adults particularly during disappointment and frustration
Alpha**(**α**)**	8 – 13	They found in the normal persons when they are awake in a quiet, resting state. During sleep they disappear.
Beta**(**β**)**	13- 22	It is observed when the person is alert active, busy, or anxious thinking, active concentration

18. Draw the electrical equivalent circuit of a surface electrode [CO1-L1-May/June 2009

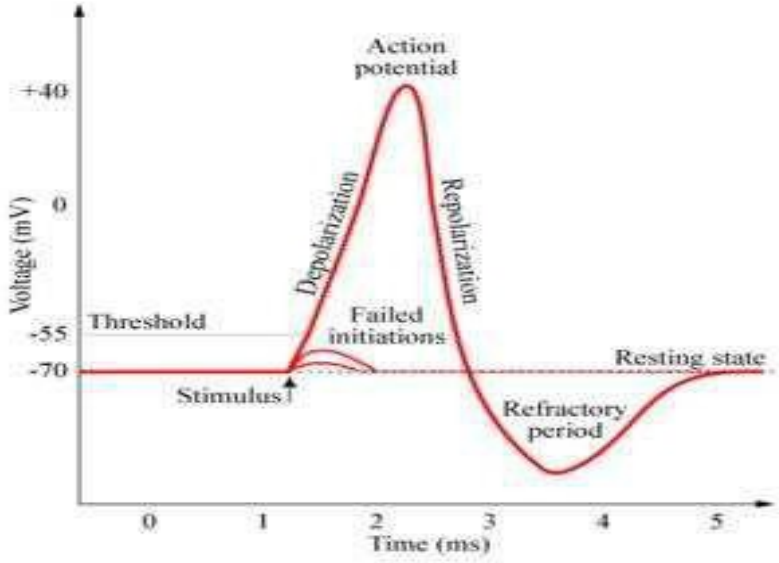


Ehc - Half cell potential
Cd - Electrolyte capacitance
Rd - Leakage resistance
Rs - Series electrolyte and skin resistance

19. Define resting and action potential.[CO1-L1-Nov/Dec 2008]

Resting potential is defined as the electrical potential of an excitable cell relative to its surroundings when not stimulated or involved in passage of an impulse. It ranges from -60mV to -100mV

Action potential is defined as the change in electrical potential associated with the passage of an impulse along the membrane of a cell.



20. Define Latency as related to EMG. [CO1-L1-Nov/Dec 2008]

Latency is defined as the elapsed time between the stimulating impulse and the muscle action potential. In other words it is the time delay between stimulus and response.

21. State all or nothing law in respect of cell bio potential. [CO1-L1-April/May 2008]

Regardless of the method by which a cell is excited or the intensity of the stimulus, the action potential is always the same for any given cell.

In the functioning of the nervous system, the rule which states that the response of an axon is independent of the intensity of the stimulus provided the stimulus exceeds the threshold intensity required to depolarize the nerve membrane. Depolarization reverses the electrical polarity from the resting potential (in which the inside of the axon is negatively charged and the outer membrane positively charged) to the action potential (positive charge inside, negative charge outside).

22. Write down the Nernst equation of action potential [CO1-L1].

An equation relating the potential across the membrane and the two concentrations of the ion is called Nernst equation.

R – gas constant(8.315×10^7 ergs/mole/degree Kelvin)

T – absolute Temperature, degrees Kelvin

n – valence of the ion (the number of electrons added or removed to ionize the atom)

F – Faraday constant (96,500 coulombs)

C1, C2 – two concentrations of the ion on the two sides of the membrane

f_1, f_2 – respective activity coefficients of the ion on the two sides of the membrane

23. List the types of bioelectric potentials [CO1-L1].

Bio electric potential related to

Heart – ElectroCardioGram (ECG)

Brain – ElectroEncephaloGram (EEG)

Muscle – ElectroMyoGram (EMG)

Eye (Retina) – ElectroRetinoGram (ERG)

Eye (Cornea - Retina) – ElectroOculoGram (EOG)

24. Define electrode and list its types[CO1-L1].

The device that convert ionic potential into electronic potential are called as electrode. The types of electrode are Micro electrode ,Depth and needle electrode ,Surface electrode

25. State the importance of PCG signals[CO1-L1].

a) Different types of heart sounds are measured.

b) Additional sounds are heard between normal heart sound due to vibration setup in the blood inside the heart by sudden closure of valves.

c) The presence of higher frequencies (murmurs) in the phonocardiogram indicates a possible hear disorder such as Aortic stenosis, Mitral regurgitation, mitral stenosis etc.

26. Enlist the electrodes used for recording EEG.[CO1-L1-May /June 2014]

Chloride silver discs Micro electrodes - metal microelectrode and micropipette.

PART- B

1.With a neat diagrams explain the formation of various lead systems used for recording ECG [May/June 2014]

Draw and Explain the different lead configuration and its significances in ECG. [May/June 2013]

Explain the 12 lead system used in ECG (8 Marks) [May/June 2012]

Draw 12 lead system used in ECG (8 Marks)[Nov/Dec 2011][April/May 2011]

Describe with suitable diagrams, the various lead systems used while recording ECG signals [Nov/Dec 2010]

Discuss various lead systems for ECG measurement (8 Marks) [Nov/Dec 2009]

Draw an Electrocardiogram waveform labeling the critical features. Include typical amplitude and time interval for a normal person. With neat diagrams explain the 12 lead systems in ECG with suitable diagrams. [CO1-L2-May/June 2009]

ECG LEAD CONFIGURATIONS

Usually surface electrodes are used with jelly as electrolyte between skin and electrodes. The potentials generated in the heart are conducted to the body surface. The potential distribution changes in a regular and complex manner during each cardiac cycle. Therefore to record electrocardiograms, we must choose standardized electrode positions. There are three types of electrode systems:

1) Bipolar limb lead (or) standard lead system
2) Augmented unipolar limb lead system
3) Unipolar Chest lead system

❖ BIPOLAR LIMB LEAD - STANDARD LEADS I, II AND III

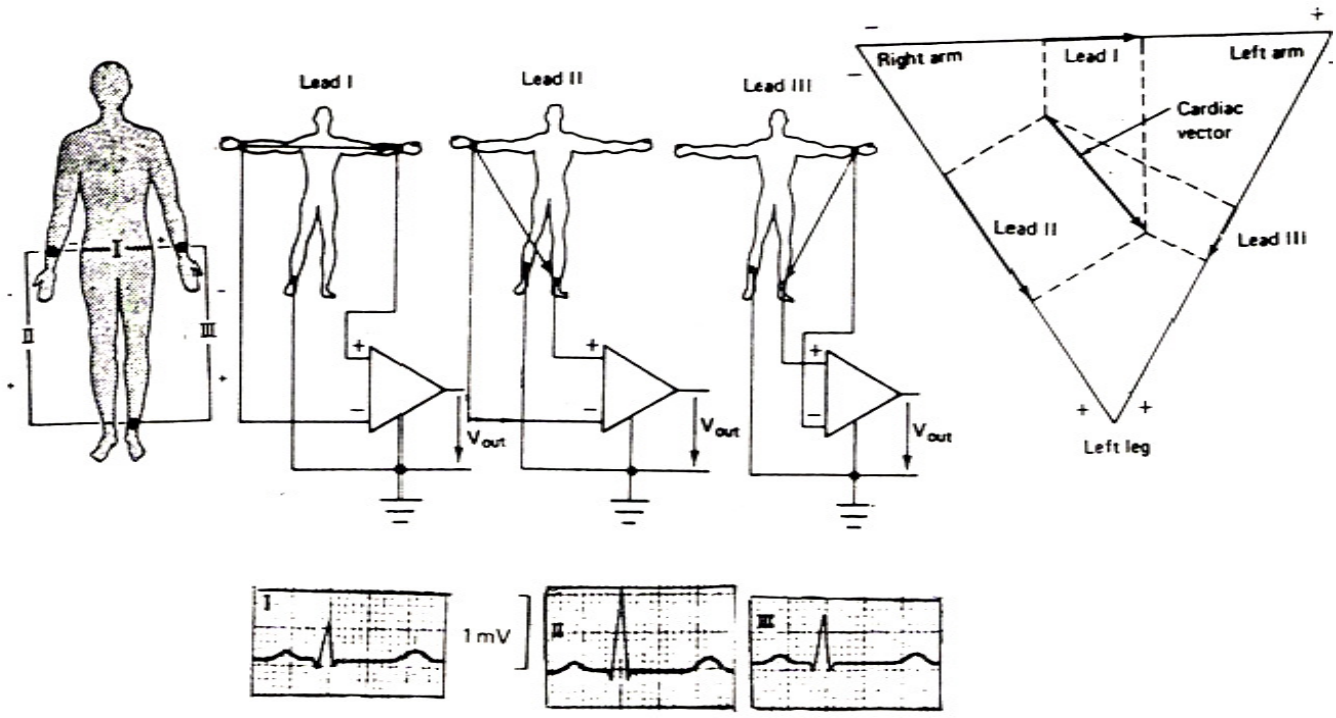
In standard leads, the potentials are tapped from four locations of our body. They are (i) right arm, (ii) left arm, (iii) right leg and (iv) left leg. Usually the right leg electrode is acting as ground reference electrode.

Figure shows the standard bipolar limb leads positions and the corresponding wave patterns.

Lead I- gives voltage V_I, the voltage drop from the left arm (LA) to the right arm (RA)

Lead II- gives voltage V_{II}, the voltage drop from the left leg (LL) to the right arm (RA)

Lead III- gives voltage V_{III}, the voltage drop from the left leg (LL) to the left arm (LA)



The closed path RA to L A to LL and back to RA is called the **Einthoven Triangle**. According to Einthoven, in the frontal plane of the body the cardiac electric field vector is a two dimensional one. ECG m asured from any one of the three limb leads is a time variant single dimensional component of that vector.

Along the sides of this triangle the three projections of ECG vector are measured as shown in figure. Further the vector sum of the projections on all the three sides is equal to zero.

Thus following Kirchhoff's law, the r wave amplitude of lead ii is equal to the sum of the r wave amplitudes of leads I and iii. For example the r wave nominal voltage from different leads is given below:

	Lead I	Lead II	Lead III
	vi	vii	viii
R wave amplitude	0.53mv	0.71 mv	0.38mv

(0.07 to 1.13) (0.18 to 1.68) (0.03 to 1.31)

The voltages given in brackets indicate the range of the measured voltage.

Thus,

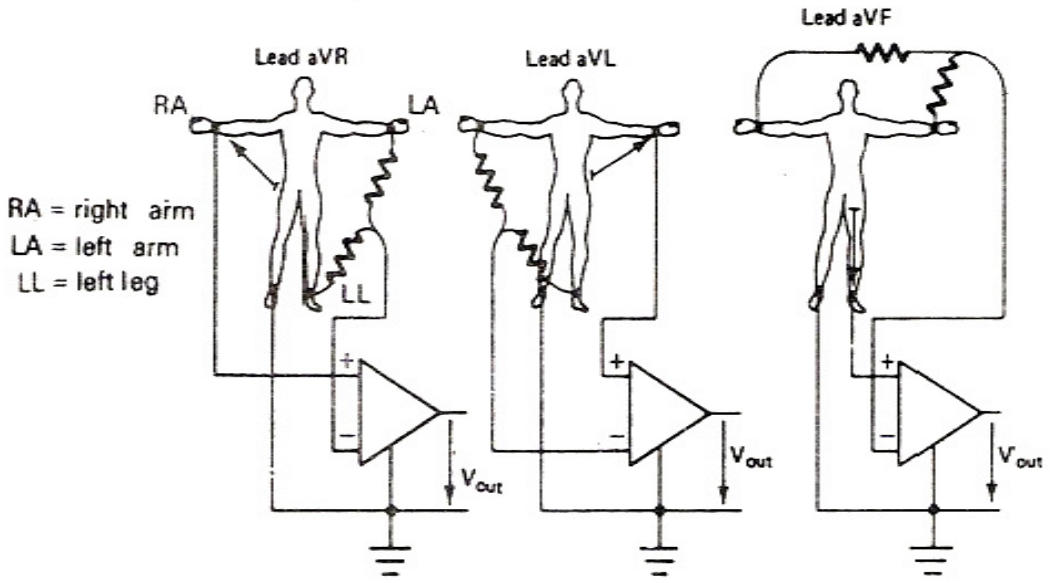
Vii = Vi+Viii

AUGMENTED UNIPOLAR LIMB LEADS

In the augmented unipolar limb leads system, which is introduced by Wilson, the electrocardiogram is recorded between a single **exploratory electrode** and the **central terminal** which has a potential corresponding to the center of the body.

Thus two equal and large resistors are connected to a pair of limb electrodes and the center of this resistive network acts as central terminal and the remaining limb electrode acts as the exploratory electrode.

By means of augmented ECG lead connections, a small increase in the ECG voltage can be realized. the augmented lead connections are augmented voltage right



Even though the resistors in these limb leads have large value, their values are s aller when we compare with the input resistance of the preamplifier. By Kirchhoff's law, the augmented voltages can be written as in terms of standard leads voltage:

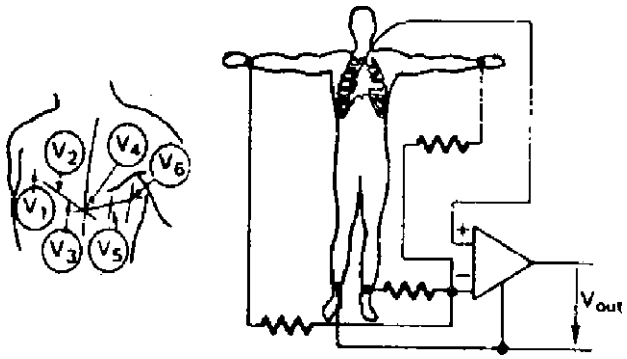
$$avR = -v_I - v_{III} / 2$$

$$avL = v_I - v_{II} / 2$$

$$avF = v_{II} - v_I / 2$$

UNIPOLAR CHEST LEADS

In the case of unipolar chest leads, the exploratory electrode is obtained from oneof the chest electrodes. The chest electrodes are placed on the six different points on the chest closed to the heart as shown in figure. By connecting three equal large resistances to the left arm, right arm and left leg a reference electrode or central terminalobtained. This lead system is known as Wilson system. Thus the electrocardiograms are recorded from these 12 lead selections such that 3 standard bipolar leads, 3 augmentedunipolar leads and 6 chest leads.



V_1 - Fourth intercostal space, at right sternal margin

V_2 - Fourth intercostal space, at left sternal margin

V_3 - Midway between V_2 and V4.

V_4 - Fifth intercostal space, at mid-davicular fine.

V_5 - Same level as V_4, on an-Urior axillary line.

V_6 - Same level at V^5, on mid-axillary line.

2. (i)Distinguish a biological amplifier from a conventional amplifier with suitable equations and circuits.(10 marks)[CO1-L2-May/June 2014].

Bio signals are recorded as potentials, voltages, and electrical field strengths generated by nerves and muscles. The measurements involve voltages at very low levels, typically ranging between 1 uV and100 mV, with high source impedances and superimposed high level interference signals and noise. The signals need to be amplified to make them compatible with devices such as displays, recorders, or A/D converters for computerized equipment. Amplifiers adequate to measure these signals have to satisfy very specific requirements. They have to provide amplification selective to the physiological signal, reject superimposed noise and interference signals, and guarantee protection from damages through voltage and current surges for both patient and electronic equipment. Amplifiers featuring these specifications are known as bio potential amplifiers.

Bio Amp amplifier is a general purpose biological amplifier. Bio Amp amplifier is optimal for a number of biological applications Bio Amp amplifier is a general purpose biological amplifier. Bio Amp amplifier is optimal for a number of biological applications.

Bio Amp's main fields of applications:

- Extracellular recording
- Microelectrode recording
- Evoked Potentials (EVP)
- Body-surface potentials (ECG, EMG, EEG, ERG, etc.)
- Micro potentials
- Multi-channel applications (EEG Brain Mapping, Cortical Depth Mapping, etc.)

The basic requirements that a bio potential amplifier has to satisfy are:

• the physiological process to be monitored should not be influenced in any way by the amplifier

• the measured signal should not be distorted

• the amplifier should provide the best possible separation of signal and interferences

• the amplifier has to offer protection of the patient from any hazard of electrical shock

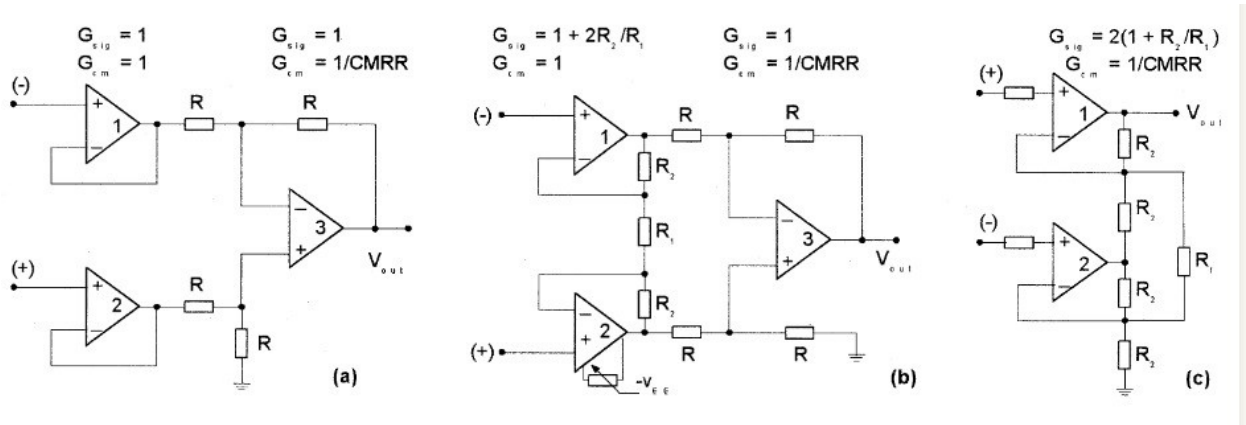
• the amplifier itself has to be protected against damages that might result from high input voltages as they occur during the application of defibrillators or electrosurgical instrumentation

A typical configuration for the measurement of bio potentials is shown in Fig. Three electrodes, two of them picking up the biological signal and the third providing the reference potential, connect the subject to the amplifier.

The input signal to the amplifier consists of five components:

(1) the desired bio potential, (2) undesired bio potentials, (3) a power line interference signal of 60 Hz (50 Hz in some countries) and its harmonics, (4) interference signals generated by the tissue/electrode interface, and(5) noise.

Proper design of the amplifier provides rejection of a large portion of the signal interferences. The main task of the differential amplifier as shown in Fig.is to reject the line frequency interference that is electrostatically or magnetically coupled into the subject. The desired bio potential appears as a voltage between the two input terminals of the differential amplifier and is referred to as the differential signal.



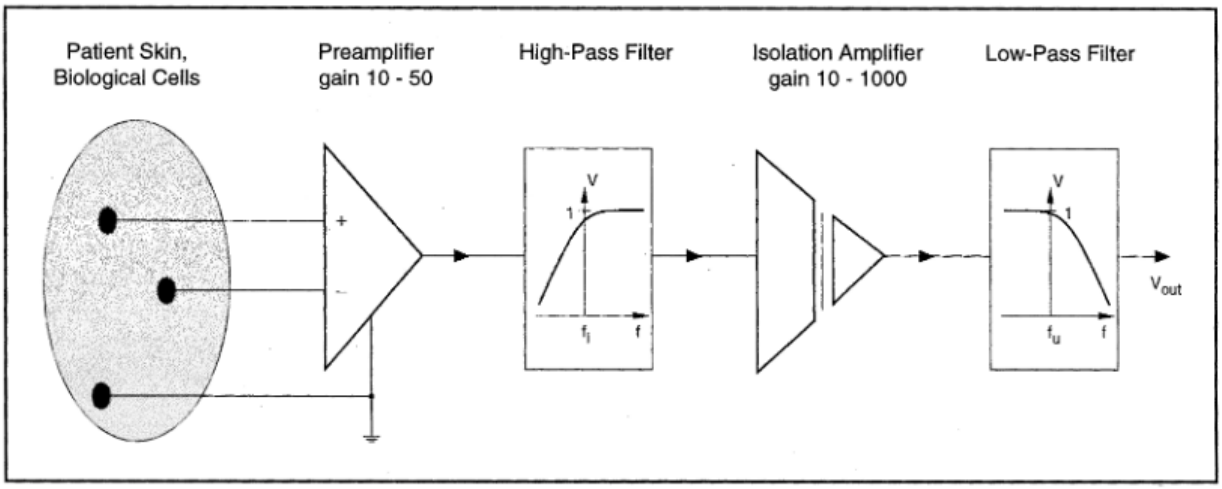
The line frequency interference signal shows only very small differences in amplitude and phase between the two measuring electrodes, causing approximately the same potential at both inputs, and thus appears only between the inputs and ground and is called the common mode signal. Strong rejection of the common mode signal is one of the most important characteristics of a good bio potential amplifier.

The common mode rejection ratio (or CMRR) of an amplifier is defined as the ratio of the differential mode gain over the common mode gain. As seen in Fig the rejection of the common mode signal in a bio potential amplifier is both a function of the amplifier CMRR and the source impedances Z1andZ2.

For the ideal bio potential amplifier with Z1= Z2 and infinite CMRR of the differential amplifier, the output voltage is the pure biological signal amplified by GD, the differential mode gain: Vout= GD — Vbiol. With finite CMRR, the common mode signal is not completely rejected, adding the interference term GD — Vc/CMRR to the output signal.

Even in the case of an ideal differential amplifier with infinite CMRR, the common mode signal will not completely disappear unless the source impedances are equal.

Main Stages of Bio Amplifier: A typical design of the various stages of a bio potential amplifier is shown in Fig.



The electrodes which provide the transition between the ionic flow of currents in biological tissue and the electronic flow of current in the amplifier represent a complex electrochemical system. The electrodes determine to a large extent the composition of the measured signal.

The preamplifier represents the most critical part of the amplifier itself since it sets the stage for the quality of the bio signal. With proper design, the preamplifier can eliminate, or at least minimize, most of the signals interfering with the measurement of bio potential. The

purpose of the high pass and low pass filters is to eliminate interference signals like electrode half-cell potentials and preamplifier offset potentials and to reduce the noise amplitude by the limitation of the amplifier bandwidth. Since the bio signal should not be distorted or attenuated, higher order sharp-cutting linear phase filters have to be used.

The total source resistance R_S , including the resistance of the biological source and all transition resistances between signal source and amplifier input, causes thermal voltage noise with a root mean square (rms) value of

$$E_{rms} = \sqrt{4kTR_sB}\,(Volt)$$

$$E_{rms} = \sqrt{4kTR_sB}\,(Volt)$$

Where, k = Boltzmann constant, T = absolute temperature, Rs=
resistance in Q B = bandwidth in Hz

The isolation stage serves the galvanic decoupling of the patient from the measuring equipment and provides safety from electrical hazards. This stage also prevents galvanic currents from deteriorating the signal-to-noise ratio especially by preventing ground loops. Various principles can be used to realize the isolation stage. Analog isolation amplifiers use either transformer, optical, or capacitive couplers to transmit the signal through the isolation barrier. Digital isolation amplifiers use a voltage/frequency converter to digitize the signal before it is transmitted easily by optical or inductive couplers to the output frequency/voltage converter. The most important characteristics of an isolation amplifier are low leakage current, isolation impedance, isolation voltage (or mode) rejection (IMR), and maximum safe isolation voltage.

(ii)Write short notes on measurement of PCG.(6 Marks)[May/June 2014]

How the PCG signals are generated? Explain the measurement of PCG (8Marks) [April/May 2011]

Write short notes on Phonocardiography (8 Marks) [Nov/Dec 2009]

Bring out the salient features of Phonocardiography [8 marks] [CO1-L1-Nov/Dec 2008]

The graphic recording of the sounds connected with the pumping action of the heart is called phonocardiogram. These sounds are produced by vibrations set up in the blood inside the heart by the sudden closure of valves, movement of heart wall, closure of walls and turbulence and leakage of blood flow.

Heart sounds:

First heart sound (Lub):

It is due to closure of mitral and tricuspid valves which permit the flow of blood from atria into the ventricles i.e. it occur at the end of the atrial contraction and at beginning of the ventricular contraction. It occurs approximately 0.05 second after the onset of QRS complex and just before ventricular systole.

It has loud deep pitch and is booming in character. It is longer in duration, lower in frequency (30 - 45Hz) and greater in intensity than the second sound. The duration is 50 to 100msec. The asculatory area i.e. it is best heard at the apex of mid pericardium.

Second heart sound (Dub):

It is occurs at the end of ventricular systole due to closure of semilunar valves (aortic and pulmonary aortic valves) in the arteries leading out of the ventricles. It occurs at 0.03-0.05 second after the end of T wave. It has higher pitch than the first sound and is snapping in character. It has frequency 50 - 70Hz. The duration is 25 to 50msec. The asculatory area i.e. it is best heard in the aortic and pulmonary areas.

Third heart sound:

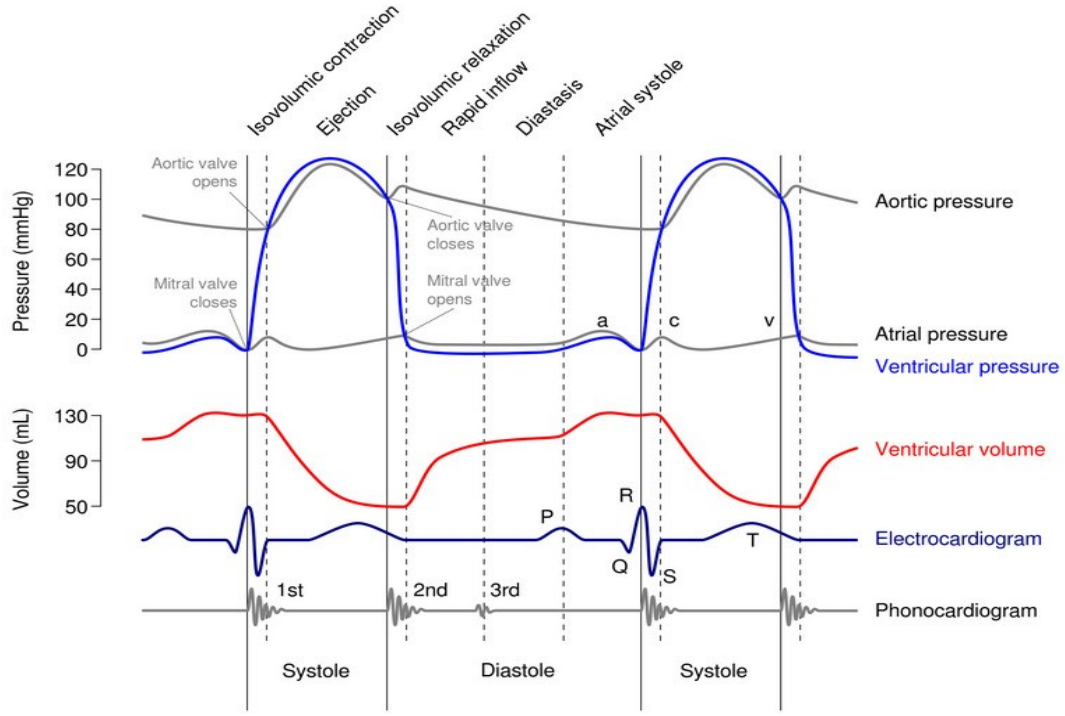
It is due to cessation of ventricular filling. It is heard in children and patient with left ventricular failure due to rapid inflow of blood from the atria into the ventricles. The accumulated blood from atria and veins causes the distention and vibration of ventricles. Frequency is below 30Hz. The duration is 0.1 to 0.2sec. It starts 0.12 – 0.18 second after the onset of second heart sound. The asculatory area i.e. it is best heard at the apex and left lateral position after lifting the legs.

Fourth heart sound or atrial heart sound :

It is produced by the contraction of the atria. It is not audible due to low amplitude and frequency of vibrations. It occurs immediately before the first heart sound. It starts 0.12 - 0.18 second after the onset of P 50Hz.

The third and fourth sounds are called diastolic sounds and are generally inaudible in the normal adult but are commonly heard among children.

The figure shows the time relationships between the first, second and third heart sounds with respect to ECG wave. The duration is 0.03 to 0.06 second. Frequency 1019.



Murmurs.

It occurs in abnormal hearts between normal heart sounds. They are higher pitched sounds in 100-600Hz range and are longer in duration compared to normal heart sounds. The causes of murmurs are

1. High velocity blood flow that occurs through small opening when there is improper opening of valves.

2. Regurgitation which results when the valves do not close completely and allow some backward flow of blood.
3. Small opening in the septum that separates the left and right sides of the heart. This forces the blood through the opening from the left ventricle into right ventricle bypassing the systemic circulation.

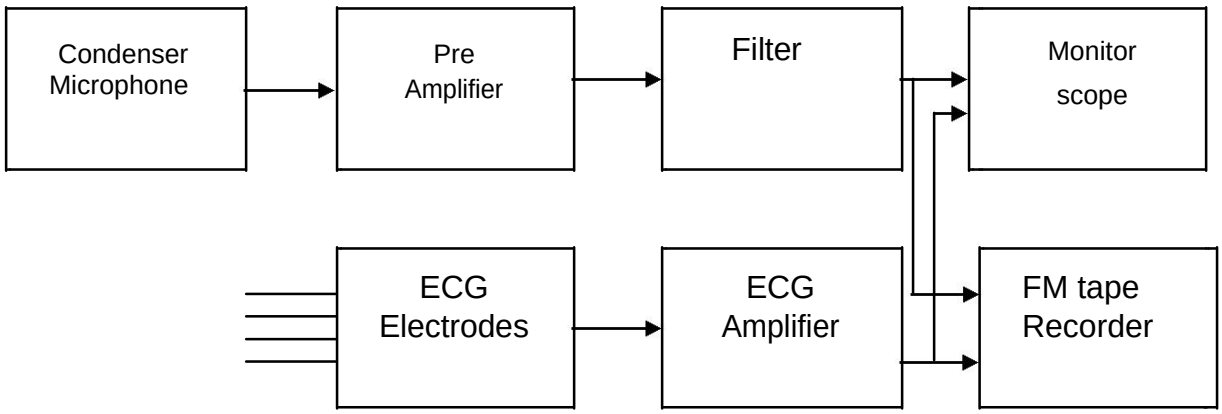
Difference between heart sounds and murmurs.

Heart sound: Transient in character and are of shorter duration. Low frequency. It is mainly due to closing and opening of valves.

Murmurs: Noisy and higher pitched sounds in characteristic and long duration. Have high frequency (100 to 600Hz). It is due to turbulent flow of blood in the heart and large vessels.

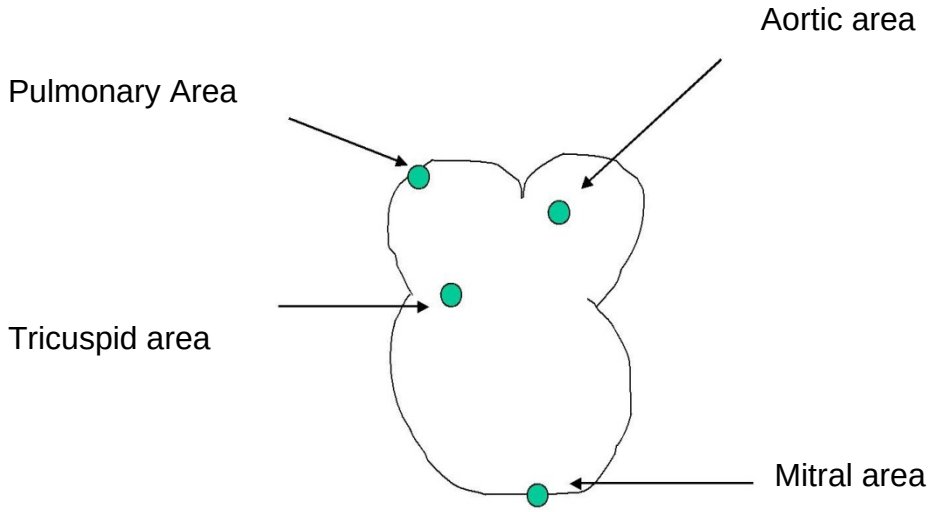
Measurement of Heart Sound:

Phonocardiography is an instrument used for recording waveforms of the heart sounds. The figure shows the block diagram of a recording setup used for PCG. The ECG is also measured for use as reference for PCG.



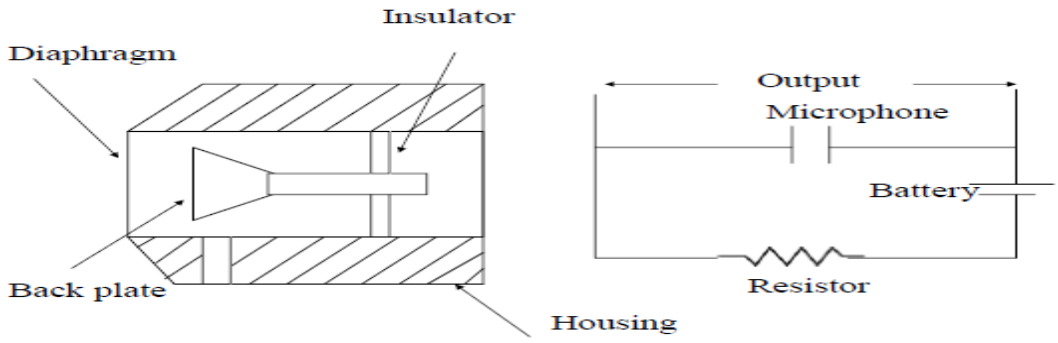
Microphone:

It has a microphone e.g. piezoelectric crystal microphone, condenser, moving coil, carbon and dynamic microphones with frequency response from below 5Hz to above 1000Hz, fastened to the chest wall by an adhesive strip, converts the heart sounds into electrical signals. The microphones are located at different areas shown in the figure below.



There are two main categories of microphones used in PCG. They are air coupled microphone and contact microphone. In the former, the movement of chest is transferred through an air cushion and presents low mechanical impedance to the chest. But the second one is directly coupled to the chest wall and presents a higher impedance, high sensitivity, low noise and light weight.

Therefore the second one is more suitable. Sometimes special microphones are placed at the tips of catheters to pick up heart sounds from within the chambers of the heart or from the major blood vessels near the heart. CONDENSER MICROPHONE AND ITS CIRCUIT:



Preamplifier:

The electrical signals from the microphone are amplified by a phonocardio graphic

preamplifier. The amplifier must have similar response characteristics. The preamplifier has two stages with gain 20 and 50 so that total gain is 1000. The gain is varied through potentiometer. The shunt capacitance in the output and the feedback loop capacitance of the second stage limit the response from 10Hz to 1000Hz. The amplifier must have wide bandwidth with frequency range of about 20 to 2000Hz.

Filter:

The high pass filters are used to separate the louder low frequency components from the medically interesting soft high frequency murmurs. For heart sounds, high pass filters with gradual slope are required and for murmurs, high pass filters with sharper slopes are required.

Read Out:

The readout is high frequency chart recorder, oscilloscope, photographic or light-galvanometer recorders, optical or high velocity ink jet recorder. Some models use envelope recording technique in which the frequency components below 80Hz are recorded directly, but the frequency components above 80Hz are integrated (averaged) before recording.

This allows use of low frequency thermal or ink pen type strip chart recorder. Sometimes a digital computer is used for spectral analysis of heart sounds because presence of higher frequencies (murmurs) in the PCG indicates heart disorder.

APPLICATIONS OF PCG:

i) Detection of Rheumatic valvular lesions: Occurs due to Rheumatic fever which is an autoimmune or allergic disease in which the heart valves are likely to be damaged or destroyed.

ii) Murmur of Aortic stenosis: The blood is ejected from the left ventricle through a small opening of the aortic valve. Because of the resistance to the ejection, the pressure in the left ventricle rises sometimes to as high as 350mm of Hg. This causes turbulent blood flow. This turbulent blood impinging the aortic valve causes intense vibration it produces loud murmur. This sound can be heard several feet away from the patient.

iii) Murmur of Mitral regurgitation: The blood flows backward through the mitral valve during systole.

Iv) Murmur of Aortic regurgitation: In aortic regurgitation, the blood flows backward from the aorta into the left ventricle causing "blowing murmur", during diastole.

v) Murmur of mitral stenosis: The blood passes with difficulty from the left atrium into the left ventricle due to the pressure difference.

3. (i) Discuss the events that generate half cell potential across an electrode electrolyte interface. Also, draw equivalent circuit of the interface. (12 Marks) [CO1-L1-Nov/Dec 2013]

The voltage developed at an electrode - electrolyte interface is designated as the **half cell potential** or electrode potential. In the case of a metal solution interface, an electrode potential results from the difference in rates between two opposite processes: (a) the passage of the ions from the metal in to the solution and (b) the combination of metallic ions in solution with electrons in the metal to form atoms of the metal. So when a metal electrode comes in to contact with an electrolyte to combine with the electrode. The net result is the creation of a charge gradient, the spatial arrangement of which is called the electrical double layer.

Electrodes in which no net transfer of charge occurs across the metal electrolyte interface are called as **perfectly polarized electrodes;** electrodes in which unhindered exchange of charge is possible across the metal electrolyte interface are called perfectly non Polaris able electrodes. Real electrodes have properties that lie between these idealized limits. In many instances the presence of an electrode potential would not be objectionable if it were stable. In practice, it is not a stable and its variations constitute a source of variable noise voltage, called **artifact.**

Figure shows the electrical equivalent circuit is in contact with the body surface

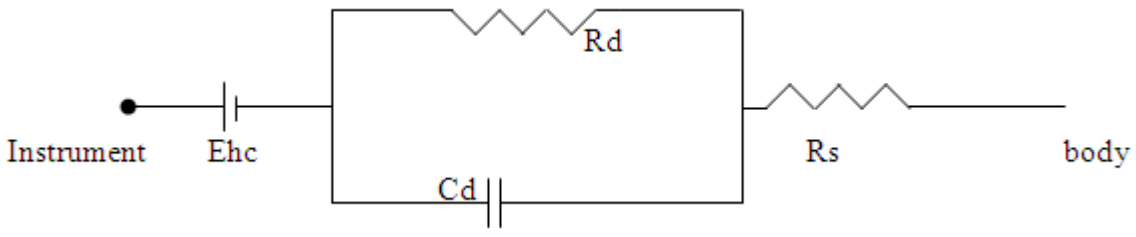


Fig : Surface electrode equivalent

Where,

Ehc - Half cell potential

Cd - Electrolyte capacitance

Rd - Leakage resistance

Rs - Series electrolyte and skin resistance

The electrode-electrolyte interface resembles a voltage source having half cell potential 'E_{hc}' which is developed due to charge gradient and a capacitor 'C_d' in parallel with a leakage resistance ''Rd'. The series resistances in the equivalent circuit 'R_s' represents the series electrolyte and skin resistance under equilibrium conditions. The impedance of this equivalent circuit can be written as

$$Z = Rs + \frac{Rd}{\frac{j + 2x3.14Cd}{Rd + 1/(j2 \times 3.14xf\, CdRd)}}$$

$$\text{i.e.} \quad Z = \quad Rs + \frac{Rd}{1 + j2 \times 3.14x\, fCd\, Rd}$$

The value of the voltage and impedance depend on the electrode metal, its area, the electrolyte, charge density and frequency of current. The half cell potential or electrode potential is measured with reference to hydrogen electrode placed in the electrolyte near the metallic electrode. The half cell potential developed can be expressed by the **Nernst equation:**

Ehc = - (RT/nF) in (C1/C2) . (f1/f2) = - 2.303 (RT/nF) log 10 (C1f1/C2f2)

Where,

R = gas constant = 8.314 kj/k mol/k

T = absolute temperature in Kelvin

F = number of coulombs transferred (or) Faraday constant = 965000 coulombs.

N = valency of the ion

C1C2 = concentration of the ion on the two sides of the membrane.

f1,f2 = activity coefficients of the ion on the two sides of the membrane.

In dilute solutions f1 = f2 = 1.

(ii) Mention any one method of half cell potential cancellation.(4 Marks) [CO1-L1-Nov/Dec 2013]

The dry outer skin of the body is highly non conductive and will not establish a good electrical contact with an electrode. The skin should therefore be washed thoroughly and rubbed briskly to remove some of the outer cells. This area should then be coated with an electrically conductive paste called **electrode paste** that should be “worked in” by further 25 rubbing. The electrode is then applied to the prepared site and held in place with a rubber strap or a length of tape. Thus the electrode paste decreases the impedance of the contact and it also reduces the artifacts resulting from movement of the electrode or patient. Generally the conductivity of the skin is directly proportional to moisture on the skin.

For example, the ECG electrode contact impedance on dry skin is about 100 kilo ohms and the equivalent capacitance component is about 0.01 microfarad. After the application of electrode paste, the contact impedance is reduced to 10 kilo ohms and the capacitance component is increased to 0.1 microfarad. Generally electrode contact impedance varies with fat content, blood supply and electrode contact pressure.

Even after the application of the electrode paste, the contact impedance decreases with increase of frequency of the signal. Among alcohol electrode paste (electrolyte), saline solution and multi point electrode (grater like electrode), multi point electrode has less contact impedance about 4 kilo ohms and alcohol has greater contact impedance around 1000 Hz.

4. With neat diagrams, explain the schematic diagram of EEG machine. Also, show the recording method of unipolar and bipolar EEGs. [CO1-L1-Nov/Dec 2013]

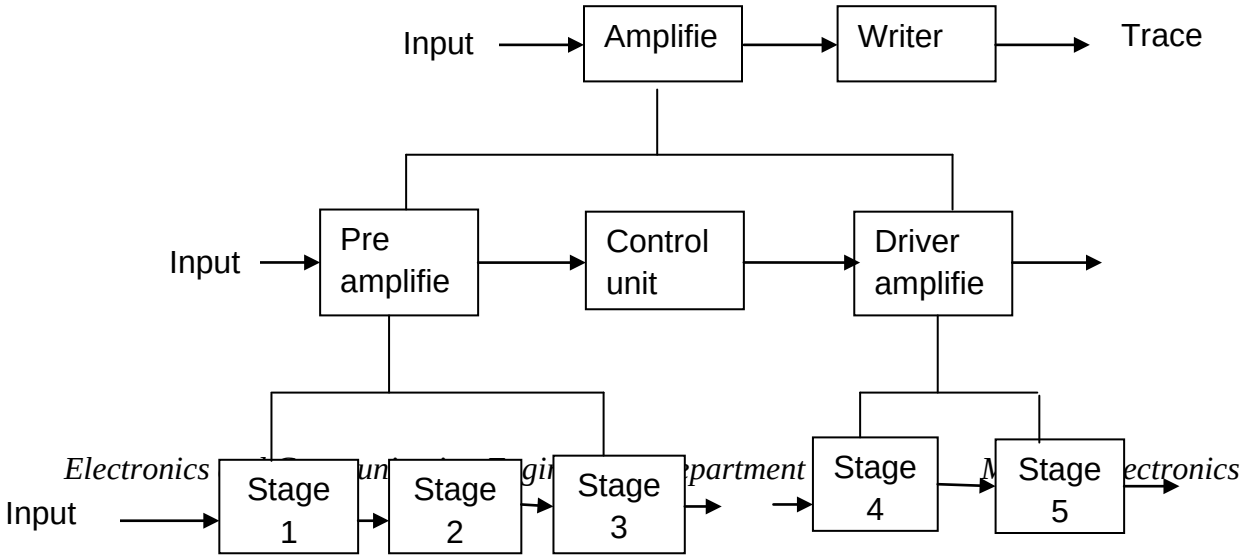
Before placing the electrodes, the scalp is cleaned, lightly abraded and electrode paste is applied between the electrode and the skin. By means of this application of electrode paste, the contact impedance is less than 10 kC2. Generally disc like surface electrodes are used. In some cases, needle electrodes are inserted in the scalp to pick up EEG.

Both bipolar and unipolar (monopolar) electrode systems are used to facilitate the location of foci, that is cortical areas from which abnormal waves spread. The phase relationship of the waves indicates the position of the focus and in some cases, it enables the velocity at which the waves spread to be calculated. In ***bipolar technique*** the difference in potential between two adjacent electrodes is measured.

In the ***monopolar technique*** the potential of each electrode is measured with respect to a reference electrode attached to ear lobe or nostrils. In the ***Wilson technique*** (or) average mode recording techniques the potential is measured between one of the electrodes (exploring electrode) and the central terminal which is formed by connecting all electrodes through high, equal resistors to a common point. Multi channel electroencephalographs having as many as the channels permit simultaneous recording from several pairs of electrodes, reducing the total time required to complete the recordings. Eight channel recorders are very popular.

Recording Setup:

Figure shows the simple block diagram of EEG recording setup. In this there are pre and driver amplifiers whose gains are increased by cascading several stages of amplification.



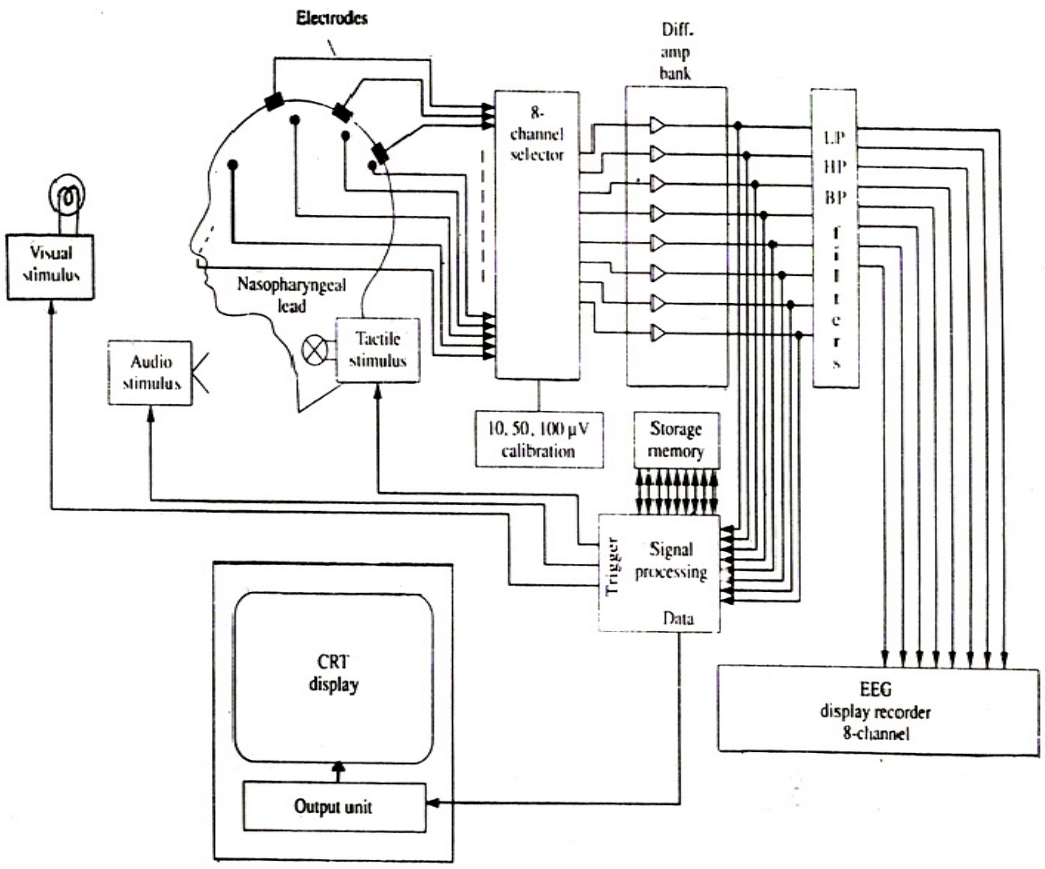


Figure: Modern EEG unit

Above Figure shows the modern 8 channel EEG recorder. The patient cable consists of 21 electrodes and is connected to the eight channel selector. The electrodes are attached to the channel selector in groups of eight called a ***montage*** of electrodes. A representative montage is shown in Figure as numbers from 1 to 8. In that case, the right ear electrode acts as reference electrode for the right brain electrodes and the left ear electrode acts as reference electrode for the left brain electrodes. The 50 Hz interference is reduced by employing differential amplifiers as preamplifiers with more than 80 dB CMRR and by use of 50 Hz notch filters.

