UNIT II: BIOSIGNAL CHARACTERISTICS AND ELECTRODECONFIGURATIONS 9

Bio-signal characteristics – frequency and amplitude ranges. ECG – Einthoven‟s triangle, standard 12 lead system. EEG – 10-20 electrode system, unipolar, bipolar and average mode. EMG– unipolar and bipolar mode. Electrodes

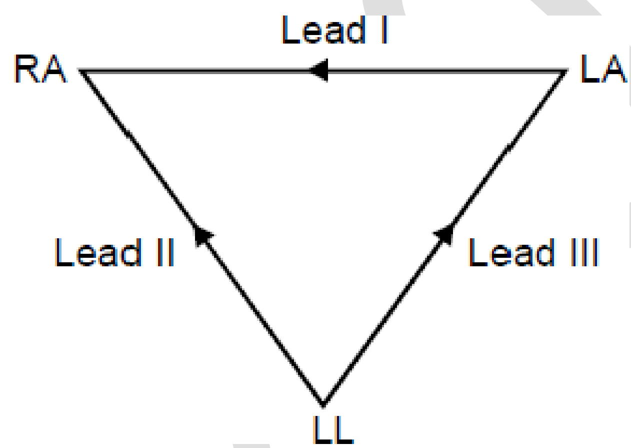
ECG – Lead System, Recording Methods and Typical Waveforms

Introduction:

- Electrocardiography (or) Electrokardiography deals with the recording and study ofelectrical activity of the heart muscles.
- The potentials originated in the individual fibers of heart muscles are added to producethe ECG waveform.
- The ECG waveform reflects the rhythmic electrical depolarization and repolarization ofthe heart muscles associated with the contractions and relaxation of the atrium and ventricles.
- The electrocardiogram gives details of the state of the heart and any disturbance in theheart rhythmic (ar hythmia) can be diagnosed.
- The typical ECG wave consists of P wave, QRS complex and T wave.
- The electrical potentials of the heart are measured by placing suitable electrodes.
- Eithersurface electrodes with proper electrode paste orneedle electrode can be used.ECG Lead system:
- There are fourdifferent ECG lead systems used universally, o
  - Bipolarlimb lead (or) standard lead system
  - Augmented limb lead system
  - Chest lead (or) Pre-cordial system
  - Frank lead system (or) corr ected orthogonal lead system
- Bipolarlimb leads:
- In bipolarlimb leads system ECG is recorded with two electrodes at a time.
- The final trace is due to difference in potential of 2 electrodes kept at 2 differentlocations on the body.
- This is also called the standard lead system.
- Forthis system, the potentials are tapped from 4 locations of the body namely,
  - Right arm – white colourelectrodes

- Left arm – Black colourelectrodes
- Right leg – Green colourelectrodes
- Left leg – Red colourelectrodes

- The right leg electrode is used as reference electrode.
- The three different leads of the system are,
  - Lead I - V1 (Voltage drop from left arm (LA) to right arm (RA)
  - Lead II - V2 (Voltage drop from left leg (LL) to right arm (RA)
  - Lead III - V3 (Voltage drop from left leg (LL) to left arm (LA)
- The closed path between RA to LA to LL and back to RA is called the Einthoven triangle.



Einthoven Triangle

- R wave amplitude of lead II is equal to sum of R wave amplitude of leads I and leads III.
- Forexample, if V1 = 0.5 mV, V2 = 0.7 mV, then,
- V3 = 0.2 mV. (i.e) V2 = V1 + V3.

2. Augmented Unipolar Limb leads:

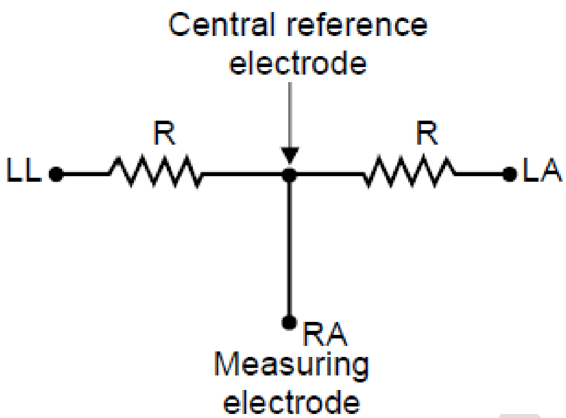
- This type of lead system is introduced by Wilson.
- ECG trace is due to potential between single measuring electrode and central referenceelectrode.
- The central reference electrode is built up by tying two electrodes with two equal andlarge resistors in between them.
- A pairof limb electrodes is tied up with 2 large resistors to make the central referenceelectrode and the third limb electrode is the measuring electrode.

aVR – augmented voltage RA aVL
– augmented voltage LA aVF –

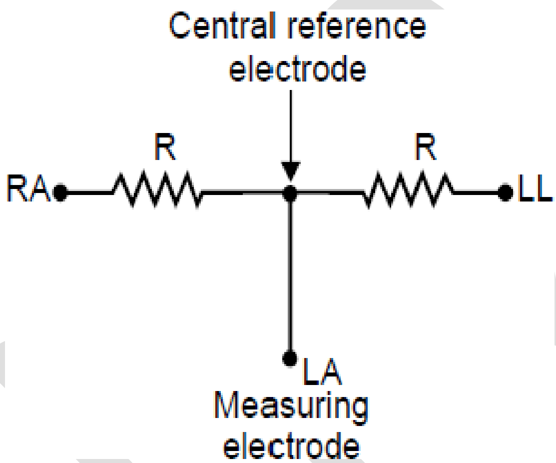
augmented voltage foot

- By Kirchoff's law,

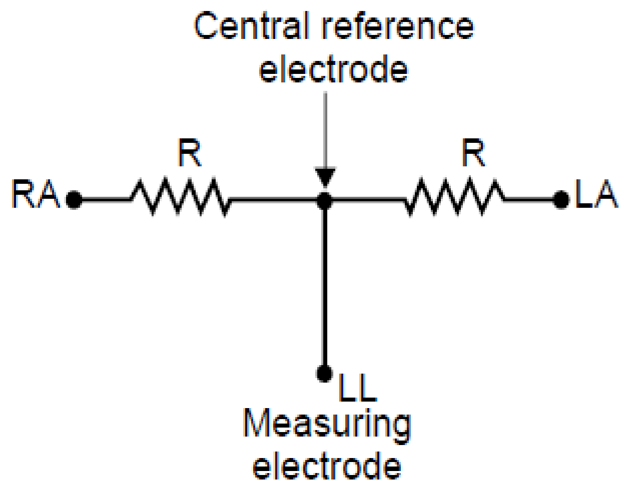
aVR = -V1 – V3/ 2



aVL = V1 – V3/ 2



aVF = V2 – V2/ 2



3. Unipolarchest lead:

- In Unipolarchest leads system, in addition to electrodes present in augmented Unipolarlimb leads there are two more electrodes placed in the chest, close to heart.
- By connecting 3 large equal resistors between LA, RA and LL reference electrode centrepoint obtained, this is the central electrode.
- This system includes an integration of 3 unipolarleads, 3 bipolarleads and 6 chestleads.
- Location of chest leads (V1 till V6)
  - V1 – 4th intercoastal space at right sternal margin
  - V2 – 4th intercoastal space at left sternal margin
  - V3 – Midpoint of V2 and V4
  - V4 – 5th intercoastal space at mid-clavicularline
  - V5 – Same level as V4 - anterior auxiliary line
  - V6 – Same level as V4 - Mid auxiliary line

4. Frank lead system:

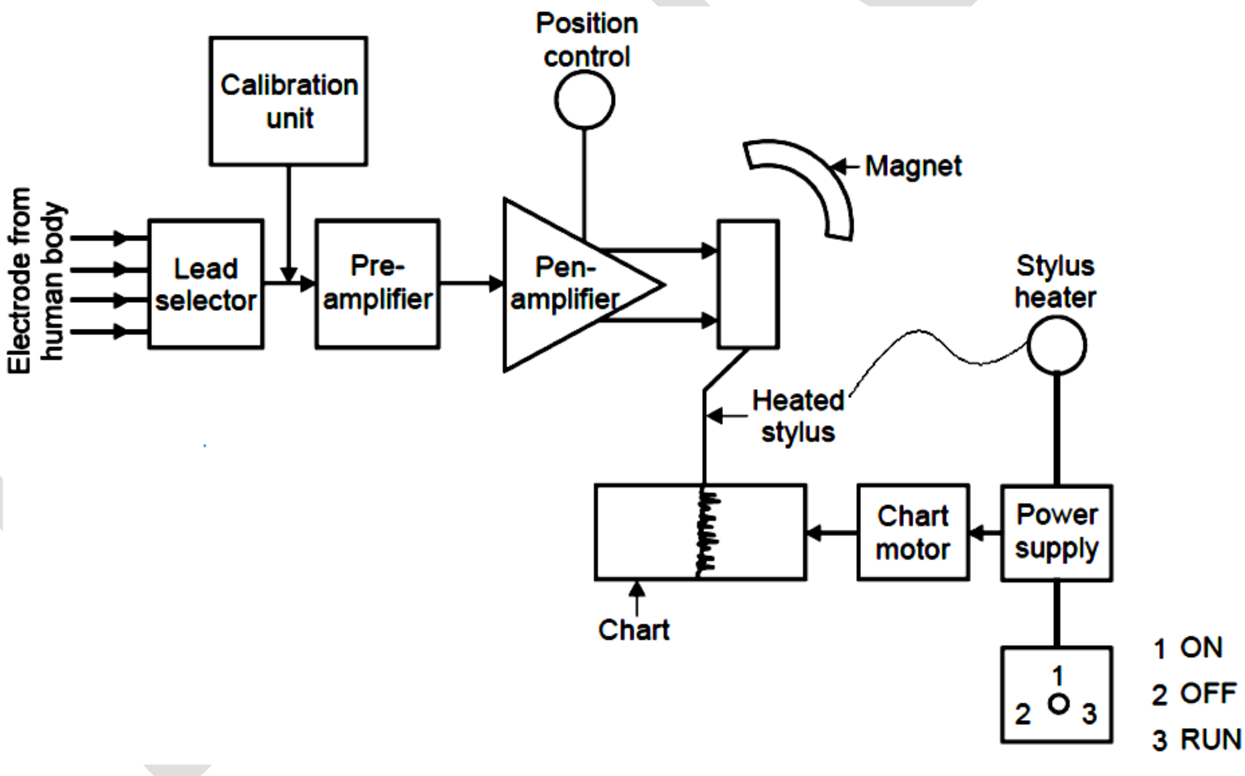
- Same as chest lead system.
- Heart's dipole field is resolved into three mutually perpendicular components andhence state of heart is studied three dimensionally.