The effect of notch filter on signal distortion is not so much because important EEG signals have frequencies below 30 Hz. Further if the room, in which EEG unit is placed, is covered with ferrous metal screen, 50 Hz a.c. interference is greatly reduced. Because the

source of brain wave has high internal impedance, the input impedance of the preamplifier should be more than 10 MQ to prevent reduction of signal amplitude.

Further by cascading, the gain of the amplifier is increased to 106 so as to drive the recorder or imaging CRT without any difficulty. The output voltage from the amplifier may either be applied directly to the eight channel display through the filter bank or it may be stored as data on a tape recorder or in a computer memory for further processing. The filter bank consists of appropriate filters to select different types of brain waves. There are other facilities are available to record evoked potentials from sensory parts of the brain such that there are external stimuli like visual stimulus, audio stimulus and tactile (touch) stimulus.

The time delay between the stimulus and response can also be measured in the signal processing unit. In the eight channel pen recorder there are 8 pens such that a pen for each channel. The normal paper chart speed is 30 mm/second. There are also 60 mm/second for higher frequency recording and 15 mm/second to conserve paper during setup time.

5. (i) Discuss the different types of electrode used in bio potential measurement(10 Marks) [May/June 2013]

Discuss the different types of bio-potential electrodes used in measurement of bio signals. [Nov/Dec 2011]

Describe bio potential electrodes (8 Marks)[April/May 2010]

Discuss the various classifications of electrode. (8 Marks) [Nov/Dec 2009]

What are the three types of electrodes and mention its use.[6 marks] [CO1-L1-Nov/Dec 2008]

Electrodes are employed to pick up the electrical signals of the body. In presenting a bio electric event to the pre amplifier of the signal processing circuit, a pair of electrodes plays the role of a transducer. Since the electrodes are transferring the bio electric event to the input of the amplifier, the amplifier should be designed such that it accommodates the characteristics of electrodes.

The type of electrode to be used depends upon the anatomical location of bio electric event and the dimensions of the bioelectric generator. The electrical characteristics of the

electrodes specify the type of pre amplifier. When the micro electrodes are employed then there are so many restrictions on the input impedance of the amplifier; since they have large impedances, high resistances and low capacitances input circuits are needed to transfer the bio electric event to the amplifying system.

Three types of electrodes are,

(i) Surface Electrodes

(ii) Micro Electrodes

(iii) Needle Electrodes

Surface electrodes

Generally larger area surface electrodes are used to sense ECG potentials and smaller area surface electrodes are used to sense EEG and EMG potentials.

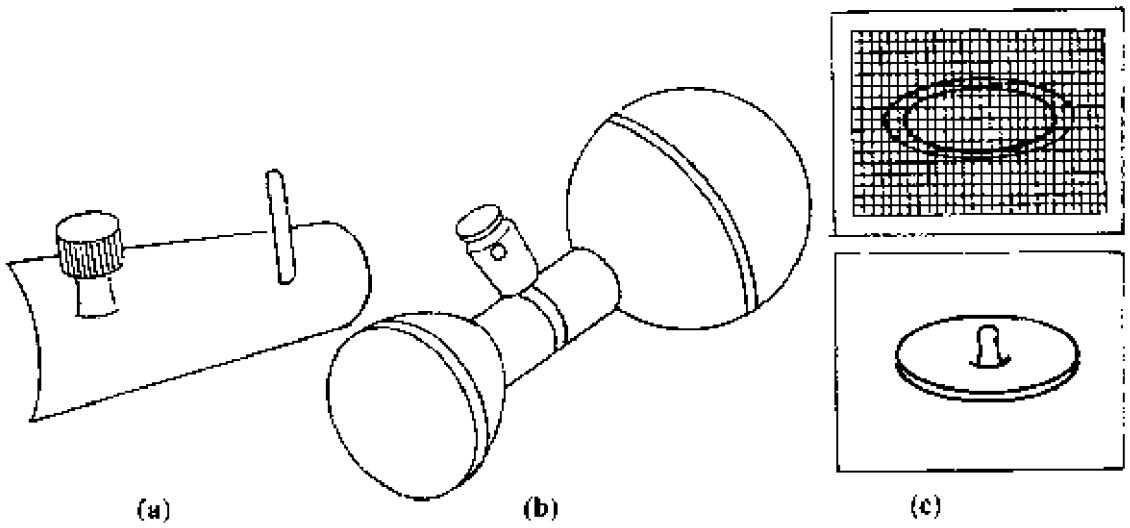


Fig. Surface electrodes: a) Metal Plate electrode b) Suction up electrode and c) Adhesive tape electrode

i) Metal plate electrodes

Rectangular (3.5 cm x 5 cm) and circular (4.75 cm dia) plates from German silver, nickel silver or nickel plated steel are used as surface electrodes in the case of ECG measurement. When these electrodes are applied on the skin with electrode paste, typical

d.c. resistance values are in the range from 2 to 10 kilo ohms, the high frequency impedance amounts to a few hundred ohms. Fig(a) shows a rectangular metal plate electrode.

ii) Suction cup electrode

It is more practical and is well suited for attachment to flat surfaces of the body and to regions where the underlying tissue is soft. Although physically large as shown in fig (b), this electrode has a small area because only the rim is in contact with the skin.

iii) Adhesive tape electrode

The pressure of the surface electrode against the skin may squeeze the electrode paste out. To avoid this problem, adhesive tape electrode is used. It consists of a light, weight metallic screen backed by a pad for electrode paste as shown in fig(c). The adhesive backing holds the electrode in place and retards the evaporation of the electrolyte present in the electrode paste.

iv) Multipoint electrode

The multipoint electrode is a very practical electrode for ECG measurements and it contains nearly 1000 fine active contact points. B this a low resistance contact is established with the subject. If the subject has hairs on the regions of interest, then one can use the multipoint electrode without removing the hair. We can use it under any environmental conditions.

v) Floating electrode

In the floating electrode, the metal does not contact the subject directly. That is the contact is made via an electrolytic bridge. By means of this electrode, movement artifact is eliminated. This is also called as liquid junction electrode.

During the application of surface electrodes, we are getting signals from a relatively large section of tissue. The activity we see is the total product of millions of nerve or muscle cells working as a team. If it becomes necessary to evaluate the activity of a small section of tissue or of cells themselves, then the surface electrodes are not useful. During long-

term monitoring or exercise testing the surface electrode is an important part of the system.

MICRO ELECTRODE:

Microelectrodes are divided in to metallic and non metallic. Non metallic micro electrode is called micropipette. The microelectrodes should have smaller diameter and during insertion of the electrode in to the cell, there will not be any damage to the cells. When a micro electrode is used to measure the potential of the cell, it is located with in the cell, while the reference electrode is situated outside the cell. The size of the electrode is determined by the size of the cell. Since the size of the cell of about 50 microns, the diameter of the tip of the micro electrodes is ranging from 0.5 to 5 microns.

METAL MICRO ELECTRODE:

Metal micro electrodes are formed by electrolytically etching the tip of a fine tungsten or stainless steel wire to a fine point. This technique is known as electro pointing.

The metal micro electrodes are coated almost to the micro tip with an insulating material. To reduce the impedance, some electrolytic processing like chloriding the tip and then developing by the photographic developer can be performed.

Figure (a) shows the position of the electrodes and figure (b) is the electrical equivalent of figure a. since the measurement of bio electric potentials requires two electrodes, the voltage measured is really the difference between the instantaneous potentials as shown in figure (b) such that

Ea - metal electrode - electrolyte potential at the micro electrode tip

Eb - reference electrode electrolyte potential

Ec - variable cell membrane potential

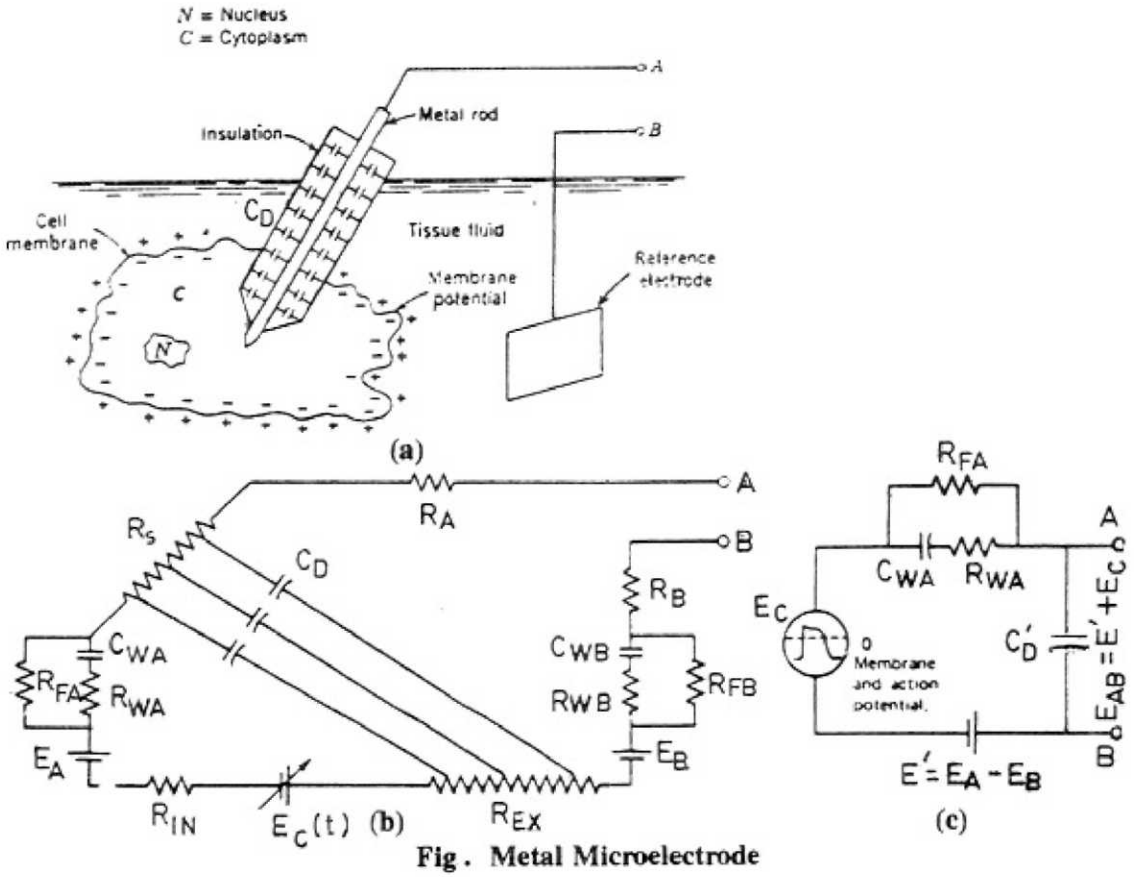


Fig . Metal Microelectrode

Referring the figure (b) R_A denotes the resistance of the connecting wire which is negligible, Rs denotes the resistance of the shaft of the micro electrode which is also negligible; R_{FA},R_{WA} and C_{WA} constitute the impedance of the micro electrode tip intracellular fluid interface; R_{IN} is the resistance of the intra cellular fluid. Similarly R_B is the resistance of the wire connected to the reference electrode which is negligible, RFB, RWB and CWB constitute the impedance of the reference electrode - extra cellular fluid interface and R_{EX} is the resistance of the extra cellular fluid. CD is the distributed capacitance between the insulated shaft of the micro electrode and the extra cellular fluid.

The capacitance between the tip of the micro electrode and intra cellular fluid is negligible because the potential difference across it does not change; figure (c) is the approximate equivalent circuit of figure (b). Since the area of the reference electrode is many times greater than the metal electrode's tip whose area of cross section is very small, its

impedance is negligible. The impedance of the micro electrode tip is inversely proportional to the area of the tip and frequency. When the electrode output is coupled with an amplifier, the low frequency components of the bio electric potential will be attenuated if the input impedance of the amplifier is not high. Thus when the impedance of the amplifier is not high enough, it behaves as a high pass filter

MICRO PIPETTE:

The non metallic micro pipette consists of a glass micro pipette whose tip's diameter is about one micrometre. The micro pipette is filled with an electrode usually 3 M KCl which is compatible with the cellular fluids. A thin, flexible metal wire from chlorided silver, stain less steel or tungsten is inserted in to the stem of the micro pipette. The friction between the wire and the stem of the micro pipette and the fluid surface tension hold the micro pipette on the wire. The other end of the metal wire is mounted to a rigid support and the other free end of it is resting on the cell as shown in the figure.

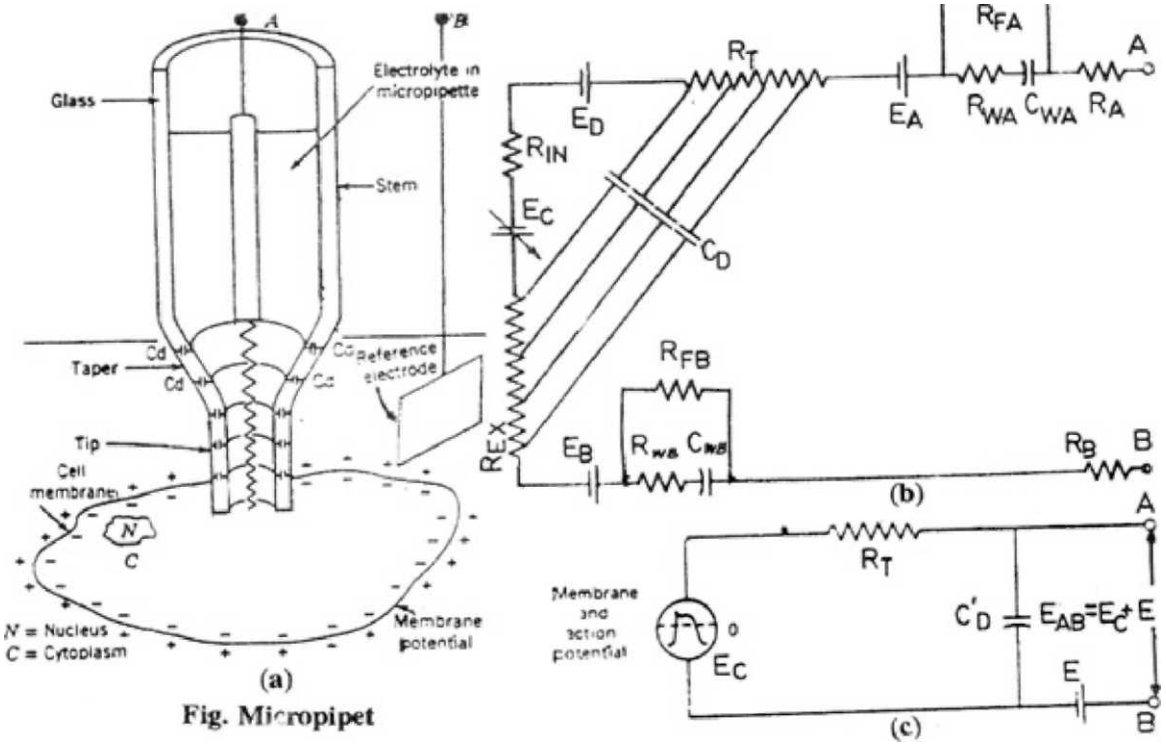


Fig. Micropipet

E_A - potential between the metal wire and electrolyte filled in the micropipette

E_B - potential between the reference electrode and the extra cellular fluid

Ec - variable cell membrane potential

ED - potential existing at the tip due to different electrolytes present in the pipette and the cell $E = E_A + E_B + E_D$

Regarding micro pipette impedances, R_A denotes the resistance of the connecting wire, R_{FA}, R_{WA} and C_{WA} constitute the impedance of the electrode -electrolyte interface in the stem of the micro pipette and RT is the resistance of the electrolyte filling the tip of the micro pipette (simply the resistance of the tip) which is very large. Ri_N and R_{EX} are the resistance of the electrolyte inside the cell and the electrolyte outside respectively. R_{FB}, R_{WB} and C_{WB} constitute reference electrode - electrolyte interface impedance and R_B is the resistance of the wire connected with the reference electrode. CD is the distributed capacitance existing between the fluid in the pipette and the extra cellular fluid.

Figure (c) shows the approximate version of the figure (b). CD is the equivalent of distributed capacitances. When the micro pipette is coupled with the amplifier terminals A and B, then the membrane potential Ec is coupled with it via a high series resistance 'RT' and a moderate shunt capacitance CD along with electrode potentials. The impedance of the electrode places a limit on the response time of the circuit such that it behaves as a low pass filter when the input impedance of the amplifier is not high enough.

Depth and needle electrodes

When it is desired to bring an electrode close to a bioelectric generator, it is often practical to penetrate the skin and advance the electrode through the penetration. So the electrode should be sharp for penetration and to obtain highly localized extra cellular recordings of bioelectric events, these are used.

a) Depth electrode

Depth electrodes are used to study the electrical activity of the neurons in superficial layers of the brain. Normally each electrode consists of a bundle of Teflon insulated platinum (90%) -iridium (10%) alloy wires, bonded to a central supporting stainless steel wire which can act as indifferent electrode by an insulating varnish. The end of the supporting wire is rounded for ease of insertion into the brain. The electrode is resting on the sub cortical nerve cells.

The ends of the individual wires in the bundle constitute individual electrode. The active area of depth electrode is about 0.5 mm^2. Therefore the depth electrode impedance is smaller than the microelectrode impedance. In some depth electrodes, the supporting steel wire is in the form of a capillary tube which is used to inject medicines into the brain or to pass a microelectrode. It is also used to measure oxygen tension.

b) Needle electrode

Generally needle electrodes are used to record the peripheral nerve's action potentials (Electroneurography). The needle electrode resembles a medicine dropper or hypodermic needle. A short length of the fine insulated metal wire is bent at its one end and the bent portion is inserted through the lumen of the needle and is advanced into the muscle. The needle is withdrawn and the bent wire is resting inside the muscle. When the reference electrode is placed on the skin, then the needle electrode is called monopolar. When we insert two insulated wires into the lumen of the needle, then the two wires constitute bipolar electrode such that one wire is active electrode and the other wire is reference electrode.

(ii)Explain the measurement of EMG(6 Marks) [May/June 2013]

Draw the block diagram of EMG measurement and explain (8 Marks) [May/June 2012]

With suitable diagrams explain the method of measurement of conduction velocity in peripheral nerves. [8 marks] [8 marks] CO1-L1- [Nov/Dec 2008]

Electromyography is the science of recording and interpreting the electrical activity of muscle's action potentials. Meanwhile the recording of the peripheral nerve's action potentials is called ***electro neurography.*** The electrical activity of the underlying muscle can be measured by placing surface electrodes on the skin. To record the action potentials of individual motor units, the needle electrode is inserted into the muscle. Thus EMG indicates the amount of activity of a given muscle or a group of muscles and not an individual nerve fiber.

The action potentials occur both positive and negative polarities at a given pair of electrodes; so they may add or cancel each other. Thus EMG appears, very much like a random noise wave form. The contraction of a muscle produces action potentials. When there is stimulation to a nerve fiber, all the muscle fibers contract simultaneously developing action potentials. In a relaxed muscle, there is no action potential.

Recording setup

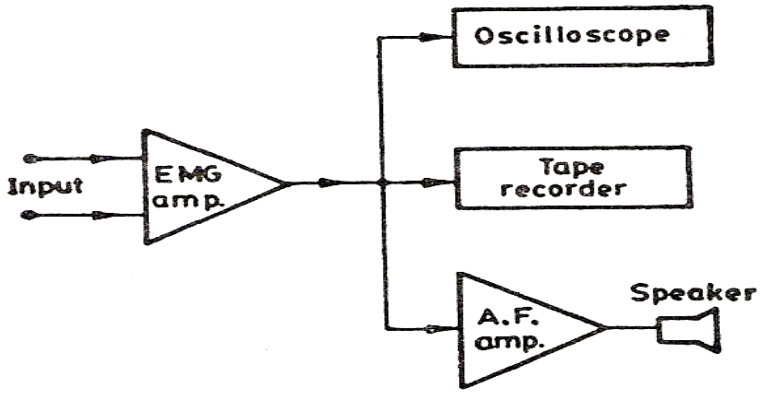


Figure (a) shows the typical setup for EMG recording. The surface electrodes or needle electrodes pickup the potentials produced by the contracting muscle fibers. The surface electrodes are from Ag-AgCl and are in disc shape.

The surface of the skin is cleaned and electrode paste is applied. The electrodes are kept in place by means of elastic bands. By that way, the contact impedance is reduced below 10 k ohms. There are two types of conventional electrodes: bipolar and unipolar type electrodes. In the case of **bipolar *electrode,*** the potential difference between two surface electrodes resting on the skin is measured. In the case of ***unipolar electrode*** the reference surface electrode is placed on the skin and the needle electrode which acts as active electrode, is inserted into the muscle. Because of the small contact area, these unipolar electrodes have high impedances ranging from 0.5 to 100 MQ. With needle electrodes, it is possible to pickup action potentials from selected nerves or muscles and individual motor units.

In the case of ***coaxial electrode*** which consists of an insulated wire threaded through a hyperdermic needle with an oblique tip for easy penetration, the surrounding steel jacket acts as reference and the metallic wire acts as exploring electrode. The needle is inserted into the muscle. Further to record the action potentials from a single nerve, microelectrodes are used.

The amplitude of the EMG signals depends upon the type and placement of electrodes used and the degree of muscular exertions. That is, the surface electrode picks up many overlapping spikes and produces an average voltage from various muscles and motor units. The needle electrode picks up the voltage from a single muscle fiber. Generally EMG signals range from 0.1 to 0.5 mV.

They may contain frequency components from 20 Hz to 10 k Hz. which are in the audio range. But using low pass filter, the electro myographerrestricts this frequency range from 20 Hz to 200 Hz for clinical purposes. The normal frequency of EMG is about 60 Hz. Therefore the slow speed strip chart recorders are not useful and the signals are displayed on a cathode ray oscilloscope and photographic recordings are made.

Normally there are two cathode ray tubes, one for viewing and other one for recording. A light sensitive paper moves over the recording cathode ray tube and the image is produced on that paper. After developing it, one can see the visible image. For continuous recording, the paper speed is about 5 to 25 cm/second. For short duration it is about 50 to 400 cm/second. The paper width is about 10 cm.

The amplifier should have uniform frequency response in the frequency range from 10 Hz to 1 kHz with high CMRR (100 dB) and input impedance greater than 10 MQ. The signal is also recorded in the tape recorder for future reference. Further the myographer can listen the sounds from the loud speaker and from that he can diagnose the neuromuscular disorders.

Thus EMG is very useful for studying the neuromuscular function, neuromuscular condition, reflex responses and extent of nerve lesion and diagnosing the muscular diseases like myasthenia gravis which can produce a highly damped impulse during contraction of the muscles due to too rapid fatigue of the neuromuscular synapses.

Determination of conduction velocities in motor nerves:

The measurement of conduction velocity in motor nerves is used to indicate the location and type of the nerve lesion. Here the nerve function is examined directly at the various segments of the nerve by means of stimulating it with a brief electric shock having a pulse duration of 0.2 - 0.5 milliseconds and measuring the latencies, we can calculate the conduction velocity in that peripheral nerve. *Latency* is defined as the elapsed time between the stimulating impulse and the muscle's action potential.

Figure (b) illustrates the measurement procedure. The EMG electrode and thestimulating electrode are placed at two points on the skin, separated by a known distanceI j. A brief electrical pulse is applied through the stimulating electrode. When the excitation reaches the muscle, this contracts with a short twitch. Since all the nerve fibers are stimulated at the same time and the conduction velocity is normally the same in all nerve fibers, there is synchronous activation of the muscle fiber.

This action potential of the muscle is picked up by the EMG electrode and is displayed on the oscilloscope along with the stimulating impulse. The elapsed time Y (latency) between the stimulating impulse and muscle's action potential is measured. Now the two electrodes are repositioned with the distance of separation as 1_2metres. Among the distances lj and 1_2,1_2<h- The latency is now measured as V seconds.

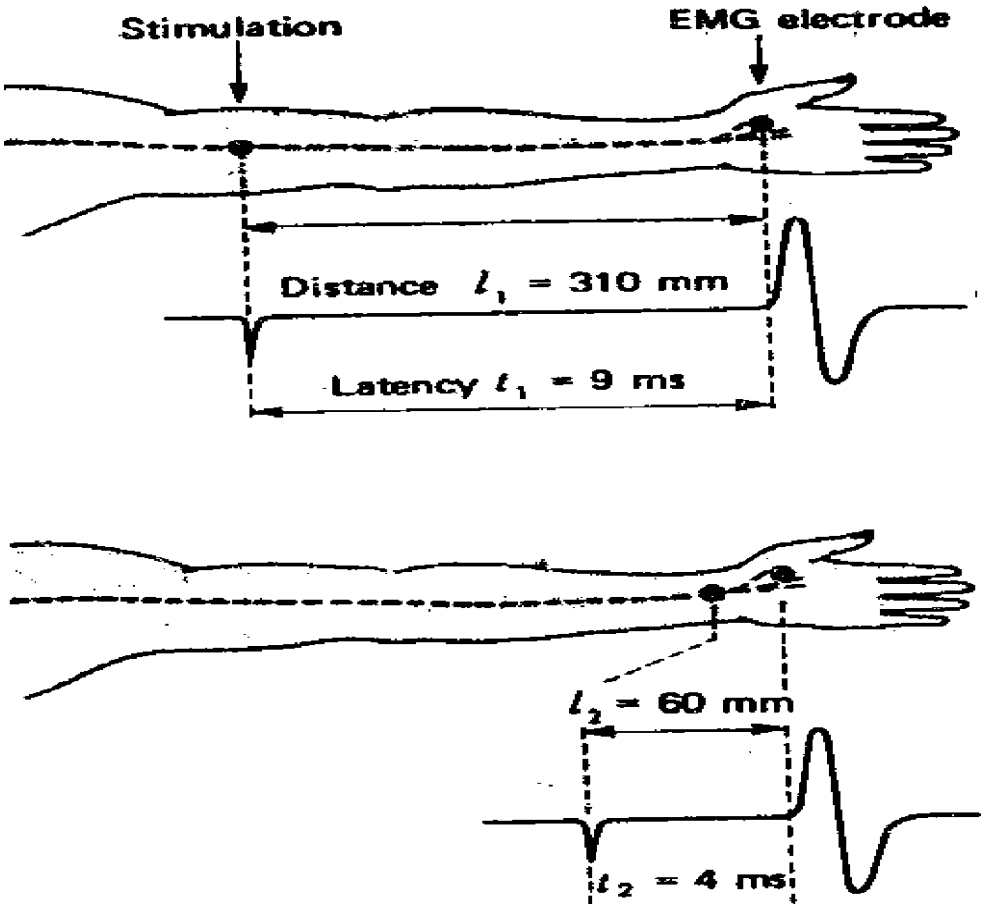


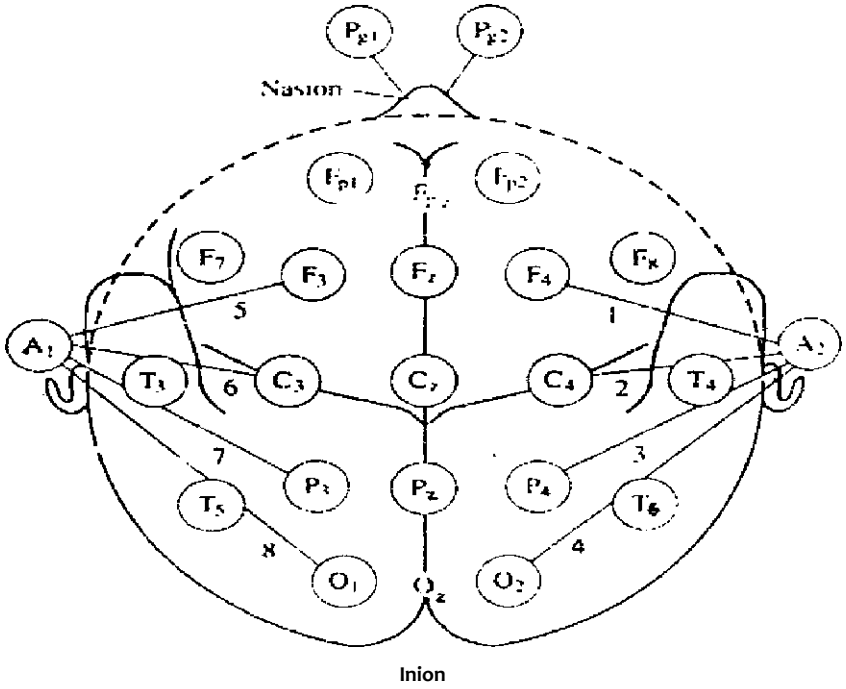
Fig. Determination of conduction velocity in a motor nerve

The conduction velocity, $v = (l_1-l_2)/(t_1-t_2)$

The conduction velocity in peripheral nerves is normally 50 m/s. When we have it below 40 m/s, there is some disorder in that nerve conduction.

6. (i) What should be the characteristics of bio potential amplifier? Explain with proper justification. (8 Marks)[Nov/Dec 2012]

(ii)Write about 10-20 system of recording EEG. (8 Marks)[Nov/Dec 2012] Draw the 10-20 electrode placement system (6 Marks) [May/June 2012] Draw the 10-20 electrode placement system used in EEG (8 Marks)[Nov/Dec 2011] Describe the 10-20 electrode system used in EEG (8 Marks) [CO1-L1-May/June 2009]



Placement of electrodes:

In EEG, electrodes are placed in standard positions on the skull in an arrangement called 10 - 20 system, a placement scheme devised by the International Federation of Societies of EEG. The electrodes in this arrangement are placed as follows:

i. Draw a line on the skull from the ***nasion,*** the root of the nose, to the ***inion,*** ossification center (bump) on the occipital lobe.

ii. Draw a similar line from the left preauricular (ear) point to the right preauricular point.

iii. Mark the intersection of these two lines as Cz which is the mid point of the distance between the nasion and inion (or) the distance between the auricular points.

iv. Mark points at 10,20, 20,20 and 10% of the total nasion - inion distance. These points are Fpz, F2, Cz,Pz and Oz.

v. Mark points at 10, 20, 20, 20, 20 and 10% of the total distance between the preauricular points.

These points are T3, C3, C_z, C4 and T4. In these odd numbered points T3 and C3 are on the left and even numbered points C4 and T4 are on the right.

vi. Measure the distance between Fpiz and Oz along the great circle passing through T_3 and mark points at 10, 20, 20, 20, 20 and 10% of this distance. These are the positions of F-j, F7, T3, T5 and Oj.

vii. Repeat this procedure on the right side and mark the positions of Fp2, Fg, T4, T6 and O2.

viii. Measure the distance between Fpj and Oj along the great circle passing through C3 and mark points at 25% intervals. These points give the positions of F3, C3 and P3. The ground reference electrode is a metal clip on the earlobe.

ix. Repeat this procedure on the right side and mark the positions of F4, C4 and

x. Check that *V-j,* F3, F_z, F4 and Fg are equidistant along the transverse circle passing through F7, Fz and Fg and check that T5, P3, Pz, P4 and T6 are equidistant along the transverse circle passing through T5, Pz and Tg. In thefigure (d) the positions of the scalp electrodes are indicated. Further there are nasopharyngeal electrodes P_g;and P_{g2} and ear electrodes A1 and A2.

7.(i)Explain the origin of bio potential (8 Marks)[Nov/Dec 2012]

Draw the action potential waveform and explain the origin of bio potential.(10 Marks) [CO1-L1-May/June 2012]

BIO ELECTRIC POTENTIALS:

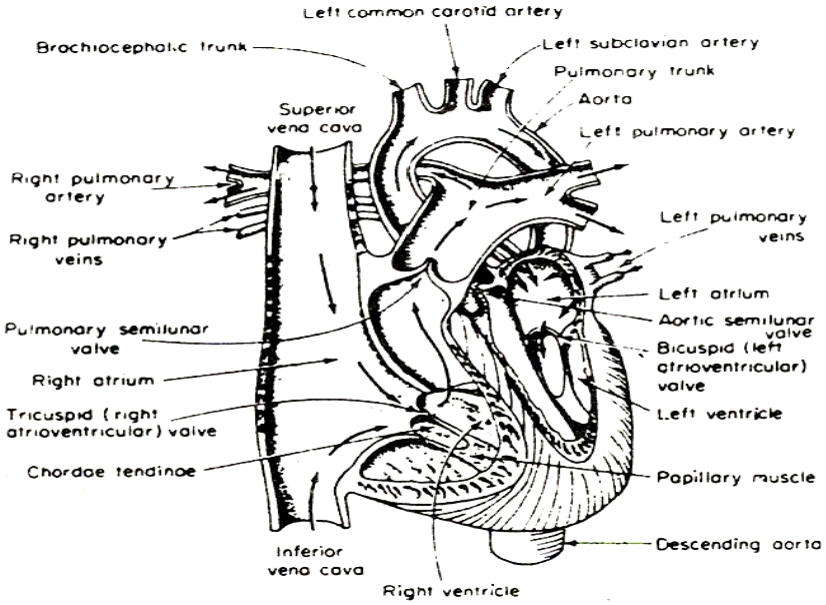
As a consequence of the chemical activity in the nerves and muscles of the body, a variety of electrical signals are generated. For example, the heart and brain produce characteristic patterns of voltage variations. Bio electric potentials are generated at a cellular level. That is, each cell is a minute voltage generator. Because positive and negative ions tend to concentrate unequally inside and outside the cell wall, a potential difference (resting potential) is established and the cell becomes a tiny biological battery.

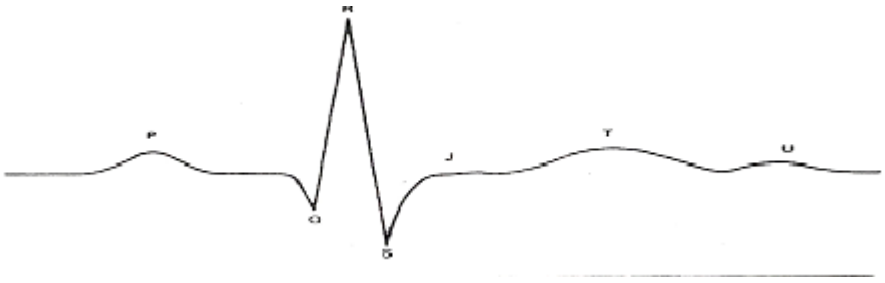
In the normal resting state of the cell its interior is negative with respect to outside. When the cell "fires" however, the outside of the cell becomes momentarily negative with respective to the interior. A short time later, a cell regains the normal state in which the inside is again negative with respective to outside. This "discharging" and "recharging" of the cell known as depolarization and repolarization respectively produces the voltage waveforms of interest to

the clinician and bio medical engineer. The table shows the various bioelectric signals, their frequency and voltage picked up by the respective electrodes.

Bioelectric signal	Frequency Range (Hz)	Voltage Range (micro V)	Electrodes used	Origin
Electrocardiogram (ECG)Vector cardiogram	0.05 to 100	10 to 5000 covers fetal range	Surface electrodes are used with jelly, paste or cream. Needle electrodes are less noisy	Heart muscles
Electroencephalogram (EEG)	0.1 to 100	2 to 200	Surface and needle electrodes	Neuronal activity of the brain
Cerebral potentials (intracranically recorded)	Pulse duration 0.6 ms to 0.1 s	10 to 100000	Deep needle electrodes	Cerebrum of the brain
Electromyography (EMG) (primary signal)	5 to 2000	20 to 5000	Surface or needle electrodes	Skin muscles
Electrogastrogram (EGG)	0.05 - 0.2	10-350	Surface electrodes	Peristaltic movements of the gastrointestinal tract
Electroretinogram (ERG)	0.01 to 200	0.5 to 1000	Corneal electrodes	Retina of the eye
Electrooculogram (EOG)	d.c to 100	10 to 3500	Miniature Surface electrodes	Corneal - retinal potential variations

ii. Draw a typical ECG waveform and mark the important features and the associated function of the heart. (8 Marks) [CO1-L1-Nov/Dec 2012]





	Origin	Amplitude mV	Duration sec.
P Wave	Atrial depolarisation or contraction	0,25	0.12 to 0.22 (P-R interval)
R Wave (QRS complex)	Repolarisation of the atria and the depolarisation of the ventricles	1.60	0.07 to 0.1
T Wave	Ventricular repolarisation (Relaxation of myocardium	0.1 to 0,5	0.05 to 0.15 (S-T interval)
S-T interval	Ventricular contraction		
U Wave	Slow repolarisation of the intraventricular (Purkinje fibers) system	< 0.1	0.2 (T-U interval)

The complete waveform is called electrocardiogram with labels PQRSTU indicating important diagnostic features. For example if the PR interval is more than 0.22 sec, the AV Block (First degree - heart attack) occurs. When the QRS complex duration is more than 0.1 second the bundle block (severe heart attack) occurs.

Each action potential in the heart originates at the ***sinoatrial****(SA)* ***node*** which is situated in the wall of the right atrium and near the entry of the Vena Cava. It is also called ***cardiac pacemaker*** and generates impulses at the normal rate of the heart, about 70 beats per minute at rest. The rate is governed by the autonomic nervous system, being increased by the sympathetic nerves and decreased by the parasympathetic nerves. These are connected with brain through the spinal cord. The action potential contracts the atrial muscle and the impulse spreads through the atrial wall during a period of about 0.04 second to the ***atrio-ventricular*** *(AV)* ***node.***

The node is located in the lower part of the wall between the two atria. The AV node delays the spread of excitation for about 0.11 second. Thus the AV node acts as a "delay

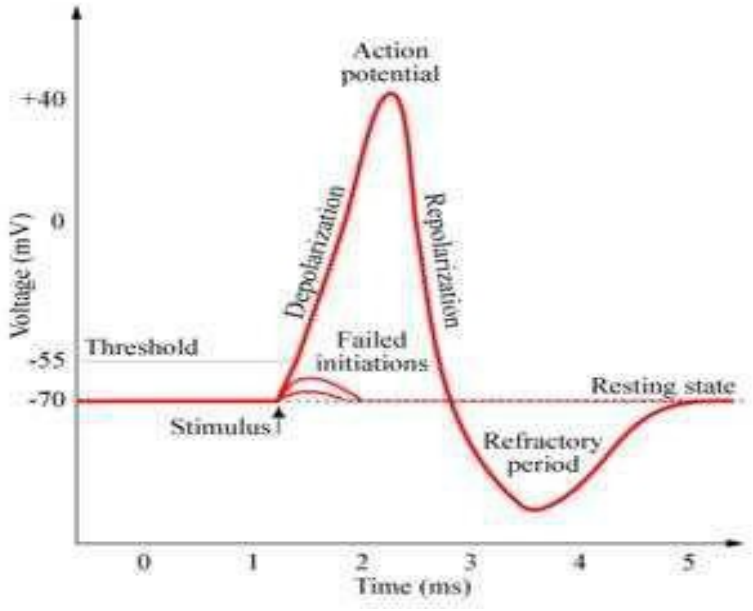
line" to provide timing between the action of the atria and the ventricles. Then a special conduction system carries the action potential to the ventricular muscles.

This system consists of a short common part ***(the bundle of His),*** two bundle branches on each of the septum and fine ***Purkinje fibers*** which arborize in the ventricular muscle. Thus the atria and ventricles are functionally linked only by the AV node and the conduction system. The AV delay is provided so that the atrial contraction can complete the ventricular filling before' the contraction of ventricles.

8.(i) Draw the action potential waveform and explain the following terms.

Resting Potential, Action Potential, Absolute Refractory period and relative refractory period (10 Marks) [CO1-L1-April/May 2011]

Explain in detail about action potential and resting potential (8 Marks)[Nov/Dec 2009]



RESTING AND ACTION POTENTIALS

The diffusion and drift process give raise to membrane potential the various ions seek a balance between the inside and outside of the cell by diffusion and drift. But the membrane of excitable cells, such as nerve and muscle cells, readily permits the entry of potassium

and chloride ions effectively blocks the entry of solid ions. For example the permeability of sodium ions is about $2x10^{-8}$ cm/sec and for potassium and chloride ions, that are $2x10^{-6}$ cm/sec $4x\ 10^{-6}$ cm/sec respectively.

Due to the difference in the permeability of different ions, the concentration of sodium ions inside the cells become much lower than the outside the cell. Since the sodium ions are positive, the outside of the cell is more positive than the inside of the cell. Similarly the concentration of the potassium and chloride ions is more inside than the outside.

Thus the charge balance is not achieved. However equilibrium is reached with a potential difference across the membrane such that negative on inside and positive on the outside. This membrane potential caused by different concentration of ions is called the resting potential of the cell.

CHARECTERISTICS OF RESTING POTENTIAL

The value of resting potential is maintained as a constant until some kindof disturbance upsets the equilibrium.

1. It is strongly depending on temperature.
2. Since the permeability of different cell types vary, the corresponding resting potentials vary as well. Thus it varies from -60 to -100 mV.
3. By Goldman's equation, the resting potential 'Vr' for a cell can be written as

$$Vr = - kT/q \ln [Pk [k^+]I + P_{Na}[Na^+]_i + P_{cl}[Cl-]_0 / Pk [k^+]_0 + P_{Na} [Na^+]_0 + P_{cl}[Cl]_i$$

Where

- k = Boltzman's constant = $1.38x10^{-23}$ J/K.
- T = absolute temperature of the cell in Kelvin.
- q = charge of electron = $1.602x\ 10^{-19}$ C.
- Pk = permeability of potassium ion.
- P_{Na} = permeability of sodium ion.

- P_{Cl} = permeability of chlorine ion.

$[k^+]$,$[Na^+]$&[Cl] = Concentration of potassium, sodium and chlorine ions and the subscripts i and 0 indicate inside the cell and outside the cell respectively.

Absolute Refractory period and Relative refractory period

The relative refractory period immediately follows the absolute refractory period, and is due to the efflux of K+ ions. During the second half of repolarization, the excitatory Na+ channels are mostly ready to open, and a small weak action potential can be generated. However, it is better to wait until the channels are fully ready before continuing with the next excitation.

Full excitability is not regained until the cardiac fiber has been fully repolarized. In order for an action potential to be generated during the relative refractory period the stimulus must be greater than that which would normally elicit a response.

Unlike the absolute refractory period, the duration of the relative refractory period can change. As heart rate increases, and systole decreases, the action potential becomes narrower due to a decrease in relative refractory period. At rest, the heart rate slows, and the action potential becomes wider as the relative refractory period increases. This allows greater oxygen supply to reach needy areas during exercise and other stress conditions.

These refractory periods are important because during this time the gradient concentrations of important ions (Na+, K+) are restored. This allows further excitation of the cardiac fiber. The results of the refractory periods can be seen in the plateau of the cardiac fiber action potential.

(ii)Discuss about the different EEG signal frequency bands (6 Marks) [April/May 2011]
Discuss the EEG waveforms in detail.(8 Marks)[April/May 2010]

Classify the EEG frequency bands and discuss when they are developed. (8 Marks)[CO1-L1-May/June 2009]

Classified into alpha, beta, thetaand delta waves.

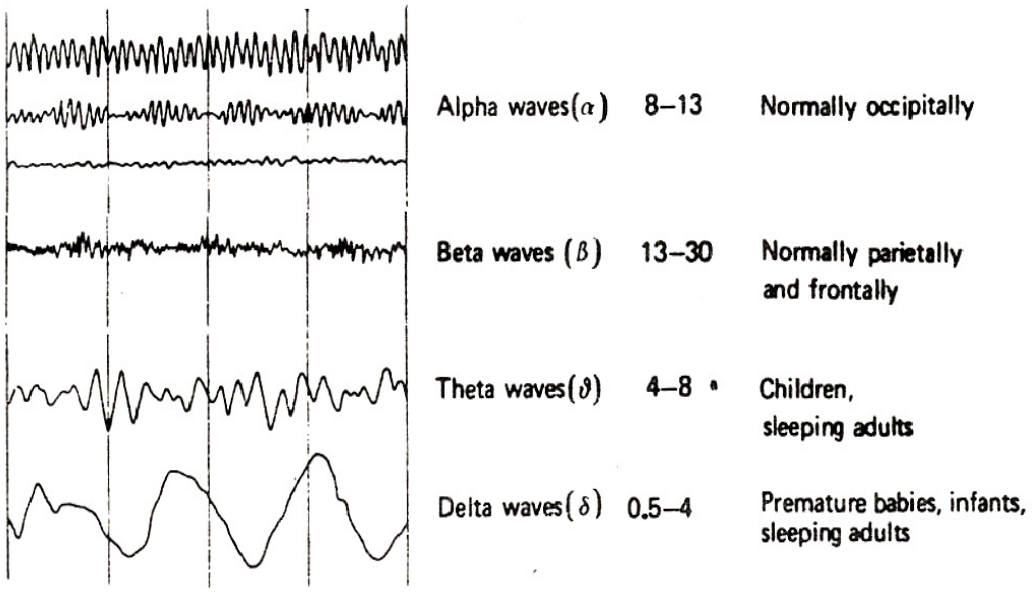


Fig . Brain Waves

alpha, beta, thetaand delta waves.