ECG recording set-up (or) ECG Instrumentation:

- The connecting wires forthe patient electrode originate at the end of a patient cable.
- The wires from the electrodes connect to the lead selectorswitch
- A push button allows the insertion of a standardization voltage of 1 mV to standardizeorcalibrate

the recorder.

- From the lead selectorswitch the ECG signal goes to a pre-amplifier, which is a differential amplifier with high common mode rejection ratio, high gain factor, highinput impedance and lowoutput impedance.
- It is AC coupled to avoid problems with small DC voltages that may originate from polarization of the electrodes.
- The pre-amplifier, is followed by a DC amplifiercalled the pen amplifierorpower amplifier, which provides the power to drive the pen motorthat records the actual ECGtrace.
- A position control in the pen amplifiermakes it possible to centre the pen on therecording paper.
- ECG recorders use heat sensitive paper, and the pen is actually an electrically heated stylus, the temperature of which can be adjusted with a stylus heat control foroptimalrecording trace.



ECG recording set-up (or) ECG Instrumentation

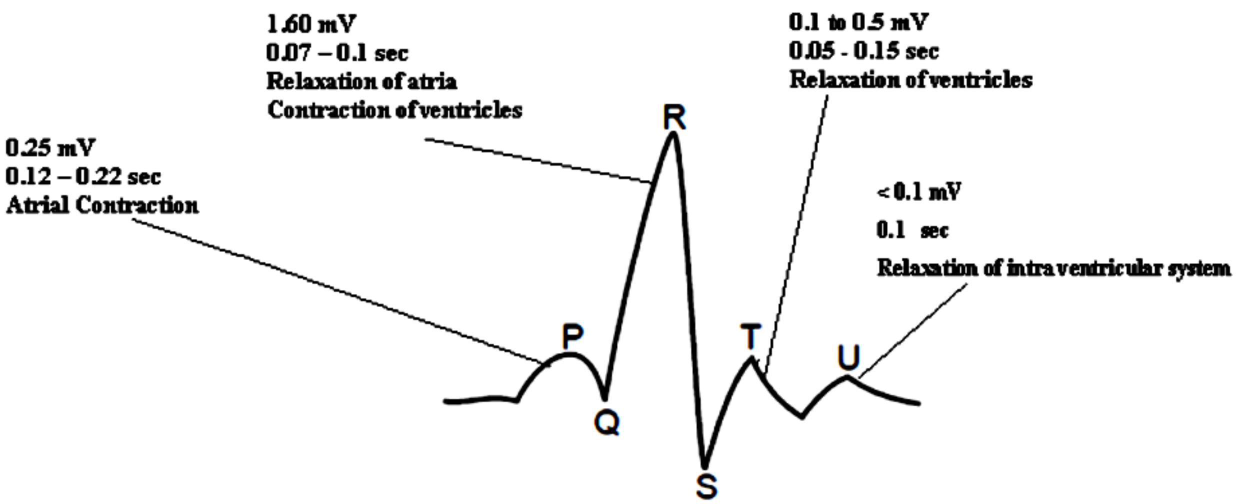
- There is a marker stylus that can be actuated by a push button and allows the operatorto mark a coded indication of the lead being recorded at the margin of the electrocardiogram.
- Normally electrocardiogram is recorded at a paperspeed of 25mm/ sec but a fasterspeed of

50mm/sec is provided to allow resolution of the QRS complex at very highheart rates.

- The power switch of an ECG record has three positions. In the "ON" position the powerto the amplifieris turned on but the paperdrive is not running. In "RUN" position paper drive starts running. In "OFF" position power is switched off.
- A push button allows the operator to check whether the recorder is connected to the powerline with polarity.
- This is done to avoid any shock hazard forthe patient.
- Isolated orfloating input amplifiers are used forthe safety aspect of electrical connections to the patient.

ECG – Typical Waveform:

- The complete waveform is called electrocardiogram with labels PQRSTU indicatingimportant diagnostic features.