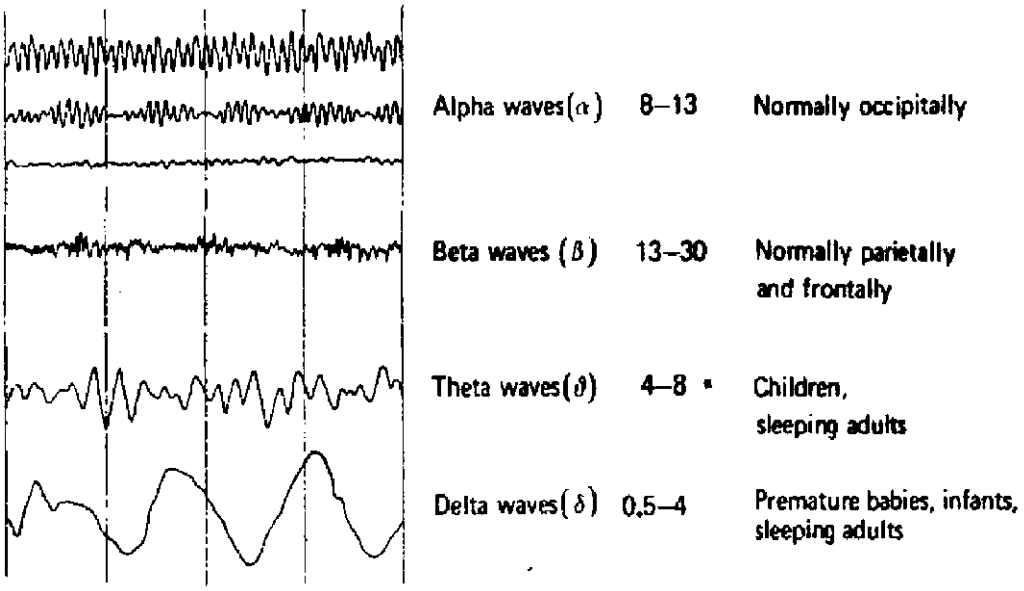


Fig . Brain Waves

Alpha waves

Frequency : 8 - 13 Hz

Occurrence : They found in normal persons when they are awake in quiet, Resting state. They occur normally occupital region. During sleep, these disappear. These have amplitude of 20-200 /micro V with mean of 50 /micro V.

Beta waves

Frequency : 13 - 30 Hz
(at intense mental activity, the frequency increases upto50Hz)

Occurrence : These are recorded from the parietal and frontal regions of the scalp. These are divided into two types as beta I which is inhibited by the cerebral activity and beta II which is excited by the mental activity, like tension.

Theta waves

Frequency : 4-8Hz

Occurrence : These are recorded from the parietal and temporal regions of the scalp of children. These also occur during emotional stress in some adults particularly during disappointment and frustration.

Delta waves

Frequency : 0.5 - 4 Hz

Occurrence : These occur only once in every 2 or 3 seconds. These occur in deep sleep, in prematurebabies and in very serious organic brain diseases. These can occur strictly in the cortex independently by the activities in the lower regions of the brain.

9. With a neat block schematic diagram, describe the ECG recording system [CO1-H1-Nov/Dec 2010]

ECG RECORDING SET UP

The important parts of ECG recorder are shown in figure**.**

1. PATIENT CABLE AND DEFIBRILLATOR PROTECTION CIRCUIT

The patient cable connects the different leads from the limbs and chest to the defibrillator protection circuit. It consists of buffer amplifiers and over voltage protection circuit. The leads are connected with the buffer amplifiers such that one buffer amplifier for each patient lead.

By this means the input impedance is increased and the effects arising from the variations in the electrode impedance are reduced. Further the over voltage protection circuit is necessary to avoid any damage to the bio amplifiers in the recorder.

The over voltage of the order of 1000 V may occur when the electrocardiograph is used during surgery in conjunction with radiofrequency diathermy units for cutting and coagulation or during the treatment of ventricular fibrillation using defibrillators.

This over voltage protection circuit consists of a network of resistors and neon lamps which fire when a pulse from a defibrillator is present. During firing of the neon lamp, there is no input to the preamplifier of the recorder.

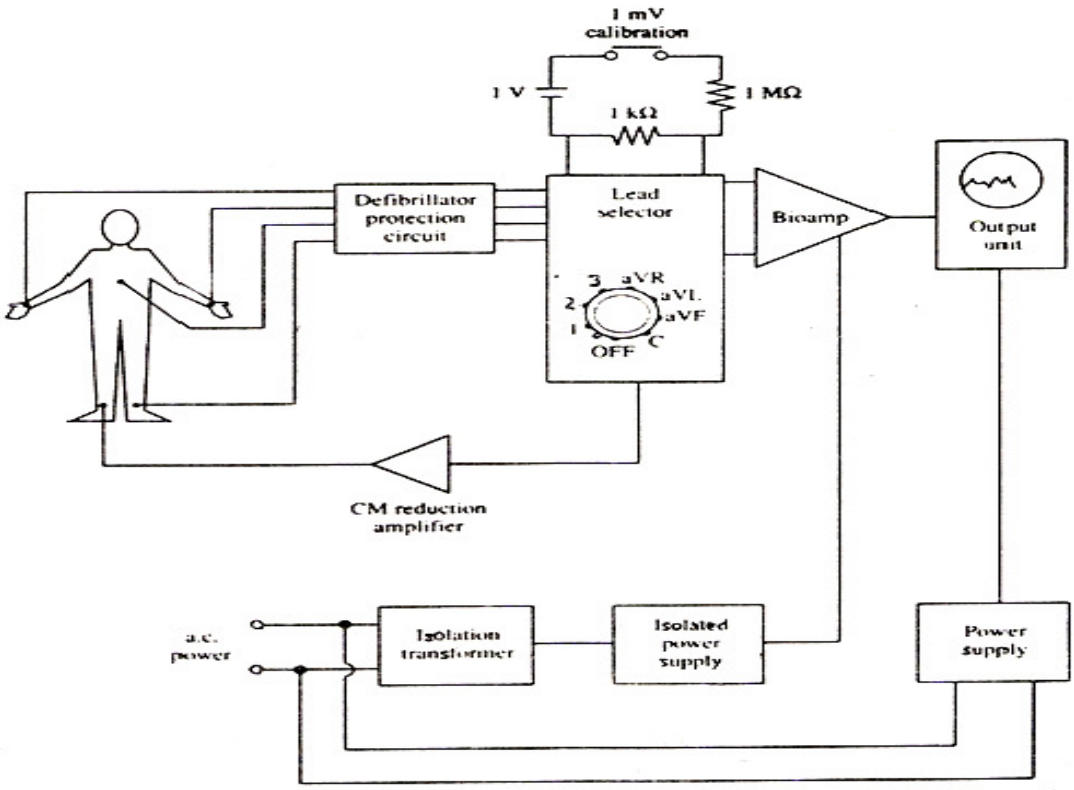


Fig - ECG Recording set up

2. LEAD SELECTOR SWITCH

After the defibrillator protection circuit, there is lead selector switch which is used to feed the input voltage from the appropriate electrode to the preamplifier.

3. CALIBRATOR

A push button allows the insertion of a standardization voltage of 1 mV to the preamplifier. This enables the technician to observe the output on the display unit and adjust the scales that a known deflection corresponds to a mV input signal. Changing the setting of the lead selector switch introduces an artifact on the recorded trace.

But by means of a special contact on the lead selector switch the amplifier is momentarily turned off during the change of setting of the lead selector switch and after the passage of the artifact the amplifier is turned on. From the lead selector switch the ECG signal goes to bio-amplifier.

4. BIO-AMPLIFIER

The bio-amplifier consists of a preamplifier and power amplifier. Already the preamplifier, as a differential amplifier with high gain and high CMRR is discussed in the last chapter. The sensitivity or the gain of the amplifier can be varied. Followed by the preamplifier, there is a power amplifier which is used to drive the recorder. Pen motors in the recorder requires sufficient electrical power to activate the recording or display.

Therefore power amplifiers are required with high power gain. Generally transistor circuits are favorable because a relatively large surface area is necessary to dissipate the heat generated in the circuit due to passage of high current.

Figure shows a power amplifier circuit used to drive ECG chart recorder stylus. It is a push pull type. Further it is provided with crossover distortion compensation and offset control. It consists of two silicon power transistors such that the emitters of the transistors are joined together and connected with a load resistor, RL. When Vg is sufficiently positive, transistor *Q2* is forward biased and conducts, while Q2 is reverse biased and remains off.

OUTPUT POWER, $P_{OUT} = V^2_{OUT} / R_L$

THE AMPLIFIER EFFICIENCY, 17 = P_{OUT} /(POUT +P LOSS)

To avoid the crossover distortion in a push pull amplifier, an ideal non inverting amplifier is inserted at the input. Since the input impedance of non inverting amplifier approaches infinity, the power gain also approaches infinity. The crossover distortion is eliminated because the feedback resistance, Rf is so large and hence it raises the gain in a linear manner and in turn raises the output voltage. The offset control is provided by the resistance R2 and is used to position the output stylus pen. Gain adjustment is provided with the resistance RQ.

5. AUXILIARY AMPLIFIER

Since the electrode impedances are not equal, a differential amplifier does not completely reject the common mode signals. The common mode signals can be reduced to a minimum level by means of adding an auxiliary amplifier between the driven right leg lead and the ECG unit.

By this way, the right leg is not connected to ground but it is connected to the output of the auxiliary amplifier. If the body common mode voltage is different from zero, a summing network produces the sum of all common mode voltages from all other electrodes and feeds that sum of the voltages as input to inverting terminal of the auxiliary amplifier.

Meanwhile its non inverting terminal is grounded. The output of the auxiliary amplifier is connected to the right leg. Therefore it drives the body to zero common voltage. Thus the common mode rejection ratio of the overall system is increased. Further in the right leg electrode the current flow is reduced.

6. ISOLATED POWER SUPPLY

The isolated power supply is used to give power to the bio-amplifier and by means of that, the electrical safety for the patient is increased (Refer isolation amplifiers in the Chapter III)

7. OUTPUT UNIT

The output unit is a cathode ray oscilloscope as shown in figure (a) or a paper chart recorder as shown in figure (b).

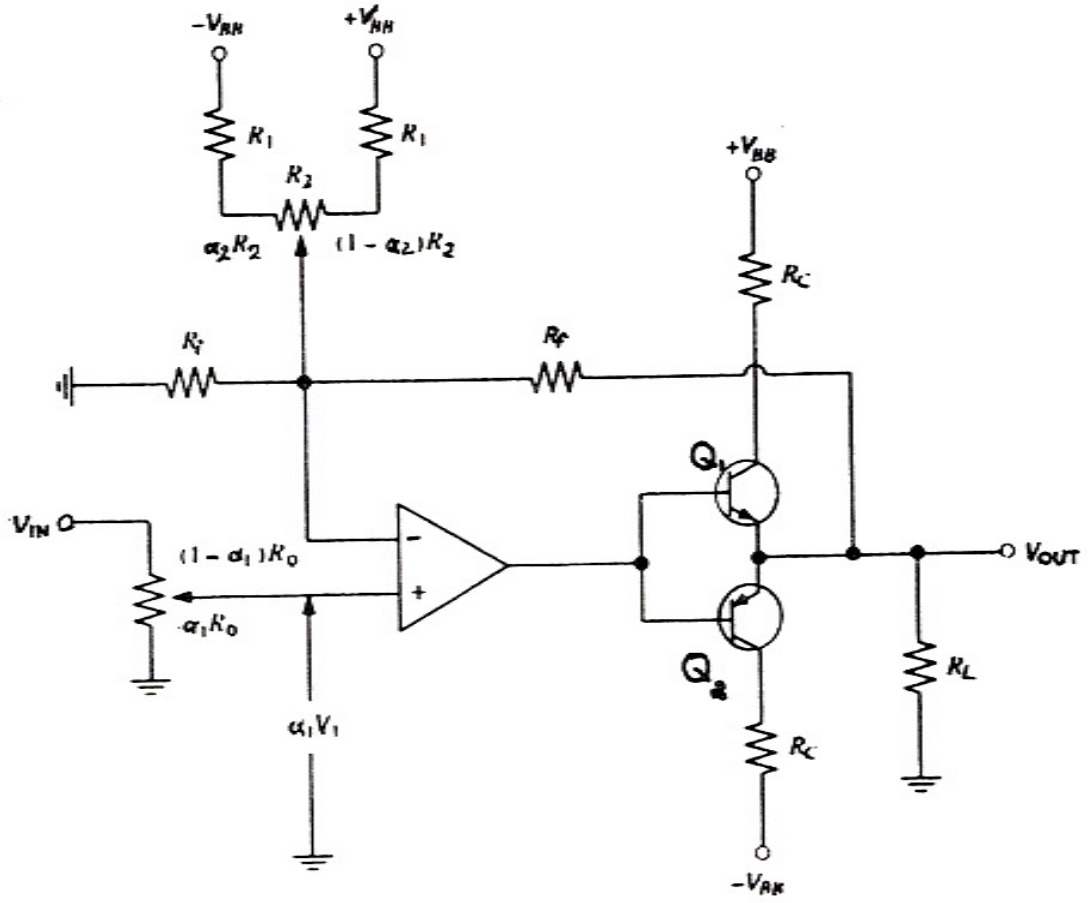


Fig - Push-Pull Power Amplifier with crossover compensation and offset control

The output voltage of this amplifier circuit is given by

$$V_{out}=(\alpha V_1)(1+(R_1/R_i)) +R_f\left[\left[\frac{\alpha_1 V_1+V_{BB}}{\alpha_2 R_2+R_1}\right]+\left[\frac{\alpha_1 V_1-V_{BB}}{(1-\alpha_2)(R_2+R_1)}\right]\right]$$

In the case of paper chart recorder, the power amplifier or pen amplifier supplies the required power to drive Pen Motor that records the ECG trace on the wax coated heat

sensitive paper. A position control on the pen amplifier is used to position the pen at the center on the recording paper.

The stylus penis heated electrically and the temperature of the stylus pen can be adjusted with a stylus heat control. There is a marker stylus which is actuated by a push button and allows the technician to mark a coded indication of the lead being recorded. The paper speed is about 25 mm/s (U.S. paper speed) or 50 mm/s (European paper speed).

The faster speed of 50 mm/s is provided to allow better resolution of the QRS complex at very high heart rates.

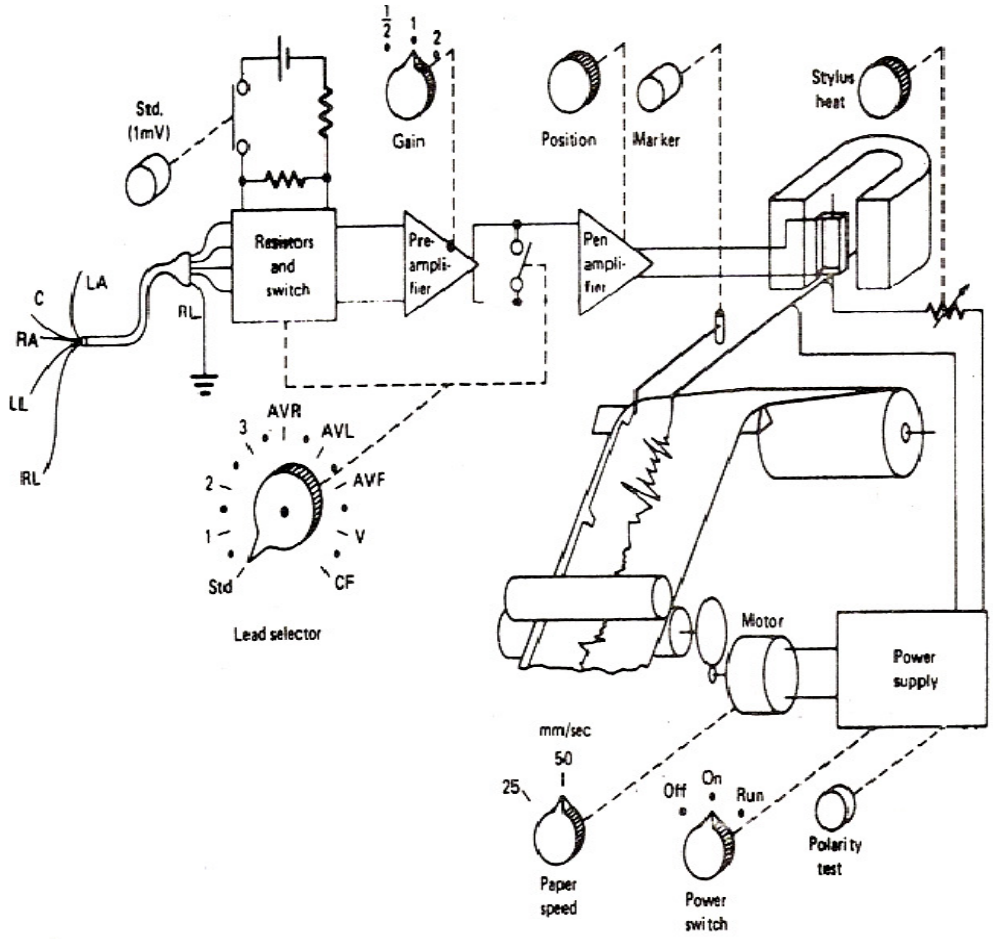


Fig. Paper chart recorder using pen as writer.

8. POWER SWITCH

The power switch of the recorder has three positions. In the ON position the power to the amplifier is turned on; but the paper drive is not running.

Switch must be placed in the R condition. N position. In OFF position, the ECG unit is in switched off.

Unit-II

Bio –Chemical and Non Electrical Parameter Measurement

Part-A

1.Write the principle behind Electromagnetic blood flow meter. [CO2-L1-May/June 2014]

Mean Arterial Pressure = [(2 x diastolic)+systolic] / 3=[(2*110)+82]/3

The operation principle behind the electromagnetic blood flow meters is Faraday's law of electromagnetic induction which states that if electrical current carrying conductor moves at right angle through a magnetic field, an electromotive force is induced in the conductor.

2. Nitrogen washout technique is meant for what measurements? [CO2-L1-May/June 2014]

Nitrogen washout (or Fowler's method) is a test for measuring dead space in the lung during a respiratory cycle, as well as some parameters related to the closure of air ways. A nitrogen washout can be performed with the single nitrogen breath, or multiple ones. Both tests use similar tools, both can estimate functional residual capacity and the degree of nonuniformity of gas distribution in the lungs, but the multiple-breath test more accurately measures absolute lung volumes.

3. If systolic and diastolic blood pressures are given as 110 mm Hg and 82 mm Hg. Calculate mean arterial pressure. [CO2-L1-Nov/Dec 2013]

Mean Arterial Pressure = [(2 x diastolic)+systolic] / 3=[(2*110)+82]/3

=91.3mm Hg

4. Mention the basic principle behind electrochemical P^H determination. [CO2-L1-Nov/Dec 2013]

An electrochemical cell for pH measurement always consists of an indicating electrode whose potential is directly proportional to pH, a reference electrode whose potential isindependent of pH, and the aqueous sample to be measured. If all three parts are in

contact with each other, a potential can be measured between the indicating electrode and the reference electrode, which depends on the p^H of the sample and its temperature.

5. What are the components of blood? [CO2-L1-May/June 2013]

Red Blood Cell

White blood cell

Platelets Plasma.

6. What is stroke volume? [May/June 2013] [CO2-L1-April/May 2011]

Stroke volume (**SV**) is the volume of blood pumped from one ventricle of the heart with each beat. SV is calculated using measurements of ventricle volumes from an echocardiogram and subtracting the volume of the blood in the ventricle at the end of a beat (called end-systolic volume) from the volume of blood just prior to the beat (called end- diastolic volume).

7. What is an auto analyzer? What are the essential units in it? [CO2-L1-Nov/Dec 2012]

An Auto analyzer is an instrument that sequentially measures the blood chemistry and displays it on the graphic readout.

The essential units of auto analyzer are sampler, proportioning pump and manifold, dialyzer, heating bath colorimeter and recorder.

8. Give the typical values of blood pressure and pulse rate of an adult. [CO2-L1-Nov/Dec 2012]

Blood Pressure Category	**Systolic mm Hg (upper #)**	**Diastolic mm Hg (lower #)**
Normal	less than **120**	less than **80**

Normal values for pulse rate depend on age and fitness level. A normal adult has a pulse rate of 72 per minute.

9. What are the various parameters measured in the blood cell counter? [CO2-L1-May/June 2012]

Blood cell counter is the determination and the number of the quantity of each type of blood cell : red blood cells, white blood cells, and platelets in a sample of blood in a given sample of blood, often including the amount of hemoglobin, and the proportions of various white cells. . Also called a complete blood counter (CBC).

The CBC provides valuable information about the blood and to some extent the bone marrow, which is the blood-forming tissue.

The CBC is used for the following purposes:

- to identify persons who may have an infection .
- to diagnose anemia .
- to identify acute and chronic illness, bleeding tendencies, and white blood cell disorders such as leukemia .
- to monitor treatment for anemia and other blood diseases .

10. How is the heart rate measured? [May/June 2012] How is pulse rate measured? [CO2-L1-April/May 2011]

Pulse rate is measured using following methods

Electrical impedance method
Strain gauge method
Photoelectric method
Microphone method

11. What is systolic pressure and diastolic pressure? [CO2-L1-Nov/Dec 2011]

Systolic pressure is peak pressure in the arteries, which occurs near the end of the cardiac cycle when the ventricles are contracting. A normal systolic blood pressure is 120 or below.

Diastolic pressure is minimum pressure in the arteries, which occurs near the beginning of the cardiac cycle when the ventricles are filled with blood. A normal diastolic blood pressure number is 80 or less.

12. How is the respiration rate measured? [CO2-L1-Nov/Dec 2011]

Human respiration rate is measured when a person is at rest and involves counting the number of breaths for one minute by counting how many times the chest rises.

Respiration rate measured is measured using following methods

Thermistor method
Impedance pneumography
CO_2 method.

13. Mention the application of auto analyzer. [Nov/Dec 2010]

How is auto analyzer useful in medical field? [CO2-L1-April/May 2010]

Auto analyzer is used to measure dozens of fluid samples an hour for a variety of markers such as cholesterol, phosphate levels and proteins.

Auto analyzer is used to measure chemical properties of various substances like urine and blood.

14. Calculate the stroke volume in millilitres if the cardiac output is 5.2 liters/minute and heart rate is 76 beats/minute. [CO2-L1-Nov/Dec 2009]

Stroke volume=cardiac output/Number of heart beats per minute

Stroke volume=5.2*1000/76=68.42 ml.

15. Name two devices for skin temperature measurements [CO2-L1-May/June 2009]

Thermometer

Thermistor

Thermocouple

16. What are the methods adopted for direct measurement of blood pressure? [CO2-L1-May/June 2009]

H2O Manometer

Electronic Manometer.

17.What are korotkoff sounds? [CO2-L1-Nov/Dec 2008]

Arterial sounds heard through a stethoscope applied to the brachial artery distal to the cuff of a sphygmomanometer that change with varying cuff pressure and that are used to determine systolic and diastolic blood pressure.

18.What is a colorimeter?State its use. [CO2-L1-Nov/Dec 2008]

A colorimeter is a device used in colorimetry. This device is most commonly used to determine the concentration of a known solute in a given solution by the application of the Beer-Lambert law, which states that the concentration of a solute is proportional to the absorbance.

Uses of Colorimeters

1. Used to test for water quality, by screening for chemicals such as chlorine, fluoride, cyanide, dissolved oxygen, iron, molybdenum, zinc and hydrazine.
2. Used to determine the concentrations of plant nutrients (such as phosphorus, nitrate and ammonia) in the soil or hemoglobin in the blood and to identify substandard and counterfeit drugs.

19.Name any four physical principles based on which blood flow meters are constructed [CO2-L1]

- Faradays law of induced emf
- transit time
- Doppler effect
- nuclear magnetic resonance

20.List the instruments used for measuring blood flow? [CO2-L1]

Electromagnetic blood flow meters
Ultrasonic Blood flow meter
Laser based Doppler Blood flow meter
NMR Blood flow meter

PART-B

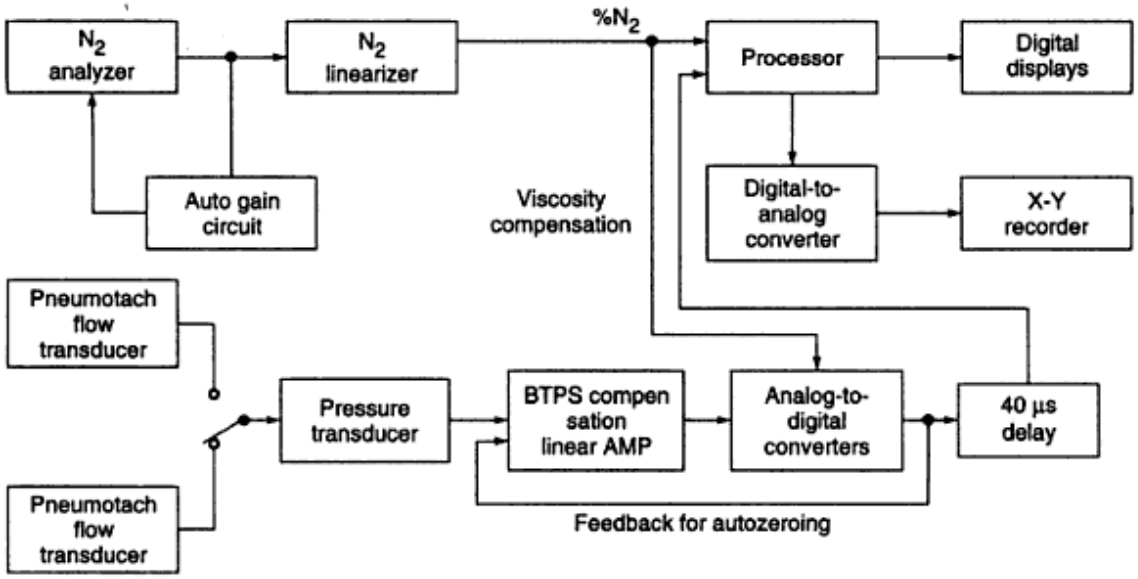
1.(i)From basic principles discuss the working of a pulmonary function analyzer. [CO2-L1-May/June 2014]

A complete pulmonary function analyzer contains all the equipment necessary for testing various parameters - It comprises a nitrogen analyzer, a vacuum pump, an X-Y recorder, pneumotachs, a digital display, plumbing and valves and other electronic circuits. A simplified block diagram of the system is shown in Fig.Modern instruments are designed to completely automate the measurements of ventilation, distribution and diffusion.

The systems are designed around computers which control the procedures by opening and closing appropriate valves, measuring flow rates and the concentrations of various gases, and calculating and printing the results. An analog-tondigital converter supplies the measurement data to the computer. Inputs to the A-D

converter are from various measurement devices, which include a pneumotach that provides a signal proportional to the air flow for various measurements and carbon monoxide and helium analyzers fur diffusion measurements. The software controlled

pulmonary measurement procedure allows new programs to be added or existing ones to be modified.



(ii)Explain how respiratory measurement is carried out using respiratory apparatus [Nov/Dec 2010]

Describe the process of respiratory measurement (8 Marks)[CO2-L1-April/May 2010]

Three basic types of measurements are made in the pulmonary clinic: ventilation, distribution and diffusion. Ventilation deals with the measurement of the body as an air pump, determining its ability to move volumes of air and the speed with which it moves the air. Distribution measurements provide an indication of where gas flows in the lungs and whether or not disease has closed some sections to air flow. Diffusion measurements test the lung's ability to exchange gas with the circulatory system.

The most widely performed measurement is *ventilation.* This is performed using devices called spirometers that measure volume displacement and the amount of gas moved in a specific time. Usually this requires the patient to take a deep breath and then exhale as

rapidly and completely as possible. Called the forced vital capacity, this gives an indication of how much air can be moved by the lungs and how freely this air flows,

Distribution measurements quantify degrees of lung obstructions and also determine the residual volume, which is the amount of air that cannot be removed from the lungs by the patients effort. The residual volume is measured indirectly, such as with the nitrogen washout procedure.

Diffusion measurements identify the rate at which gas is exchanged with the blood stream. This is difficult to do with oxygen since it requires a sample of pulmonary capillary blood, so it is usually done by measuring the diminishment of a small quantity of carbon monoxide mixed with the inhaled air.

Spirometer :

Principle of Operation: The respiratory tract consists of the trachea, the right and left lungs, and two types of branching airways in each lung--bronchi and bronchioli. The main purpose of the respiratory tract is to conduct air between the external environment and the respiratory unit to permit exchange of oxygen and carbon dioxide.

A unique organ, the lung not only provides a means for the transfer of oxygen from air into the blood and the removal of carbon dioxide, it is also capable of metabolizing and detoxifying a wide range of substances, protects against infectious agents and environmental pollution, and synthesizes certain key materials such as surfactant, which helps maintain surface tension in the lung, and prostaglandins, whichare important in inflammatory reactions.

From the trachea, the airways divide progressively like branching trees in both symmetrical and asymmetrical fashion. Each branch of airways away from the trachea becomes smaller, but in turn the total area of cross-sectional airways actually increases. As a result, airflow resistance decreases as air moves from the large airways to the smaller bronchioli. This exchange occurs in the respiratory unit, consisting of bronchioli, alveolar duct, alveolar sac, and individual alveoli. The alveoli have a surface area for gas exchange that is equivalent to the size of a tennis court.

The lung is served by two blood supplies--pulmonary circulation, which involves cardiac output and oxygenation of the blood; and bronchial circulation arising from the aorta, which receives only a small amount of cardiac output with oxygenated blood. The bronchial arteries are the principle blood supply for the pulmonary tissue itself, and ultimately join the pulmonary circulation at the level of the respiratory bronchioli.

PNEUMOTACHOMETERS

Pneumotachometers are devices that measure the instantaneous rate of volume flow of respired gases. Basically, there are two types of pneumotachometers, which are:

(i) ***Differential manometer*** — It has a small resistance, which allows flow but causes a pressure drop. This change is measured by a differential pressure ransducer, which outputs a signal proportional to the flow according to the Poiseuille law, assuming that the flow is laminar. The unit is heated to maintain it at 37*C to prevent condensation of water vapour from the expired breath.

(ii) ***Hot - wire anemometer*** – uses a small heated element in the pathway of the gas flow. The current needed to maintain the element at a constant temperature is measured and it increases proportionally to the gas flow that cools the element.

Pneumotachometer is commonly used to measure parameters pertaining to pulmonary function such.as forced expiratory volume (FEV), maximum mid-expiratory volume, peak flow and to generate flow-volume loops. Although these devices direedy measure only volume flow, they can be employed to derive absolute volume changes of the lung (spirometry) by electronically integrating the flow signal. Conventional mechanical spirometers, though more accurate than pneumotachometers, have limitations due to their mechanical inertia, hysteresis and $C0_2$ buildup. Pneumotachometers, on the other hand, are relatively non-obstructive to the patient and this makes them suitable for long-term monitoring of pa dents with respiratory difficulties.

A basic requirement of pneumotachometers (PTM) is that they should present a minimum resistance to breathing. An acceptable resistance would be between 0.5 and 1.0 cm H_20 s/l. The pressure drop across the flow head at peak flow is also indicative of PTM

resistance, Fleisch PTMs normally have a peak flow pressure drop of around 1.5 cm H_20, Normal respiratory phenomenon has significant frequency components up to only 10 Hz and devices with this response should be quite suitable for most applications. More often, it is not the frequency response but the response time, which is generally specified. The response time of a typical ultrasonic Spirometer is 25 ms. The dead space volume of the flow head should be as small as possible. A bias flow into the flow head is sometimes introduced to prevent rebreathing of expired air. A good zero stability is a prerequisite of PTMs to prevent false integration during volume measurements.

MEASUREMENT OF VOLUME

The volume of gas flowing into and out of the lungs is a factor of considerable importance in investigations of lung function. Whilst the volume of a single breath, or the total volume expired in a given time, can be measured by continuously acting spirometers, continuous breath-by-breath measurements are often difficult.

One method is to integrate the flow rate electronically and record the resulting signals. The flow rate is measured as the pressure change across a pneumotachograph head with a micromanometer whose output is a voltage proportional to the pressure difference at the manometer input, i.e.

$$V_1 = K(P_1 - P_2)$$

where K is a constant.

The output from the integrator is *a* voltage V_0 such that

$$V_0 = \frac{1}{RC}\int_{t1}^{t2} V_i \, dt$$

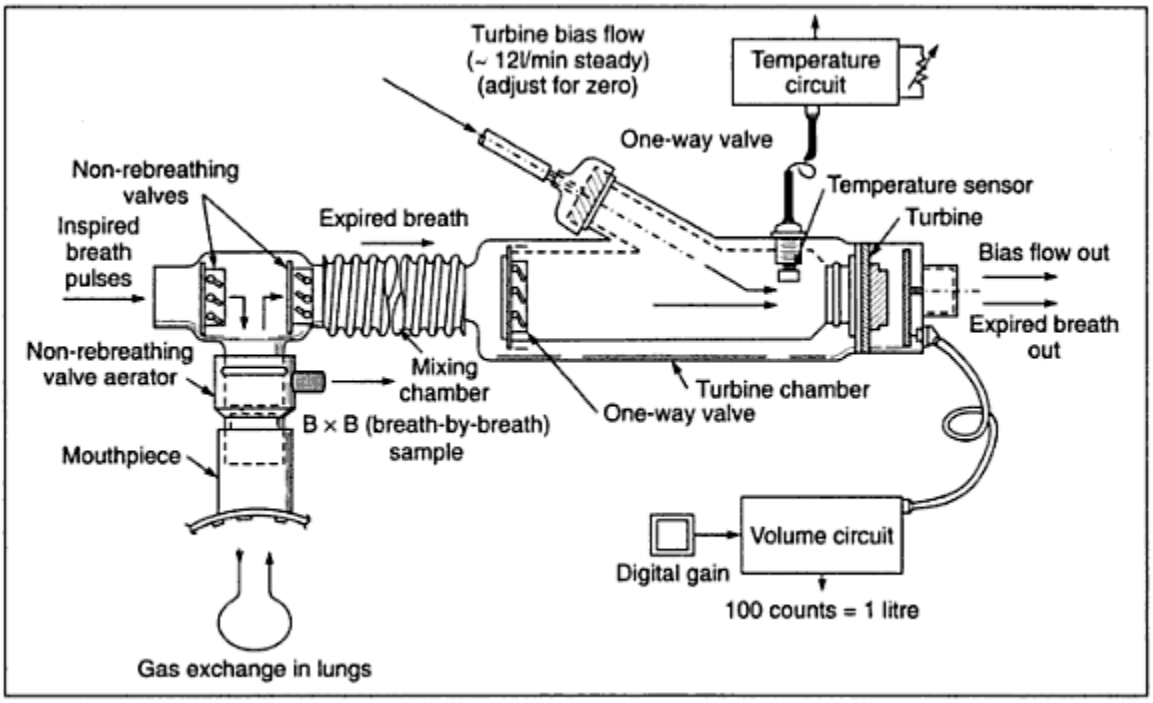


Fig. ***Turbine type volume transducer***

A simplified integrator set up is shown in Fig- for flow and volume measurement. It consists of an 'autozero' flowmeter together with a threshold detector and an integrator. The threshold detector selects which portion of the flow signal is to be integrated and this is normally set to switch on when the flow signal moves past zero in a positive direction, and off again when the flow signal returns to zero. This means either inspiration or expiration can be measured depending on how the flow head is connected.

When it is intended to measure tidal volume, the flow signal moves positive and continues until the flow output returns to zero, when the integrator output is reset. The display shows the size of each breath which is referred to as constant baseline. In case cumulative volume is to be measured the volume displayed after each breath is held up. The next breath integrated is added to its predecessor, thus producing a staircase pattern. The pattern can be recorded on a chart paper.

Unless extremely high quality amplifiers are used, the integrator circuit will drift and give false readings. Drift can be minimized by starting each volume from a fused baseline on the record.

MEASUREMENT OF RESPIRATION RATE

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 blnod. 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. Some of the commonly used methods for the measurement of respiration rate are explained below.

Displacement Method

The respiratory cycle is accompanied by changes in the thoracic volume. These changes can be sensed by means of a displacement transducer incorporating a strain gauge or a variable resistance element. The transducer is held by an elastic band, which goes around the chest. The respiratory movements result in resistance changes of the strain gauge element connected as one arm of a Wheatstone bridge circuit. Bridge output varies with chest expansion and yields signals corresponding to respiratory activity.

Changes in the chest circumference can also be detected by *a* rubber tube filled with mercury. The tube is fastened firmly around the chest. With the expansion of the chest during an inspiratory phase, the rubber tube increases in length and thus the resistance of the mercury from one end of this tube to the other changes. Resistance changes can be measured by sending a constant current through it and by measuring the changes in voltage developed with the respiratory cycle.

Thermistor Method

Occasionally, unconscious patients display a tendency for the uncontrolled tongue to block the breathing system. Under such systems, we are often faced with the situation that not a single millilitre of air is inhaled but the patient's thorax is carrying out large, even though frustral breathing motions. In this condition, the impedance pneumograph and switch methods will show the correct state. Putting the thermistor in a tracheal cannula is not simple. There it is very soon covered with excretions, in the case of suffocated patients with no spontaneous respiration motions, those few millilitres that pass through the cannula are sufficient to drive the breath rate meter. This is a drawback in the technique of usine thermistors for the detection of respiration rate.

Impedance Pneumography

This is an indirect technique for the measurement of respiration rate. Using externally applied electrodes on the thorax, the impedance pneumograph measures rate through the relationship between respiratory depth and thoracic impedance change. The technique avoids encumbering the subject with masks, tubes, flowmeters or spirometers, does not impede respiration and has minimal effect on the psychological state of the subject. Impedance method for measuring respiration rate consists in passing a high frequency current through the appropriately placed electrodes on the surface of the bod y (Fig, } and detecting the modula ted signal. The signal is modulated by changes in the body impedance, accompanying the respiratory cycle. The electrode used for impedance pneumograph are of the self-adhesive type Contact with the skin is made through the electrode cream layer for minimizing motion artefacts. The electrodes, when the skin is properly prepared, offer an impedance of ISO to 200fi. The change in impedance corresponding to each respiratory cycle is of the order of 1% of the base impedance.

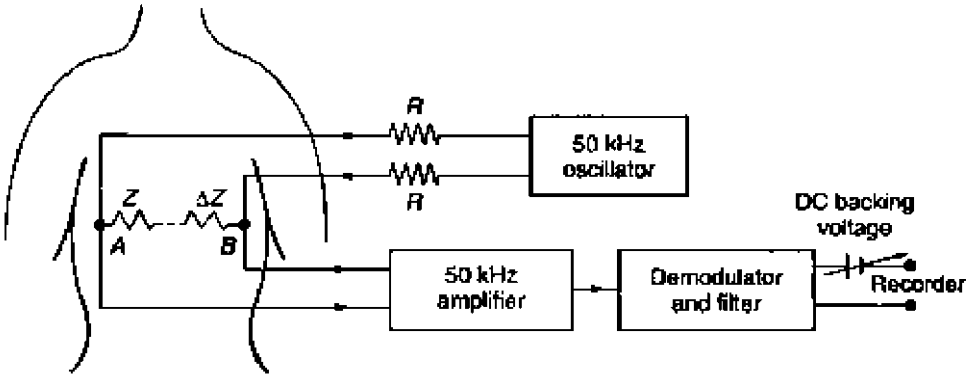


Fig. ***Principle of impedance pneumograph (two electrode method)***

CO_2 Method of Respiration Rate Measurement

Respiration rate can also be derived by continuously monitoring the CO, contained in the subject's alveolar air. Measurement of $C0_2$ in expired air is otherwise useful in several ways; for example, for originally setting up the respirator and in making adjustments to it afterwards, supervising patients suffering from respiratory paralysis, and other cases where there is respiratory involvement.

The measurement is based on the absorption property of infrared rays by certain gases. Suitable filters are required to determine the concentration of specific gases (like COj, CO, and NOj) constituting the expired air. Rare gases and diatomic gases do not absorb infrared rays.

When infrared rays are passed through the expired air containing a certain amount of $CO_:$, some of the radiations are absorbed by it. There is a proportional Loss of heat energy associated with the rays. The detector changes the loss in heating effect of the rays into an electrical signal. This signal is used to obtain the average respiration rate.

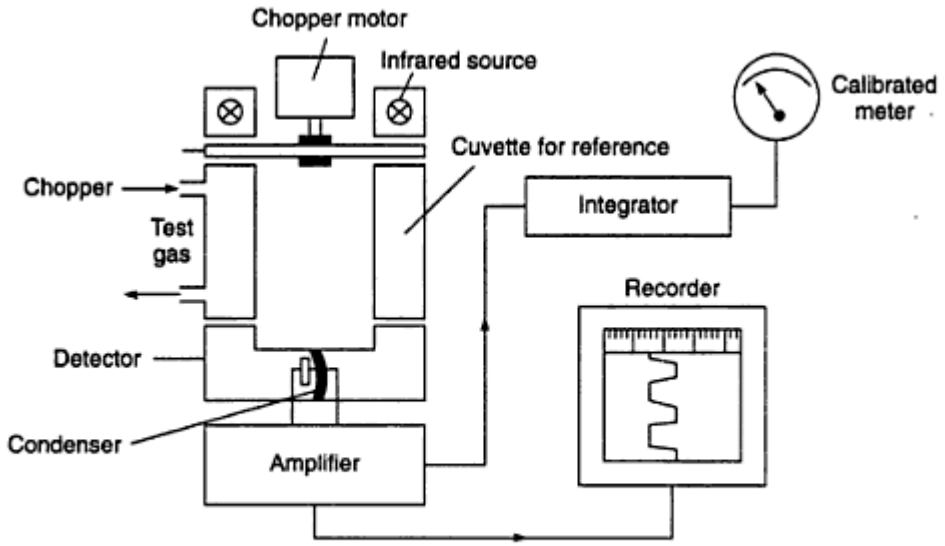


Fig. ***Schematic diagram for detection of CO_2 in the expired air for continuous monitoring of respiration rate***

Figure shows the arrangement for the detection of CO_2 in expired air. Two beams of equal intensity of infrared radiations from the hot-wire spirals fall on one half of each of the condenser microphone assembly. The detector has two identical portions separated by a thin, flexible metal diaphragm. The detector is filled with a sample of pure CO_2. Because of the absorption of CO_2 in the analysis cell, the beam falling on the test side of the detector is weaker than that falling on the reference side. The gas in the reference side would, therefore, be heated more than that on the analysis side. As a result, the diaphragm is pushed slightly to the analysis side of the detector. The diaphragm forms one plate of a capacitor. The infrared beams are chopped at 25 Hz and the alternating signal which appears across the detector is amplified, shaped and suitably integrated to give the respiration rate.

2. Explain the following:

(i) Photometer (8 Marks) [CO2-L1-May/June 2014]

Principles of operation

Flame photometry relies upon the fact that the compounds of the alkali and alkaline earth metals can be thermally dissociated in a flame and that some of the atoms produced will be further excited to a higher energy level. When these atoms return to the ground state they emit radiation which lies mainly in the visible region of the spectrum. Each element will emit radiation at a wavelength specific for that element. The table below gives details of the measurable atomic flame emissions of the alkali and alkaline earth metals in terms of the emission wavelength and the colour produced.

Element	**Emission Wavelength (nm)**	**Flame Colour**
Sodium (Na)	589	Yellow
Potassium (K)	76G	Violet
Barium (Ba)	554	Lime Green
Calcium (Ca)	622*	Orange
Lithium (Li)	67D	Red

***Note**: Calcium is measured by using the calcium hydroxide band emission at 622nm as the Calcium main atomic emission occurs at 423nm.

Over certain ranges of concentration the intensity of the emission is directly proportional to the number of atoms returning to the ground state. This is in turn proportional to the absolute quantity of the species volatized in the flame, i.e. light emitted is proportional to sample concentration.

It can be seen that if the light emitted by the element at the characteristic wavelength is isolated by an optical filter and the intensity of that light measured by a photo-detector, then an electrical signal can be obtained proportional to sample concentration. Such an electrical signal can be processed and the readout obtained in an analogue or digital form.

A simple flame photometer consists of the following basic components:

a) The burner: a flame that can be maintained in a constant form and at a constant temperature.

b) Nebuliser and mixing chamber: a means of transporting a homogeneous solution into the flame at a steady rate.

c) Simple colour filters (interference type): a means of isolating light of the wavelength to be measured from that of extraneous emissions.

d) Photo-detector: a means of measuring the intensity of radiation emitted by the flame.

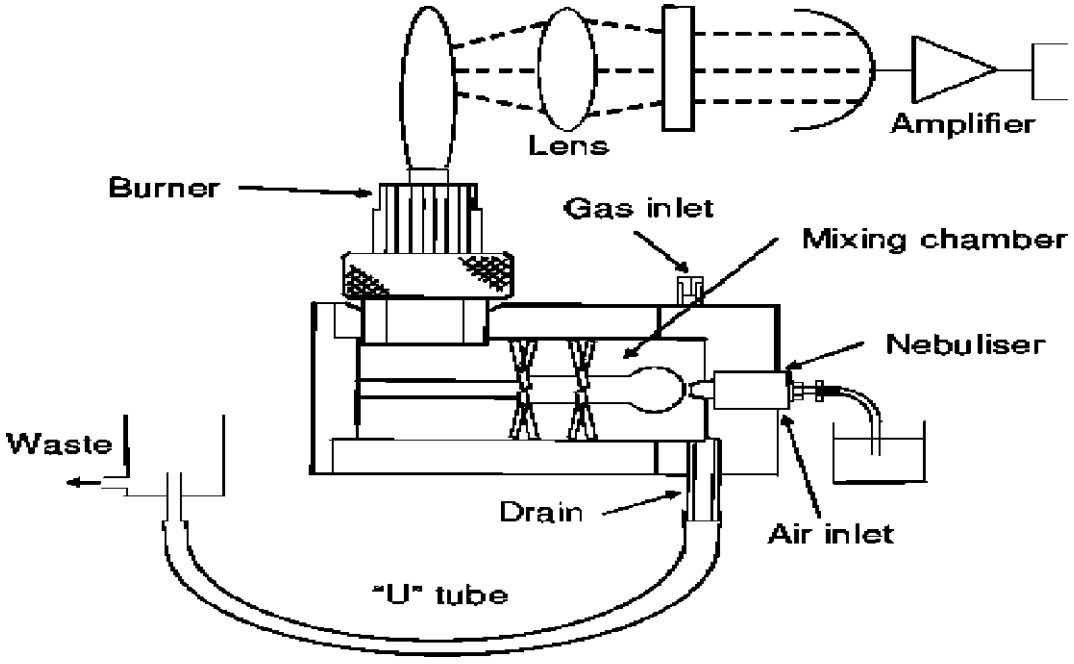


Figure : Schematic diagram, showing the component parts of a flame photometer

ii. Auto Analyzer (8 Marks) [May/June 2014]

Explain the principle of Auto Analyzer (8 Marks) [May/June 2012][CO2-L1-April/May 2011]

An autoanalyzer sequentially measures blood chemistry through a series of steps of

- mixing,
- reagent reaction and
- Colorimetric measurements.