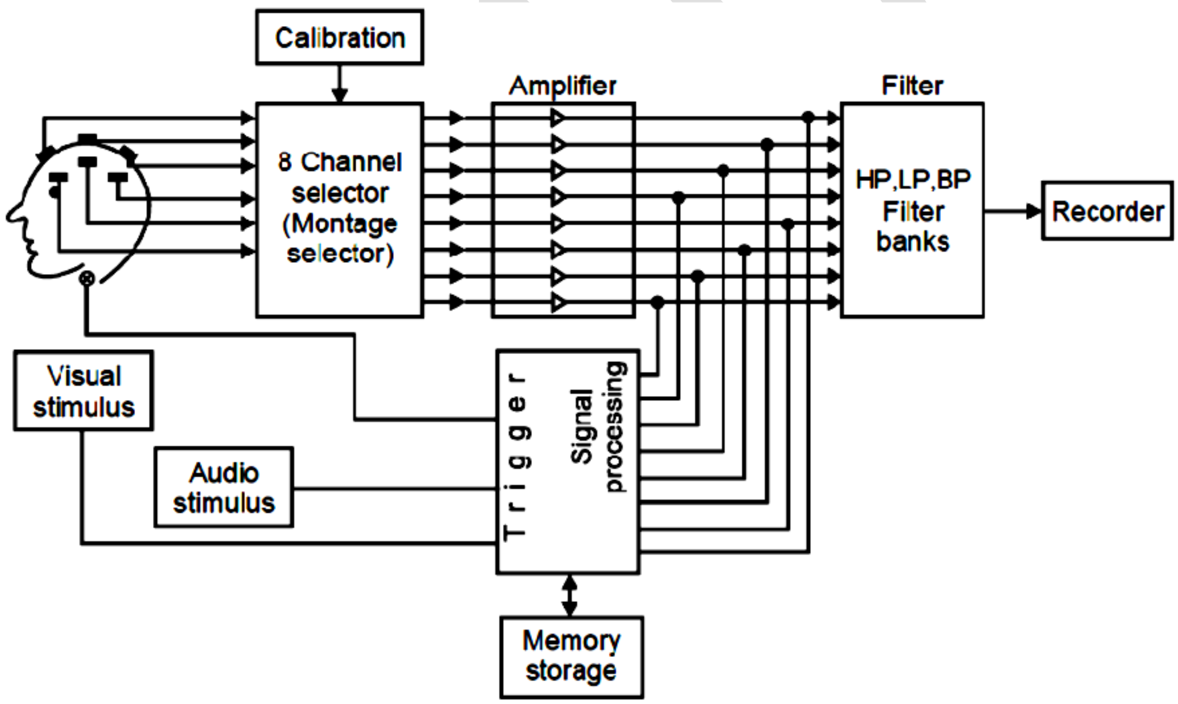
ECG – Typical Waveform

- The instrumental set up used for recording is called electrocardiograph.
- The process of recording and studying electrical potentials of heart is called electrocardiography.
- If the PR interval is more than 0.22 sec, then it is an indication of AV block (first degreeblock)
- When QRS complex duration is more than 0.1 sec, then it is an indication of the bundleblock.

EEG – Lead System, Recording Methods and Typical Waveforms

Recording System:

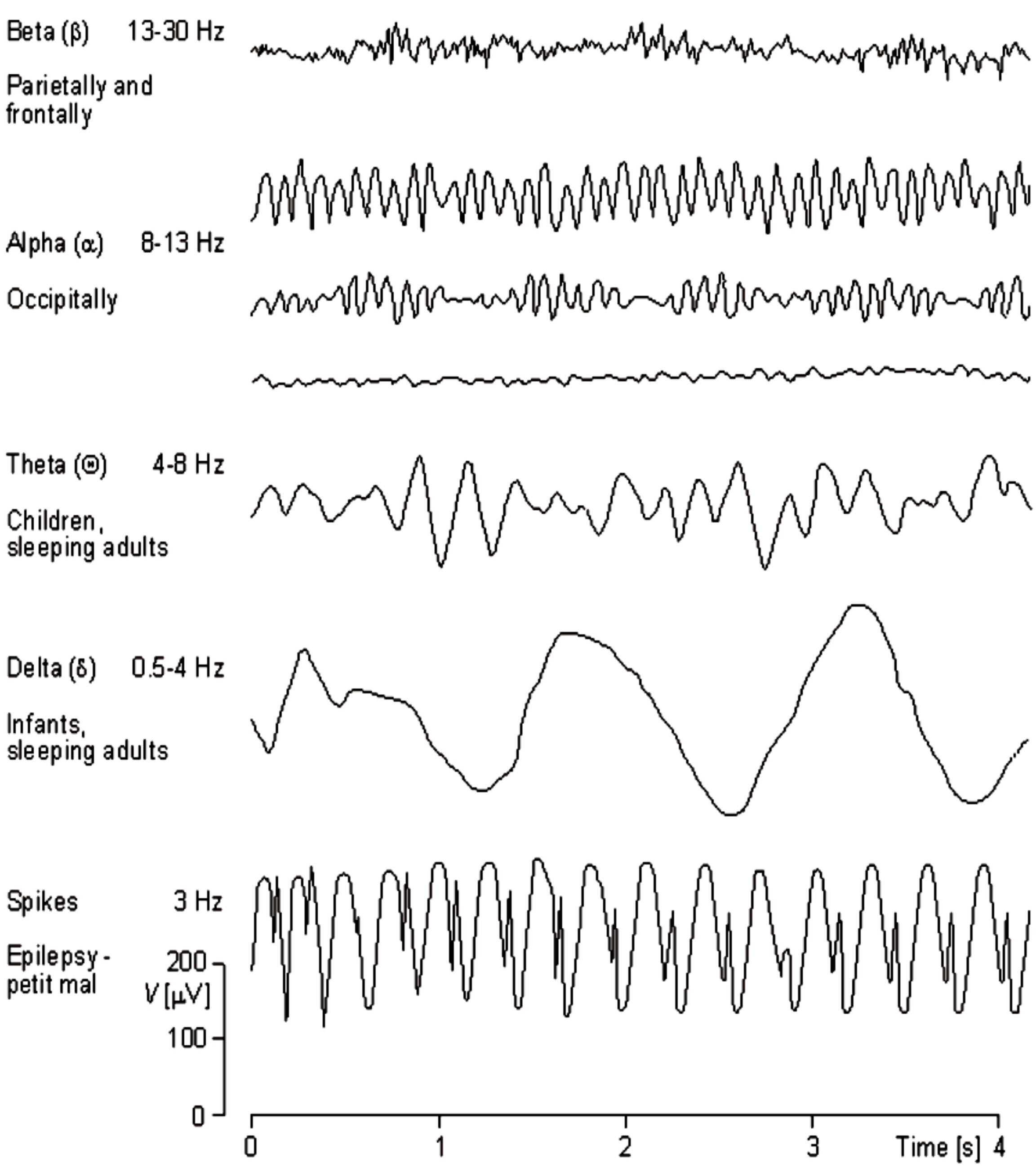
- Electro encephalography (EEG) deals with the recording and study of electrical activityof the brain.
- By means of electrodes attached to the skull of a patient, the brain waves can be picked up and recorded.
- Electrical potentials of the brain are due to gradient in concentration of dendrite gradedpotentials.
- EEG recording set up includes the patient cable consisting of 21 electrodes and isconnected to the eight channel selector.
- Every channel of the channel selectorconsists of an individual, multistage, ac coupled, differential, adjustable gain amplifier.
- These amplifiers must have high gain and lownoise characteristics since the EEGpotentials are in micro Volt range.