Auto analyzer 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 colorimeter.

Principle of operation:

- A stream of material is divided by air bubbles into discrete segments in which chemical reactions occur.
  - 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 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 € each apparatus performs different function, such as distillation, dialysis, extraction and subsequent recording of a signal.

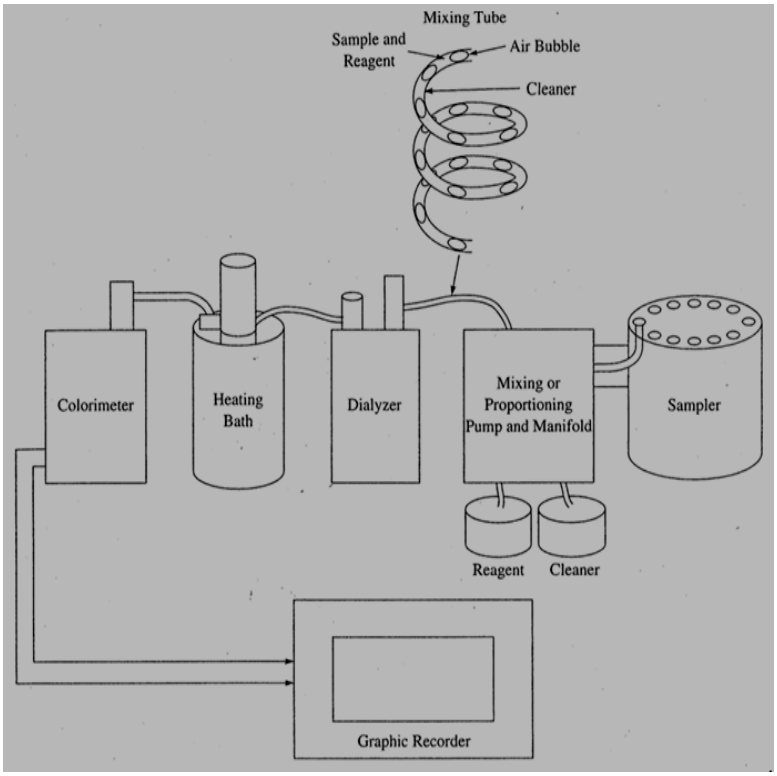
In Segmented Flow Analyzers (SFA), the sample is mixed with small reproducible volumes of the required reagents

→ air bubbles are introduced into the flow,

→ creating about 20 - 100 segments of liquid for each sample

- The sample / reagent mixture flows through mixing coils (heated coils) a color proportional to the amount of analyte in each sample is developed
- The samples with developed color flow through a colorimeter to measure the color.

Block diagram



Auto analyzer consists of

- ❖ Sampler:
  - ✍ Aspirates samples, standards, wash solutions into the system
- ❖ Proportioning pump:
  - ✍ Mixes samples with the reagents so that proper chemical color reactions can take place, which are then read by the colorimeter

- Dialyzer:
  - 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 analyte infuses through the diaphragm into a separate flow path going on to further analysis

- Heating bath:
  - Controls temperature (typically at 37 °C), as temp is critical in color development

- Colorimeter:
  - Monitors the changes in optical density of the fluid stream flowing through a tubular flow cell. Color intensities proportional to the substance concentrations are converted to equivalent electrical voltages (Pulses, square wave signal)

- Recorder:
  - Displays the output information in a graphical form.

3. Illustrate the procedure of modern spirometer test conduction. Discuss the clinical implications of flow-volume graph. [CO2-L1-Nov/Dec 2013]

Spirometry testing

The spirometry test is performed using a device called a spirometer, which comes in several different varieties. Most spirometers display the following graphs:

a volume-time curve, showing volume (liters) along the Y-axis and time (seconds) along the Xaxis a flow-volume loop, which graphically depicts the rate of airflow on the Y-axis and the total volume inspired or expired on the X-axis.

The most commonly used guidelines for spirometric testing and interpretation are set by the American Thoracic Society (ATS) and the European Respiratory Society (ERS).

Procedure

The basic FVC test varies slightly depending on the equipment used.

Generally, the patient is asked to take the deepest breath they can, and then exhale into the sensor as hard as possible, for as long as possible. It is sometimes directly followed by a rapid inhalation (inspiration), in particular when assessing possible upper airway obstruction.

Sometimes, the test will be preceded by a period of quiet breathing in and out from the sensor (tidal volume), or the rapid breath in (forced inspiratory part) will come before the forced exhalation.

During the test, soft nose clips may be used to prevent air escaping through the nose. Filter mouthpieces may be used to prevent the spread of microorganisms, particularly for inspiratory maneuvers.

Limitations of test

The maneuver is highly dependent on patient cooperation and effort, and is normally repeated at least three times to ensure reproducibility. Since results are dependent on patient cooperation, FEV1 and FVC can only be underestimated, never overestimated.

Due to the patient cooperation required, spirometry can only be used on children old enough to comprehend and follow the instructions given (typically about 4-5 years old), and only on patients who are able to understand and follow instructions - thus, this test is not suitable for patients who are unconscious, heavily sedated, or have limitations that would interfere with vigorous respiratory efforts. Other types of lung function tests are available for infants and unconscious persons.

Related tests

Spirometer can also be part of a bronchial challenge test, used to determine bronchial hyper responsiveness to either rigorous exercise, inhalation of cold/dry air, or with a pharmaceutical agent such as methacholine or histamine.

Sometimes, to assess the reversibility of a particular condition, a bronchodilator is administered before performing another round of tests for comparison. This is commonly referred to as a reversibility test, or a post bronchodilator test (Post BD), and is an important part in diagnosing asthma versus COPD.

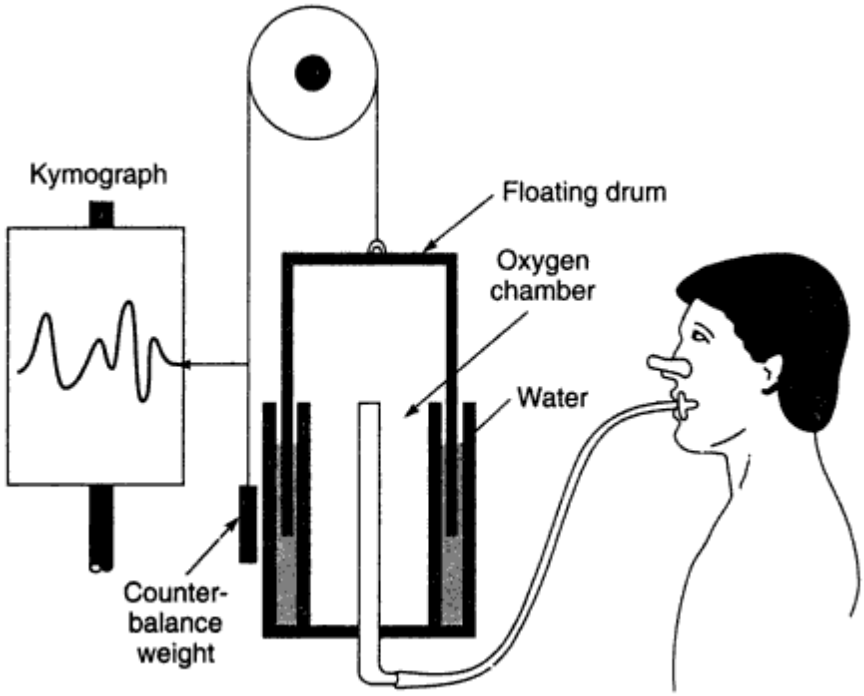


Fig. ***Basic water sealed spirometer***

The spirometer is a mechanical integrator, since the input is air flow and the output is volume displacement- An electrical signal proportional to volume displacement can be obtained by using a linear potentiometer connected to the pulley portion of the spirometer. The spirometer is a heavily damped device so that small changes in inspired and expired air volumes are not recorded. The spirometers can be fitted with a linear motion potentiometer, which directly converts spirometer volume changes into an electrical signal The signal may be used to feed a flow-volume differentiator for the evaluation and recording of data. The response usually is ± 1% to 2 Hz and ±10% to 10 Hz.

Tests made using the spirometer are not analytical. Also, they are not completely objective because the results are dependent on the cooperation of the patient and the coaching efforts of a good respiratory technician.

There have been efforts to develop electronic spirometers which could provide greater information-delivering and time-saving capabilities. Also, there have been efforts to obtain more definitive diagnostic information than spirometry alone can provide,

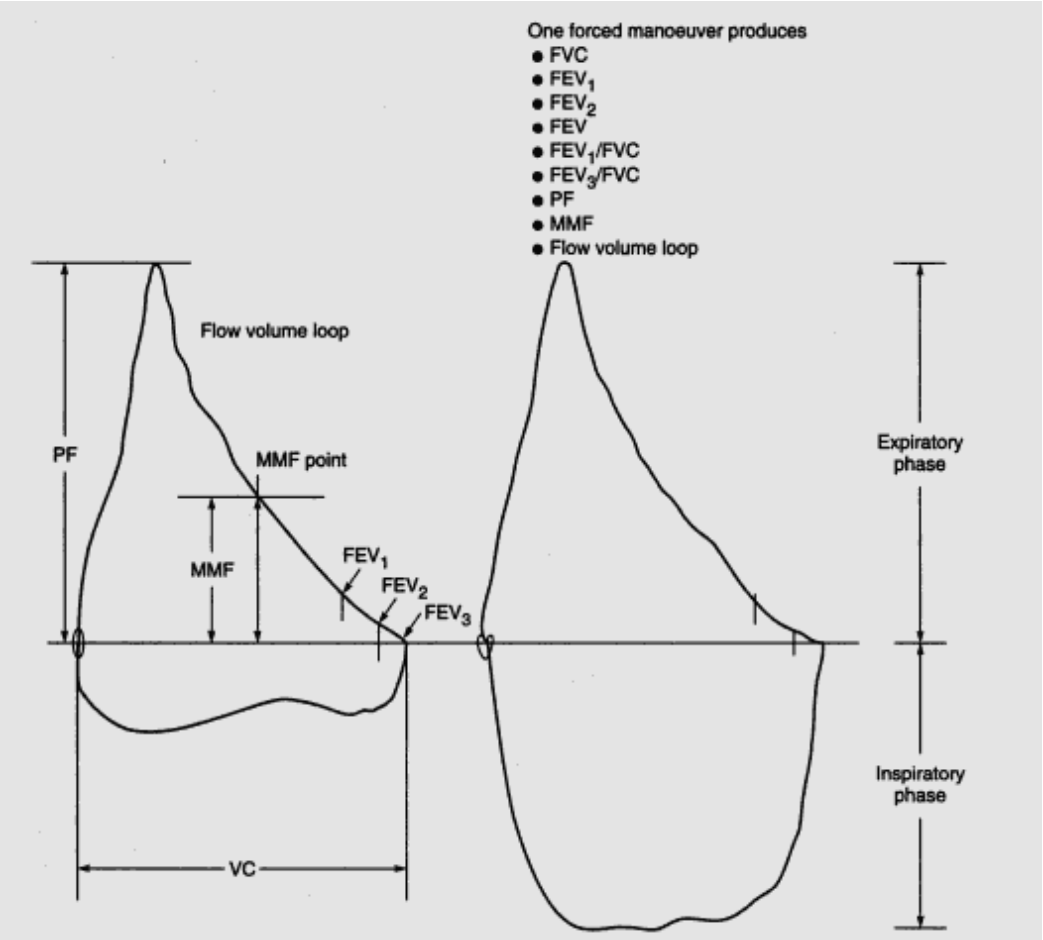
Calculating results manually from the graph of the mechanical volume spirometer requires considerable time, Transducers have been designed to transform the movement of the bell, bellows or piston of volume spirometers into electrical signals. These are then used to compute the numerical results electronically. The popularity and low cost of personal computers have made them an attractive method of automating both volume and flow spirometers. An accurate spirometer connected to a personal computer with a good software programme has the potential of allowing untrained personnel to obtain accurate result,

Flow-Volume Curve

This is a plot of instantaneous maximum expiratory flow rate versus volume. The shape of the flow-volume curve does not vary much between normal subjects of different age, size and sex, although absolute values of flow rate and volume may vary considerably, in patients with obstructive airway disease, the shape of this curve is drastically altered. For this reason, the flow-volume curve is a good early indication of abnormality. Typical MEFV curves a re shown in Fig,

There are various methods of producing the flow-volume curve. The method which has been very common in the past was to record it on the storage oscilloscope and then make a permanent record by photographing it with a polaroid camera. This procedure, obviously, is time consuming and expensive.

General purpose X-Y recorders are not fast enough to follow the rapid changes encountered in the signals while recording flow-volume curves. Therefore, special recorders have been designed to meet this requirement. For example, in the HP, Pulmonary Function Analyzer, the recorder used has an acceleration of 76.2 m/s^2 and a slewing speed of over 0.762 m/s will result in approximately a 7.5 cm deflection. The recorder will thus be able to accurately plot a MEFV curve in which the subject reaches a peak flow of 10 l/s in less than one-tenth of a second.



A plot of the inspiratory flow-volume curve is also found to be useful in the detection of certain lung abnormalities, though it does not yield as much information about the lung mechanics as does the expiratory flow-volume curve. A useful indicator of the relative degrees of inspiratory and expiratory obstruction is the MEF50%/MIF50% ratio (Jordanoglou and Pride, 1968) MIF50% is maximum inspiratory flow at 50% of vital capacity.

A microcomputer is incorporated in the modern equipment to calculate the maximum spirometer value stored; FVC, the FEV1 and the ratio FEVI/FVC Besides these, some other indices were also evaluated. For example, the average flow over the middle portion of the spirogram has been the most widely accepted parameter for the early detection of

increased airway resistance. A microcomputer based system facilitates automating many of such indices which are under investigation.

4. (i) Show the application of ultrasonic waves in measuring Blood Flow (8 Marks) [Nov/Dec 2013]

Explain Ultrasonic blood flow meter (8 Marks) [May/June 2013]

With a neat diagram, describe an ultrasonic blood flow meter. [Nov/Dec 2010]

Explain the principle of operation of an ultrasonic blood flow meter (8 Marks)[Nov/Dec 2009]

What is the use of a blood flow meter? With neat diagrams explain how an ultrasonic blood flow meter is used to measure the velocity of blood flowing in the blood vessels.[CO2-L2-May/June 2009]

ULTRASONIC BLOOD FLOWMETER

Ultrasonic blood flow meters are used to measure the velocity of a stream of blood a moving heart valve or the motion of an artery in response to a pressure pulse. Early ultrasonic flow meters were based on the transit time principle.

ULTRASONIC BLOOD FLOWMETER BASED ON TRANSIT TIME PRINCIPLE

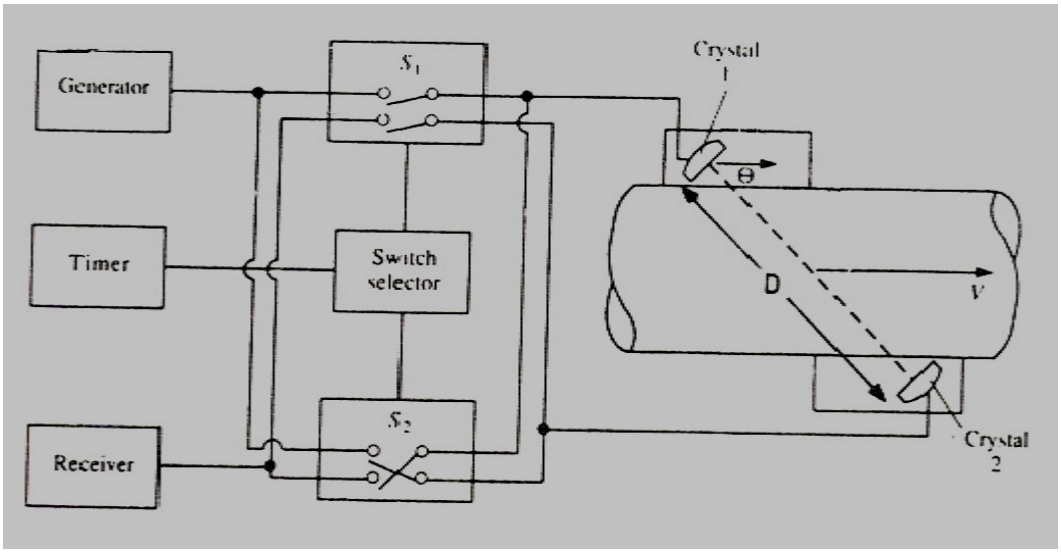


FIG - BLOOD FLOW MEASUREMENT BY TRANSIT TIME DIFFERENCE

Figure shows the ultrasonic blood flow meter based on transit time principle. A *Piez*o electric crystal emits a brief p '1 ~, of ultrasound which propagates diagonally across the blood vessel. If the flow is in the same direction as the pulse, then the pulse reaches a receiving crystal situated on the opposite side wall of the blood vessel.

Appropriate electronics can convert the change in transit time to velocity. In the figure 'D' is the distance traveled by sound waves along the downstream of the blood flow and it is the distance between the transmitter and receiver of ultrasonic waves.

Thus the blood flow velocity can be measured by determining the difference between upstream and downstream transit time. Here 0 is the angle between the direction of blood flow and the central axis of the ultrasonic beam, C is the ultrasonic velocity in blood. Using the circuit given in figure 6.12, AT can be measured. First the switch selector closes Sj and opens S_2.

This connects the R.F. generator to crystal 1 and the receiver to crystal 2 and the upstream transit time is measured. Subsequently the switch selector opens Sj and closes S_2. This connects the R.F. generator to crystal 2 and the receiver to crystal 1 and measures the downstream transmit time. In this AT is about 0.01% of transit time. Therefore the measurement of such a small time difference or the corresponding phase difference creates error and limits the accuracy of the measurement. Now a days Doppler reflection methods are adopted.

(II) ULTRASONIC DOPPLER BLOOD FLOWMETERS

Doppler effect refers to the apparent change in frequency of the sound wave emitted by the source when there is a relative motion between the source and observer. Due to motion of the blood there is a change in frequency of the reflected ultrasonic wave when it is crossing the blood. Let V be the velocity of the blood flow (reflector), 0 be the angle between the direction of movement of the reflector and the effective direction of ultrasonic beam, C be the ultrasonic velocity in the stationary blood and f is the original frequency of the ultrasonic wave. When the ultrasonic wave is transmitting through the blood, the blood cells will scatter the ultrasonic wave. First there is a change in frequency as the ultrasound

arrives at the scatterer. It can be treated as a stationary source (transmitter) and observer (blood cell) who is moving away.

There fore F = F[C-VCOS0 / C]

Here V Cos 0 is the effective velocity of the observer along the direction of the ultrasonic velocity. Secondly there is a change in frequency as the ultrasound arrives at the receiver after it is scattered by the blood cells. This can be treated as a source (blood cell) moving away from the stationary observer (receiver).

Thus

$$f' = f\left[\frac{C}{C + V\,Cos\theta}\right]$$

$$= f\left[\frac{C - V\,Cos\theta}{C}\right] \quad \left[\frac{C}{C + V\,Cos\theta}\right]$$

$$= f\left[\frac{C - V\,Cos\theta}{C + V\,Cos\theta}\right]$$

$$= f\left[\frac{(C - V\,Cos\theta)^2}{C^2 - V^2\,Cos^2\theta}\right]$$

Since $C^2 >> V^2$,

$$f' = f\left[\frac{C^2 + V^2\,Cos\theta - 2CV\,Cos\,\theta}{C^2}\right]$$

$$= f\left[1 + \frac{V^2}{C^2}Cos^2\theta - 2\frac{V\,Cos\,\theta}{C}\right]$$

$$\Delta f = f - f' = \frac{2f\ V\ Cos\,\theta}{C}$$

$$\text{(or) } V = \frac{C\Delta f}{2f\ Cos\,\theta}$$

If $\theta = 0°$, V = 100 mm/s, C = 1500 m/s, a 2 MHz ultrasonic beam is shifted in frequency by about 267 Hz on reflection from the moving blood. This shift in frequency can be easily detected. For practical purposes,

Δf is proportional to V.

In obstetrics and cardiology f = 2 - 3 MHz

In blood flow studies f = 10 MHz

A) DOPPLER BLOOD FLOWMETER USING CONTINUOUS WAVES

In this, the transmitter operates continuously providing a R.F. output of constant amplitude and frequency. The ultrasonic probe contains separate transmitting and receiving transducers. This arrangement is necessary to minimize the direct transfer of energy from the transmitter to the radiofrequency amplifier; otherwise it will overload the receiver.(Now-a-days there are flow meters in which a single transducer can operate as transmitter and receiver alternatively). The output from the R.F. amplifier consists of a mixture of signals, some signals having frequency' equal to that of the transmitter (these are due to reflections from stationary structures in the ultrasonic field and electrical leakage) and some signals having the frequencies shifted by the doppler effect due to reflections from the moving structures. These signals are mixed in the demodulator.

The output from which contains the difference frequencies between the transmitted ultrasonic wave and the Doppler shifted received waves. The output from the demodulator is filtered to allow these difference frequencies to pass whilst unwanted (higher) frequencies are stopped. The difference frequencies which in general fall in the audible range are amplified. The amplified output may be given to the loud speaker to hear the sound by which a doctor can easily diagnose any abnormality in the blood flow and to spectrum analyzer to analyze the frequency components electronically.

B) RECORDING FETAL HEART MOVEMENTS AND BLOOD CIRCULATION USING DOPPLER ULTRASONIC METHOD

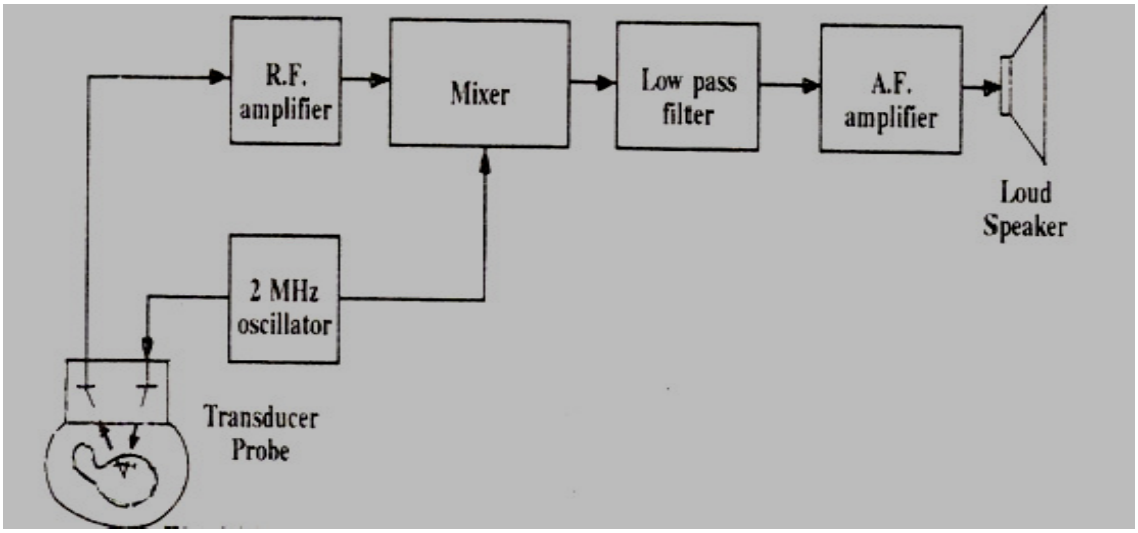


FIG - RECORDING FETAL HEART MOVEMENTS AND BLOOD CIRCULATION

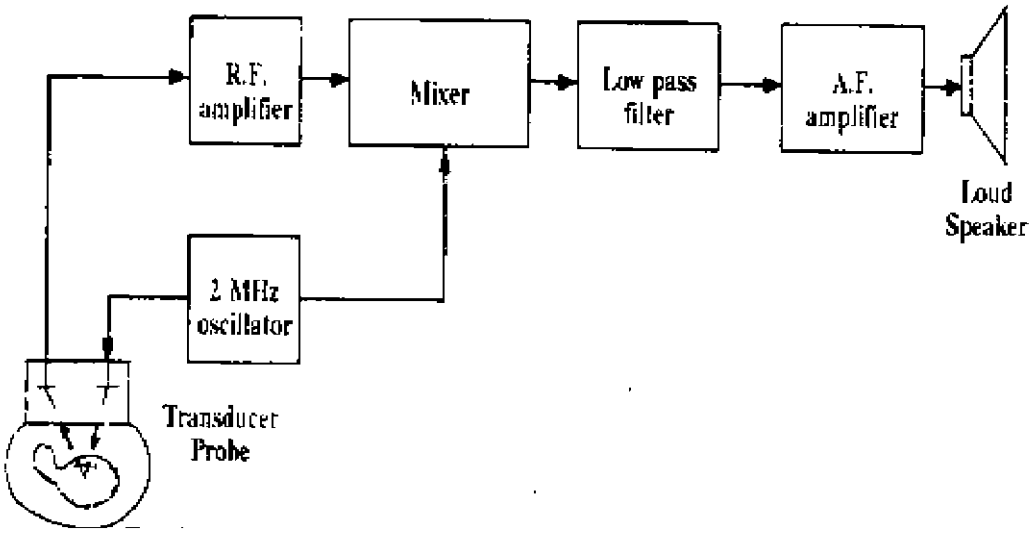


FIG- RECORDING FETAL HEART MOVEMENTS AND BLOOD CIRCULATION

Figure (b)shows the arrangement for recording fetal heart movements and blood circulation using doppler ultrasonic method. The transmitting and receiving transducers are placed in a single probe which is held against the mother's abdominal wall. A small

amount of oil or gel is placed between the probe and the abdominal wall to get good acoustic coupling. The ultrasonic beam of frequency about 2MHz is directed at the heart or umbilical cord of the fetus. The reflected signal is amplified and mixed with the emitted signal. The resulting beat frequency is proportional to the blood velocity in the fetus and mother. The mother's blood flow can be distinguished from that of the fetus by the higher pulse rate of the fetus. The beat frequency is amplified and can be heard with a loud speaker. By this method the presence of a pulsating heart and blood flow in the fetus can be determined. The echo can be obtained from the fetal heart as early as the 10th - 12th fetal week and from that time until delivery.

The following diagnostic sounds can be heard.

1. Thump, Thump - low frequency note, rapid rhythm - fetal heart movement.
2. Swish, Swish - high frequency note, rapid rhythm - umbilical cord mother's bodv sound.
3. Thuummp, Thuummp - lowfrequencynote, slowrhythm movements due to vibrations transmitted from the heart.
4. Wooooch, Wooooch - mid frequency note, slow rhythm - mother's arteries.

Thus the status of the fetus in the mother's abdomen can be studied completely without any danger.

C) PULSED DOPPLER BLOOD FLOWMETER

Many of the difficulties associated with continuous wave Doppler system can be eliminated if the ultrasonic source is pulsed and the doppler shift of the returning echo is measured. If the return signal is range gated, the distance to the moving interface (or) diameter of the blood vessel as well as blood velocity can be measured accurately. Figure (c)shows the circuit diagram of the pulsed Doppler blood flowmeter. The working of that circuit can be explained in various steps.

- The pulse repetition rate is controlled by the clock which triggers the mono stable to open the gate to allow the transmitting transducer to be excited for a period corresponding to the width of the target volume which is desired to study.

- Echoes returning from within the blood vessel are amplified and mixed in the demodulator with the signal from the oscillator.
- Thedelay monostable triggers the monostable controlling the receiver gate so that the gate opens to allow a voltage which is in effect a sample corresponding to the doppler shift due to the motion in the target volume, to be stored in the sample and hold circuit.
- The << sample and hold >> is reset immediately prior to being updated by a new sample resulting from the following ultrasonic pulse.
- The output from the << sample and hold >> is thus a rectangular wave with a long << mark >> and a short << space >>.
- These rectangular waves are amplified and given to the loud speaker or spectrum analyzer for further analysis after passing through the low pass filter.
- A zero crossing rate meter is a comparator that produces an output pulse every time when the signal crosses the zero line going from negative to positive. Normally the blood flow signal contains a wide frequency spectrum in the audio range. By using pulsed doppler, the received signal can be limited to narrower frequency range.
- Because of some limitations of the zero crossing rate meter, spectrum analyzers are used to derive blood flow velocity information from doppler signals. A spectrum analyzer processes short length of audio signal to produce spectral displays which have frequency as abscissa, time as ordinate and spectral intensity represented by record darkening.

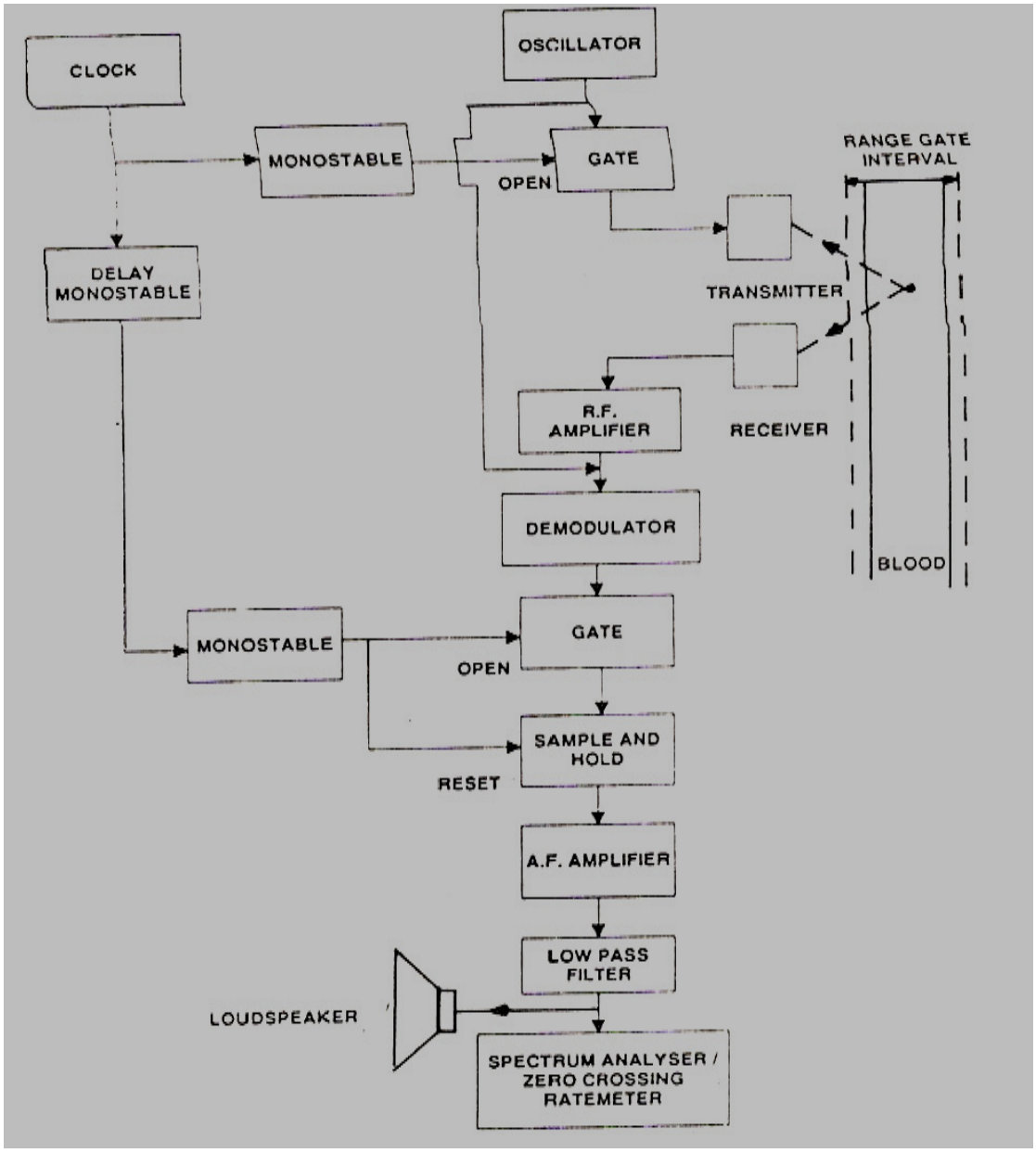


FIG - PULSED DOPPLERBLOOD FLOWMETER

(D) L ASER BASED DOPPLER BLOOD FLOWMETERS

Similar to ultrasonic blood flow meter, laser based Doppler blood flow meters are used to measure the blood flow velocities in various blood vessels. Light from a He-Ne laser of 5 mW power and 632.8 nm wavelength (figure(c)) is coupled into the quartz fiber using a

converging lens which results in an increased power density at the skin surface and thus enables to detect flow in more deeply seated veins and arteries.

The receiving plastic fiber collects the scattered signal and the collected signal is coupled to the photodiode through a laser line filter.

The photo diode is a square law device and gives out current which is proportional to the intensity of the reflected light and to the beating frequency of the shifted and un shifted signals. The diode output is given to the low noise preamplifier and then to the wide band amplifier having wide band performance (40 Hz - 40 kHz). System output is obtained by taking the RMS value of the total signal separating it from the total zero light noise and normalizing it for total back scattered light. An audio output of the signal before RMS conversion is also available to hear the flow pattern.

Here the instrument measures an averaged blood cell velocity and not the absolute velocity of the flow. Laser doppler flow meter is also a non invasible one and it offers a high reproducibility and high sensitivity.

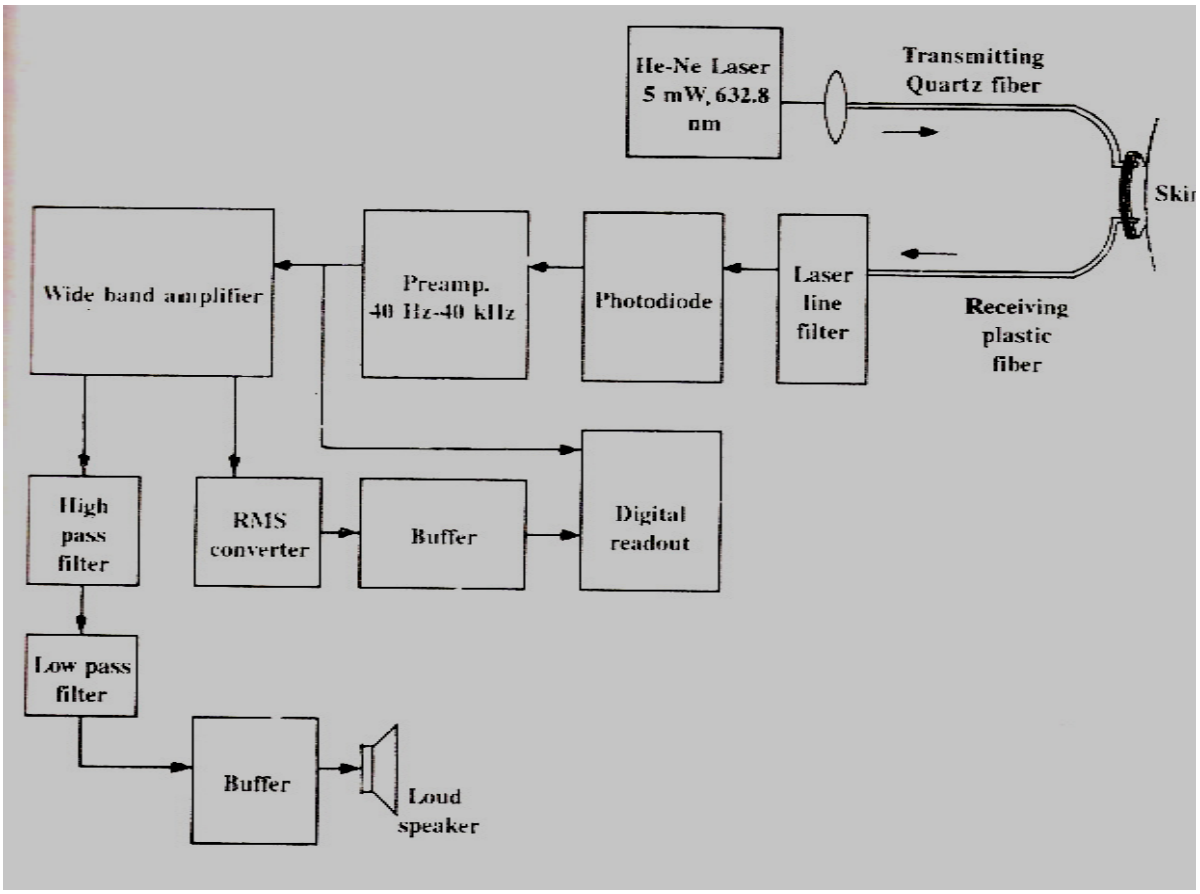
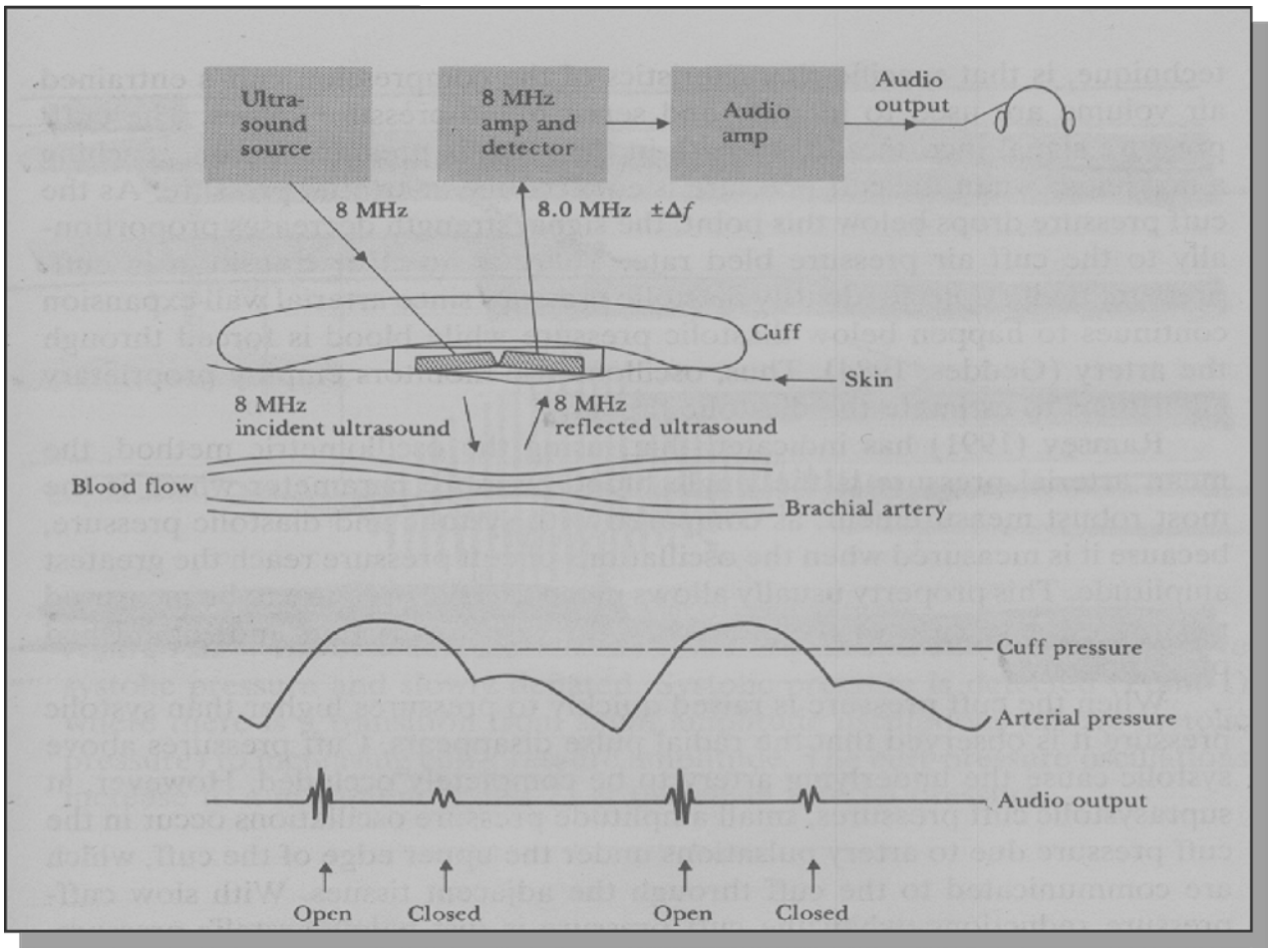


FIG-LASER DOPPLER BLOOD FLOWMETER NMR BLOOD FLOWMETERS

(ii) Show the application of ultrasonic waves in measuring Blood Pressure (8 Marks) [Nov/Dec 2013]

Explain the blood pressure measurement using ultrasonic (8 Marks) [C02-L1-April/May 2011]



A transcutaneous (through the skin) Doppler sensor is applied here. The motion of blood-vessel walls in various states of occlusion is measured. The vessel opens and closes with each heartbeat when

DP < Pcuff < SP

The frequency difference between transmitted (8 MHz) and received signal is 40-500 Hz and it is proportional to velocities of the wall motion and the blood.

As the cuff pressure is increased, the time between opening and closing decreases until they coincide with Systolic pressure Again as the cuff pressure is decreased, the time between opening and closing increases until they coincide with Diastolic pressure Again

as the cuff pressure is decreased, the time between opening and closing increases until they coincide with Diastolic pressure.

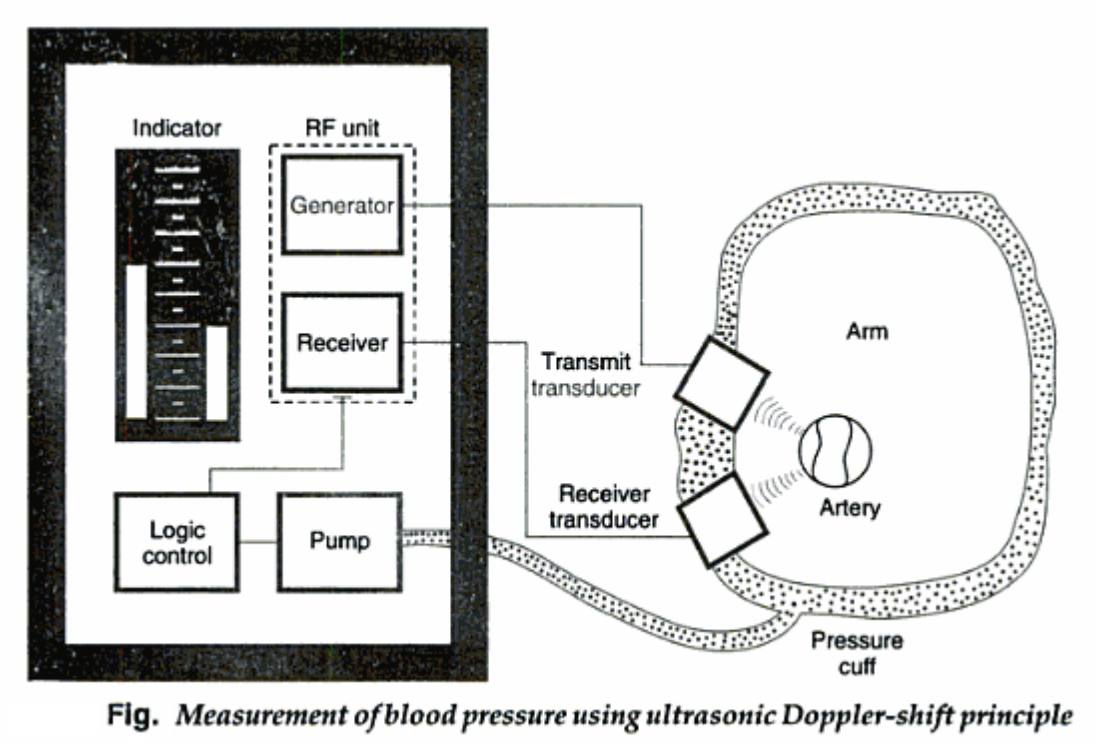


Fig. ***Measurement of blood pressure using ultrasonic Doppler-shift principle***

An occlusive cuff is placed on the arm in the usual manner, with an ultrasonic transducer on the arm over the brachial artery. The cuff is inflated first to above systolic pressure and then deflated at a specified rate. A low energy ultrasonic beam (less than 50 mw/cm^1) at a frequency of 2 MHz is transmitted into the arm. Hie portion of the ultrasound that is reflected by the arterial wall shifts in frequency when the wall of the artery moves.

Above systolic, the vessel remains closed due to the pressure of the occluding cuff, and the monitor signals are not received -As the cuff pressure falls to the point where it is just overcome by the brachial artery pressure, the artery wall snaps open. This opening wall movement, corresponding to the occurrence of the first Korotkoff sound, produces a Doppler-shift which is interpreted by logic in the instrument as systolic and displayed accordingly. With each subsequent pulse wave, a similar frequency shift is produced until at the diastolic pressure the artery is no longer occluded.

ADVANTAGES

1.Can be also used in noisy environment

2.Can be used with infants and hypotensive individuals

DISADVANTAGES

1. Subject's movements change the path from sensor to vessel

5.(i)Explain Fick's method for the determination of cardiac output (8 Marks) [May/June 2013]

(ii) Explain the blood flow measurement using dye dilution? (8 Marks) [Nov/Dec 2011]

(iii)Explain the measurement of cardiac output by indicator dilution method.(8 Marks) [April/May 2010][Nov/Dec 2009]

Describe the measurement of cardiac output by indicator dilution method.(8 Marks)[May/June 2009]

Define cardiac output. Explain the measurement of cardiac output by indicator dilution method. What are the drawbacks of indicator dilution method and how is it overcome? [CO2-L2-Nov/Dec 2008]

CARDIAC OUTPUT MEASUREMENTS

Cardiac output is the amount of blood delivered by the heart to the aorta per minute. During each beat, in the case of adults, the amount of blood pumped ranges from 70 to 100 ml and hence for normal adults the cardiac output is about 4-6 liters /minute. The measurement of cardiac output is necessary to study the various cardiac disorders. A decrease in cardiac output may be due to low blood pressure, reduced tissue oxygenation, poor renal function, shock and acidosis.

Using implanted electromagnetic flow probe on the aorta, we can find the cardiac output per minute directly by multiplying the stroke volume with the heart beat rate per minute. Since this direct method involves surgery, it is not adopted practically. Only the indirect methods are adopted in routine applications and are given below.

(I) FICK'S METHOD

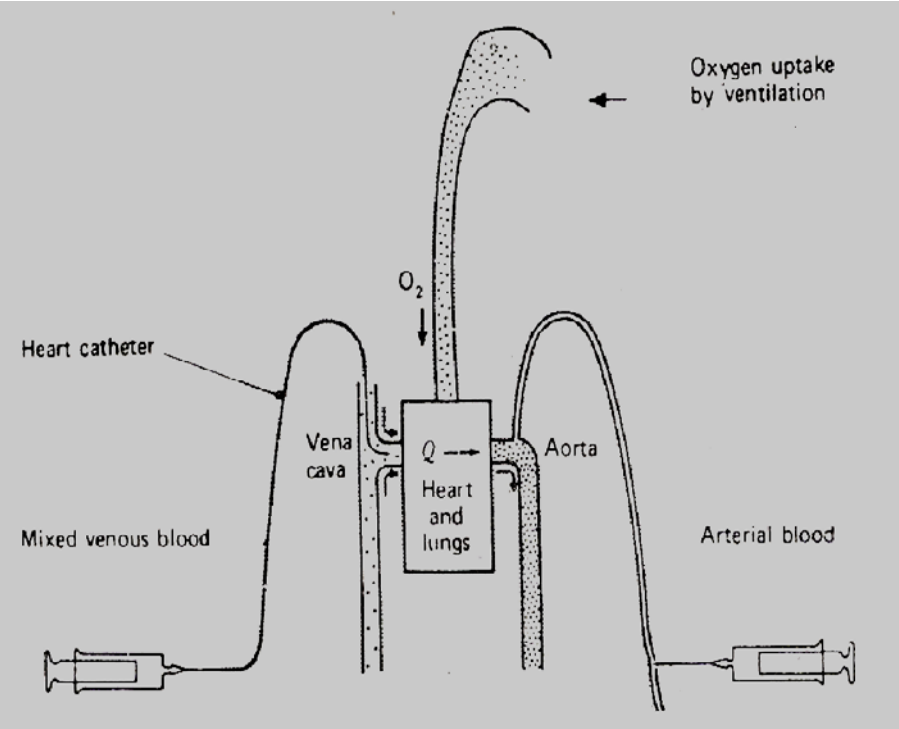


FIG - FICK'S METHOD FOR CARDIAC OUTPUT MEASUREMENT

The Fick's method is based on the determination of cardiac output by the analysis of the gas-keeping of the organism. Thus the cardiac output can be calculated b\ continuously infusing oxygen into the blood or removing it from the blood and measuring the amount of the oxygen in the blood before and after its passage.

Let I be the amount of infused or removed oxygen per unit time and is equal to the difference between the amounts in the blood arriving at and departing from the site of measurement.

Thus,

$I = C_A Q - C_V Q$

$Q = I/C_A - C_V$

where Q is the cardiac output in terms of litres/minute. C_A and C_V are the concentration of oxygen in terms of milli litres of oxygen per litre of blood in the arterial blood (outgoing blood) and mixed venous blood (incoming blood) respectively. I is the volume of oxygen uptake by ventilation which is expressed in terms of milli litres of oxygen per litre of blood.

The oxygen consumption is determined by analyzing the exhaled air collected in a bag during 10 minutes. The oxygen concentration of mixed venous blood is measured by taking samples from a central vein through a cardiac catheter. For analysis of arterial blood, samples are taken from an artery in the fore arm. Even though this method is somewhat complicated, difficult to repeat, necessitates catheterization, it is practiced at some places.

(I) INDICATOR DILUTION METHOD

Indicator dilution method is based on the principle that if we introduce a known amount of dye or radioisotope as an indicator in the blood circulation and then measuring the concentration of the indicator with respect to time at the measurement site, we can estimate the volume flow of the blood. Let M mg of an indicator be 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 the indicator in the peripheral artery is detected by a detector by drawing the blood from an artery through a measuring chamber where the detector continuously analyses the blood. The output of the detector is directly proportional to the concentration of the indicator.

The detector is displayed on a chart recorder with respect to time. Let an increment of volume, dV passes the sampling site in time dt. Let the mass of the indicator in dV = dM. Therefore the concentration of the indication c = dM/dV.

Now

$$DM/DT = C * DV/DT$$

Here the concentration of the indicator V is a function of time. By drawing a curve between concentration and time and the area of the curve gives directly the value of $0J^t$ c dt.

Thus Q = M / AREA OF CURVE

It is not easy to find the area of the dilution curve correctly because of occurrence of some recirculation which results that indicator substance is present in the sampling artery on the second time round the circuit before the concentration has fallen to zero.

Figure shows the dilution curve. During the first Circulation period, the indicator would mix up with the blood small quantity. After that there is a rapid change of concentration. This is shown by the rising portion of the Action curve. After reaching maximum, the concentration of a indicator decreases exponentially, since the circulation 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. Itis therefore necessary to extrapolate to zero concentration before integrating. The extrapolation is made as dotted lines in the curve.

Therefore now-a-days ***thermo dilution method*** is a dapted to measure cardiac output. A*bolous* of about 10 milliliters of 5% Dextrose in water at room temperature is injected as a thermal indicator in to the right atrium. Meter mixing, "it is detected in &e pulmonary artery by means of a thermistor mounted at the tip of a miniature catheter probe.

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The temperature differenc e between the injectated temperature and the circulating blood temperature in the pulmonary artery is measured. The reduction in temperature is integrated with respect to time. After applying proper corrections, a meter reads the cardiac output.

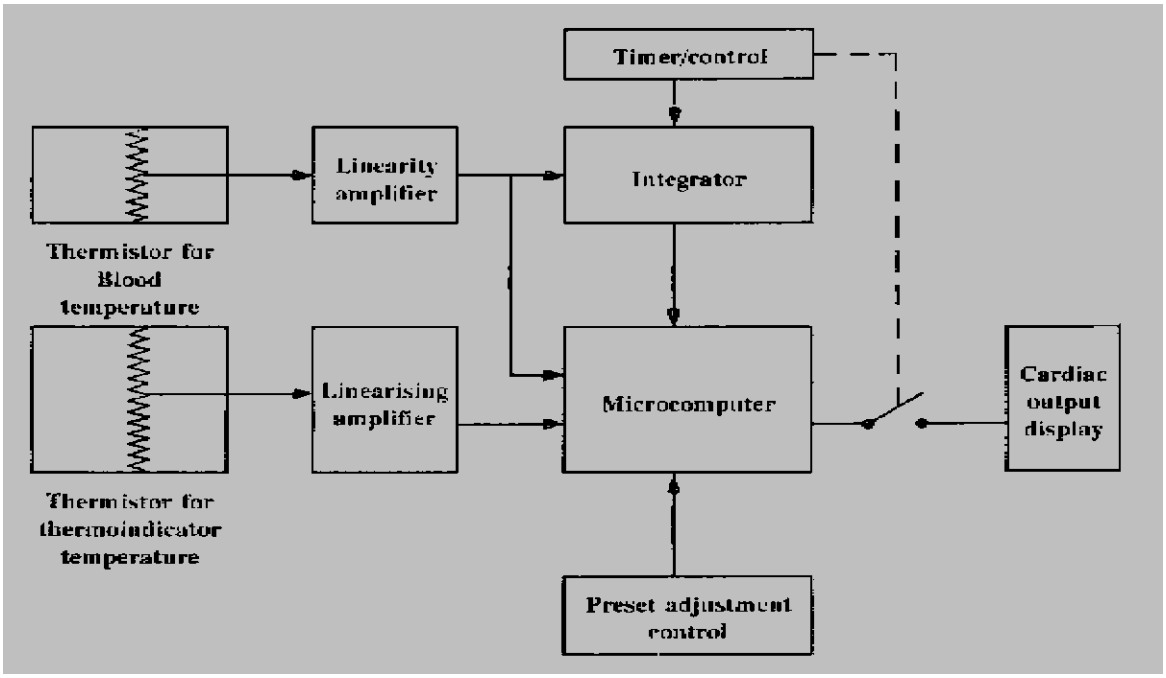


Fig. block diagram of the thermo dilution system cardiac output by impedance change

$$R = \frac{\rho L}{A} = \frac{\rho L^2}{AL} = \frac{\rho L^2}{V}$$

$$\text{(or)} \quad V = \frac{\rho L^2}{R}$$

Where V is the volume of the thorax

Corresponds to the peak negative value of (dZ/dt) found during systole and t is the interval between (dZ/dt) = 0 and the second heart sound.

$$dV = -p \quad \frac{L^2}{R^2} dR$$

$$\therefore \quad dV = -p \quad \frac{L^2}{Z^2} dZ$$

$$\text{Taking } dZ = t \left[\frac{dZ}{dt} \right]_{max} \quad \text{where} \quad \left[\frac{dZ}{dt} \right]_{max}$$

$$\textit{Thus } dV = -p \quad \frac{L^2 . t \left[dZ / dt \right]_{max}}{Z^2}$$

The impedance of the basal is found to be 25 Q when a constant current at 100 kHz is applied between 1 and 4. and this diminishes to 0.1 Q with each systole. The voltage signal due to changes in impedance is amplified and demodulated to obtain impedance 'Z' of the thorax.

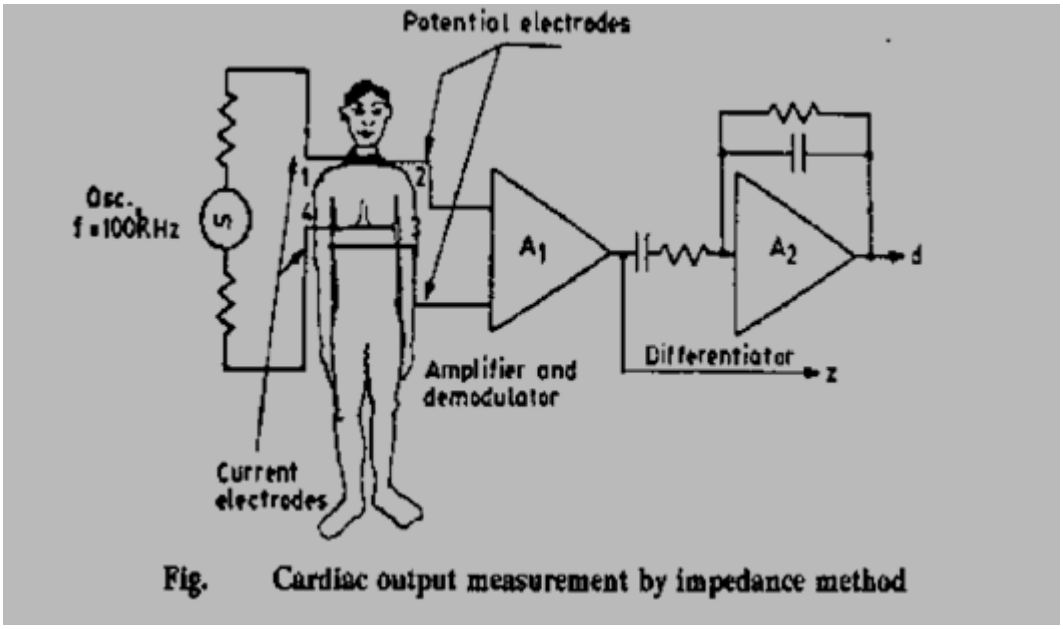


Fig. Cardiac output measurement by impedance method

During ejection of stroke volume, the change in volume is dV and the corresponding decrease in resistance is dR. Differentiating the above expression for V, we get

$$dV = -p \frac{L^2}{R^2} dR$$

$$\therefore \quad dV = -p \frac{L^2}{Z^2} dZ$$

$$\text{Taking } dZ = t \left[\frac{dZ}{dt}\right]_{max} \quad \text{where } \left[\frac{dZ}{dt}\right]_{max}$$

(dZ/dt)is calculated using a differentiator and its output is recorded on a recorder. From that $(dZ/dt)_{max}$ can be noted. By determining dV, the cardiac output can be measured by with heart beat rate per minute.

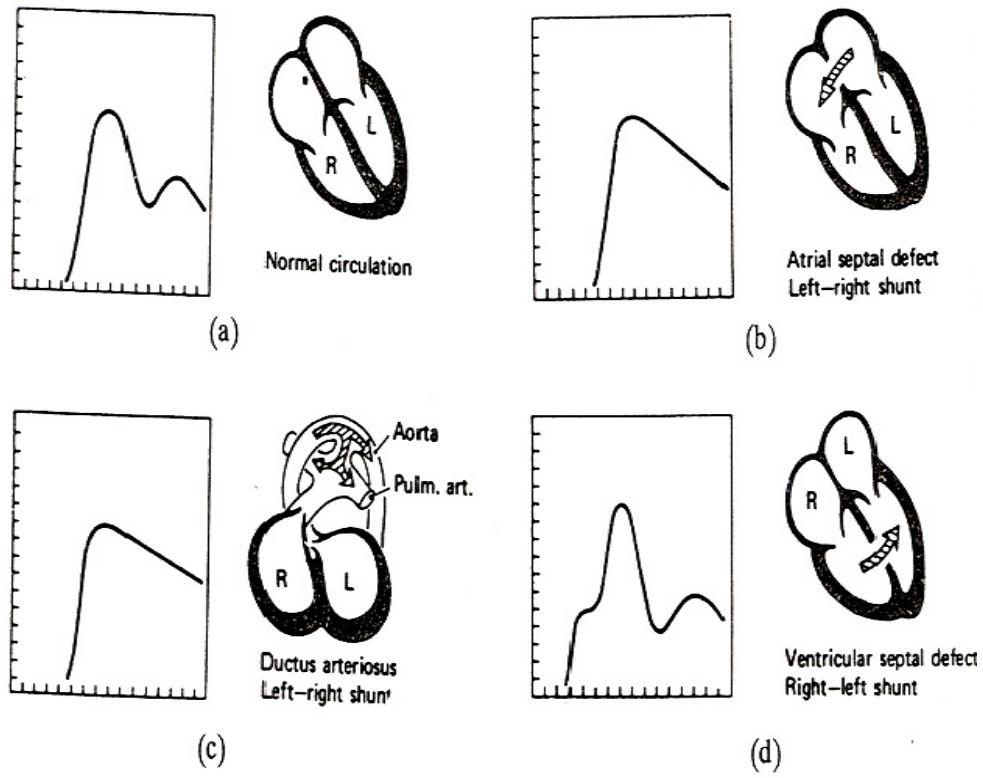


Fig - Dye dilution curves during presence of shunts advantages of cardiac output measurements

1. Indicator dilution is more useful when there is no severe heart defect such as congenital mal formations where the blood recirculates more rapidly due to presence of shunts between the right and left halves of the heart. These shunts may be holes in the wall separating the two halves and produce atrial septal defect and ventricular septal defect. Further there may be ductusarteriosus which is a communication between aorta and pulmonary artery. In the above cases the cardiac output cannot be determined correctly by the indicator method but valuable diagnostic information can be obtained from the characteristic change in the shape of the dilution curve as shown in figure.

Figure (a) shows the normal curve corresponding to the normal circulation of the blood. Figure (b) is obtained when there is atrial septal defect. Due to that blood is flowing internally from left atrium to right atrium.

Figure (c) shows the presence of ductusarteriosus. Here the blood flows from aorta to pulmonary artery. Figure (d) is due to ventricular septal defect. Here the blood is flowing from right ventricle to left ventricle. Therefore it is called right - left shunt.

2. The impedance method is a non-invasive one, by which one can monitor the cardiac output during each stroke volume.

6. Explain the following:

(i) Sphygmomanometer (8 Marks) [May/June 2013]

Explain the principle of sphygmomanometer (10 Marks)[May/June 2012]

Explain the blood pressure measurement using sphygmomanometer (8 Marks) [April/May 2011]

Explain any one indirect method to measure blood pressure (8 Marks)[CO2-L2-May/June 2009]

The most common noninvasive blood pressure (NIBP) measurement method involves a blood pressure cuff and a stethoscope(see Figure). The cuff is connected to a gauge that displays pressure in the cuff. The cuff and gauge together are termed a sphygmomanometer. The blood pressure cuff is usually placed around the arm and inflated to pressures displayed on the gauge.

The manual technique involves a person who listens using the stethoscope to Korotkoff sounds. Listening to body sounds is an auscultatory method of measurement. These sounds are related to the equalization of pressures between the arm blood vessels and the pressure in the heart. This technique has been in use for many, many years.

Sphygmomanometers can use air or mercury (Hg) within the gauge to determine the pressure. The pressures are reported in millimeters of mercury (mm Hg), even though most hospitals have disallowed the use of mercury gauges.

Systolic pressure is the highest pressure in the heart and is measured when the heart is contracting. Diastolic pressure, the lowest pressure in the heart, occurs when the heart is filling. Blood pressure typically is reported as a two-number ratio, systolic “over” diastolic pressure. Typical adult pressures are 120 mm Hg for systolic pressure and 80 mm Hg for the diastolic pressure.

The automated measurement technique is meant to allow people with limited training to record blood pressure. As the nursing shortage has persisted, assigning tasks such as measuring and recording blood pressure to less-skilled workers has been a strategy for continued quality of patient care. Using automated devices requires less

clinical experience and training.

Many NIBP devices are designed to be moved from bed to bed by a nursing assistant to record the vital signs (not just blood pressure) of patients at regular intervals (often every four hours).

7. Explain the working principle of electromagnetic blood flow meter. What are its advantages and disadvantages? [Nov/Dec 2012]

Explain the blood flow measurement using electromagnetic principle? (8 Marks) [CO2-L2-Nov/Dec 2011]

The electromagnetic flow meter measures instantaneous pulsatile flow of blood and thus has a greater capability than indicator-dilution methods, which measure only average flow. It operates with any conductive liquid, such as saline or blood.

PRINCIPLE

The electric generator in a car generates electricity by induction. Copper wires move through a magnetic field, cutting the lines of magnetic flux and inducing an emf in the wire. This same principle is exploited in a commonly used blood flow meter, shown in Figure. Instead of copper wires, the flow meter depends on the movement of blood, which has a conductance similar to that of saline.

Faraday's law of induction gives the formula for the induced emf.

$$e - \int_o^L u \times B.dL$$

where

$_B$ = magnetic flux density, $_T$

$_L$ = length between electrodes, m

$_U$ = instaneous velocity of blood, m/s

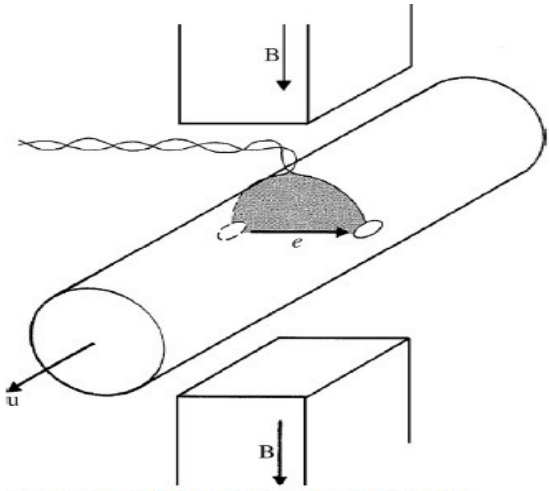


Figure Electromagnetic flowmeter

When blood flows in the vessel with velocity u and passes through the magnetic field B. the induced emf *e* is measured at the electrodes shown. When an ac maenetic field is used any flux lines cutting the shaded loop induce an undesired transformer voltage.

For a uniform magnetic field B and a uniform velocity profile u, the induced emf is e = BLu

where these three components are orthogonal.

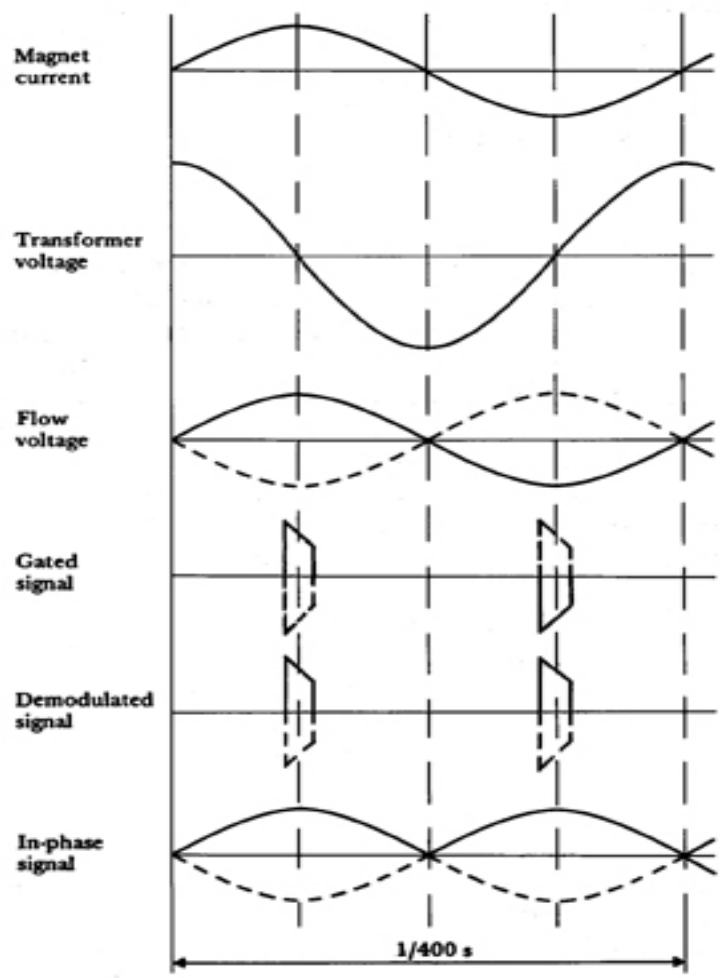


Figure Electromagnetic flowmeterwaveforms:The transformer voltage is 90º out of phase with the magnet current. Other waveforms are shown solid for forward flow and dashed for reverse flow. The gated signal from the gated-sine-wave flowmeter includes less area than the in-phase signal from the quadrature-suppression flowmeter.

Advantages:

* Minimum obstruction in the flow path yields minimum pressure drop.
* It can measure forward as well as reverse flow with equal accuracy.
* Low maintenance cost because of no moving parts.
* corrosive or slurry fluid flow.

Disadvantage:

* Requires electrical conductivity of fluid.

8. (i) Explain the principle of PH measurement? (8 Marks) [May/June 2012] [Nov/Dec 2011] [April/May 2011]

Describe the measurement of PH in blood (8Marks)[Nov/Dec 2008]

The pH of a solution is a measure of the molar concentration of hydrogen ions in the solution and as such is a measure of the acidity or basicity of the solution. The letters pH stand for "power of hydrogen" and the numerical value is defined as the negative base 10 logarithm of the molar concentration of hydrogen ions.

$$pH = -\log_{10}[H^+]$$

The measurement of the pH of a sample can be done by measuring the cell potential of that sample in reference to a standard hydrogen electrode, as in the accepted procedure for measuring standard electrode potentials. This procedure would give a value of zero for a 1 Molar solution of H^+ ions, so that defines the zero of the pH scale. The cell potential for any other value of H^+ concentration can be obtained with the use of the Nernst equation. For a solution at 25 °C this gives

$$E_{ccll} = -0.0592 \log_{10}[H^+]$$

or

$$pH = E_{ccll}/0.0592$$

For this expression, a base change from the natural log to the base 10 logarithm was made in the Nernst equation.

In practice, the pH is not usually measured in this way because it requires hydrogen gas at standard pressure, and the platinum electrode used in the standard hydrogen electrode is easily fouled by the presence of other substances in the solution (Ebbing). Fortunately, other practical electrode configurations can be calibrated to read the H^+ ion concentration. Laboratory pH meters are often made with a glass electrode consisting of a silver wire

coated with silver chloride immersed in dilute hydrochloric acid. The electrode solution is separated from the solution to be measured by a thin glass membrane. The potential which develops across that glass membrane can be shown to be proportional to the hydrogen ion concentrations on the two surfaces. In the measurement instrument, a cell is made with the other electrode commonly being a mercury-mercury chloride electrode. The cell potential is then linearly proportional to the pH and the meter can then be calibrated to read directly in pH.

Examples of pH Values

The pH of a solution is a measure of the molar concentration of hydrogen ions in the solution and as such is a measure of the acidity or basicity of the solution. The letters pH stand for "power of hydrogen" and numerical value for pH is just the negative of the power of 10 of the molar concentration of H^+ ions.

The usual range of pH values encountered is between 0 and 14, with 0 being the value for concentrated hydrochloric acid (1 M HCl), 7 the value for pure water (neutral pH), and 14 being the value for concentrated sodium hydroxide (1 M NaOH). It is possible to get a pH of -1 with 10 M HCl, but that is about a practical limit of acidity. At the other extreme, a 10 M solution of NaOH would have a pH of 15.

In pure water, the molar concentration of H^+ ions is 10^{-7} M and the concentration of OH^- ions is also 10^{-7} M. Actually, when looked at in detail, it is more accurate to classify the concentrations as those of $[H_3O]^+$ and $[OH]^-$. The product of the positive and negative ion concentrations is 10^{-14} in any aqueous solution at 25°C.

An important example of pH is that of the blood. Its nominal value of pH = 7.4 is regulated very accurately by the body. If the pH of the blood gets outside the range 7.35 to 7.45 the results can be serious and even fatal.

If you measure the pH of tap water with a pH meter, you may be surprised at how far from a pH of 7 it is because of dissolved substances in the water. Distilled water is necessary to get a pH near 7.

Meters for pH measurement can give precise numerical values, but approximate values can be obtained with various indicators. Red and blue litmus paper has been one of the common indicators. Red litmus paper turns blue at a basic pH of about 5, and blue litmus paper turns red at an acid pH of about 8. Neither changes color if the pH is nearly neutral. Litmus is an organic compound derived from lichens.

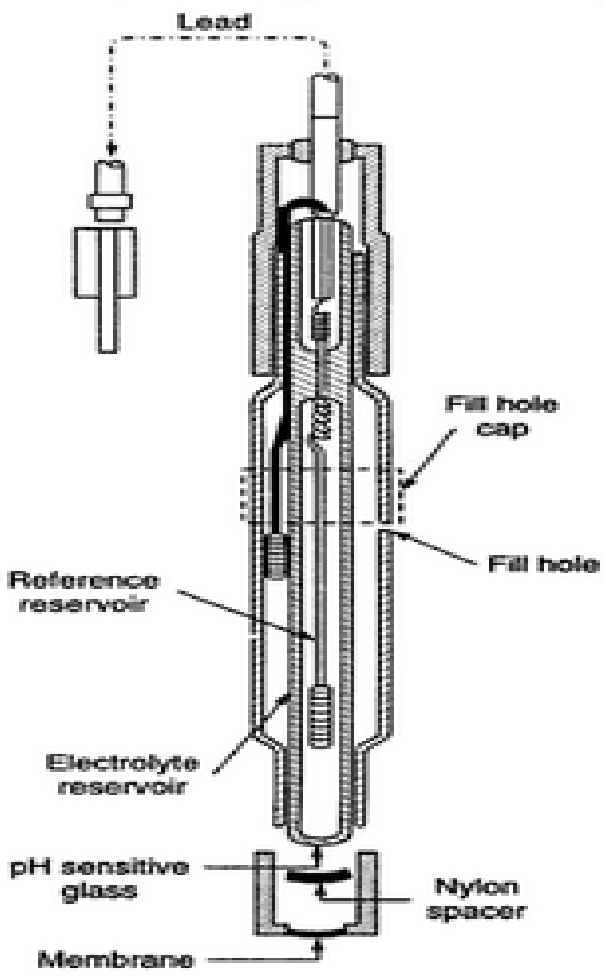
Phenolpthalein is also a common indicator, being colorless in solution at pH below 8 and turning pink for pH above 8.

9. i) Explain how PCO_2 can be measured.(8 Marks) [April/May 2010]

The blood pCO_2 Is the partial pressure of carbon dioxide of blood taken anaerobically. It basically consists of a pH sensitive glass electrode having *a* rubber membrane stretched over it, with a thin layer of water separating the membrane from the electrode surface. The technique is based on the fact that the dissolved COj changes the pH of an aqueous solution.

$C0_2$ from the blood sample defuses through the membrane to form H_2CO_3, which dissociates into (H^+) and (HCO_3) ions. The resultant change in pH is thus a function of the $C0_2$ concentration in the sample. The emf generated was found to give a linear relationship between the pH and the negative logarithm of $pC0_2$. Although the electrode could not provide sensitivity and stability required for clinical applications, it made way for realizing a direct method for the measurement of pCO_2.

Construction of PCO2 electrode:



The emf generated by a $pC0_2$ electrode is a direct logarithmic function of $pC0_2$. It is observed that a ten-fold change in $pC0_2$ causes the potential to change by 58 ± 2 mV. The pH versus log pCO_2 relationship is linear within ±0.002 pH unit from 1 to 100% carbon dioxide. Since 0.01 unit pH change corresponds to a 2.5% change in $pC0_2$ or 1 mmHg in 40 mmHg, for achieving an accuracy of 0,1 mmHg, it is desirable to read 0001 pH unit, i,e, a resolution of 60 uv. This order of accuracy can be read only on a digital readout type pH meter or on an analog meter with expanded scale. The instrument

should have a very high degree of stability and a very low drift amplifier. The input impedance of the electronic circuit must be atleast $I0^{12}\Omega$

It is essential to maintain the temperature of the electrode assembly constant within close limits. It is experimentally shown that variation in the temperature of + 1°C produces an error of ±1.5 mmHg or about +3% at 5 mm $pC0_2$- The combined effects of temperature change upon the sensitivity of the pH electrode and upon the $pC0_2$ of the blood sample amount to a total variation in sensitivity of 8% per degree centigrade.

(ii) With a schematic diagram, describe the operation of the blood cell counter (8 Marks) [April/May 2010]

Blood cell counter is the determination and the number of the quantity of each type of blood cell : red blood cells, white blood cells, and platelets in a sample of blood in a given sample of blood, often including the amount of hemoglobin, and the proportions of various white cells. . Also called a complete blood counter (CBC).

The CBC provides valuable information about the blood and to some extent the bone marrow, which is the blood-forming tissue. The CBC is used for the following purposes:

- to identify persons who may have an infection .
- to diagnose anemia .
- to identify acute and chronic illness, bleeding tendencies, and white blood cell disorders such as leukemia .
- to monitor treatment for anemia and other blood diseases .

The CBC is commonly performed on an automated hematology analyzer using well mixed whole blood that is added to a chemical called EDTA to prevent clotting. A CBC is a group of tests used to quantify the number of RBCs, WBCs, and platelets, provide information about their size and shape, measure the hemoglobin content of RBCs, determine the percentage and absolute number of the five white blood cell types, and identify early and abnormal blood cells. These tests are performed simultaneously, (usually in less than one minute), using an automated hematology analyzer. When the

performance limit of the automated hematology analyzer is exceeded, sample dilution or pretreatment, manual smear review, or manual cell counts may be required. Each laboratory has established rules for determining the need for manual smear review based upon specific CBC parameters. For example, a manual differential is always performed when nucleated immature red blood cells are found on an electronic cell count .

Red Blood Cell Count

The red cells, the most numerous of the cellular elements, carry oxygen from the lungs to the body's tissues. The red blood cell (RBC) count determines the total number of red cells (erythrocytes) in a sample of blood. Most anemias are associated with a low RBC count and hemoglobin.

White Blood Cell Count

The majority of CBCs include both a WBC count and an automated differential. A differential determines the percentage of each of the five types of mature white blood cells. An elevated WBC count occurs in infection, allergy, systemic illness, inflammation, tissue injury, and leukemia. A low WBC count may occur in some viral infections, immunodeficiency states, and bone marrow failure. The WBC count provides clues about certain illnesses, and helps physicians monitor a patient's recovery from others. The differential will reveal which WBC types are affected most.

Platelet Count

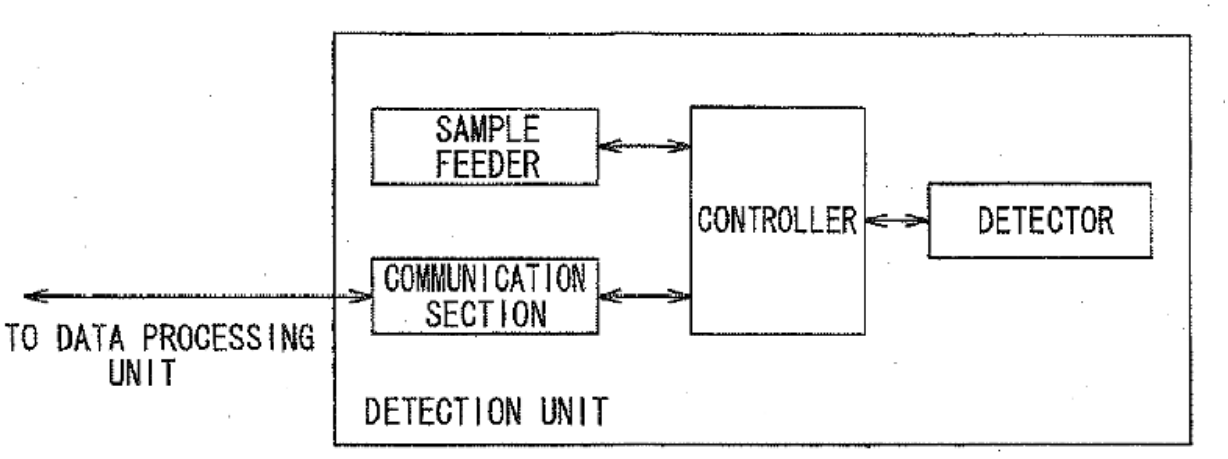
Platelets are disk-shaped structures formed by the detachment of cytoplasm from megakaryocytes. They aid in the coagulation process by attaching or adhering to the walls of injured blood vessels, where they stick together to form the initial platelet plug. A low platelet count may occur in patients with AIDS.

CBC values vary by age and sex. Normal values are ultimately determined by the laboratory performing the test. As a guide, the normal values for men and nonpregnant women are as follows:

- WBCs: 4,500 - 11,000 per microliter for women and men, with neutrophils representing 50-70%, lymphocytes 25-35%, monocytes 4-6%, eosinophils 13%, basophils 0.4-1%, and bands 0-5%.
- RBCs: 4.2-5.0 million per microliter for women; 4.5-6.2 million per microliter for men.
- Hemoglobin: 12-15 g/dL for women; 13.6-17.2 g/dL for men. Hematocrit: 35-47% for women; 42-52% for men. Platelets: 150,000 and 350,000 per microliter.

A blood cell counter comprising:

A detector for detecting blood cells in blood of a subject; and a controller for obtaining, based on a detection result by the detector, first analytical information about hemoglobin amount of red blood cells in the blood and second analytical information about granulocytes in the blood, and for outputting diagnosis support information for supporting determination of whether an inflammatory response of the subject is an infectious inflammatory response or a noninfectious inflammatory response, based on the first analytical information and the second analytical information that have been obtained.

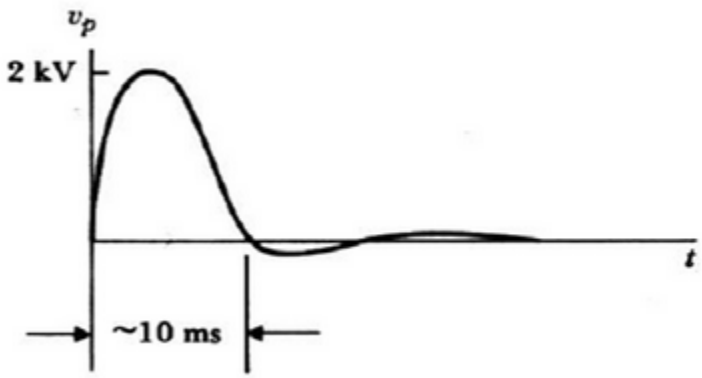


Unit-III

ASSIST DEVICES

PART-A

1. **Draw the typical discharge pulse of a DC defibrillator. [CO3-L1-May/June 2014]**



2. **What is meant by a demand pacemaker?[CO3-L1-Nov/Dec 2013]**

If R wave is missing for a preset period of time, the pacemaker will supply a stimulus. Therefore if the heart rate falls below a predetermined level, then pacemaker will turn on and provide the heart a stimulus. For this reason it is called as demand pacemaker.

3. **What are pacemakers? [CO3-L1-May/June 2013]**

Pacemaker is an electrical pulse generator for starting and/or maintaining the normal heart beat.

4. **What are the batteries used for implantable pacemakers? [CO3-L1-Nov/Dec 2012]**

Lithium/Iodine cell

Poly2-VinylPyridine

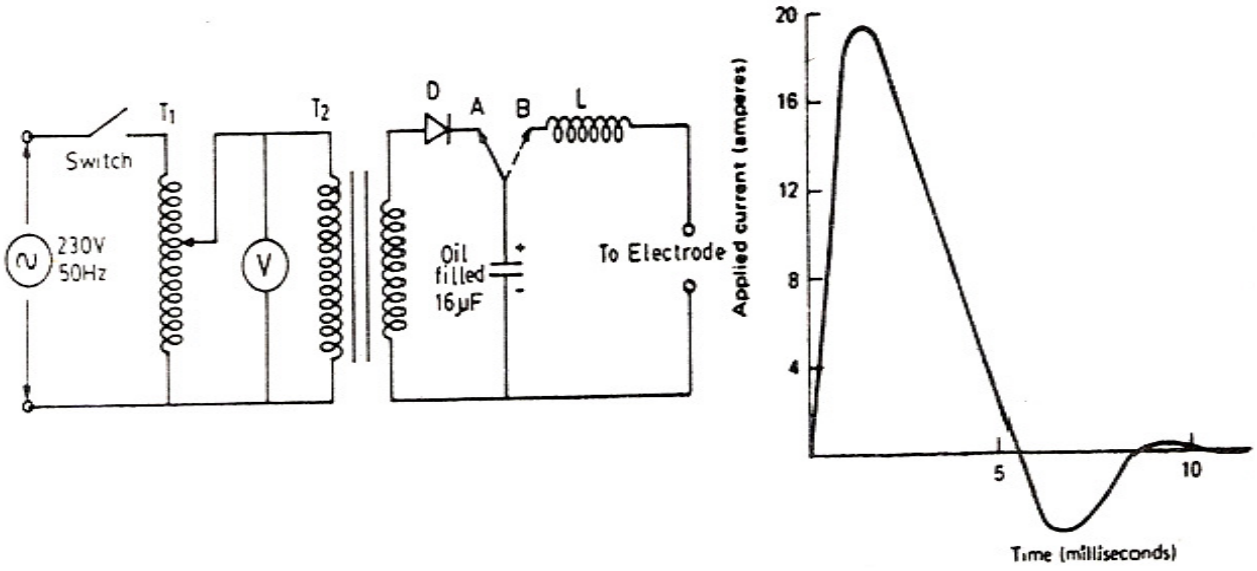
Battery Mercury Cell

5. Mention the different types of pacemakers.[CO3-L1-May/June 2012]

Internal Pacemaker

External Pacemaker

6. Draw the circuit of Dc defibrillator and give its output specifications. [CO3-L1-April/May 2011]



7. What is meant by fibrillation?[CO3-L1-April/May 2010]

The condition at which the necessary synchronizing action of the heart is lost is known as fibrillation. During fibrillation the normal rhythmic contractions of either atria or the ventricles are replaced by rapid irregular twitching of the muscular wall

8. Calculate energy stored in a 16μF capacitor of a defibrillator that is charged to a potential of 5000V (dc). [CO3-L1-Nov/Dec 2009]

C = 16μF

V = 5000

$E = (1/2)\ CV^2$

$= (1/2) \times 16 \times 10^{-6} \times 25 \times 10^{6}$

= 200 Joules

9. What is meant by defibrillator? [May/June 2009][CO3-L1-Nov/Dec 2008]

A defibrillator is an electronic device that creates a sustained myocardial depolarization of a patients heart in order to stop ventricular fibrillation or atrial fibrillation.

10. Why do we require heart-lung machine? [CO3-L1-May/June 2009]

A device used in open heart surgery to support the body during the surgical procedure while the heart is stopped. The heart-lung machine is often referred to as the "pump", and does the work of the heart and lungs during the operation.

11. Distinguish between internal and external defibrillators [Nov/Dec 2008]

S.No	Internal defibrillator	External defibrillator
1	Used when chest is open	It is used on the chest
2	Large spoon shaped electrodes are used	Paddle shaped electrodes are used
3	Voltage is in the range of 50 to 1000 V	Voltage is in the range of 1000 to 10000 V

12. Classify defibrillator based on applied voltage.

(i) A.C Defibrillator

(ii) D.C Defibrillator

(iii) Synchronized D.C Defibrillator

(iv) Square pulse Defibrillator

(v) Double square pulse Defibrillator

(vi) Biphasic D.C Defibrillator

13. Based on the modes of operation list the types of cardiac pacemaker

Fixed rate cardiac pacemaker

Standby pacemaker

Demand Pacemaker

Atrial synchronous pacemaker

Atrial sequential ventricular inhibited pacemaker

14. Name the methods of dialysis?

Hemodialysis

Peritoneal dialysis

PART-B

1. Explain the function and characteristics of various types of on-demand cardiac pacemakers.[May/June 2014]

Explain any two types of pacemaker with neat block diagram. [Nov/Dec 2011]

What is the need of pacemaker? Explain the different types of pacemakers? [April/May 2011]

With a suitable diagram, explain the operation of any one type of cardiac pacemaker [Nov/Dec 2010]

Explain the working of Pacemaker.(8Marks) [Nov/Dec 2009]

Discuss with suitable block diagram the different modes of operation of cardiac pacemakers [CO3-L1-Nov/Dec 2008]

A device capable of generating artificial pacing impulses and delivering them to the heart is known as *a pacemaker system* (commonly called pacemaker) and consists of a pulse generator and appropriate electrodes.

- The pacemaker sends *a* tiny electrical signal, a pacing impulse.

- This impulse travels through the Insulated wires of a pacing lead until it reaches the metal electrode at the tip of the lead.
- The electrode, which is In direct contact with the heart, delivers the electrical impulse to the heart,
- The electrical impulse causes the heart tissue to begin a heartbeat

Broadly pacemakers are classified as :

1. Internal pacemaker (Implantable pacemaker).
2. External pacemaker.

Interna! pacemakers can be permanently implanted in patients whose SA node has failed to function properly or who suffer from permanent heart block because of a heart attack. An internal pacemaker is defined as one in which the entire system is inside the body i.e. the electrodes into the heart, the electronic circuitry and the power supply are implanted (internally) within the body

In contrast, External pacemaker usually consists of an externalfy worn pulse generator connected to electrodes located on or within the myocardium. External pacemakers are used on patients with temporary heart irregularity, such as those encountered in the coronary patient, including heart blocks. They are also used far temporary management of certain arrhythmias that may occur in patients during critical postoperative periods and in patients during cardiac surgery, especially if the surgery involves valves or septum.

Modes of operation of the pacemaker are,

1. Fixed rate pacemaker or ventricular asynchronous space maker
2. Stand by pacemaker or ventricular synchronous space maker
3. Demand pacemaker or R-wave Inhibited pacemaker or ventricular Inhibited pace maker
4. Atrial synchronous pacemaker

5. Atrial sequential ventricular inhibited pacemaker.

Ventricular Asynchronous Pacemaker

This type of pacemaker is intended for patients having permanent heart blocks, it is the first type of pacemakers and can be used in atrium or ventricle. It has the simplest mechanism and the longest battery life. It is so cheap and easy to check and is the least sensitive device to outside interference. This pacemaker is suitable for patients with a stable, total AV block, a slow atrial rate or atrial arrhythmia. It is basically astable multivibrator. This produces a stimulus at a fixed rale irrespective of the behavior of heart rhythm. The rale is pre-set, say at 70 bpm.

The rate can be varied externally In implanted units by magnetically actuating a buiit-fn relay. There may be competition between the natural heart beats and the pacemaker beats. It is possible that such an event can be dangerous because if the pacemaker impulse reaches the heart during a certain vulnerable period (the apex of the T wave), the ventricular fibrillation may occur.

Disadvantages :

1. Using the fixed rate pacemaker, the heart rate cannot be increased to match greater physical effort
2. Stimulation with a fixed impulse frequency results in the ventricles and beating at different rates. This varies the stroke volume of Ihe heart which causes some loss in the cardiac output.
3. Possibility Tor ventricular fibrillation will be more, when we use it for patients with unstable black, due to interference between the ventricular contractions evoked by the pacemaker and the atria.

Ventricular Synchronous Pacemaker (Standby Pacemaker)

The ventricular synchronized demand type (R wave triggered) pacemaker is meant for patients who are generally in heart block with occasional sinus rhythm. The pacemaker delects ventricular activity <R wave of ECG) and stimulates Ihe venlricies after a very short delay lime of some milliseconds.

If there is sinus rhythm, the stimulating impulse will occur in the ventricular de-polarization. If there is asystole, Ihe unit will stimulate the heart afler a pre-set time. This type of pacemaker does not compete with the normal heart activity.

Fig. shows Ihe block diagram of ventricular synchronous pacemaker. A single transverse electrode placed in the right ventricle both senses the R from an atrial and delivers Ihe stimulation; thus no separate sensing electrode is required. A R-wave from an atrial generated ventricular contraction triggers the ventricular synchronized pacemaker which provides an impulse falling in the lower part of the normal QRS complex.

This ensures that the pacemaker does not interfere with the sinus rhythm. If atrial generated ventricular contractions are absent, the pacemaker provides impulses at a basic frequency of 70 impulsesfiminute. Thus it provides impulses only when the atrial generated ventricular contractions are absent, thus conserving energy.

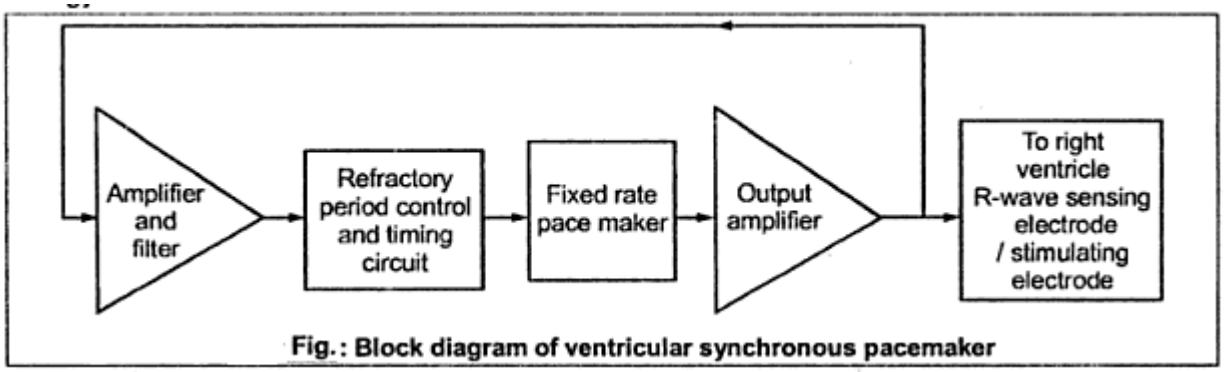


Fig.: Block diagram of ventricular synchronous pacemaker

Working :

Using the sensing electrode, the heart rate is detected and is given to the timing circuit in the pacemaker. If the detected heart rate is below a certain minimum level, the fixed rate pacemaker is turned on to pace the heart. The lead used to detect the R wave is used to stimulate the heart. If a natural contraction occurs, the asynchronous pacer's timing circuit is reset so that it will time its next pulse to detect heart beat. Otherwise the asynchronous pacemaker produces pulses at its preset rate.