EEG – Recording Set Up

- The common mode rejection ratio of the EEG amplifiers should be high to minimizestray interference signals.
- They should have input impedance and lowoutput impedance.
- The amplifiermust be free from drift so as to prevent the slowmovement of recordingpen.
- The EEG signal frequency ranges between large values so it becomes necessary to use set of filters including lowpass, high pass and band pass.

- The amplified EEG signals are passed through this filter bank.
- Typical cut off frequencies forthe lowpass filters are 5.3, 1.6, 0.53 and 0.16Hz.
- Band pass filters tuned for 60 Hz are used to eliminate mains frequency interference.
- The high pass filters have typical cut off frequencies 15, 30, 70, 300 Hz.
- The output voltage from the amplifiermay eitherbe applied directly to the eight channeldisplay through the filter bank orit may be stored as data on a tape recorder or computermemory forfurther processing.



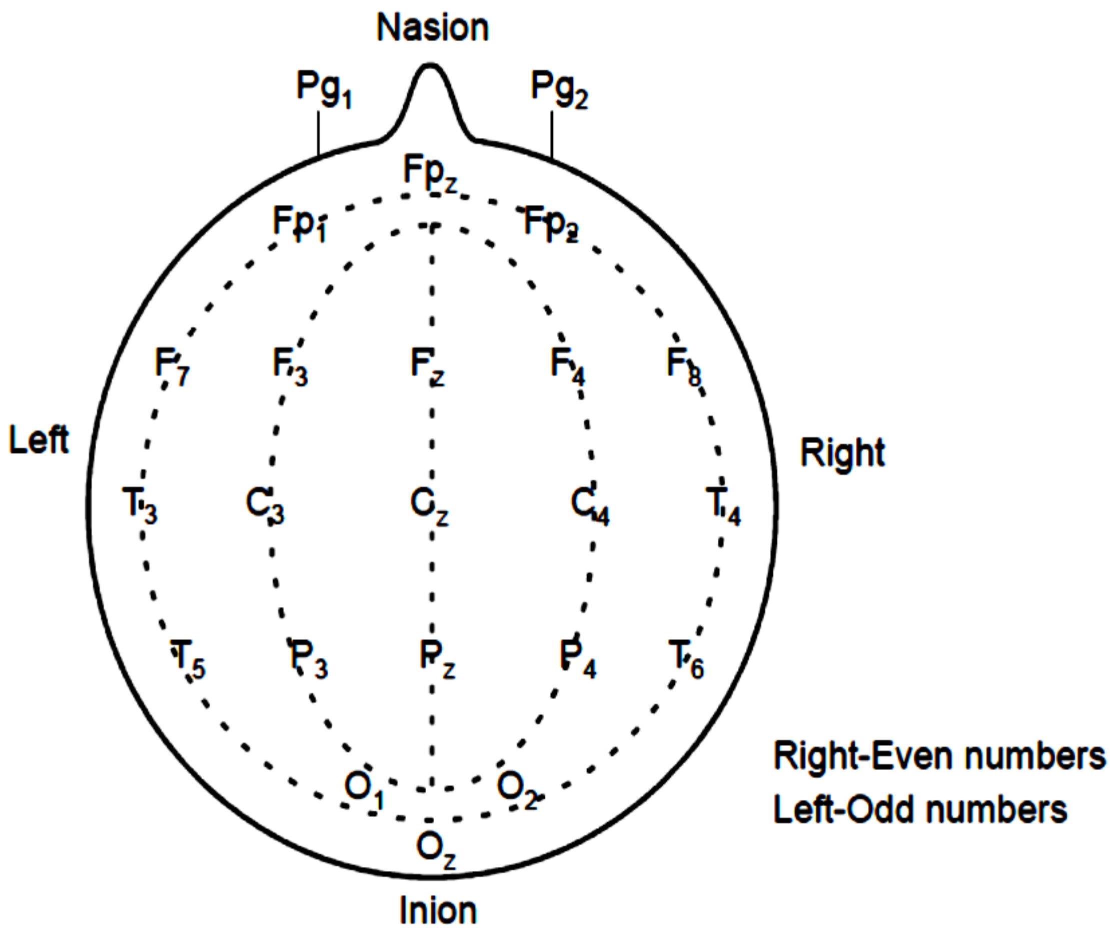
EEG – Typical Waveform

- There are otherfacilities available to record evoked potentials from the brain due toexternal stimuli like visual stimulus, audio stimulus and tactile stimulus.
- The time delay between the stimulus and response can also be measured in the signalprocessing unit and can be accounted forevoked potentials.
- EEG helps in diagnosing disorders orabnormalities related to brain such as, tumors,Epilepsy, sclerosis, sleep disorders, mis-functioning of neurons etc.