Suppose the pacemaker may detect noise and interpret as its ventricular excitation. But this is eliminated by the incorporation of refractory period circuit or gate circuit after either a paced or natural contraction. In heart blocks. P-waves occur at random times with respect to ventricular excitation. However P and R waves have their principal energy in different frequency bands. A high pass filter with a lower cut off frequency at 20 Hz almost completely eliminates the P-wave, The R-wave is differentiated by such a filter and its peak lo peak amplitude is increased using an input amplifier.

Advantages ;

1. To delect the ventricular fibrillation, this circuit can be used.
2. If the R-wave occurs with its normal value in amplitude and frequency then it would not work. Therefore the power consumption is reduced and there is no chance of getting side effects due to competition between natural and artificial pacemaker pulses. When the R-wave is appearing with lesser amplitude, the circuit amplifies it and delivers it in proper form. If the R wave period is too low or too high, the asynchronous pacer in the circuit ts working up to the returning of the heart into normal one.

Disadvantages :

1. Atrial and ventricular contractions are not synchronized.
2. In the olden type when the pacemaker is attached with the patients, the circuit is more sensitive to external electromagnetic interferences such as electric shavers microwaves ovens, car ignition systems, airport security metal detectors and so on. Therefore the patients could not work In radio or T.V. stations. They could not undergo diathermy treatment and could not be exposed to airport security metal detector, Further they could not ride motor or scooters. But in the newer pacemakers this is eliminated by connecting a low pass filter in the input circuit of the pacemaker.

Demand pacemaker:

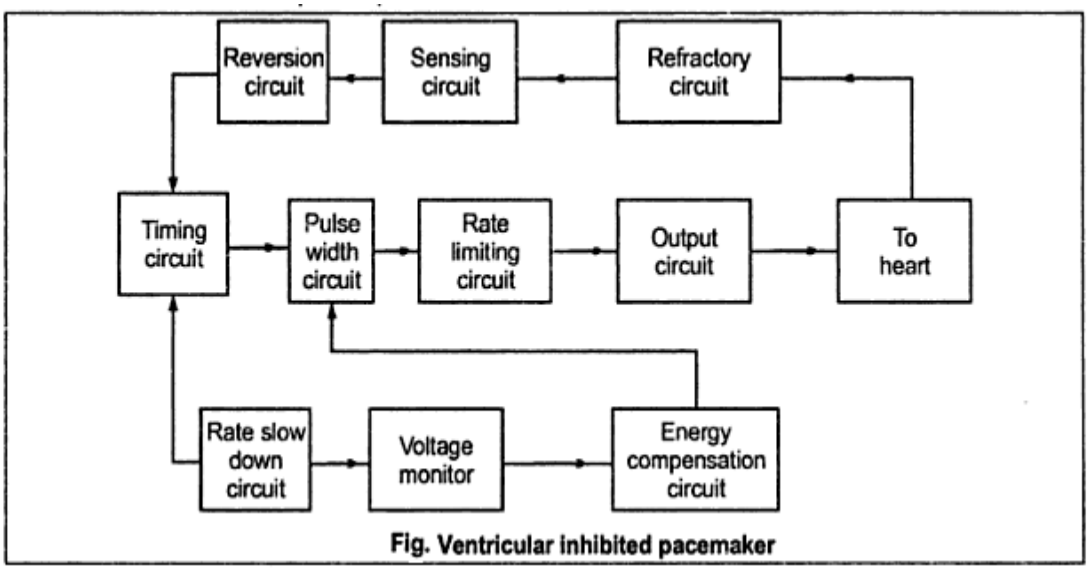


Fig. Ventricular inhibited pacemaker

The sensing electrode picks up R- wave:

The refractory circuit provides a period of time following an output pulse or sensed R-wave during which the amplifier in the sensing circuit will not respond to outside signals. The sensing circuit detects the R-wave and resets the oscillator. The reversion circuit allows the amplifier to detect R-wave in low level signal to noise ratio. In the absence of R-wave, it allows the oscillator in the timing circuit to deliver pulses at its preset rate.

The timing circuit consists of an RC network, a reference voltage source and a comparator which determines the basic pulse rate of the pulse generator. The output of the timing circuit is fed info pulse width circuit which is also a RC network. The pulse Width circuit determines the duration of the pulse delivered to the heart. Then the output of the pulse width circuit Is fed into the rate limiting circuit which limits the pacing rate to a maximum of 120 pulses per minute.

The output circuit provides a proper pulse to stimulate the heart. Thus the timing circuit, pulse width circuit, rate limiting circuit and output circuit are used to produce the desired pacemaker pulses to pace the heart. There is a special circuit called voltage monitor who senses the cell depletion and signals the rate slow-down circuit and energy compensation circuit of this event.

The rate slow-down circuit shuts off some of the current to the basic liming network to cause, the rate to slow-down 8 +/- 3 beats per minute when cell depletion has occurred. The energy compensation circuit produces an increase in the pulse battery voltage decreases to maintain constant stimulation energy to the heart.

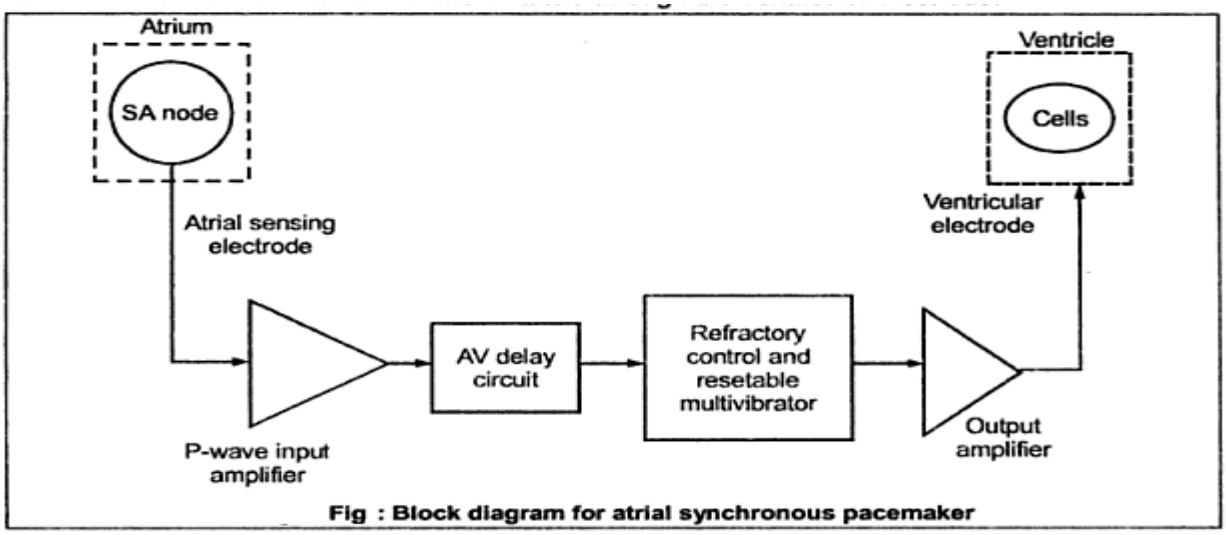


Fig : Block diagram for atrial synchronous pacemaker

If the rate of atrial excitation becomes too fast as in atrial fibrillation or too slow or absent a preset fixed rate pacemaker (resetable multivibrator) takes over until the abnormal situation is over. Normally pacemaker pulse is so large that it would be detected by the atrial pick up leads and cause the heart to beat This problem has been eliminated by refractory period control circuit. That is. any signal detected on the atrial lead within 400 milliseconds of a paced heart beat is Ignored.

2. i)Explain DC defibrillator (8 Marks) [May/June 2013]

Explain the principle of DC Defibrillator with neat diagram [Nov/Dec 2011]

Discuss the working Principle of a DC defibrillator with a neat circuit diagram.(8Marks) [CO3-L1-Nov/Dec 2009]

D.C. Defibrillator

Unlike a.c. defibrillator, the d.c. defibrillator would not produce undesirable side effects and at the same time, it produces normal heart beat effectively. Here the ventricular fibrillation is terminated by passing a high energy shock through discharging a capacitor to the exposed heart, or to the chest of the patient.

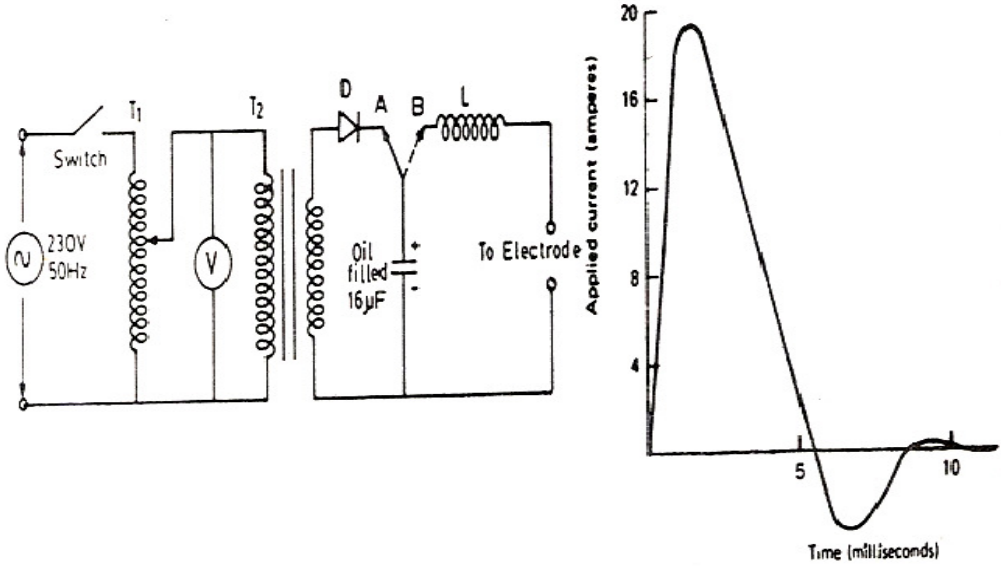


Fig.. D.C. defibrillator (ordinary type) and its output

Figure shows a d.c. defibrillator circuit. Available auto transformer Tj forms the primary of a high voltage transformer T_2. The output voltage of the transformer T_2 is rectified by a diode rectifier and is connected to a vacuum type high voltage change over switch. In position A, that switch is connected to one end of an oil filled capacitor having capacity of 16 *pF.* In this position the capacitor charges to a voltage, set by the positioning of the auto transformer.

During the delivery of shock to the patient, a foot switch or a push button switch mounted on the handle of the electrode is operated; so that the high voltage switch changes over to position B and the capacitor is discharged across the heart through the electrodes. An inductor 'L' is placed in one of the electrode leads so that the discharge from the capacitor is slowed down by the induced counter voltage.

This gives the output pulse in a physiologically favorable shape in order to eliminate a sharp undesirable current spike that could otherwise occur at the beginning of the discharge. The shape of the waveform (Figure 5.17) that appears across the electrodes will depend upon the value of capacitor and inductor used in the circuit and its amplitude depends upon the discharge resistance which is regarded as purely ohmic resistance of 50 to 100 ohms approximately.

The success of defibrillation depends upon the energy stored in the capacitor and not with the value of voltage used. Both for external and internal defibrillation, 0 - 400 joules of energy is sufficient. Thus if C = 16 /j¥ and the voltage used is 6000 V, then the energy stored in the capacitor,

$$E = \frac{1}{2} CV^2 = \frac{1}{2} \times 16 \times 10^{-6} \times 36 \times 10^{6}$$

$$= 288 \text{ joules}$$

For internal defibrillation, energies up to 100 joules are required whereas for external defibrillation energies up to 400 joules are required. The discharging duration is in the range from 5 milliseconds to 10 milliseconds.

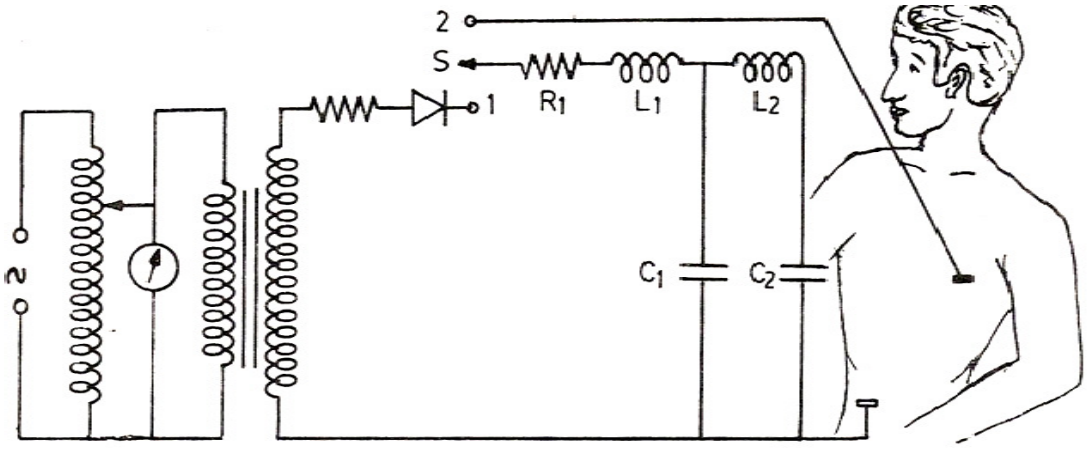


Fig (a) Dual peak d.c defibrillator

The passage of high current may damage the myocardium and the chest wall. To reduce this risk, some defibrillators produce dual peak waveform. This keeps the stimulus at peak voltage for longer duration. Same energy can be applied to the heart with low current level. Such defibrillators are called ***dual peak defibrillators*** or delay line capacitive discharge D.C. defibrillators. There is also another type called ***truncated defibrillatorsin*** which the capacitor discharge is adjusted so that the effective defibrillation is obtained at the desirable lower voltage levels as shown in figure 5.19. Here the voltage level of the wave is almost constant but its duration is extended to obtain the required energy.

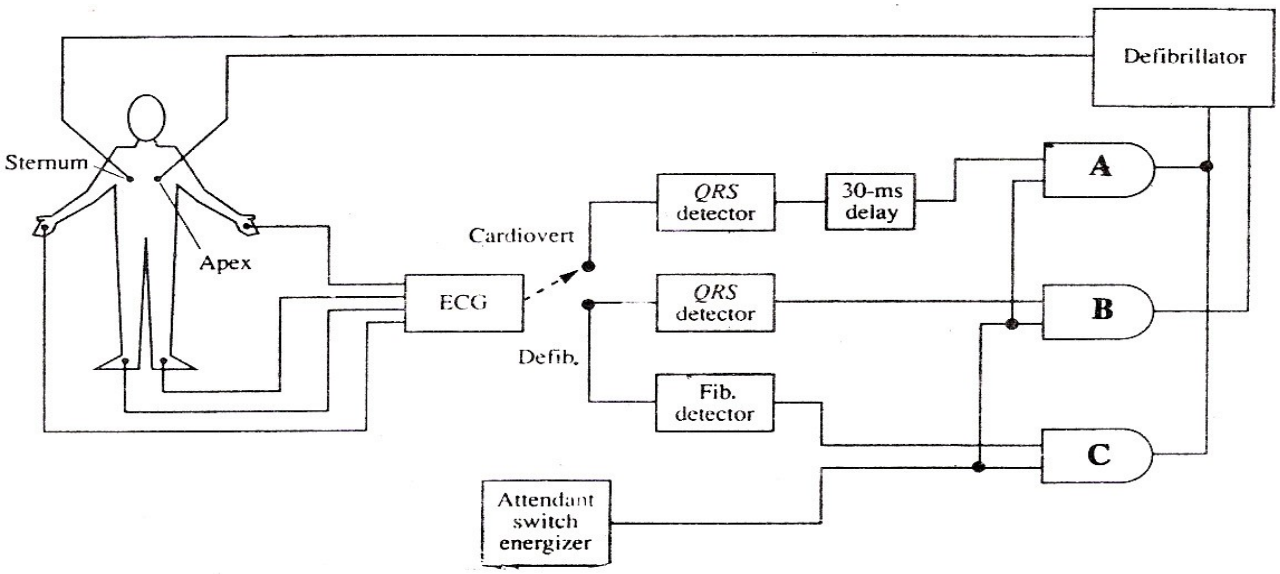
3. How is atrial fibrillation arrested? Explain with the help of relevant diagram of the setup? [Nov/Dec 2012]

Explain the principle of Synchronized DC Defibrillator with neat diagram? [May/June 2012]

Explain the function of Synchronized DC Defibrillator with neat diagram? [April/May 2011]

With block diagram describe the operation of Synchronized DC Defibrillator [CO3-L1-Nov/Dec 2008]

Synchronized D.C. defibrillator:



Defibrillation is a risky procedure since if it is applied in correctly; it could induct fibrillations in a normal heart. There must be proper diagnosis for ventricular fibrillation. *A* simple d.c. defibrillator can arrest the ventricular fibrillation. But for termination of ventricular tachycardia, atrial fibrillation and other arrhythmias it is essential to use 2 defibrillator with synchroniser circuit. It is known that there are two vulnerable zones in *I*normal cardiac cycle, T wave and U wave segments. If the counter shock falls in the T wave segment then the ventricular fibrillation is developed. If the counter shock falls in the U wave segment then atrial fibrillation is produced.

Figure shows the modern D.C. defibrillator circuit consisting of defibrillator, electro cardio scope and pacemaker. The pacemaker is used in the case of emergency as a temporary pacing.

It includes diagnostic circuitry which is used to assess the fibrillation before delivering the defibrillation pulse and synchroniser circuitry which is used to deliver the defibrillation pulse at the correct time, so as to eliminate the ventricular fibrillation or atrial fibrillation without inducing them.

Working

1. The electrocardiogram is obtained by means of an ECG unit, connected to the patient who is going to receive defibrillation pulse.
2. The switch is placed in the ***defibrillator*** mode if ventricular fibrillation is suspected.
3. The QRS detector in that mode consists of a threshold circuit that would pass **a *signal as output if R wave is absent*** in the electrocardiogram. Otherwise it would not give any output if R wave is present.
4. Mean while the medical attendant energizes the switch to deliver a defibrillation pulse.
5. The AND gate 'B' delivers on signal to the defibrillator only when the R wave is absent, provided the signal from the medical attendant is also present at one of the two inputs of that AND gate.
6. At the two inputs of AND gate 'B' if any one of the inputs is missing, then it would not give any output. By this way the defibrillator is inhibited and would not deliver the defibrillation pulse.
7. The fibrillation detector searches the ECG signal for frequency components above 150 Hz. If they are present, fibrillation is probable and the fibrillation detector gives an output signal. A defibrillator pulse is delivered only if the fibrillation detector produces an output at the same time that the attendant energizes the switch. This is provided by the AND gate 'C.
8. Thus when the AND gate B and AND gate C are simultaneously triggering the defibrillator, the defibrillation pulse is delivered.
9. In the *cardiacersian*(or) synchronization mode, the defibrillator is synchronised with the ECG unit. Suppose a patient is suffered by atrial fibrillation. First the doctor diagnosed that correctly. Then the treatment is initiated using this circuit.
10. The ECG signal in the instrument is given to QRS detector. Its output is used to

time the delivery of the defibrillation pulse with a delay of 30 milliseconds. At this time, the ventricles will be in an uniform state of depolarisation and the normal heart beat will not be disturbed. This delay of 30 milliseconds after the occurrence of R wave allows the attendant to defibrillate atrium without inducing ventricular fibrillation.

4. i)Explain with relevant diagrams, the principles of on demand pacemaker (8Marks) [CO3-L2‑April/May 2010]

Ventricular Synchronous Pacemaker (Standby Pacemaker)

The ventricular synchronized demand type (R wave triggered) pacemaker is meant for patients who are generafty in heart block with occasional sinus rhythm. The pacemaker detects ventricular activity {R wave of ECG) and stimulates Ihe venlricies after a very short delay lime of some milliseconds. If there is sinus rhythm, the stimulating impulse will occur in the ventricular de-polarization, if there is asystole, ihe unit will stimulate the heart after a pre-set time, This type of pacemaker does not compete with the normal heart activity.

Fig. shows the block diagram of ventricular synchronous pacemaker. A single transverse electrode placed in the right ventricle both senses the R from an atrial and delivers the stimulation; thus no separate sensing electrode is required. A R-wave from an atrial generated ventricular contraction triggers the ventricular synchronized pacemaker which provides an impulse falling in the lower part of the normal QRS complex. This ensures that the pacemaker does not interfere with the sinus rhythm. If atrial generated ventricular contractions are absent, the pacemaker provides impulses at a basic frequency of 70 impulses/minute. Thus it provides impulses only when the atrial generated ventricular contractions are absent, thus, conserving energy.

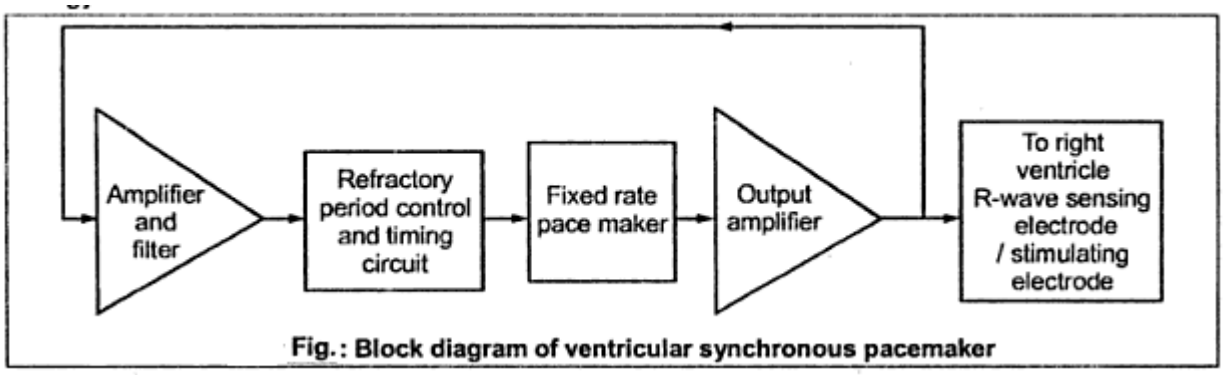


Fig.: Block diagram of ventricular synchronous pacemaker

Working :

Using the sensing electrode, Lhe heart rate is detected and is given to the timing circuit in the pacemaker. If the detected heart rate is below a certain minimum level, the fixed rate pacemaker is turned on to pace the heart. The lead used to detect the R wave is used to stimulate the heart. If a natural contraction occurs, the asynchronous pacer's timing circuit is reset so that it will time its next pulse to detect heart beat. Otherwise the asynchronous pacemaker produces pulses at its preset rate.

Suppose the pacemaker may detect noise and interpret as its ventricular excitation. But this is eliminated by the incorporation of refractory period circuit or gate circuit after either a paced or natural contraction. In heart blocks, P-waves occur at random times with respect to ventricular excitation. However P and R waves have their principal energy in different frequency bands. A high pass filter with a lower cut off frequency at 20 Hz almost completely eliminates the P-wave. The R-wave is differentiated by such a filter and its peak to peak amplitude is increased using an input amplifier.

Advantages ;

1. To detect the ventricular fibrillation, this circuit can be used.
2. If the R-wave occurs with its normal value in amplitude and frequency then it would not work. Therefore the power consumption is reduced and there is no chance of getting side effects due to competition between natural and artificial pacemaker pulses. When the R-wave is appearing with lesser amplitude, the circuit amplifies it and delivers it in proper form. If the R wave period is too low

or too high, the asynchronous pacer in the circuit its working up to the returning of the heart into normal one.

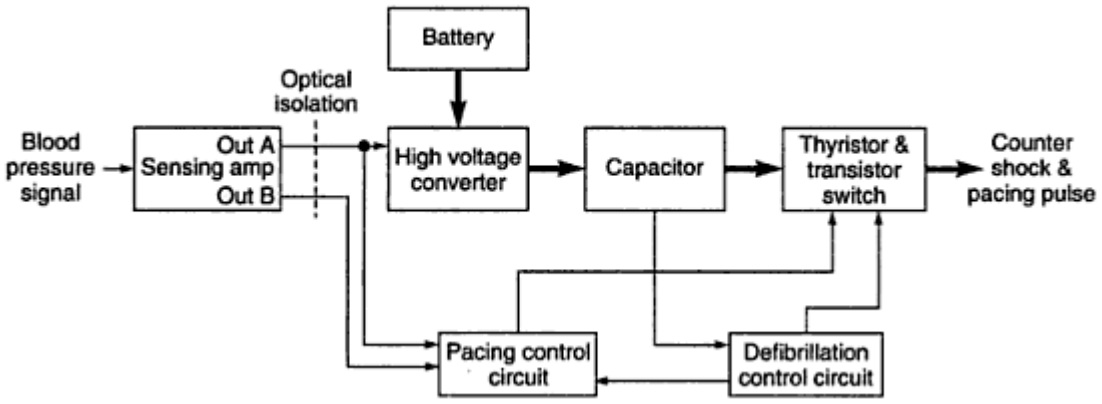
Disadvantages :

1. Atrial and ventricular contractions are not synchronized,
2. In the olden type when the pacemaker is attached with the patients, the circuit is more sensitive to external electromagnetic interferences such as electric shavers microwaves ovens, car ignition systems, airport security metal detectors and so on, Therefore the patients could not work in radio or T.V. stations. They could not undergo diathermy treatment and could not be exposed to airport security metal detector, Further they could not ride motor or scooters. But in the newer pacemakers this is eliminated by connecting a low pass filter in the input circuit of the pacemaker.

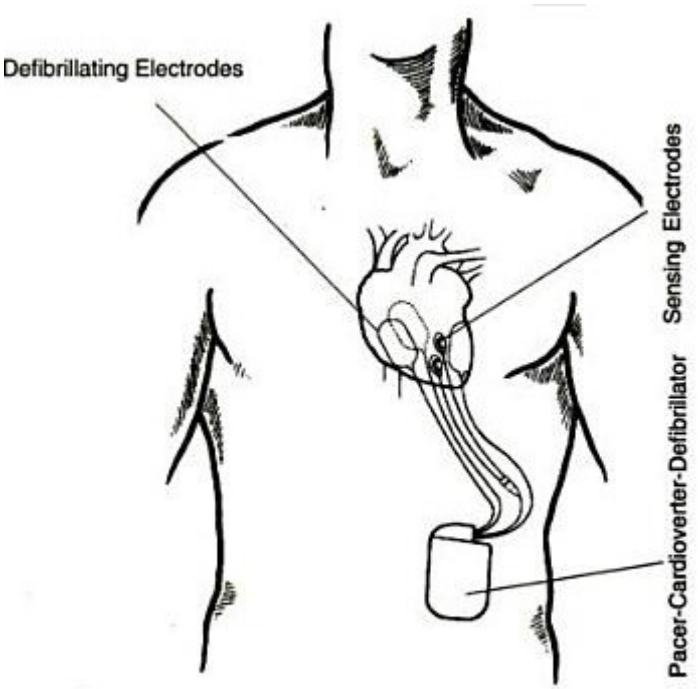
(ii) Describe the applications of DC Defibrillator (8Marks) [April/May 2010]

Pacer-Cardioverter-Defibrillator:

The vast majority of cardiac arrest patients suffer from tachyarrhythmias which generally develop into ventricular fibrillation. However, a smaller percentage of cardiac arrest victims suffer from extreme brady arrhythmias which require pacing. Hence, it is logical to have a multi-function defibrillator, capable of external pacing as a standard feature. Therefore, most manual defibrillators currently in the market offer both demand and asynchronous (fixed rate) external pacing facility**.**



A block diagram of the experimental device is shown in Fig. It is composed of five battery-powered units: sensing circuit, high- voltaic converter switching circuit, defibrillation control circuit, and pacing control circuit. The heartbeat signal, which is detected by a catheter-type heartbeat sensor, is amplified for heartbeat monitoring. The absence of a heartbeat fur 3.5 s causes the fibril] at ion detecting circuit to deliver the turn-on signal which then switches on the high voltage converter. At a predetermined voltage level (S00 V), the thyristor switch allows the capacitor to discharge its current through the right ventricular electrode After defibrillation, high output demand pacing is activated by 11 sing the residential energy i n the output-capacitor. The pacing rate and pulse width are controlled by the pacing control circuit, and the heartbeat signal is used for demand function.


Defibrillating Electrodes
Sensing Electrodes
Pacer-Cardioverter-Defibrillator

Unit - IV

Physical Medicine and Biotelemetry

Part-A

1.Mention the situations which account for hazards from electric shock [May/June 2014]

How do electrical hazards occur due to medical equipment's? [CO4-L1-Nov/Dec 2010]

Wet conditions increase risk of electrical shock by lowering skin resistance.

Immediately replace worn or damaged extension cords and power tools. You can prevent innocent use of a bad cord or tool by cutting the male plug off the cord (while it's unplugged from the receptacle, of course)

Power lines are very dangerous and should be avoided at all costs. If you see a line about to hit the ground, stand on one foot or run (only one foot contacting the ground) to prevent shock from voltage dropped across the ground between the line and the system ground point.

2. What are the precautions necessary to avoid micro shock? [CO4-L1-Nov/Dec 2013]

Micro shock is most often caused when current exceeds 10μ A through an insulated catheter to the heart. To avoid micro shock the catheter may be insulated. Conductive fluid filled tube or solid wire pacemaker cable can be used to avoid micro shock.

3. Bring out the need for patient plate in surgical diathermy. [CO4-L1-Nov/Dec 2013]

- Electrical plate is placed on patient and acts as indifferent electrode
- Current passes between instrument and indifferent electrode
- As surface area of instrument is an order of magnitude less than that of the plate

- Localised heating is produced at tip of instrument
- Minimal heating effect produced at indifferent electrode

4.What is macro shock? [May/June 2014] [Nov/Dec 2008] Define macro shock [May/June 2012]

Define the term macro shock [CO4-L1-Nov/Dec 2009]

A physiological response to a current applied to the surface of the body that produces unwanted stimulation like tissue injury or muscle contractions is called as macro shock.

5.Give the types and frequencies of operation of diathermy units [CO4-L1-Nov/Dec 2012]

- Shortwave diathermy:300 KHz-3000 KHz
- Microwave diathermy:450 MHz
- Ultrasonic diathermy :800 KHz-1 MHz

6.Define Let-go current? [Nov/Dec 2011] [May/June 2009] [CO4-L1-Nov/Dec 2008]

Let – go current is the minimum current to produce muscular contraction.

- For men—about 16mA
- For Women—about 10.5 mA

7. What is the use of ultrasonic diathermy? [CO4-L1-Nov/Dec 2011]

Used to cure few diseases like Neuritis,Arthritis,Skin ulcers.

8. What is micro shock? [April/May 2011] [CO4-L1-Nov/Dec 2008]

A physiological response to a current allied to the surface of the heart that results in unnecessary stimulation like muscle contractions or tissue injury is called as micro shock.

9. What are the electrical safety methods used in hospitals? [CO4-L1-Nov/Dec 2010]

The use of devices like ground fault interrupter,isolation transformer and line isolation monitor protect patients and health care workers from hazardous electric currents.

10. What is meant by diathermy? [CO4-L1-April/May 2010]

Diathermy is the treatment process by which cutting,coagulation,blending etc. of tissues are obtained.

11. What is the frequency of currents used in surgical diathermy units? Why?[CO4-L1-May/June 2009]

A frequency of 300-3000 KHz is used in surgical diathermy.At these frequencies,large current flow into the cells causing it to vaporize and thereby causing a rupture of the tissue close to the cutting electrode.

12. What are the essential requirements of the FM telemetry receiver? [CO4-L1-May/June 2014]

Essential requirements of the FM telemetry receiver: strain gage sensors, full bridge, digital technique include elimination of ripple, temperature drift characteristics and higher signal resolution.

13. List the two types of multiplexing involved in multichannel wireless telemetry.[CO4-L1-Nov/Dec 2013]

Frequency Division Multiplexing

Time Division Multiplexing

14. List the applications of Bio telemetry.[May/June 2013][CO4-L1-April/May 2011]

(i) Monitoring ECG even under ergonomic conditions

(ii) Monitoring the health of astronauts in space

(iii) Patient monitoring in an ambulance and other location away from hospital)

(iv) Research on unanaesthetized animals

15. Specify the frequencies used for biotelemetry. [CO4-L1-Nov/Dec 2012]

100 KHz to 1MHz (for short distance)

10MHz to 100 MHz (for long distance)

16. What is radio pill?[May/June 2012][Nov/Dec 2010][April/May 2010][CO4-L1-Nov/Dec 2009]

Radio pill is a silicon coated capsule containing a miniature radio tramitter that can be swallowed by a patient.During its passage through the digestive tract a radio pill transmits information about internal conditions

17. Name the instruments needed for a bio-telemetry system.[CO4-L1Nov/Dec 2010]

Transducer, Conditioner, FM transmitter, FM receiver and Recorder

18. Mention the advantages of bio telemetry system [CO4-L1].

(i) Major advantage of bio-telemetry is removing the cables from patient and providing a more comfortable medium to patient. Patient needs to carry only a small transmitter.

(ii) Isolation of patient from high voltage completely. Transmitters in the patient side work with batteries without any danger of electrical shock.

19.Mention the scheme of modulation techniques used for bio-telemetry. Also mention the reason for such scheme[CO4-L1].

(i) Double modulation:either AM/AM,AM/FM,FM/FM,FM/AM-to avoid loading effect

(ii) Pulse width modulation:More than one bio signal can be transmitted and recorded.

PART B

1. With a neat block diagram, show the operation of a combined single channel telemetry system for ECG signal and respiration rate. [Nov/Dec 2013]

With the help of a block diagram explain a single channel telemetry system suitable for transmission of electrocardiogram [May/June 2009]

Explain in detail the design requirements of an ECG telemetry receiver. Also, mention the role of IF amplifier in the receiver. Use suitable illustration. [CO4-L1] Nov/Dec 2013]

For distortion-free transmission of ECG, the following requirements must be met:

The subject should be able to carry on with his normal activities whilst carrying the instruments without the slightest discomfort. He should be able to forget their presence after some minutes of application, Motion artefacts and muscle potential interference should be kept minimum, The battery life should be long enough so tha t a complete experimental procedure may be carried out.

While monitoring paced patients for ECG through telemetry, it is necessary to reduce pacemaker pulses. The amplitude of pacemaker pulses can be as large as 80 mV compared to 1-2 mVf which is typical of the ECG. The ECG amplifiers in the transmitter are slew rate (rate of change of output) limited so that the relatively narrow pacemaker pulses are reduced in amplitude substantially.

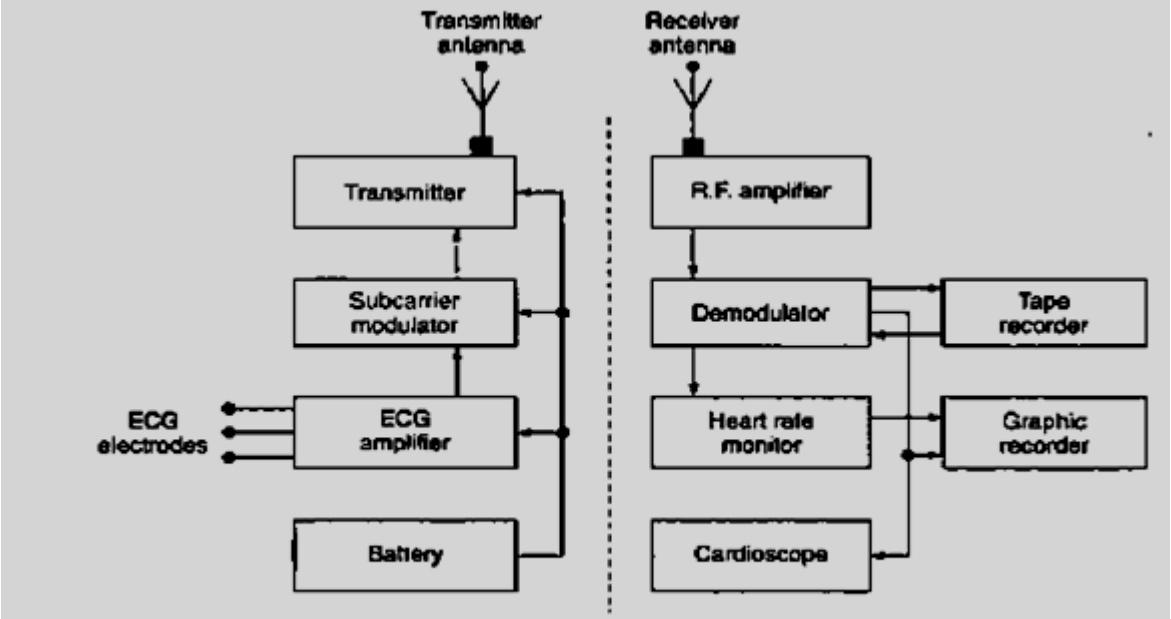


Fig. ***Block diagram of a single channel telemetry system***

The ECG input amplifier is ac coupled to the succeeding stages. The coupling capacitor not only eliminates dc voltage that results from the contact potentials at the patient-electrode interface, but also determines the low-frequency cut-off of the system which is usually 0.4 Hz. That sub-carrier oscillator is a current-controlled multi-vibrator winch provides ±320 Hz deviation from the "1 kHz centre frequency for a full range (± 5 mV) ECG signal. The sub-carrier filter removes the square-wave harmonic and results in a sinusoid for modulating the RF earner. In the event of one of the electrodes failing off, the frequency of the multi-vibrator shirts by about 400 Hz, This condition when sensed in the receiver turns on an 'Electrode inoperative' alarm.

The carrier is generated in a crystal-controlled oscillator operating at 115 MHz. The crystal is a fifth overtone device and is connected and operated in the series resonant mode. This is followed by two frequency doubler stages. The first stage is a class-C transistor doubler and the second is a series connected step recovery diode doubler. With the output power around 2 mW, the system has art operating range of 60 m within a hospital.

Receiver: The receiver uses an omnidirectional receiving antenna which is a quarter-wave monopole, mounted vertically Over the ground plane of the receiver top cover. This arrangement works well to pick up the randomly polarized signals transmitted by moving patients.

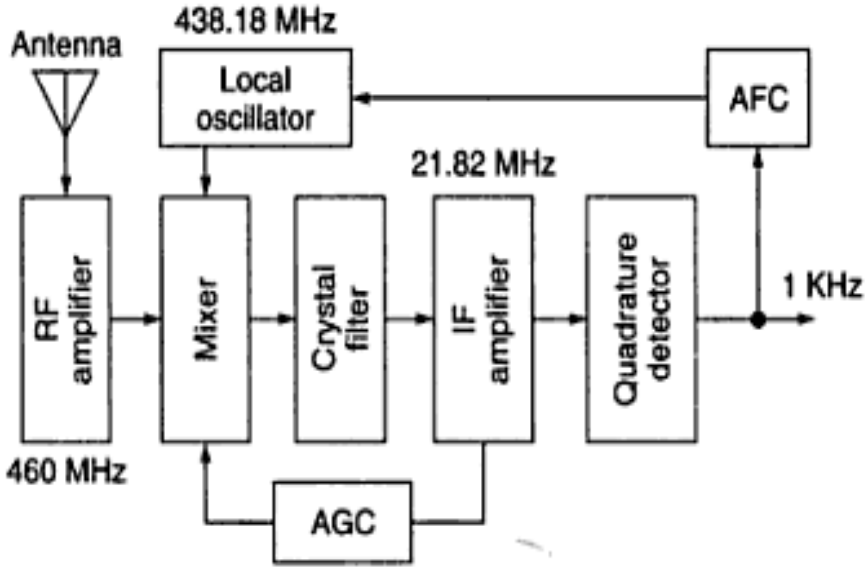


Fig. *Block diagram of high frequency section of ECG telemetry receiver*

The receiver comprises an RF amplifier, which provides a low noise figure, RF filtering and image-frequency rejection. In addition to this, the RF amplifier also suppresses local oscillator radiation to -60 dbm to minimize the possibility of cross-coupling where several receivers are used in one central station- The local oscillator employs a crystal (115 MHz) similar to the one in the transmitter and x4 multiplier and a tuned amplifier. The mixer uses the square law characteristics of a FET to avoid interference problems due to third-order intermodulation. The mixer is followed by an 8-pole crystal filter that determines the receiver selectivity.

This filter with a 10 kHz bandwidth provides 60 dB of rejection for signals 13 kHz from the IF centre frequency (21,82 MHz). The IF amplifier provides the requisite gain stages and operates an AGC amplifier which reduces the mixer gain under strong signal conditions to avoid overloading at the IF stages.The IF amplifier is followed by a

discriminator, a quadrature detector. The output of the discriminator is the 1 kHz sub-carrier.

This output is averaged and fed back to the local oscillator for automatic frequency control. The 1 kHz sub-carrier is demodulated to convert frequency-to-voltage to recover the original ECG waveform. The ECG is passed through a low-pass filter having a cut-off frequency of 50 Hz and then given to a monitoring instrument. The 1 kHz sub-carrier is examined to determine whether or not a satisfactory signal is being received.

This is done by establishing a window of acceptability for the sub-carrier amplitude. If the amplitude is within the window, then the received signal is considered valid. In the case of AM or FM interference, an 'inoperative' alarm lamp lights up.

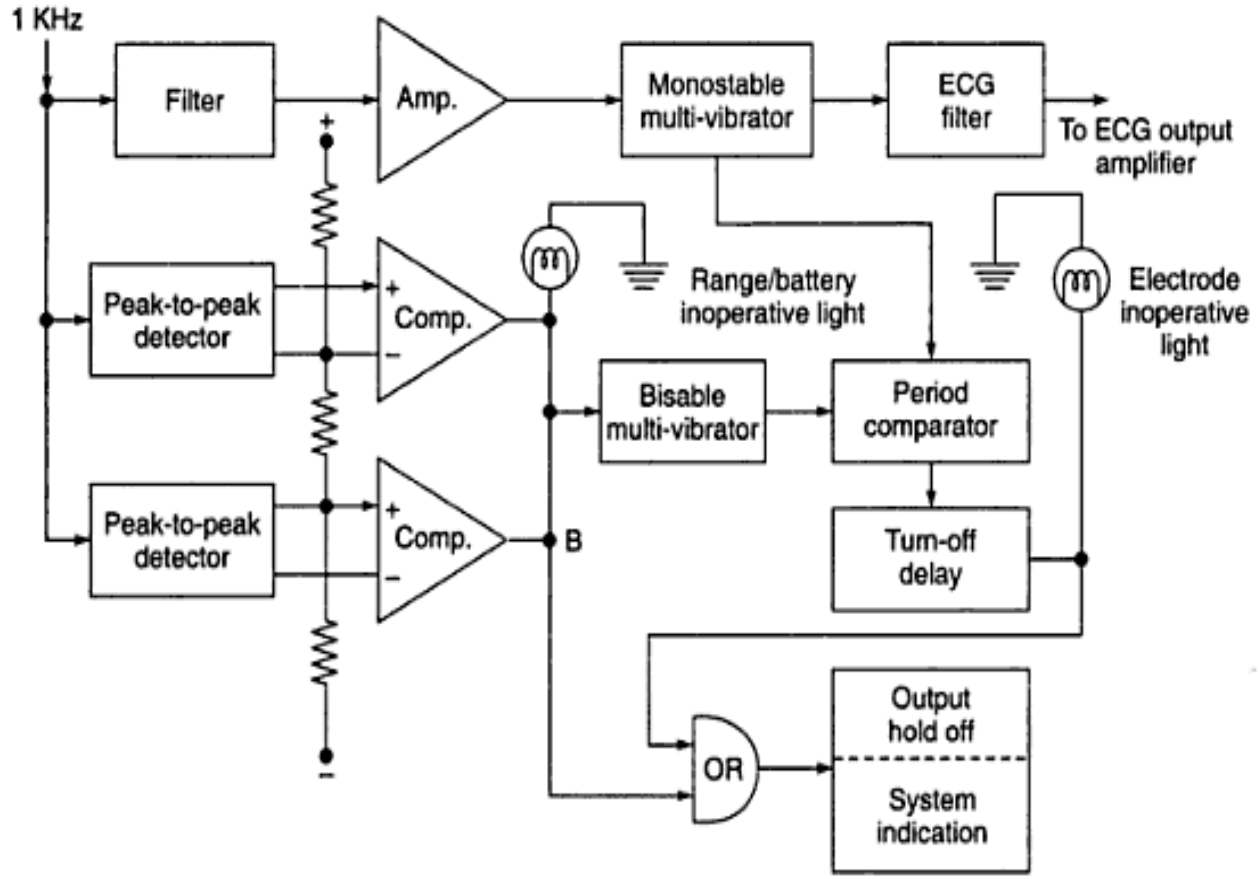


Fig. *Schematic diagram of ECG demodulation and 'inoperate' circuits in ECG telemetry receiver*

2. Explain the multi-channel bio-telemetry system with neat diagram. [May/June 2013] With a suitable block diagram, explain a multi-channel bio-telemetry system [Nov/Dec 2010]

Describe the operation of multichannel bio-telemetry system. (8Marks) [CO4-L2-April/May 2010

MULTIPLE CHANNEL TELEMETRY SYSTEMS

In biomedical instrumentation, it is desirable to have simultaneous recording of multiple signals for correlation study. In fact, each channel requires a telemetry channel. The cost involved in having separate telemetry channel for each variable is very high. Adopting multichannel telemetry system reduces the cost and number of equipment. Multichannel telemetry systems are;

(i) Frequency division multiplexing system

(ii) Time division multiplexing system

(iii) Pulse width modulation (PWM) multiple channel system.

Frequency Division Multiplex System

A typical three-channel frequency division multiplex system is shown in Figure . Each channel is frequency modulated on a sub-carrier frequency. These sub-carriers are added and they modulate the main RF carrier signal. At the receiver end, after demodulating the RF carrier signal the sub-carrier signals will be passed through proper band pass filters. The individual signals are obtained by individually demodulating the sub-carriers. In this method, the frequency of the sub-carrier has to be selected with care to avoid interference. At the final stage, a low pass filter may be incorporated as shown in Figure to avoid noise.

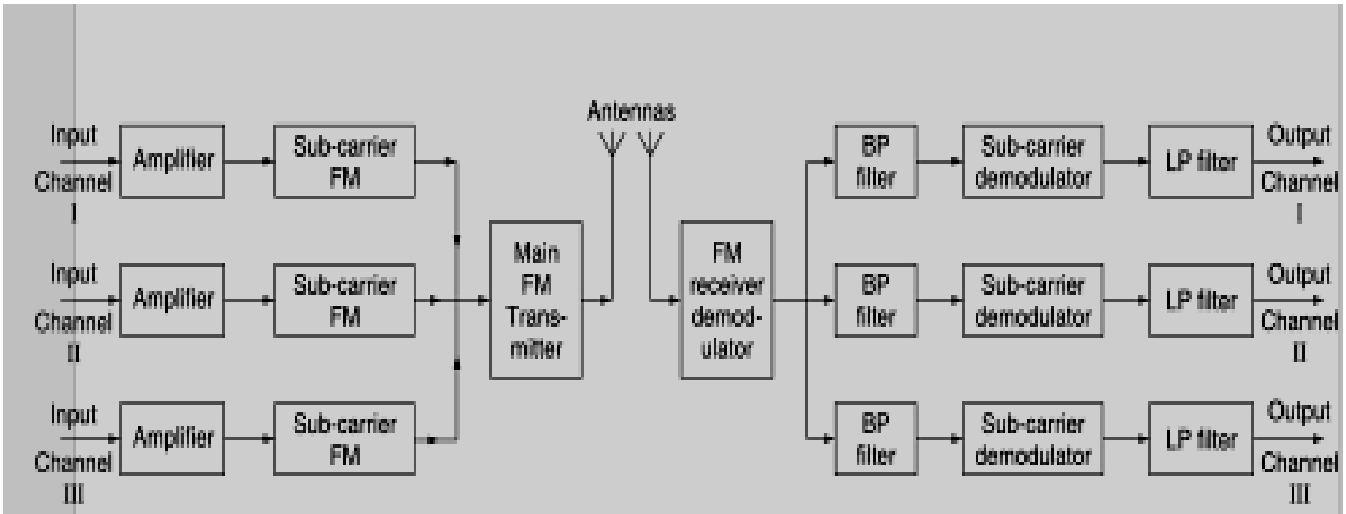


Figure Frequency division multiplex system.

Time-division multiplexing (TDM) is a method of transmitting and receiving independent signals over a common signal path by means of synchronized switches at each end of the transmission line so that each signal appears on the line only a fraction of time in an alternating pattern.

Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a modulation technique used in communications systems to encode the amplitude of a signal into the width of the pulse (duration) of another signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors.

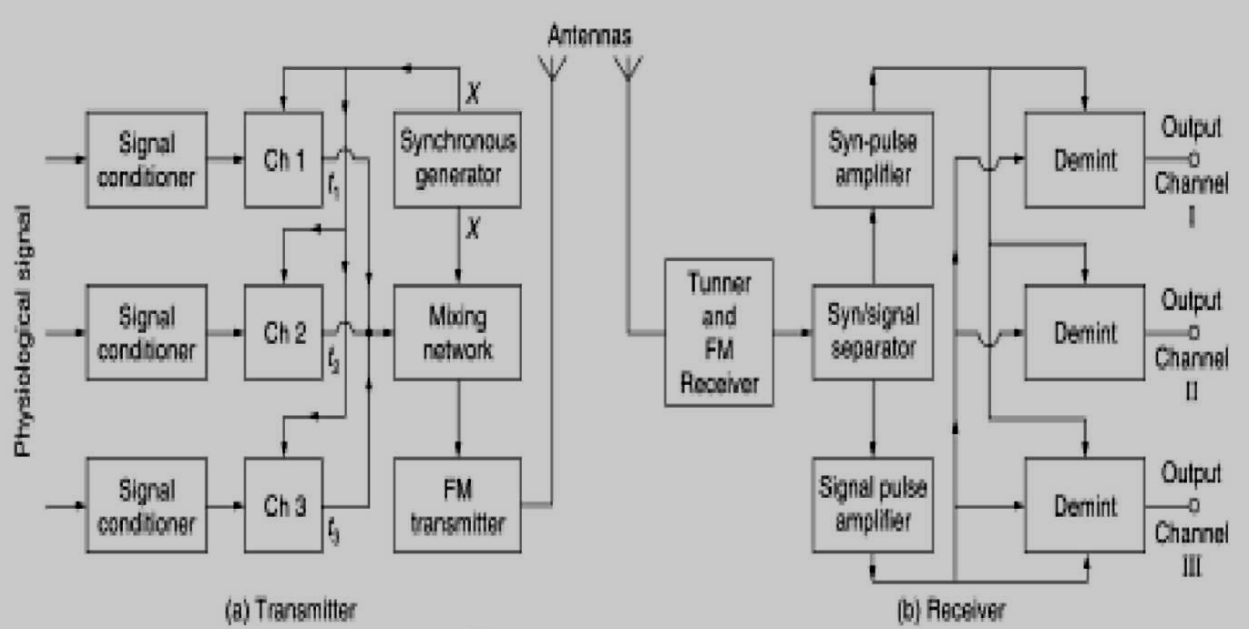


Figure PWM multiple channel telemetry.

3. (i)What is radio pill? Explain with the help of example.(8 Marks) [Nov/Dec 2012]

Discuss about radio pill (4 Marks) [CO4-L1-April/May 2011]

RADIO PILL

Radio pill when swallowed, will travel the GI tract (Gastrointestinal tract) and simultaneously perform multi parameter in physiological analysis.

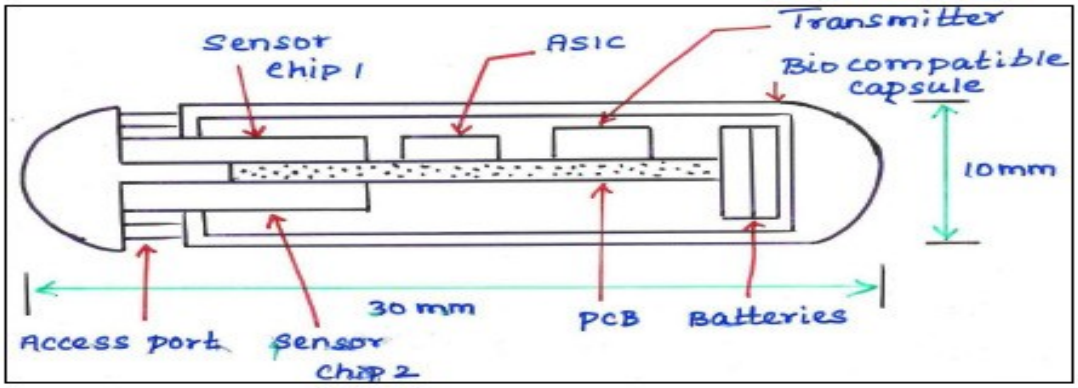
After completing its mission it will come out of the human body by normal bowel movement.

The pill is 10mm in diameter and 30mm long weighing around 5gm and records parameters like temperature, pH, conductivity and dissolved oxygen in real time.

The pill comprises an outer biocompatible capsule encasing micro sensors, a control chip, radio transmitter and two silver-oxide cells.

INSIDE THE CAPSULE

The schematic diagram of the microelectronic pill is as shown in figure below.



The outer casing of the pill is made by machining chemically resistant polyetheterketone, which is biocompatible. It is made up of two halves, which are joined together by screwing.

The pill houses a PCB chip carrier that acts as a common platform for attachment of,

- ❖ sensors,
- ❖ application- specific integrated circuit (ASIC),
- ❖ radio transmitter and
- ❖ batteries.

TASK OF THE SENSORS

The device is provided with four micro sensors, namely

- ❖ a silicon diode,
- ❖ an ion-selective field effect transistor (ISFET),
- ❖ a pair of direct- -contact gold electrodes and
- ❖ a 3-electrode electrochemical cell.

SILICON DIODE

The silicon diode is used to measure the body core temperature and also identify local changes associated with tissue inflammation and ulcers.

ISFET

- It is used to measure pH.
- It is used to determine the presence of pathological conditions associated with abnormal pH levels, particularly associated with pancreatic disease, hypertension, inflammatory bowel disease, the activity of fermenting bacteria, the level of acid excretion, reflux to the oesophagus and the effect of GI-specific drugs on target organs.

GOLD ELECTRODES

A pair of direct contact gold electrode is used to measure conductivity.

The conductivity sensor is used to monitor the contents of the GI tract by measuring water and salt absorption, bile secretion and the breakdown of organic components into charged colloids.

3-ELECTRODE ELECTROCHEMICAL CELL

The 3-electrode electrochemical cell is used to detect the level of dissolved oxygen in solution.

The oxygen sensor measures the oxygen gradient from the proximal to the distal GI tract. This enables a variety of syndromes to be investigated including the growth of aerobic bacteria or bacterial infection. The implementation of a generic oxygen sensor will also enable the development of a first generation enzyme linked amperometric biosensors, thus extending the range of future applications to include (eg.) glucose and lactate sensing, as well as immunosensing protocols.

The microelectronic sensors are attached to the PCB chip carrier by a 10 pin, 0.5mm pitch polyimide ribbon connector. The PCB carrier is made from 1.6mm thick fiberglass board. The transmitter and the ASIC are also integrated on the board. The integrated radio transmitter sends the signal to a local receiver prior to data acquition on a computer.The unit is powered by two standard 1.55V silver-oxide cells with a capacity of 175mAh.The batteries are connected in series and provide an operating time of 40 hours at the rated power consumption of 12.1mW.

The sensor chips are provided at the front end of the pill and are exposed to the ambient environment through access ports. They are scaled by two sets of stainless-steel clamps incorporating an o.8mm thick sheet of fluoroelastomer seal. The 3mm diameter access channel in the center of each steel clamp exposes the sensing region of the chips to the ambient environment.

SENSORS

The schematic diagram of sensor chips is as shown below

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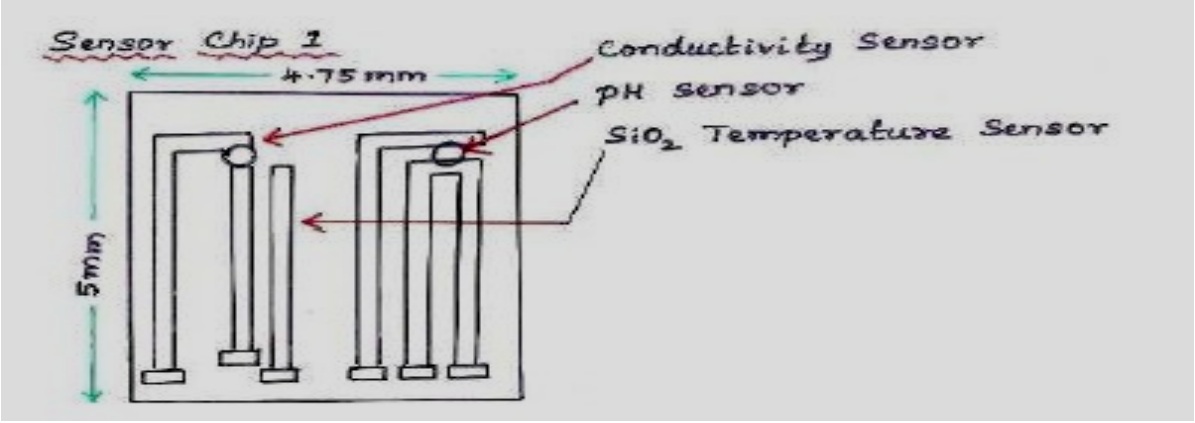
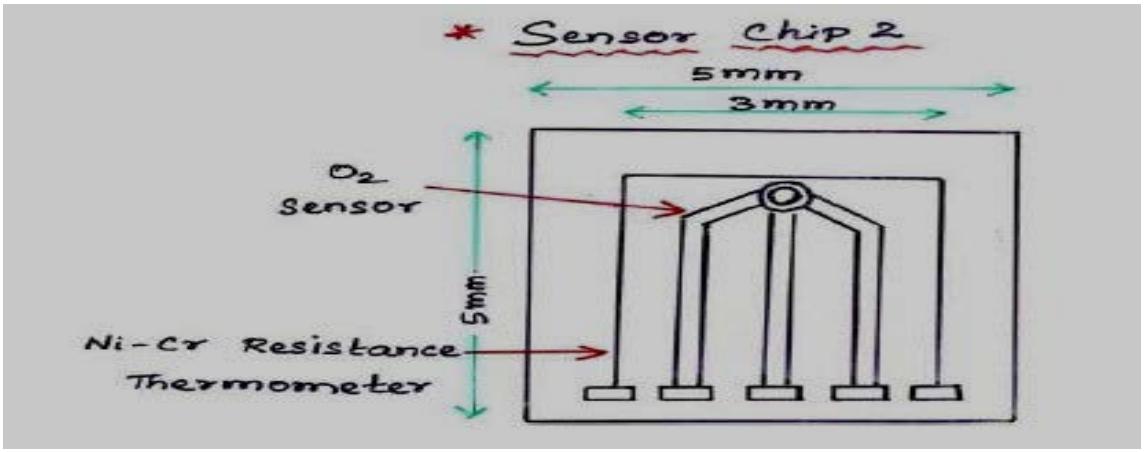


The sensors are fabricated on two silicon chips located at the front end of the capsule. Chip1, measuring 4.75 x 5mm2, comprises the silicon diode temperature sensor, the pH ISFET sensor and the two-electrode 5x 10-4mm2 conductivity sensor.

Predefined n-channels in the p-type bulk silicon form the basis for the diode and the ISFET. The 15x600mm floating gate of the ISFET is precovered with a 50nm thick

proton- sensitive layer of Si3N4 for pH detection. The pH sensor consists of the integrated 3x 10- 2mm2 Ag/Agcl reference electrode, a 500mm diameter and 10-nL electrolyte chamber and 15x600mm floating gate of the ISFET sensor.

Chip2, measuring 5 x 5mm^2, comprises the electrochemical oxygen sensor and a NiCr resistance thermometer. The oxygen sensor is embedded in the electrolyte chamber. The 3- electrode electrochemical cell of the oxygen sensor comprises the 1x10-1 mm2 counter electrode made of gold, a microelectrode array of 57x10mm diameter working gold electrodes and an integrated 1.5x 10-2mm2 Ag/Agcl reference electrode.



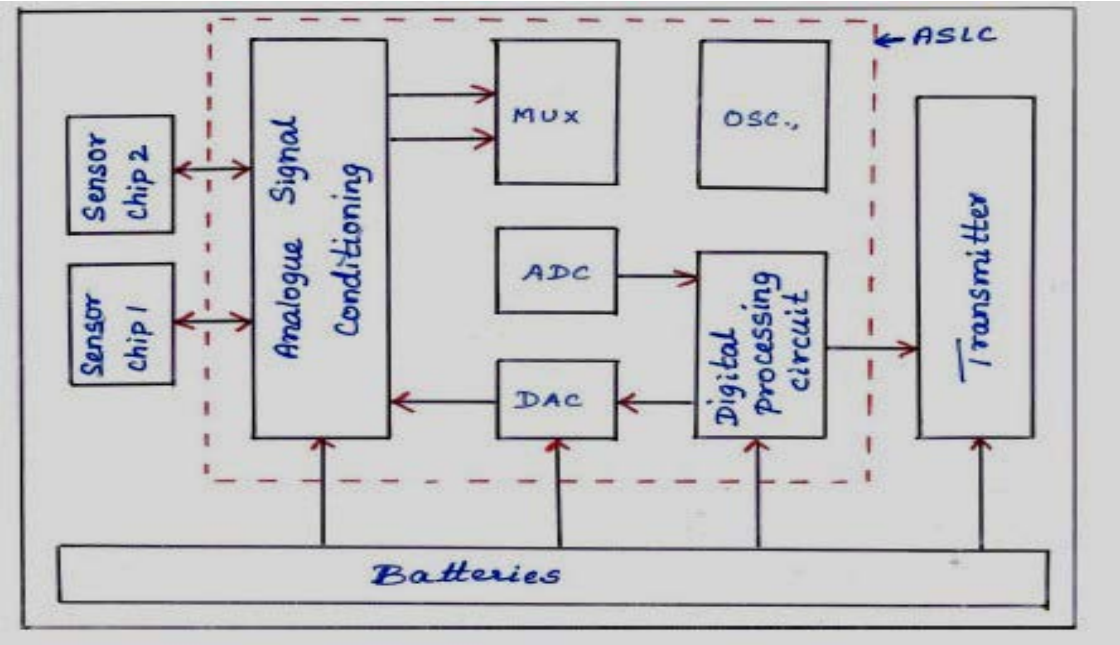
The microelectrode array has an inter-electrode spacing of 25mm and a combined area of 4.5x 10-3mm2. It promotes electrode polarization and reduces response time by enhancing transport to the electrode surface.

The NiCr resistance thermometer is made from a 100nm thick layer of NiCr and is 5mm wide and 11mm long.

The 500nm thick layer of thermally evaporated silver is used to fabricate the reference electrode. It is then oxidized to Ag/Agcl by chronopotentiometry.

CONTROL CHIP

The ASIC is the control unit that connects together other components of the microsystem as ,



It contains an analogue signal conditioning module operating the sensors, 10-bit ADC and DAC converters and a digital data processing module. An oscillator provides the clock signal.

The temperature circuitry biases the diode at constant current so a change in temperature reflects a corresponding change in diode voltage.

The pH ISFET sensor is biased as a simple source and drain follower at constant current with the drain-source voltage changing with the threshold voltage and pH.

The conductivity circuit operates at direct current, measuring the resistance across the electrode pair as an inverse function of solution conductivity. An incorporated potentiosial circuit operates the amperometric oxygen sensor with a 10-bit DAC controlling the working electrode potential with respect to the reference.

The analogue signals have a full-scale dynamic range of 2.8V with the resolution determined by the ADC. These are sequenced through a multiplexer prior of being digitized by the ADC. The bandwidth for each channel is limited by the sampling interval of 0.2msec.

The digital data processing module processes the digitized signals through the use of a serial bit stream data compression algorithm, which decides when transmission is required by comparing the most recent sample with the previous sampled data. The digital module is clocked at 32KHz and employs a sleep mode to conserve power from the analogue module.

RADIO TRANSMITTER

The size of the transmitter is 8x5x3mm. The transmission range is one meter and the modulation scheme frequency shift keying has a data rate of 1 kbps. The transmitter is designed to operate at a transmission frequency of 40.01 MHz at 20^{o}C generating a signal of 10KHz bandwidth.

POWER CONSUMPTION

Two SR44 Ag_2O batteries are used, which provide an operating time of more than 40 hours of the micro system. The power consumption of the system is around 12.1mW and current consumption is around 3.9mA at 3.1V supply.

The ASIC and sensor consume 5.3mW corresponding to 1.7mA of current and the free running radio transmitter consumes 6.8mW at 2.2mA of current.

RANGE OF MEASUREMENT

The microsystem can measure,

- Temperature from 0 to $70^{\square}$C,
- pH from 1 to 13,
- Dissolved oxygen up to 8.2mg/litre,
- Conductivity from 0.05 to 10 ms.cm-1(s=siemens).

ii) Write about the bio-telemetry. (6 Marks) [May/June 2012] Explain the operation of bio-telemetry system. [Nov/Dec 2011]

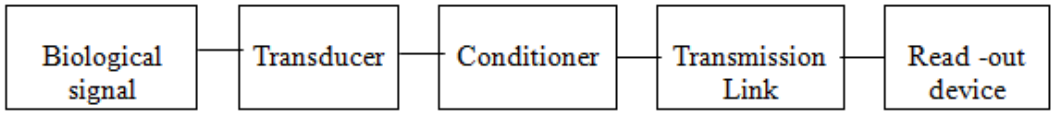
Explain the working principle of bio-telemetry system with a neat block diagram (8Marks) [CO4-L1-Nov/Dec 2009]

Bio telemetry is the electrical technique fir conveying biological information from a living organism and its environment to a location where its information can be observed or recorded. Thus it refers to the communication between a living system and an observer.

Today bio telemetry is extended for monitoring patients in a hospital from a remote location, for monitoring astronauts in space, for monitoring patients who are on the job or at home and carrying implanted pace makers or other simulators. Further it is also used to monitor the athletes running a race or doing exercise in an effort to improve their performance.

ELEMENTS OF BIO – TELEMETRY SYSTEM:

The essential bocks of a bio – telemetry system are shown in the figure. The transducer converts the biological variable in to electrical signal. The signal conditioner amplifies and modifies this signal for effective transmission. The transmission link connects the signal input blocks to the read out device by wire (or) wireless mean.



ECG
EEG
EMG ⇒ Electrodes — Amplifier & filter — Radio Frequency F.M. Transmitter — Video recorder / Tape recorder / X-Y Recorder

Temperature - Thermistor
Blood pressure - Strain gauge
Stomach pH - Glass Electrode

Fig: Block diagram of bio telemetry system

DESIGN OF A BIO – TELEMETRY SYSTEM:

1. The telemetering system should be selected to transmit the bio electric signals with maximum fidelity and simplicity.
2. There would not be any constraint for living system due to these telemetry systems and there would not be any reaction (or) any interference with the living system.
3. The size and weight of the telemetry system should be small. In the case of long term units or implant units, the weight and size limit is the order of 1%of that living subject. For shorter duration it is about 5%. Using micro electronic circuits, the complete unit can be made to weigh less than a gram.
4. It should have more stability and reliability.
5. The power consumption should be very small to extend the source life time in the case of implanted units.
6. For wire transmission, shielding of cable is a must to reduce noise level. At the transmitter side, the amplifiers should be differential amplifier to reject common mode interface.

The miniaturized radio telemetering system should be used to reduce noises.

The biotelemetry measurements can be applied to two categories:

1. Bioelectrical variables such as ECG, EMG and EEG. Here the signal is obtained directly in electrical form.
2. Physiological variables that require transducers such as blood pressure, gastrointestinal pressure, blood flow and temperatures. It requires excitation because the physiological parameters are measured as variations of resistance, inductance or capacitance.

Bio signal that can be telemetered:

a. ECG telemetry:

The most widespread use of biotelemetry for bioelectric potentials is in the transmission of ECG. Instrumentation at the transmitting end is simple because only electrodes and amplification are needed.

Examples ECG telemetry:

1. Transmission of ECGs from an ambulance or site of emergency to a hospital. A cardiologist in the hospital, immediately interprets the ECG, instructs emergency resuscitation procedures to the trained rescue team and arranges for any special treatment that is necessary on arrival of the patient at the hospital. The telemetry is also supplemented by two-way voice communication.
2. For exercise ECGs in the hospitals so that the patient can run up and down steps, unencumbered by wires.
3. The individuals with heart problems can wear ECG telemetry units always and relay ECG data periodically to the hospital for checking.
4. Monitoring of athletes running a race for improving their performance
5. Human performance laboratories in college campuses.

The actual equipment worn by the subject is comfortable and usually does not impede movement, since the electrodes are taped into place and the patient wears a belt around the waist with a pocket for the transmitter. The transmitter is about the size of package of king- size cigarettes. The wire antenna is incorporated in the belt or hung loosely. The clothing has opening to allow the lead wires from the electrodes to come through the transmitter. The power for the transmitter is from a battery usually a mercury cell with useful life of about 30hours.

For cardiovascular research performed with experimental animals, the electrodes are needle type and animals interfere with equipment. Hence miniature transmitters are surgically implanted subcutaneously.

b. EEG telemetry:

The applications are

1. EEG electrodes are implanted in the brain of the chimpanzees in the Space biology program in the Brain research institute at the University of California, Los Angeles. A small transmitter installed on the animal's head, transmits the EEG. Some times instead of this, special helmets with surface electrodes are used.

2. Special helmets with surface electrodes are also used for collection of EEGs of football players during the game.
3. For study of mentally disturbed children. The child wears specially designed “football helmet” or “spaceman’s helmet” with built-in electrodes so that the EEG can be monitored without traumatic difficulties during play.

c. EMG telemetry:

The third type of bioelectrical signal that can be telemetered is the electromyogram (EMG). It is used for studies of muscle damage and partial paralysis problems and human performance studies.

Physiological variables that can be measured using telemetry:

The transducer circuit is designed as a separate “plug-in” module to fit into the transmitter so that one transmitter is used for different measurements.

a. Skin or systemic body temperature Temperature by rectal or oral thermistor
b. Respiration by impedance pneumograph
c. Indirect blood pressure by contact microphone and cuff.
d. Measurement of blood pressure and heart rate research in anaesthetized animals. The transducers are surgically implanted with leads brought out through the animal’s skin. A male plug attached to the leads, is connected to the female socket contained in the transmitter unit.
e. Blood flow measurement using Doppler-type and electromagnetic type transducers.
f. Monitoring of vaginal temperature for long-term studies of natural birth control in obstetrics and gynecology
g. Use of radiopills for monitoring stomach pressure or pH.

FREQUENCY SELECTION & MODULATION TECHNIQUES

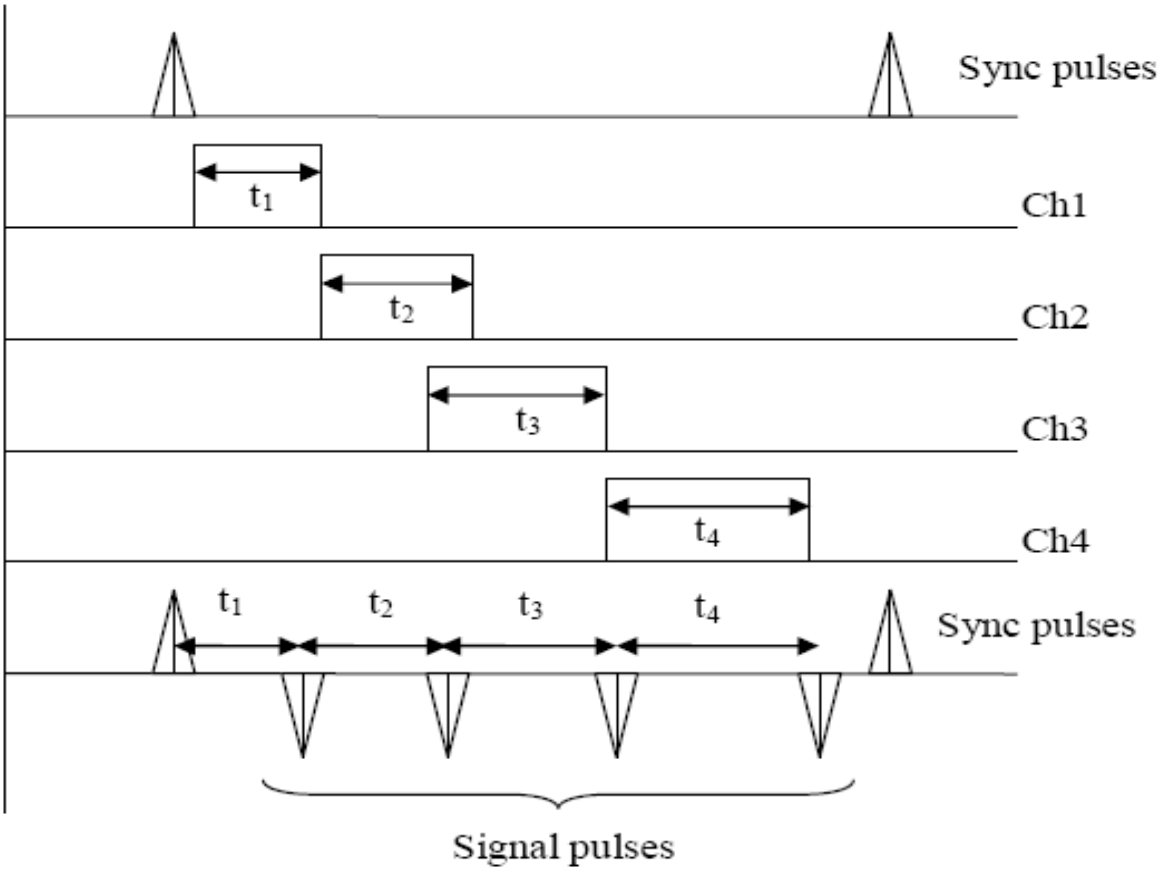
The radio frequency biotelemetry uses either the VHF or UHF band set aside by the Federal Communications Commission (FCC) exclusively for the medical telemetry or the unused television channels. It is often desired that the frequency and power considerations for the proposed telemetry system does not affect the existing, nearby

telecommunication transmissions.

Amplitude Modulation (AM) and Frequency Modulation (FM) are the most commonly used analog modulation techniques in the biotelemetry. Pulse Amplitude Modulation (PAM), Pulse Width Modulation (PWM) and Pulse Code Modulation (PCM) are the most commonly used digital modulation techniques in the biotelemetry.

While multiplexing many channels of data, the most commonly used multiplexing method is the Frequency Multiplexing (FM). Each channel of data is either frequency- or amplitude-modulated using separate sub-carrier and these sub-carriers are either frequency or amplitude-modulated using a RF carrier. For example, if sub-carriers frequency-modulate

individual data channels and RF carrier amplitude-modulates these sub-carriers, then such system is termed as FM/AM. Hence FM/FM denotes that sub-carriers frequency-modulate individual data channels and RF carrier frequency-modulates these sub-carriers.



APPLICATIONS

- Monitoring physiological conditions of astronauts in space, workers in deep
- mines.
- Monitoring physiological conditions of subjects during exercise or in a normal
- working environment.
- Monitoring physiological conditions of patients in an ambulance or in a location
- away from the hospital.
- Remote medical data collection from home or office.
- Monitoring animals for research in their natural habitat.

4. Write a brief note on the functioning of microwave diathermy unit (8 Marks) [May/June 2014]

Describe the principles involved in the Microwave diathermy (8 Marks) [Nov/Dec 2010] [CO4-L1-April/May 2010]

Microwave:

They are electromagnetic radiation with frequency range of 300 – 30000MHz and wavelengths varying from 10mm to 1m. They lie between short waves and IR rays in the electromagnetic spectrum.

The most used microwave frequency for therapeutic heating is 2450MHz corresponding to a wavelength of 12.25cm.

Principle:

Microwave diathermy involves irradiating the tissues of the patient's body with microwave. The duration of irradiation ranges from 10 – 25 min. These waves pass through the intervening air space and are absorbed by the surface of the body. The heating effect is produced by the absorption. Microwave is produced using magnetron.

Production of microwaves:

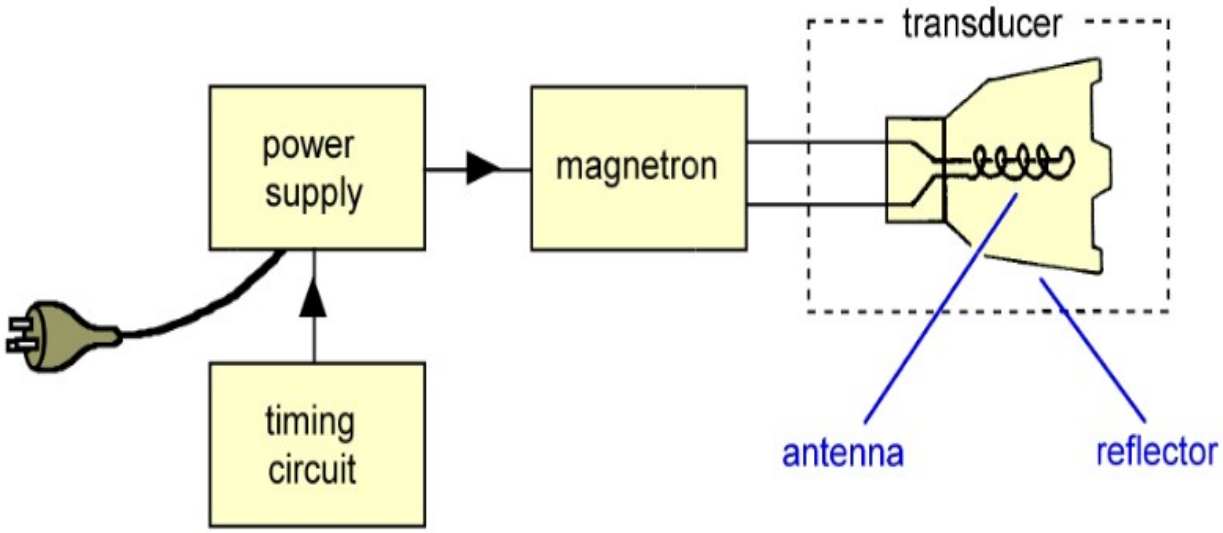
A magnetron has a cylindrical cathode surrounded by an anode structure containing cavities opening into the cathode-anode space through slots. The output energy is picked up from the resonator system through a coupling loop forced into one of the cavities and is carried out of the magnetron, to a director through a cable.

The director has an antenna which transforms the current into electromagnetic radiation and a reflector which focuses the electromagnetic energy to the tissues of the patient. The tissue absorbs, reflects or refracts the electromagnetic energy according to the electrical properties of the tissues.

The tissues of the lower water content (i.e. subcutaneous) absorb less electromagnetic energy whereas the tissues of high water content (i.e. muscle) absorb more electromagnetic energy. The output power of magnetron depends on anode voltage, magnetic field and magnitude and phase of the load impedance to which the magnetron

output power is delivered.

A part of the energy fed to the magnetron is converted into heat in the anode, due to collision of the electrons with the anode. Hence output energy is less than the input energy and the efficiency of the magnetron is usually 40 to 60%. The heat produced is removed using water or air as means of cooling. The figure shows the schematic circuit diagram of microwave diathermy unit. The mains supply is applied to an interference suppression filter which helps to bypass the high frequency pick-up generated by the magnetron.



Delay circuit: The magnetron has to warm up for 3-4 min before power is derived from it. A delay circuit connects anode supply to the magnetron and a lamp lights up indicating that the apparatus is read for use after 4 minutes.

Magnetron circuit: The magnetron filament heating voltage is obtained directly from a separate secondary winding of a transformer. The filament cathode circuit has interference suppression filters. The anode supply to the magnetron can be DC or AC.
DC voltage is obtained by a full wave rectifier followed by a voltage doubler circuit. A high wattage variable resistance, connected in series controls the current applied to the anode.

When using AC, the voltage is applied to the anode through a series is connected thyratron so that AC voltages of both tubes are equal in phase. By shifting the phase of the control grid voltage w.r.t the phase of the anode voltage, the amount of current through the magnetron and hence the output power can be varied. The phase shift is achieved using a capacitor resistor network.

Safety circuit: A fuse (500mA) is inserted in the anode supply circuit of the magnetron, to protect the magnetron from damage due to excessive flow of current. The considerable interference produced by the apparatus necessitates the use of large self-inductance coils in the primary supply. Since the cores become saturated due to the small dimensions, the coils are split up and fitted such that there is no magnetization.

Advantage:

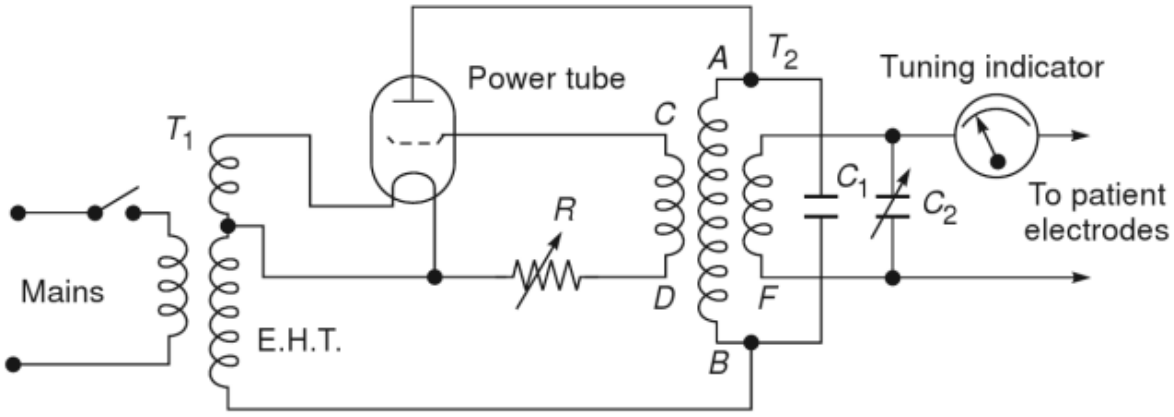
1. The technique of application of microwave diathermy is very simple and does not require tuning for individual treatments. Since microwaves are transmitted from an emitter and directed towards the portion of the body to be treated directly.
2. Better therapeutic results are obtained by using microwave diathermy than short wave diathermy.
3. There is no pad shaped electrode.

Limitations:

1. Excessive dosage can cause skin burns and in all cases the sensation experienced by patient is primary guide for application.
2. Skin should be dry as these waves are rapidly absorbed by water.

5. Write brief notes on short wave diathermy (8 Marks) [CO4-L1-May/June 2012]

The figure shows the circuit diagram of a short wave diathermy unit.



Simplified circuit diagram of a short-wave diathermy unit

A step-up transformer (T1) with primary connected to mains supply, provides EHT for the anode of a triode valve and heating current for cathode of the triode valve. The coil AB in parallel with the condenser C1 forms a tank circuit. The coil CD generates positive feedback. Another coil (EF) and a variable condenser (C2) form the patient's resonator circuit due to its coupling with the oscillator coil AB. The oscillator circuit and the patient's resonator circuit are tuned with each other by adjusting variable condenser (C2) to achieve maximum reading on the ammeter.

The triode current conducts during positive half cycle and high frequency is generated only during this period. High frequency 27.12MHz and wavelength = 11m is produced continuously and hence more power is available if supply voltage is rectified before applying to the anode. The max.power delivered by these machines is 500W. The anode supply of the circuit is around 4000W. A thermal delay in the anode supply prevents the passage of the current through this circuit until the filament of the valve attains adequate temperature. The patient circuit is then switched ON followed by a steady increase of current through the patient.

The current supplied to the patient can be regulated by

1. Controlling anode voltage
2. Controlling filament heating current
3. Adjusting grid bias by change of grid leak resistance (R)
4. Adjusting the position of resonator coil w.r.t oscillator coil.

Automatic tuning:

Any short wave therapy unit gives out desired energy to the patient only if the unit is correctly tuned to the electrical values of the part of the body. Therefore, the tuning must be carefully carried out at the beginning of the treatment and continuously monitored during treatment.

The tuning get affected due to the unavoidable involuntary movements of the patient. The RF current in the patient circuit changes a capacitor to a voltage whose polarity and magnitude indicates detuning. This voltage moves a servomotor and adjusts the tuning capacitor so that resonance is restored.

Application technique:

1. Capacitor plate method
2. Inductive method

Capacitor plate method or condenser method:

The output of the short-wave diathermy machine is connected to the metal electrodes (called pads) positioned so that portion of the body to be treated is sandwiched between them Ref fig. 5.5 usually layers of towels are interspersed between the electrodes and the surface of the body, so that these pads or electrodes do not directly contact the skin.

The metal pads act as two plates while the body tissues between the pads, acts as dielectric. When the RF output is applied to the pads, the dielectric losses due to the vibration of ions and rotation of dipoles in the tissue fluids and molecular distortion in tissues, manifest as heat in the intervening tissues.

Inductive method:

The output of diathermy is connected to a flexible cable instead of pads (Ref. fig. 5.6). This cable is coiled around the arm, knee or any other portion of the patient's body where plate electrodes are inconvenient to use.

When RF current is passed through the cable, an electrostatic field is setup between its ends and a magnetic field around its center. The electrostatic field results in deep heating and eddy currents set up by magnetic field, provides heating of superficial tissues. This technique is known as inductothermy.

Advantages: When currents having very high frequencies, the motor or sensory nerves are not stimulated and there is no contraction of the muscles. Thus there is no discomfort to the patient.

Disadvantages:

Though most short-wave diathermy machines have output power control, there is no indication of the amount converted and absorbed heat within the body tissues. Therefore intensity of treatment depends on the subjective sensation of warmth felt by the patient.

6. (i)Write short notes on Ground fault interrupter (8 Marks)[April/May 2011]

Discuss working principle of a ground fault interrupter (8 Marks)[Nov/Dec 2009]

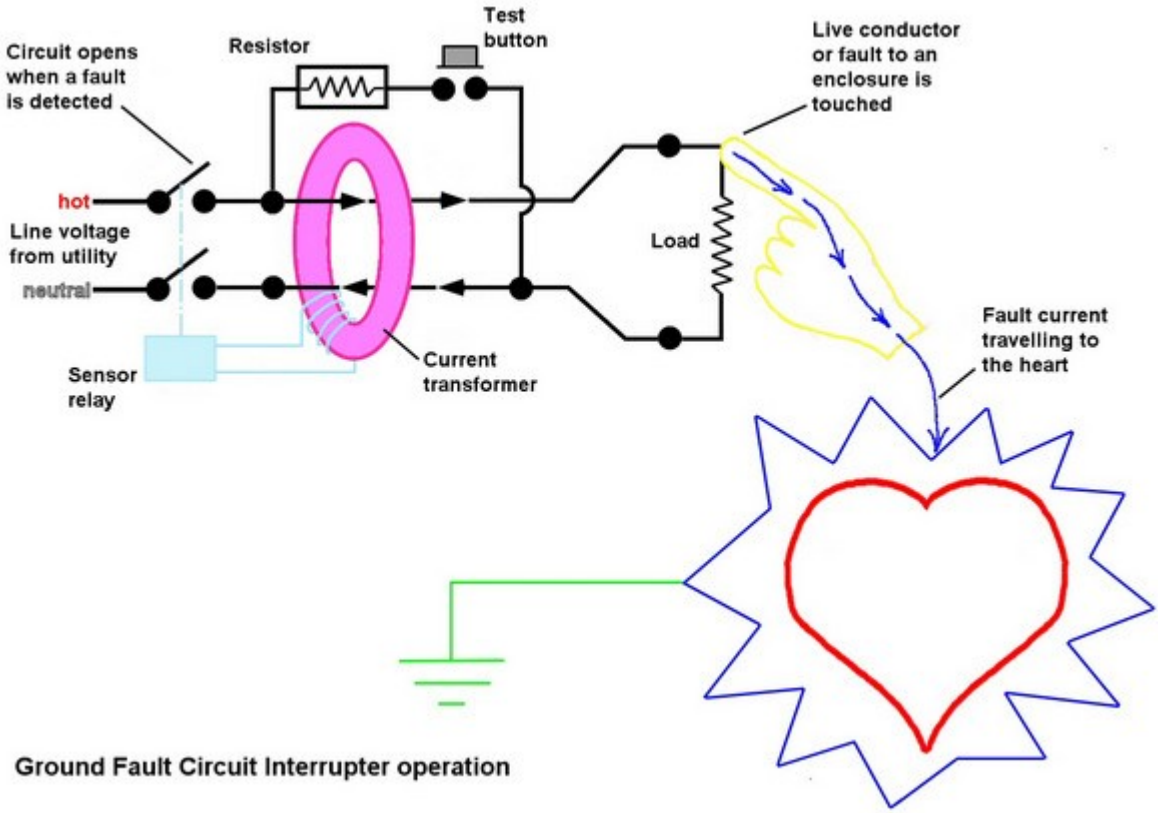
Explain the working of Ground Fault interrupter(4 Marks)[CO4-L1-Nov/Dec 2008]

Basic Operating Principle

A high amperage GFCI consists of a number of components. The primary component is the Differential Current Transformer (CT) which is a ring of ferrous metal (usually iron) that the current carrying wires pass through. An imbalance in current between the conductors running through the CT because of leakage to ground generates a net

Magnetic Flux in it. The amount of Flux is an indication of the amount of current traveling back to the source on the ground. This Magnetic Flux induces a current in a Pick Up Coil.

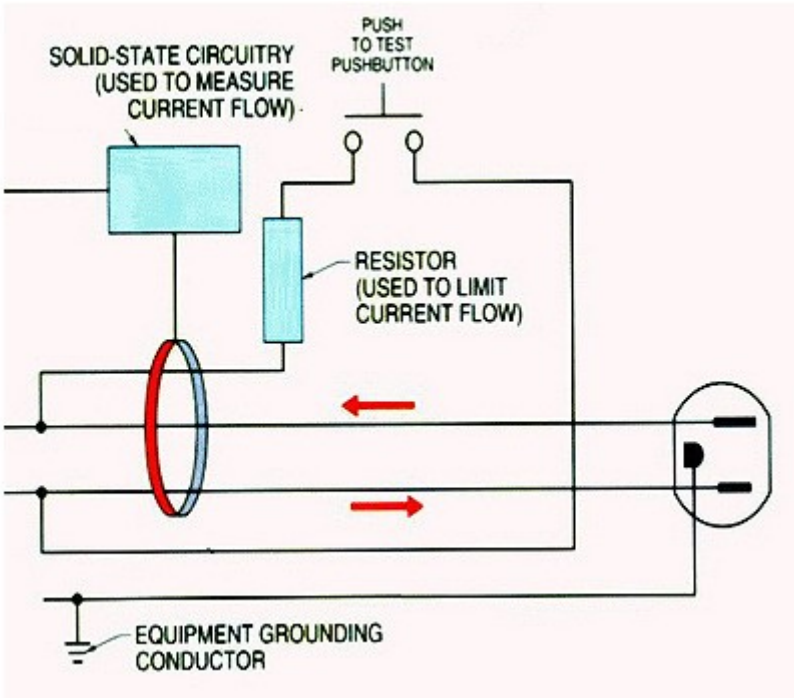
The strength of the current reflects the degree to which the conductors are out of balance. Control circuitry compares this current to a prescribed pre-set and activates a shunting device which opens Switching Contactors, interrupting the supply of power, when the level of imbalance between current carrying wires exceeds the prescribed level (6mA in the case of Class A devices.)



Ground Fault Circuit Interrupter operation

In addition to the Hot-to-Ground sensing components above, to meet UL Standards a GFCI must also de-energize a circuit if there exists a load side Neutral-to-Ground leak – commonly called a "Grounded Neutral Fault". For this purpose, GFCI devices employ a Grounded Neutral Detection Circuit. A Neutral-to-Ground Fault is typically the result of mis-wiring (common in production trailers) or a short circuit in a load that creates a low resistance path between the Neutral and Ground wires downstream of the GFCI.

Since the Neutral conductor is also grounded at the source, such double grounding of the Neutral conductor could create a situation where, if there were a fault from Hot to Ground, a portion of the Ground Fault Current from the Hot conductor returns to the source through the Neutral Conductor. As a consequence, the current differential showing up in the CT would not be truly indicative of the magnitude of the ground leakage current. This has the effect of desensitizing the GFCI. But since, UL requires that GFCIs trip with a 6mA Ground Fault even when the Neutral and Ground are connected, rather than leave the circuit energized when the GFCI in incapacitated, as a pre-emptive measure manufacturers design their devices so that they trip as soon as power is applied to the circuit. The Grounded Neutral Detection Circuit serves this purpose.



In addition to the Neutral-to-Ground sensing components above, to meet UL Standards a GFCI must also include a Test Circuit so that the user can ascertain if the GFCI is operating properly. The Test Circuit consists of a switch (the test button) that closes the test circuit. A resistor in the circuit causes current to flow through the circuit conductor as well as limits the amount of current flowing and so is called the Limiting Resistor.