<u>EEG - Electrode System:</u>

- The commonly used electrode system for recording EEG signals is termed as 10-20electrode system or Montage electrode System.
- The electrodes are placed at a distance of 10% and 20% appropriately from the total distance between the extreme end points of the skull namely appropriately from the total distance between the extreme end points of the skull namely appropriately from the total distance between the extreme end points of the skull namely nasion, inion, rightand left earlobes.
- This type of a system is otherwise called montage electrode system.
- In montage system the electrodes are placed symmetrically on both sides of the skull.
- Both bipolarand unipolarsystem can be used. In bipolarthe differences in potential betweentwo neighboring electrodes are considered.
- For Unipolartype the reference electrodes are placed on the non-active part of the head like forehead oron the earlobes.
- Firstly the distance between nasion and inion is determined and the distance betweenthe right and left earlobe is also determined.
- The central electrode is placed at the intersection of the imaginary lines joining nasionand inion and right earand the left ear.
- Electrode placement along imaginary line between inion and nasion,o Fpz – 10% of distance between nasion-inion
  - Fz – 20% of distance between nasion-inion
  - Cz – Centre point of nasion-inion and right earlobe-left earlobe
  - Pz – 20% of distance between nasion-inion
  - Oz – 10% of distance between nasion-inion
- Electrode placement along imaginary line between right earlobe and left earlobe,
  - T3 – 10% of distance between right and left earlobe
  - C3 – 20% of distance between right and left earlobe
  - Cz – Already placed [centre point of nasion-inion and right and left earlobe]
  - C4 – 20% of distance between right and left earlobe
  - T4 – 10% of distance between right and left earlobe
- Electrode placement between Fpz and Oz passing through T3

- o Fp1 – 10% of distance between Fpz and Oz
- o F7 – 20% of distance between Fpz and Oz
- o T3 – already placed (10% distance between right and left lobe at the left)
- o T5 – 20% of distance between Fpz and Oz
- o O1 – 10% of distance between Fpz and Oz



10-20 EEG Electrode System

- Electrode placement between Fpz and Oz through T4,
  - o Fp2 – 10% of distance between Fpz and Oz
  - o F8 – 20% of distance between F¬pz and Oz
  - o T4 – already there (10% distance between right and left earlobe at the right)
  - o T6 – 20% distance between Fpz and Oz

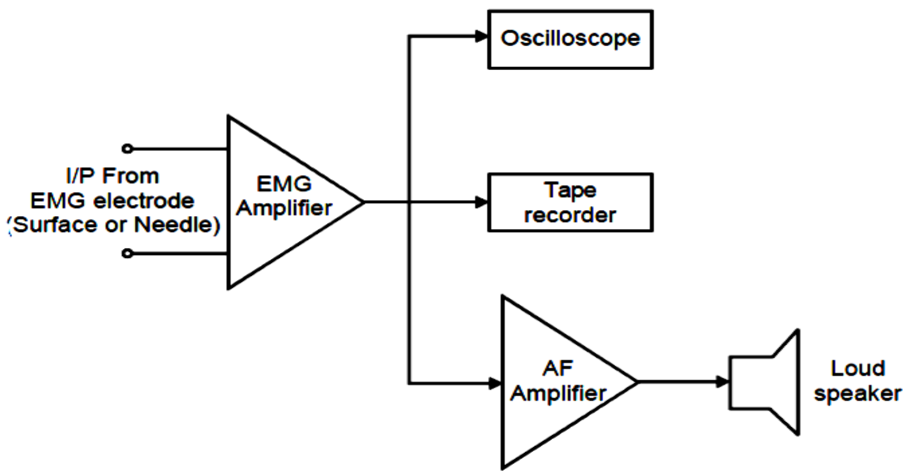
- O2 – 10% distance between Fpz and Oz
- Electrode placement between Fp2 and O2 through C4,
  - F4 – 25% of distance of Fp2 and O2
  - C4 – 20% of distance between right and left earlobe (already present) (right side)
  - P4 – 25% of distance between Fp2 and O2
- Electrode placement between Fp1 and O1 through C3,
  - F3 – 25% of distance between Fp1 and O1
  - C3 – 20% of distance between right and left earlobe (already present) (left side)
  - P3 – 25% of distance between Fp1 and O1

<u>EMG – Lead System, Recording Methods and Typical Waveforms:</u>

- Electromyograph is the instrument for recording and interpreting the electrical activityof muscles action potential.
- The electrical activity of the underlying muscle can be measured by placing surfaceelectrodes on the skin.
- To record the action potential of individual motorunit the needle electrode is insertedinto the muscle.
- EMG indicates the amount of activity of a given muscle ora group of muscles.
- EMG waveform appears, very much like a random noise signal.
- Contraction of a muscle produces action potential. When a muscle is relaxed there isno action potential.
- The surface of the skin is cleaned and electrode paste is applied.
- The electrodes are kept in place by means of elastic bands.
- The amplitude of the EMG signals depends upon the type and placement of electrodesused and degree of muscularexertions.
- The surface electrode picks up many overlapping spikes and produces an averagevoltage from various muscles and motorunits.
- The EMG signal ranges from 0.1 mV to 0.5 mV.
- The frequency components of the EMG signal vary from 20 KHz to 10 KHz and they arerestricted to the frequency range of 20Hz to 200Hz forclinical purposes by using a low