The circuit conductor passes through the CT only once - on the return after passing through the Limiting Resistor - creating a Flux in the CT. The value (Ohms) of the Limiting Resistor is such that it generates sufficient Flux to activate the Shunt to open the Switching Contacts to interrupt power - thereby demonstrating that the GFCI is operational.

(ii)Describe the principles involved in the ultrasonic diathermy (8 Marks)[CO4-L1-Nov/Dec 2010]

ULTRASONIC THERAPY UNIT

The figure shows the block diagram of the ultrasonic therapy unit.

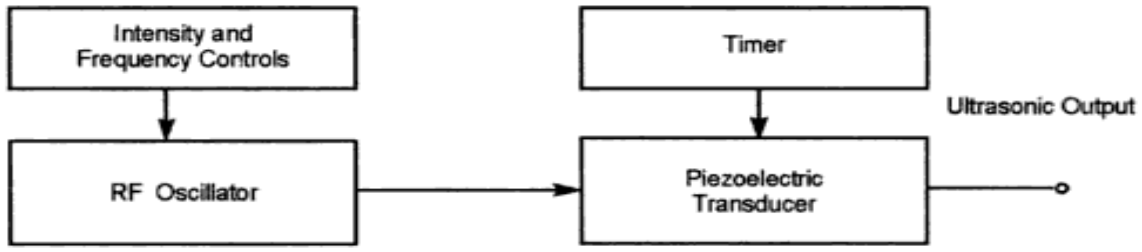


Figure *Block Diagram of an Ultrasonic Diathermy Unit*

Timer:

A mechanical spring loaded type time or a electronic timer is used to switch on the circuit so that ultrasound power is delivered to the patient for a given time. This timer allows time setting from 0-30minutees.

Half wave rectifier and full wave rectifier: The machine is operated in continuous or pulsed mode.

In pulsed mode, the oscillator supply is provided by passing mains supply through a half

wave rectifier and oscillator get supply only for a half cycle. Hence output 1MHz is produced only for one half of the cycle and is pulsed.

In continuous mode, the oscillator supply is provided by passing mains supply through a full wave rectifier. Hence the supply voltage is at 100Hz (2 times the 50Hz) which causes the output 1MHz to amplitude modulated by this 100Hz.

Timed oscillator:

The timed oscillator produces the electrical oscillations of high frequency 0.75-3MHz. The output of the oscillator can be controlled by

a. Using a transformer with a primary winding having multi-tapped windings and switching them as per the requirement.
b. Controlling the firing angle of a triac place in the primary circuit of the transformer and thereby varying the output of the transformer. The power output in the case of traic controlled machine can be continuously varied from 0-3W/cm2.

Power amplifier:

The oscillator output is given to a power amplifier. Power amplification is achieved by replacing the transistor in a typical LC tuned colpitt oscillator by four power transistors placed in bridge configuration.

Piezoelectric crystal:

The power amplifier drives a piezoelectric crystal to generate ultrasound wave. The voltage is applied to the crystal through a metal electrode pressed against its back surface by a coiled spring. A front diaphragm is grounded and provides return path for the excitation voltage.

A metal face plate in front of the crystal vibrates the by the oscillations of the crystal and emits ultrasonic waves.

Transducer:

A cable connects the oscillator with a transducer. The length of the cable is of critical

dimension and should not be altered. The acoustic vibration of the crystal causes mechanical vibration of a transducer head located directly in front of the crystal.

The crystal may be barium titanate or lead zirconatetitanate crystal having 5-6cm2 effective radiating area.

These mechanical vibrations then pass through a metal cap and into the body tissue through a coupling medium.. The therapeutic ultrasonic intensity varies from 0.5 – 3.0 W/cm2. Applicators range from 70 to 130 mm in diameter. The larger the diameter of the applicator, the smaller would be the angle of divergence of the beam and the less the degree of penetration.

Effects of ultrasonics:

1. Heating effect due to the ultrasonic energy absorption property of the tissues.
2. Direct mechanical effect (high speed vibration of micromassage used in the treatment of soft tissue lesions).

The thermal effects are dependent on the amount of energy absorbed, length of time of the ultrasound application and the frequency of the ultrasound generator.

Dosage control:

The dosage can be controlled by varying the

1. Frequency of ultrasound
2. Intensity of ultrasound
3. Duration of exposure

Frequency of ultrasound:

The absorption of ultrasonics by the tissues is frequency dependent. Higher the frequency, the quicker the energy loss and less is the penetration. A frequency below 1MHz, the ultrasonic energy beams diffuse and there is no efficient treatment. Therefore the frequency in the range of 800 KHz to 1MHz is most widely adopted.

Intensity of ultrasound:

The therapeutic ultrasonic intensity is varied from 0.5 – 3W/cm2 of the transducer area that is in contact with the part of the body to be treated. The intensity is in terms of electric power converted into acoustic energy.

Some instruments have dose tabulator having a dose mark for every indication (disease). By setting pointer appropriately it is ensured that the apparatus is providing correct output intensity.

Duration of exposure:

The predominant effect of ultrasound is direct mechanical effect (micromassage) and not heating effect. The thermal effect is reduced by repeatedly interrupting the supply of energy through brief pauses.

Application technique:

For long areas, the probe is moved up and down for small areas, a circular motion if given to obtain uniform distribution of ultrasonic energy.

The probe is put in direct contact with the body through a couplant if the to-be-treated part is smooth and uninjured.

If there is wound or uneven part (joints etc) the treatment is done in warm water bath so as to avoid mechanical contact with the tissues which may damage the already injured surface. It should be ensured that the air bubbles are not present on probe or skin. The to-be-treated body is rubbed with alcohol or soaped. The probe is held at a distance of 1-2cm from the area under treatment and moved over the area to be treated. This method is not generally preferred because exact amount of dosage is difficult to control.

Advantages:

1. Ultrasonic energy enables this massage to be carried out to greater depth than is possible manually and in acute injuries when pressure cannot be exerted by hand because of intolerable pan caused to the patient.
2. Unlike the operation of a short wave therapy unit, tuning is not needed during

treatment.

3. The operating frequency is also not very critical and may vary to the extent +10%.

Use:

It is used where shortwave treatment failed and in cases where localizing of heat is required. It is very useful in curing of diseases of peripheral nervous system like neuritis, skeletal muscle system like arthritis and skin like ulcers.

7. Explain about electro surgical diathermy with a block diagram[CO4-L1].

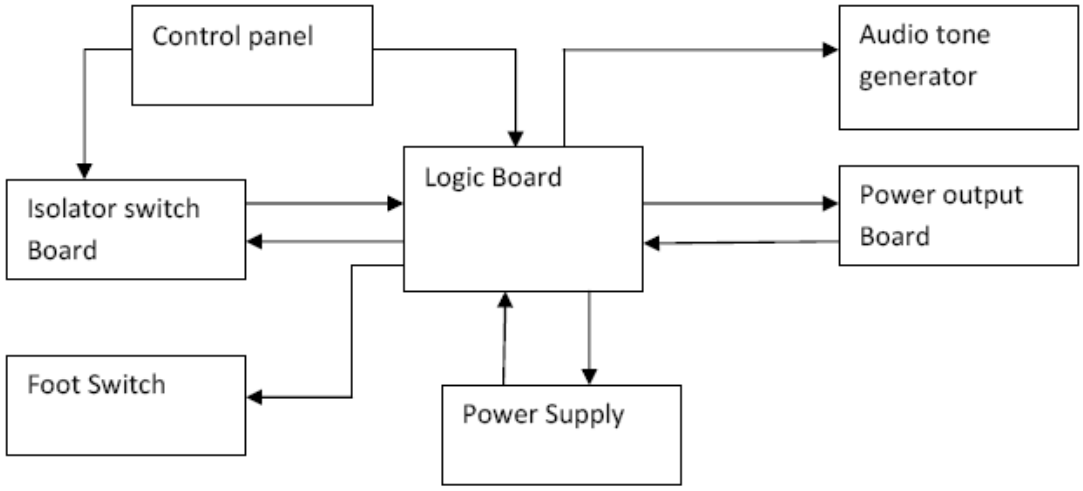


Figure . Block diagram of electrosurgical diathermy

- Logic board is the main part of the unit which produces the necessary waveforms for cutting, coagulation and hemostasis modes of operation.
- An astable multivibrator generates 500 kHz square pulses. The output from this oscillator is divided into a number of frequencies using binary counters.
- These frequencies are used as system timing signals, A frequency of 250 KHz provides a split phase signal to drive output stages on the power output board.
- Frequency of 250 Hz is used for cutting , after the high power amplification by push pull amplifier.
- The output of the push pull amplifier is given to a transformer so that the voltage is

stepped up and the output signal from the unit is well isolated.

- The isolator switch provides an isolated switching control between the active hand switch and the rest of the unit.

UNIT-V

RECENT TRENDS IN MEDICAL INSTRUMENTATION

PART-A

1. List the parts of endoscope unit. [CO5-L1-May/June 2013]

An endoscope is a medical device consisting of a long, thin, flexible (or rigid) tube which has a light and a video camera.

2. Mention the applications of Laser in ophthalmology. [CO5-L1-Nov/Dec 2012]

Used to treat eye problems like retinal bleeding, excessive growth vessels in eye and also used for spot welding reattaching retina that have become partly detached from the back surface of the eye.

3. What is endoscopy? [CO5-L1-May/June 2012]

Endoscope is a tubular optical instrument to inspect or view the body cavities which are not visible to the naked eye normally

4. Which Laser is used for surgery? [CO5-L1-April/May 2011]

1. Nd-YaG laser
2. CO_2 laser
3. Argon Ion

5. What is thermograph? [April/May 2010][CO5-L1-Nov/Dec 2008]

The instrument used to record the temperature distribution over the surface of the body or skin is called as thermograph.

6. Mention the advantages of Laser in surgery.[CO5-L1-Nov/Dec 2009]

1. Highly sterile
2. Non-contact surgery
3. Highly localized and precise

4. Prompt surgery
5. Short period of surgical time

7. State the applications of thermography? [CO5-L1-Nov/Dec 2008]

i. Diagnosis of Breast cancer ii)Detect Tumors iii)Inflammation
ii. Detects Diseases of pheripheral vessels
iii. Detects Burns and perniones
iv. Detects Skin grafts and organ transplantation
v. Detects Collagen diseases
vi. Detects Orthopedic Diseases
vii. Detects Brain and nervous diseases
viii. Detects Harmone diseases

8. What are the functions of endoscopic unit? [CO5-L1-Nov/Dec 2008]

i. An endoscopy involves examining the inside of a person's body.
ii. used to examine the interior surfaces of an organ or tissue
iii. used to confirm a diagnosis when other devices, such as an MRI, X-ray, or CT scan are considered inappropriate.
iv. Some surgical procedures can be carried out with a modified endoscope, such as the removal of the gallbladder, tying and sealing the fallopian tubes, and taking out small tumors and foreign objects from the lungs or digestive system.
v. The function of endoscopy unit is to observe the diseases in food pipe, stomach, lungs, abdomen, urinary bladder, kidney, large intestine, blood vessels, rectum, joints and tympanic membrane.it aid the physician in diagnosis of diseases.

9.What is the principle of cryogenic technique? Give any two medical applications of the same[CO5-L1].

Tissues can be killed when their temperature is below -20 degree Celsius. When the tissue is at -20 degree Celsius there is a formation of ice crystals and increase of salt

concentration within the cells. Thus necrosis of the tissue takes place. This method of killing diseased cells is called cryogenic surgery or cryogenic technique.

The process of freezing the cells by applying agents at very low temperature is called as cytogeneses.

Applications:

Cancer Therapy Dermatology
Rhythm disorders of heart Treatment of arrhythmia

10. List the properties of LASER or List out the characteristics of LASER[CO5-L1].

Monochromocity
Spatial and temporal coherence Directionality
Brightness

PART-B

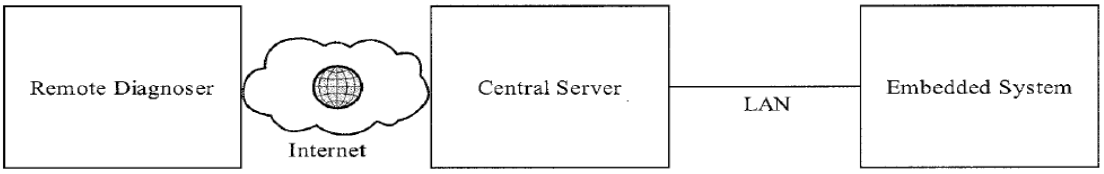
1.Show how tele-stimulation is achieved and write the merits and demerits of E-health. [CO5-L1-May/June 2014]

Discuss tele-stimulation briefly (8Marks) [April/May 2010] Explain in detail about telemedicine?

Tele-stimulation:

- Diagnosis by remote means has been an interesting idea for the medicine.
- Remarkable changes in the quality and speed of service, and consequent benefits to the health centers in terms of reduced costs and better image
- Adaptability is added by the fact that if the firmware in the embedded system
- Adaptable software agent combined with an adaptable embedded system together comprises what we call adaptable remote diagnosis system

General Configuration of remote diagnose



Expert diagnose is the person who will run a series of tests on the embedded system.

- Expert diagnose will be accessing the central server over the internet
- Software agents are programs that will run the diagnostics on the embedded system and retrieve results
- Results are then displayed to the expert diagnose by the central server
- Embedded systems are connected to the central server over a LAN

Telemedicine may be as simple as two health professionals discussing a case over the telephone, or as complex as using satellite technology and videoconferencing equipment to conduct a real-time consultation between medical specialists in two different countries. Telemedicine generally refers to the use of communications and information technologies for the delivery of clinical care.

Types of telemedicine

Telemedicine can be broken into three main categories: store-and-forward, remote monitoring and interactive services.

Store-and-forward telemedicine involves acquiring medical data (like medical images, biosignalsetc) and then transmitting this data to a doctor or medical specialist at a convenient time for assessment offline. It does not require the presence of both parties at the same time. Dermatology (cf: teledermatology), radiology, and pathology are common specialties that are conducive to asynchronous telemedicine. A properly structured

Medical Record preferably in electronic form should be a component of this transfer. A key difference between traditional in-person patient meetings and telemedicine encounters is the omission of an actual physical examination and history. The store-and-forward process requires the clinician to rely on a history report and audio/video information in lieu of a physical examination.

Remote monitoring, also known as self-monitoring/testing, enables medical professionals to monitor a patient remotely using various technological devices. This method is primarily used for managing chronic diseases or specific conditions, such as heart disease, diabetes mellitus, or asthma. These services can provide comparable health outcomes to traditional in- person patient encounters, supply greater satisfaction to patients, and may be cost-effective.

Interactive telemedicine services provide real-time interactions between patient and provider, to include phone conversations, online communication and home visits. Many activities such as history review, physical examination, psychiatric evaluations and ophthalmology assessments can be conducted comparably to those done in traditional face- to-face visits. In addition, “clinician-interactive” telemedicine services may be less costly than in-person clinical visits.

Benefits and Uses of Telemedicine

Telemedicine is most beneficial for populations living in isolated communities and remote regions and is currently being applied in virtually all medical domains. Specialties that use telemedicine often use a "tele-" prefix; for example, telemedicine as applied by radiologists is called Teleradiology. Similarly telemedicine as applied by cardiologists is termed as telecardiology, etc.

Telemedicine is also useful as a communication tool between a general practitioner and a specialist available at a remote location.

Telecardiology

ECGor electrocardiograph can be transmitted using telephone and wireless. Einthoven, the inventor of the ECG, actually did tests with transmission of ECG through telephone

lines. This was because the hospital did not allow him to move patients outside the hospital to his laboratory for testing of his new device. In 1906 Einthoven came up with a way to transmit the data from the hospital directly to his lab.

This system enabled wireless transmission of ECG from the moving ICU van or the patients home to the central station in ICU of the department of Medicine. Transmission using wireless was done using frequency modulation which eliminated noise. Transmission was also done through telephone lines. The ECG output was connected to the telephone input using a modulator which converted ECG into high frequency sound. At the other end a demodulator reconverted the sound into ECG with a good gain accuracy. The ECG was converted to sound waves with a frequency varying from 500 Hz to 2500 Hz with 1500 Hz at baseline.

This system was also used to monitor patients with pacemakers in remote areas. The central control unit at the ICU was able to correctly interpret arrhythmia. This technique helped medical aid reach in remote areas. In addition, Electronic stethoscopescan be used as recording devices, which is helpful for purposes of telecardiology.

Teleradiology

Teleradiology is the ability to send radiographic images (x-rays) from one location to another. For this process to be implemented, three essential components are required, an image sending station, a transmission network, and a receiving / image review station. The most typical implementation are two computers connected via Internet. The computer at the receiving end will need to have a high-quality display screen that has been tested and cleared for clinical purposes. Sometimes the receiving computer will have a printer so that images can be printed for convenience.

The teleradiology process begins at the image sending station. The radiographic image and a modem or other connection are required for this first step. The image is scanned and then sent via the network connection to the receiving computer.

Merits of E-health:

Researchers have examined the benefits of E-Health by considering clinical, organizational, and societal outcomes.

Clinical outcomes include improvements in the quality of care, a reduction in medical errors, and other improvements in patient-level measures that describe the appropriateness of care.

Organizational outcomes, on the other hand, have included such items as financial and operational performance, as well as satisfaction among patients and clinicians who use it.

Lastly, societal outcomes include being better able to conduct research and achieving improved population health.

Demerits of E-health:

It includes financial issues, changes in workflow, temporary loss of productivity associated with E-Health adoption, privacy and security concerns, and several unintended consequences.

Financial issues, including adoption and implementation costs, ongoing maintenance costs, loss of revenue associated with temporary loss of productivity, and declines in revenue, present a disincentive for hospitals and physicians to adopt and implement E-Health system.

Another disadvantage of an E-Health system is disruption of work-flows for medical staff and providers, which result in temporary losses in productivity. This loss of productivity stems from end-users learning the new system and may potentially lead to losses in revenue.

The risk of patient privacy violations, which is an increasing concern for patients due to the increasing amount of health information exchanged electronically.

E-Health system may cause several unintended consequences, such as increased medical errors, negative emotions, changes in power structure, and overdependence on technology.

2. With a neat block diagram explain the working of an endoscopy unit (8 Marks) [CO5-L1-May/June 2014]

Write brief notes on endoscopy unit (8 Marks) [May/June 2013] [Nov/Dec 2011]

What is an endoscope? Justify the need for each of the essential components in it. What are the applications of endoscope? [Nov/Dec 2012]

With a suitable schematic diagram, explain the endoscopy unit [Nov/Dec 2010]

Describe the principles involved in endoscopy unit with relevant diagrams [April/May 2010]

What is endoscopy?(8 Marks)[Nov/Dec 2009]

What are the uses of endoscopes in medicine?(8 Marks)[May/June 2009]

ENDOSCOPY

An endoscopy involves examining the inside of a person's body using an endoscope. An endoscope is a medical device consisting of a long, thin, flexible (or rigid) tube which has a light and a video camera. Images of the inside of the patient's body can be seen on a screen. The whole endoscopy is recorded so that doctors can check it again. Endoscopy is a minimally invasive diagnostic medical procedure. It is used to examine the interior surfaces of an organ or tissue.

Endoscopy is a noninvasive alternative to surgery for foreign object removal from the gastrointestinal tract.

WHEN IS AN ENDOSCOPY USED?

An endoscopy is often used to confirm a diagnosis when other devices, such as an MRI, X- ray, or CT scan are considered inappropriate.

An endoscopy is often carried out to find out the degree of problems a known condition may have caused. The endoscopy, in these cases, may significantly contribute towards

the doctor's decision on the best treatment for the patient.

The following conditions and illnesses are most commonly investigated or diagnosed with an endoscopy:

- Breathing disorders
- Chronic diarrhea
- Incontinence
- Internal bleeding
- Irritable bowel syndrome
- Stomach ulcers
- Urinary tract infections

BIOPSIES

Endoscopies are commonly used for the diagnosis of cancer. They are used for biopsies - taking samples of tissue to find out whether it is cancerous. Thanks to an endoscope, biopsies of the intestines or lungs can be done without the need for major surgery. This study explains that colonoscopy is the most effective screening option for colorectal cancer.

SURGERY

Some surgical procedures can be carried out with a modified endoscope, such as the removal of the gallbladder, tying and sealing the fallopian tubes, and taking out small tumors and foreign objects from the lungs or digestive system. A study found that the removal through endoscopy of tumors that affect only the superficial layers of the esophagus can avoid complete extirpation of this part of the digestive tract.

A laparoscope is a type of endoscope which is used for keyhole surgery or laparoscopic surgery. Laparoscopic surgery requires only a small incision and is commonly used today for appendectomies, hysterectomies, and prostatectomies. Patients lose much less blood during and after surgery and recover much faster, compared to other surgical procedures.

SHORT HISTORY OF ENDOSCOPY

Reports indicate that the first endoscope was devised in 1805. It consisted of a large tube and a candle. Because it was cumbersome and large it had very limited uses. Fiber optics, which appeared in the 1960s, was a major factor in the endoscopy revolution. With fiber optics it really became possible for the doctor to see and record the inside of the patient's body with a small and relatively painless device.

ENDOSCOPY HAS MANY USES TODAY

An endoscope can be fitted with surgical instruments; it can send pulses or heat and electricity and destroy small tumors or gallstones. Specialized endoscopes have their own names, such as:

- Bronchoscopes - they examine the air passages and the lungs.
- Colonoscopes - they examine the colon.
- Gastroscopes - they examine the small intestine, stomach and esophagus (throat).
- Arthroscopes - they examine the joints.
- Hysteroscopes - they examine a woman's uterus.
- Cystoscopes - they examine the urinary bladder.

TYPES OF ENDOSCOPIES

- Amnioscopy - examination of the amniotic cavity and fetus.
- Arthroscopy - examination of the joints.
- Bronchoscopy - examination of the air passages and the lungs.
- Colonoscopy - examination of the colon.
- Colposcopy - examination of the cervix and the tissues of the vagina and vulva.
- Cystoscopy - examination of the urinary bladder.

- Egd (esophageal gastroduodenoscopy), also known as panendoscopy - examination of the esophagus, stomach and duodenum.
- Ercp (endoscopic retrograde cholangio-pancreatography) - examination of the liver, gallbladder, bile ducts, and pancreas.
- Fetoscopy - examination of the fetus.
- Laparoscopy - a small incision to examine the abdominal cavity.
- Laryngoscopy - examination of the back of the throat, including the voice box (larynx) and vocal cords.
- Proctoscopy - examination of the rectum and the end of the colon.
- Rhinoscopy - examination of the inside of the nose.
- Thoracoscopy - examination of the lungs or other structures in the chest cavity.

3. Explain the application of different types of Lasers in medicine (8 Marks) [CO5-L2-May/June 2014]

A bloodless surgery is being planned using Laser. Find what type of Laser would be suitable to achieve this. Discuss on the process involved in the Laser production and application. [Nov/Dec 2013]

Explain Argon Laser and its medical application (8 Marks) [May/June 2013] Write short notes on Argon Laser (8 Marks) [Nov/Dec 2011]

Write short notes on (i) NdYag Laser[May/June 2012]

(ii) CO_2 laser [May/June 2012] [Nov/Dec 2011]

Discuss the various applications of Lasers in different fields of medicine (10 Marks)[Nov/Dec 2008]

(ii) Mention the specific advantages of Laser surgery (6 Marks) [CO5-L1-Nov/Dec 2008]

LASERS IN MEDICINE

The use of lasers in medicine began soon after the first laser was invented in 1960. In recent years, the number and variety of applications of lasers to medicine have increased rapidly.

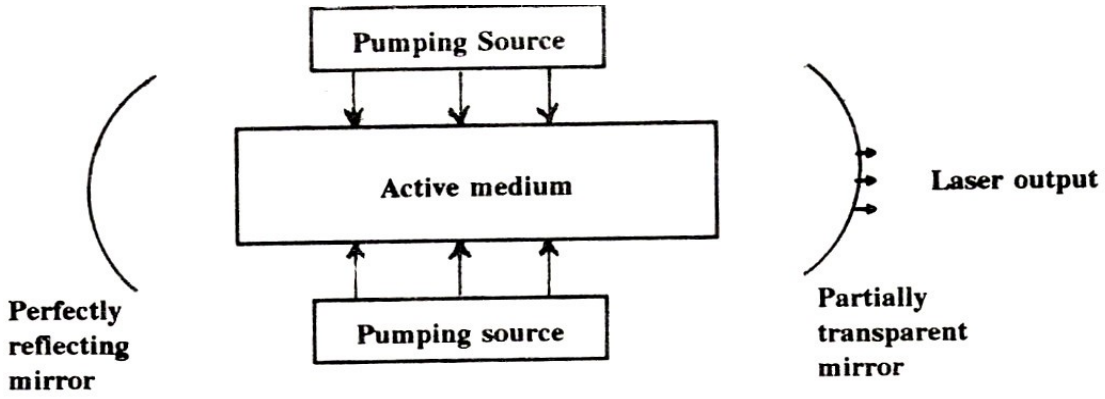


FIG - LASER PRINCIPLE

Laser is acronym for Light Amplification by Stimulated Emission of Radiation. Laser beam consists of high intense radiation in unique direction without spreading of its energy in other directions. Further it has high monachromacity and high directionality. Stimulated emission can alone produce such coherent radiation. For continuous stimulated emission output, population inversion or population reversal of atoms should be maintained. This can be done by optical pumping or electrical pumping of the atoms of active medium.

Population of atoms in higher energy level is normally smaller than the lower (ground) energy level in an atomic system. During population inversion, the number of atoms in the higher level is more than the number of atoms in the ground level. This can be done by pumping the matter by photons of appropriate energy given by pumping source or by an applied electric field. Assume that there is population inversion such that the number of atoms in the higher, excited, metastable energy level is more. There are two types of emissions. In the case of spontaneous emission, the emission takes place without any inducement. That is, the transition from higher energy state to any lower energy state takes place volunteerly with the emission of polychromatic radiation.

Suppose a photon emitted by spontaneous emission has an energy equal to the energy

difference between the laser transmission levels, then it can now stimulate the excited atom in the metastable state to undergo transition with the emission of a photon such that the stimulated photon (emitted wave) falls precisely in phase with the stimulating photon (incident wave).

These two photons have same energy and same phase. This is called stimulated emission. Now these two photons stimulate other two atoms. This chain reaction goes on with the help of multiple reflections taking place between the mirrors (Figure 10.3). Finally amplification of light takes place. Through one of the (partially transparent)mirrors, the laser output can be obtained.

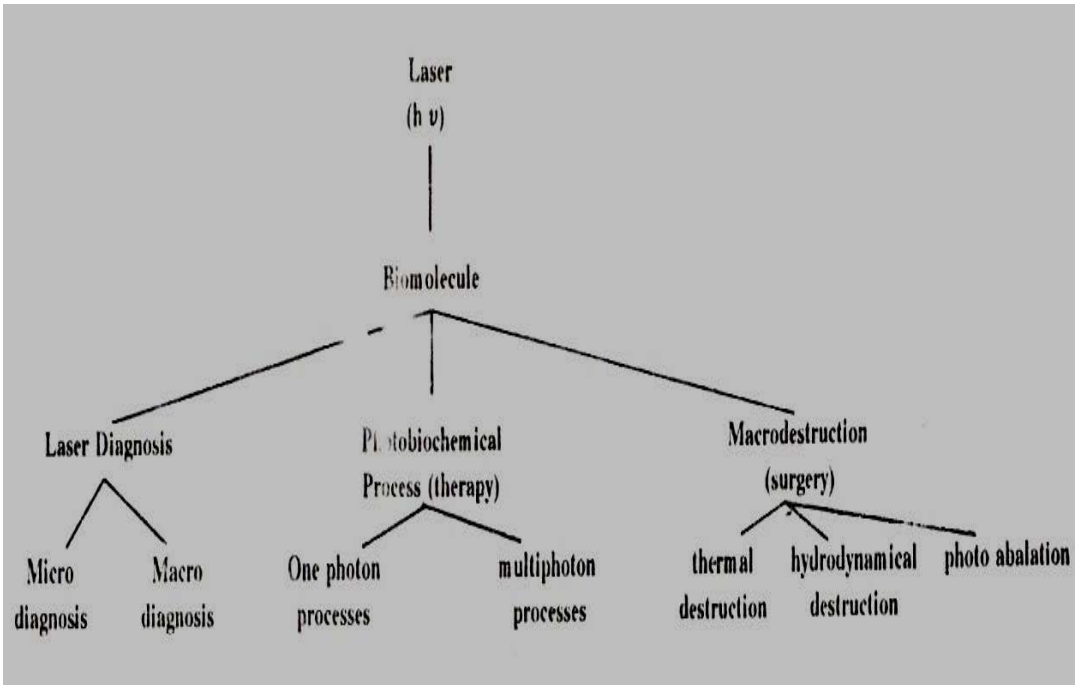


Fig. Various degrees of laser interaction with biomolecules

All biomedical applications of laser are based on the fact that lasers could produce high photon flux (of MW cm^2) 01 a localised spot (of micron diameter). Such high power density causes a broad spectrum of effects and one can utilize these effects for different medical applications. This is shown schematically in figure.

Out of many properties of the laser such as monochromaticity, spatial and temporal

coherence, directionality and brightness, monochromaticity of laser has only minor importance than the spectral width of laser beam with or without focusing.

The higher brightness of the coherent laser beam produces internal local heating and localised specific photochemical reaction. In addition, he directionality of the beam which is intimately related to spectral brightness helps to pass the beam into the optical fiber. Further they can be operated either in continuous wave mode or pulsed mode and can produce ultra short pulses of femto second pulses.

Over and above the lasers with wavelengths varying from UV to IR are now available and hence one can choose a certain type of laser to bring about an optimum interaction with the biomolecules.

Though a single laser can provide a combination of several of the above properties, only one or two of the above properties are essential for a particular application, depending upon the specific modes for a interaction (i.e. various processes of conversion) of the incident electromagnetic energy with biomolecules. From the understanding of mechanisms of laser- tissue interactions, one can initiate selective laser interaction to use it for a particular type of application.

When light photons fall on the tissue, four basic optical processes may occur

- Direct reflection at the boundaries of the layer due to change, in the refractory index.
- Scattering by molecules, particles, fibers, cell organdies and cells within the layer.
- Absorption (which may lead to photochemistry or dissipation of the absorbed energy via heat, fluorescence, or phosphorescence).
- Direct transmission through the layer.

Direct transmission through the layer may result in changes in the primary, secondary, tertiary, or quarternary configuration of macromolecules within the tissue. This may result in alteration of membranes, denaturation, dehydration or carbonization of molecules. These changes may be accompanied by breaks in tissue continuity.

These alterations may be expressed microscopically and macroscopically as acute changes in viscosity, density, optical properties and state of hydration. They may also be measured as ablation, cutting, drilling, shearing, or discontinuous phases within the tissue. Tissue optics are acutely altered which leads to the whitening of tissues sometime seen after laser impact.

All the above processes (i.e., photophysical events and hence biological responses) depend on

- wavelength of laser
- energy density
- pulse duration
- irradiation time and
- absorption characteristics of target molecule.

The wavelength interval between 600-1300 nm forms a window of low optical absorption by the skin and blood; laser photon of such wavelengths can penetrate into tissue to a depth of more than a centimeter and that fact is important for phototherapy and selective surgery.

LASER INSTRUMENTATION

Laser irradiation of patients with skin tumors is performed in a specially designed operating unit which consists of three separate sections. In the first section, a pulsed Nd-YAG laser (with pulse energy more than 10^6 W) and a continuous wave CO_2 laser (50 W) and continuous wave Argon ion laser (4 W) are installed.

The laser irradiation is transmitted by a suitable optical fiber light guide system to the scanning device in the second section. The second section contains necessary operation theatre equipment and remote controlled scanning device. The third section is imended for remote control circuit. The operation can be observed by means of a television arrangement. A radio communication is also maintained between the biomedical engineer who is in charge of lasers and the surgeon in the operating theatre. The lasers are equipped with a water cooling system.

The apparatus includes a vacuum trap for smoke and dust particles and a device for focusing the radiation and aiming it on the target.

Normally a low power He-Ne laser output is used as a guiding beam so as to locate the spot correctly for irradiation since the lasers used in laser surgery have their wavelengths in the invisible region. The energy of the radiation is indicated by the energy meter and the irradiation time is controlled properly by a timer.

The rooms are equipped with warning signal circuits and a blocking system that prevents the laser system from working unless the doors of that room are closed. The beam with lowest TEM, mode is used for surgery because it has the maximum focusing capability and minimum beam divergence.

By pressing the foot switch after locating the point where the irradiation to be given a preset dosage of pulsed radiation is emitted from the laser at the target. During laser surgery the patient and the surgeon should wear protective goggles to protect the eyes.

The pulsed radiation of the Nd-YAG laser and the unfocussed radiation of the CW CO_2 laser are used for the destruction of tumors by coagulation whereas focused beam of GO_2 laser functions as a nonmaterial, *tight) knife* for performing tissue incisions and tumor nodule excisions. The partially focused beam of CW Argon ion laser is used for the treatment of haemangiomas by means of blood vessel coagulation.

Different types of lasers : The knowledge about different types of lasers and their potential use in medicine is presented. A very rapid development of laser technology in the world imposes a need for up-to-date information about the characteristics of different laser instruments. Without this kind of information it would be difficult to keep in touch with the latest developments in the world's technology. Different types of lasers have different indication range in the medical practice. An inquiry into the fundamental principles of lasers physics is an important prerequisite for successful application of this technology in medicine. Laser as a surgical knife has shown certain advantages over scalpel, electrocautery and cryosurgery, as the laser surgery is a noncontact method, bloodless, precise, with better visualization, minimal postoperative edema, painless

healing, without complications. Although laser cannot entirely replace conventional surgical instruments, it is still the instrument of choice for treatment of numerous pathological conditions.

The carbon dioxide laser is a highly precise, bloodless light scalpel used for incising and excising tissues and sealing small blood vessels. The infrared beam at 10,600 nm wavelength is absorbed by water and tissue destruction is due to the instantaneous vaporization at relatively low temperature of 100 degrees C. The beam seals blood vessels of up to 0.5 mm in diameter and if the beam is defocused, larger vessels may be controlled. The beam also seals lymphatic, possibly reducing the spread of tumor cells by this route, and seals nerve endings: there is no incidence of neuroma formation.

Carbon dioxide laser has shown a great efficiency in otorhinolaryngology, in maxillo-facial surgery and plastic surgery, in urology and gynecology. Provides true "no touch" surgery, and is used increasingly in neurosurgery for the precise atraumatic removal of tissue and for creation of precise lesions for the control of pain. The carbon dioxide laser beam cannot, at present, be transmitted via a flexible fiber, although a number of fibers are being investigated.

Delivery of laser energy to microscope, colposcope or hand piece is via an articulated arm which is a hollow tube with mirrors at the articulations. The argon laser produces blue-green coherent light at a number of wavelengths but 80% of the energy is at wavelengths of 488 and 514 nm. This laser was first used in ophthalmology to treat diabetic retinopathy through, and without damage to, the clear anterior parts of the eye.

The argon laser is used for blood vessel coagulation but can be used to perform slow, thermal tissue destruction at higher power levels. Argon laser is most commonly used in ophthalmology for otological micro-surgery, particularly in the treatment of otosclerosis and tympanosclerosis. Very good results have been achieved in the argon laser treatment of gastrointestinal bleeding ulcers, vascular lesions and polyps.

Dermatology is another field where argon laser has shown great efficiency: hemangyomas, telangiectasias, tattoos, small benign and malignant tumors are

amenable to argon laser treatment. In neurosurgery it is used to control both normal and abnormal blood vessels but at present much work on treatment of arteriovenous malformations and aneurysms is experimental.

Both the argon laser energy can be transmitted via flexible fibre optic delivery system which can then be attached to an operating microscope, slit lamp, endoscope delivery fibre or hand piece. The Neodymium-YAG laser is used both for tissue destruction with good haemostasis and for the control of normal and abnormal blood vessels. This laser produces infrared coherent light at 1060 nm wavelength, which is deeply absorbed in the tissues without colour or tissue specificity. Neodymium-YAG laser is mostly used in tracheobronchial, gastrointestinal and urologic pathology in the treatment of stenosis, granulomas, benign tumors, and for reduction of malignant tumors.

ADVANTAGES OF LASER SURGERY

- Highly sterile
- Highly localized and precise
- Non contact surgery
- Dry-field, almost bloodless surgery
- Clear field of view and easy access in confined areas
- Prompt healing with minimal post operative swelling and scarring
- Apparent reduction in post operative pain
- No electromagnetic interference on monitoring instruments
- More advantageous for children since it is a painless surgery
- Short periods of surgical time.

4. Write brief notes on Thermography (8 Marks) [May/June 2013] [May/June 2012] [Nov/Dec 2011]

Draw the basic setup of a medical thermograph unit and explain the function of each unit in it. Mention the applications of thermograph. [Nov/Dec 2012]

Write short notes on thermograph (8 Marks)[April/May 2011]

Discuss the working principle of an infrared thermography with a neat block diagram?(8 Marks)[Nov/Dec 2009]

Describe the various medical thermo graphic techniques. State its different medical applications [CO5-L1-May/June 2009]

Thermograph, thermal imaging, or thermal video, is a type of infrared imaging. Thermo graphic cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 900–14,000 nanometers or 0.9–14 µm) and produce images of that radiation. Since infrared radiation is emitted by all objects based on their temperatures, according to the black body radiation law, thermograph makes it possible to see one's environment with or without visible illumination.

The amount of radiation emitted by an object increases with temperature, therefore thermograph allows one to see variations in temperature (hence the name). When viewed by thermo graphic camera, warm objects stand out well against cooler backgrounds; humans and other warm-blooded animals become easily visible against the environment, day or night. As a result, thermograph's extensive use can historically be ascribed to the military and security services. Thermal imaging photography finds many other uses. For example, firefighters use it to see through smoke, find persons, and localize the base of a fire.

With thermal imaging, power lines maintenance technicians locate overheating joints and parts, a telltale sign of their failure, to eliminate potential hazards. Where thermal insulation becomes faulty, building construction technicians can see heat leaks to improve the efficiencies of cooling or heating air-conditioning.

Thermal imaging cameras are also installed in some luxury cars to aid the driver, the first

being the 2000 Cadillac Deville. Some physiological activities, particularly responses, in human beings and other warm-blooded animals can also be monitored with thermo graphic imaging. The appearance and operation of a modern thermo graphic camera is often similar to a camcorder.Enabling the user to see in the infrared spectrum is a function so useful that ability to record their output is often optional. A recording module is therefore not always built-in.Instead of CCD sensors, most thermal imaging cameras use CMOS Focal Plane Array (FPA). The most common types are InSb, InGaAs, HgCdTe and QWIP FPA.

The newest technologies are using low cost and uncooled microbolometers FPA sensors.Their resolution is considerably lower than of optical cameras, mostly 160x120 or 320x240 pixels, up to 640x512 for the most expensive models. Thermo graphic cameras are much more expensive than their visible-spectrum counterparts, and higher-end models are often exportrestricted.Older bolometer or more sensitive models as require cryogenic cooling, usually by a miniature Stirling cycle refrigerator or liquid nitrogen.

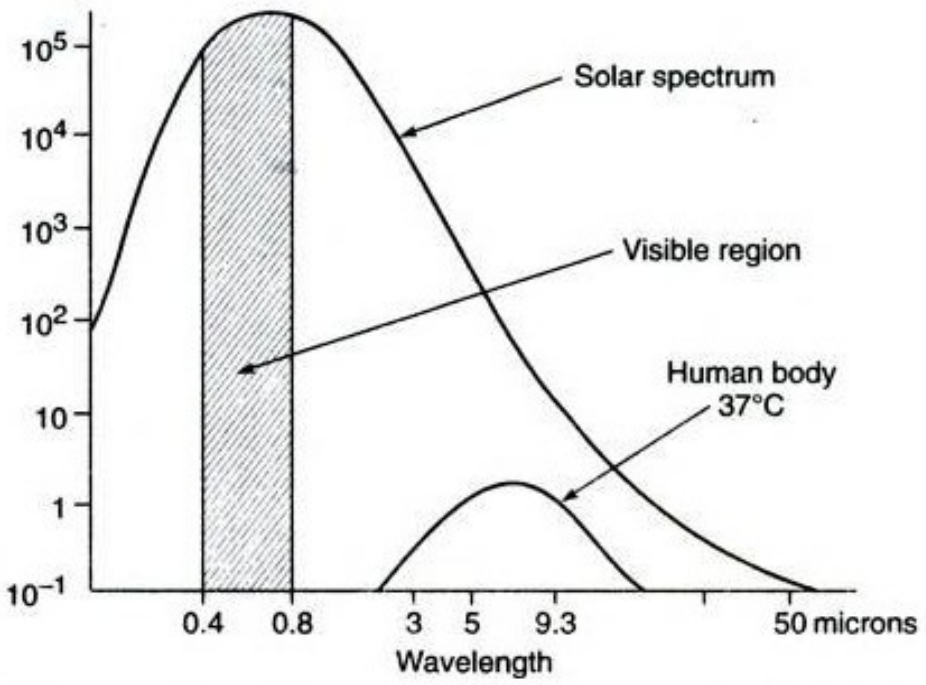


Fig. ***Spectral distribution of infrared emission from human skin. The emission peaks at around 9 microns regardless of pigmentation***

Methods of Thermography Infrared thermography Liquid crystal thermography Microwave thermography**.**

INFRARED THERMOGRAPHY

Infrared thermography is the science of acquisition and analysis of thermal information by using non contact thermal imaging devices.Human skin emits infrared radiation as an exponential function of its absolute temperature and the emissive properties of the skin temperature.The maximum wavelength λmax = 10 μm and range from 4 to 40μm.The thermal picture is usually displayed on a TV tube may be photographed to provide a permanent record.

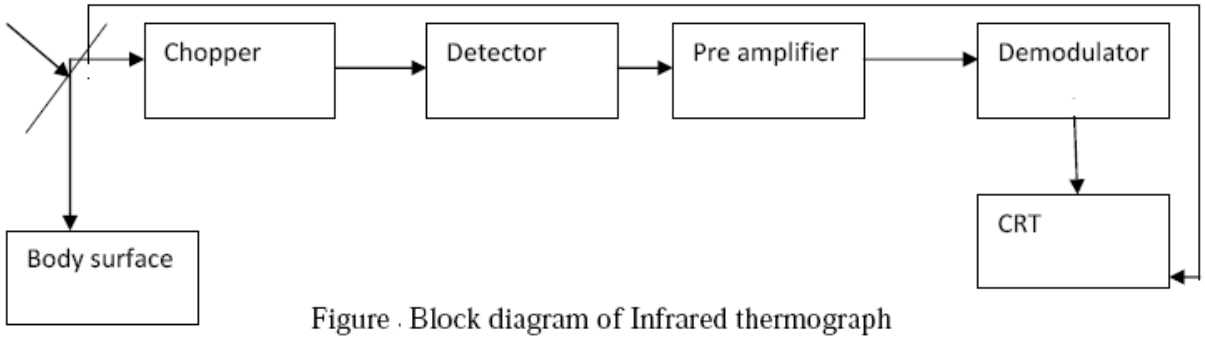


Figure . Block diagram of Infrared thermograph

Every thermo graphic equipment is provided with a special infrared camera that scales the object. The camera contains an optical system in the form of an oscillating plane mirror which scans the field of view at a very high speed horizontally and vertically and focuses the collected infrared radiations onto chopper.

The chopper disc interrupts the infrared beam so that a.c signals are produced. Then they are given to detector. The detector is infrared radiation detector. The detected output by detector is amplified and led to phase sensitive.

LIQUID CRYSTAL THERMOGRAPHY

Liquid crystals are a class of compounds which exhibit colour temperature sensitivity in the cholestric phase. Scattering effects with the material give rise to iridescent colours, the dominant wavelength being influenced by very small changes in temperature.The high temperature sensitivity makes cholesteric liquid crystals useful for thermal mapping.In this

technique, the temperature sensitive plate consists of a blackened thin flim support into which encapsulated liquid crystals cemented to a pseudo solid powder (with particle sizes between 10 to 30) have been incorporated.

Thermal contact between the skin surface and plate produces a color change in the encapsulated liquid crystals; red for relatively low temperatures through the visual spectrum to violet for high temperatures. But in infrared thermograms, the violet colour is used to identify the low temperature regions and the bright colour or red is used to identify the temperature regions.If we want to study a breast's temperature distribution, several different plates are necessary to cover a breast temperature range from 280C to360C. Each plate covers a range of temperature 30C. A record of the liquid crystal image may be obtained by colour photography.The response time varies according to the thickness of plate (ranges from 0.06mm to 0.3 mm) and is 20 to 40 seconds.

MICROWAVE THERMOGRAPHY

Eventhough we get microwave emissions from the skin surface, that intensity is very small when we compare with Infra red radiation intensity . (10 wavelenght emission intensity is 108 times greater than 10 cm wavelength emission intensity). But using modern microwave radiometers one can detect temperature change of 0.1K. since body tissues are partially transparent to microwave radiations which orginates from a tissue volume extending from the skin surface to a depth of several centimeters.

Microwave radiometers consisting of matched antennae placed in contact with the skin surface for use at 1.3 G Hz and 3.3 G Hz have been used to sense subcutaneous temperature.

The present day thermographic systems, using Infrared radiation, only give a temperature map of the skin due to low penetration depth of the short wavelength of the

infrared component of the emitted radiation. Using a microwave receiver with a frequency response from 1.7 GHz to 2.5 GHz a penetration depth of 1 cm in tissue and 8 cm in fat and bone can be obtained.

A severe problem is the unknown emissivity of the body surface for microwaves, as part of the radiation is reflected back into the body. In a conventional radiometer this gives rise to a measurement error proportional to the temperature difference between the body surface and the applied antenna. This error lies in the order of 1-2 K which is too high for medical applications. The problem has been solved iv an elegant way by adding artificial microwave noise from the antenna, thus providing a radiation balance between the receiver and body surface. With this a temperature sensitivity of 0.1 K could be obtained. Based on the transducer attachment on the skin surface, we can classify the thermography into contact thermography and telethermography.

Advantages of Thermography

Get a visual picture so that you can compare temperatures over a large area It is real time capable of catching moving targets

Able to find deteriorating components prior to failure Measurement in areas inaccessible or hazardous for other methods It is a non-destructive test method

Limitations & disadvantages of thermography

Quality cameras are expensive and are easily damaged

Images can be hard to interpret accurately even with experience

Accurate temperature measurements are very hard to make because of emissivities Most cameras have ±2% or worse accuracy (not as accurate as contact)

Training and staying proficient in IR scanning is time consuming Ability to only measure surface areas

Applications

Healthy Cases Tumors Inflammation

Diseases of peripheral Vessels Burns and Perniones

Skin Grafts and Organ Transplantation Collagen diseases

Orthopedic Diseases

Brain and Nervous Diseases Harmone Diseases

Examination of Placenta Attachment