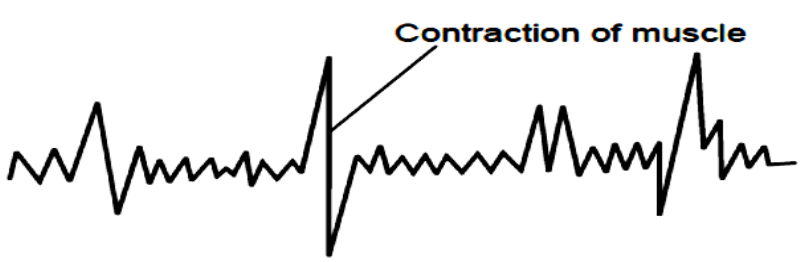
pass filter.

- The normal frequency is 60 Hz.
- Slowspeed strip chart recorders and the signals are displayed or CRO and photographic recordings are also made.



EMG – Recording Set Up

- Usually two cathode ray tubes one forviewing and otherfor recording is used.
- A light sensitive papermoves overthe recording cathode ray tube and the image isproduced on that paper.
- Forcontinuous recording, the paperspeed is about 5 to 25 cm/ sec.
- The amplifiershould have uniform frequency response in the frequency range from 10Hz to 1 KHz with high CMRR (100 dB) and input impedance greater than 10 MΩ with lowoutput impedance.
- The signal is also recorded in a tape recorder forfuture reference.



Typical EMG Waveform

- EMG waveforms are very useful forstudying the neuromuscular function, neuromuscular condition, reflex responses, extent of nerve lesion and diagnosing themusculardiseases.

Nerve conduction Velocity:

- Nerve conduction velocity is used to identify the location and extent of nerve lesion.
- To find out the nerve conduction velocity two electrodes are used namely, 1) Stimulating electrode and 2) Measuring electrode.
- When a short brief electric pulse of 0.1 ms or 0.2 ms is given to the muscle, the muscleundergoes contraction ortwitch giving rise to action potential.
- The stimulating electrode gives the stimulation pulse.
- The measuring electrode records the EMG and hence the action potential due to contraction.
- The time between stimulation and contraction helps in determining velocity, if thedistance between them is known.
- Firstly, the stimulating and measuring electrode are separated by a known distance l1.
- The time between stimulation and contraction is noted t1. This time is also calledlatency.
- Then the stimulating and measuring electrode are removed and replaced at differentlocations separated by a distance l2, which is lesserthan l1.
- Nowlatency cor esponding to l2, which is t2 is noted.
- The conduction velocity, V is calculated by, l1 – l2/ t1- t2.
- Normal nerve conduction velocity is 50 m/ s.
- If it is below 40 m/ s, then a disorder orlesion is detected at the location.

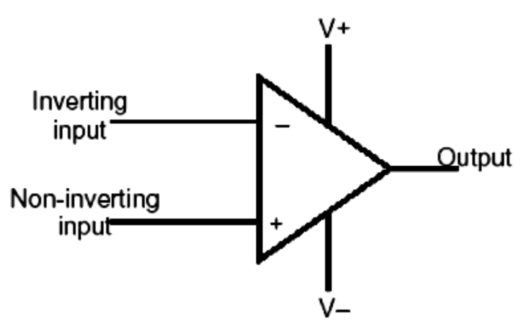
- B – Due to later receptor potentials produced by syruptic ending of the photo receptors.C to D – Wave recorded at the offset of the light stimulus.

UNIT III SIGNAL CONDITIONING CIRCUITS 9

Need for bio-amplifier - differential bio-amplifier, Impedance matching circuit, isolation amplifiers, Power line interference, Right leg driven ECG amplifier, Band pass filtering

Amplifiers

- Amplifieris a device which amplifies orincreases an input of current orvoltage.
- Most bio-electric signals are of very lowamplitude thus requiring amplification.
- Amplifiers are also used forinterfacing sensors/ transducers that senses body motions,temperature and chemical concentrations to signal conditioners.
- Thus it can be said that an amplifierused to process bio-potentials are called bio-electric amplifiers.
- Some bio-electric amplifiers are ac-coupled and some are dc-coupled.
- Linearintegrated circuits are being used in a numberof electronic applicationsincluding medical electronic instruments.
- An important linearintegrated circuit is operational amplifier.
- The operational amplifier(OP-AMP) is a multi-terminal, high gain differential amplifier.
- It is normally used in circuits that have characteristics determined by external negative feedback networks.
- The circuit symbol foran OP-AMP is shown in figure below.
- The inverting input produces an output signal that is 180 degrees out of phase with theinput signal, which is termed as inversion of the signal.
- The non-inverting input produces an output signal that is in phase with the input signal.



Operational Amplifier Circuit Diagram

- The properties of an ideal op-amp include,

    i. Infinite open loop voltage gain.

ii. Zero output impedance

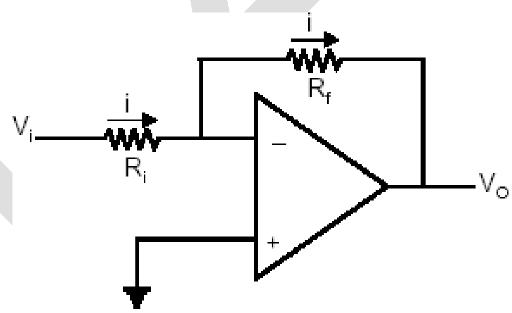
iii. Infinite input impedance

iv. Infinite frequency response

v. Zero noise contribution

vi. Both input followeach otherin feed back circuits.

- There are three basic classes of voltage amplifiers namely,
- Inverting follower
- Non-inverting followerwith gain
- Unity gain non inverting follower.
- There are two basic rules orinput terminal restrictions that are very helpful in designingop-amp circuits.
- They are,
- When the op-amp output is in its linear range, the two input terminals are at the samevoltage.
- No current flows into eitherinput terminal of the op-amp.
- In the basic inverting amplifiercircuits, a portion of the output voltage V_o is fed back via feed back resistor R_f to negative input terminal.
- The positive input of the op-amp is at 0V. This condition is called as virtual ground.
- Since the input voltage is V_i the current through R_i is $i = V_i/R_i$



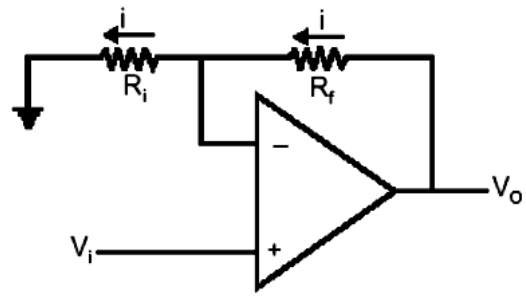
Inverting Amplifier

- By rule (2) no current can enterthe op-amp and thus I flows through R_f.
- Hence there is a voltage drop $i R_f$ across R_f.
- Therefore, $V_o = -i.R_f$

$V_o = -V_i.R_f/R_i$

(or) $V_o/V_i = -R_f/R_i$

- In the basic non inverting amplifiercircuit V_i is connected to positive input terminal.



Non-inverting AmplifierBy

rule (1), Vi also exists at negative terminal.

This causes cur ent i = Vi/ Ri to flowto ground through Rf.

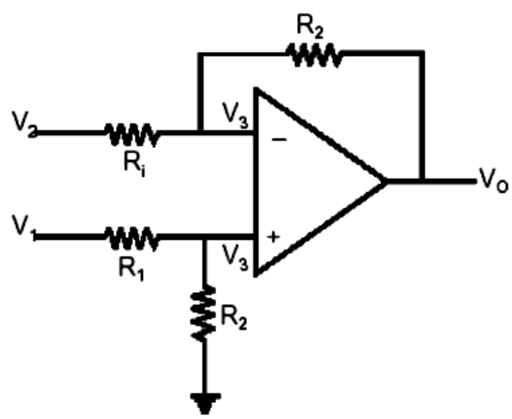
$V_o = i(R_f + R_i)$

$V_o / V_i = i(R_f + R_i) / i.R_i$ $V_o /$

$V_i = (R_f + R_i) / R_i$

Differential Amplifier

- In medical electronics, the differential amplifieris employed when it is necessary to measure the voltage difference between two points, both of them varying in amplitudeat different rates and at different patterns.
- Example: Differential amplification of heart generated voltages picked up by means ofelectrodes on the arms and legs.
- A differential amplifierproduces an output voltage that is proportional to the differencebetween the voltages applied to the two input terminals.



Differential Amplifier

Since an operational amplifierhas a pairof differential input terminals, it is easilyconnected foruse in a differential amplifierconfiguration.

The differential voltage at the input terminals of the op-amp is zero, that is nodes a and bare at the same potential designated as V3.

The nodal equation at ‘a’ is

$((V3 - V2)/R1) + ((V3 - V0)/R2) = 0$ ....(1)

The nodal equation at ‘b’ is

$((V3 - V1)/R1) + (V3/R2) = 0$ ....(2)

Rear anging we get,

$((1/R1) + (1/R2))V3 - V2/R1 = Vo/R2$ ....(3)

$((1/R1) + (1/R2))V3 - V1/R1 = 0$ ....(4)

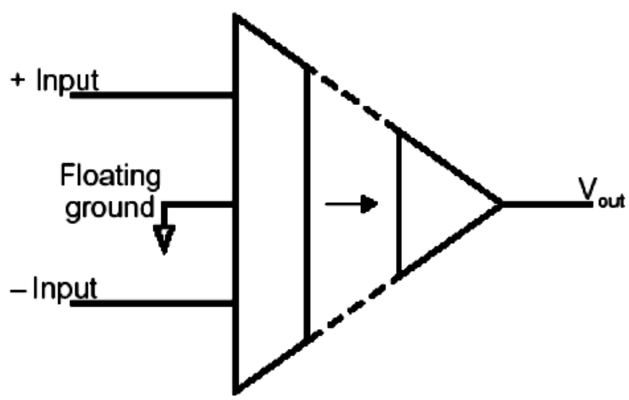
Subtracting (4) from (3) we get, 1/

R1.(V¬1 – V2) = V0/R2

$V0 = R2/R1.(V1 - V2)$

Isolation Amplifier

- Isolation amplifiers are used forproviding protection against leakage cur ents.
- Isolation amplifiers are used mainly in ECG recording, to prevent accidental internalcardiac shock.



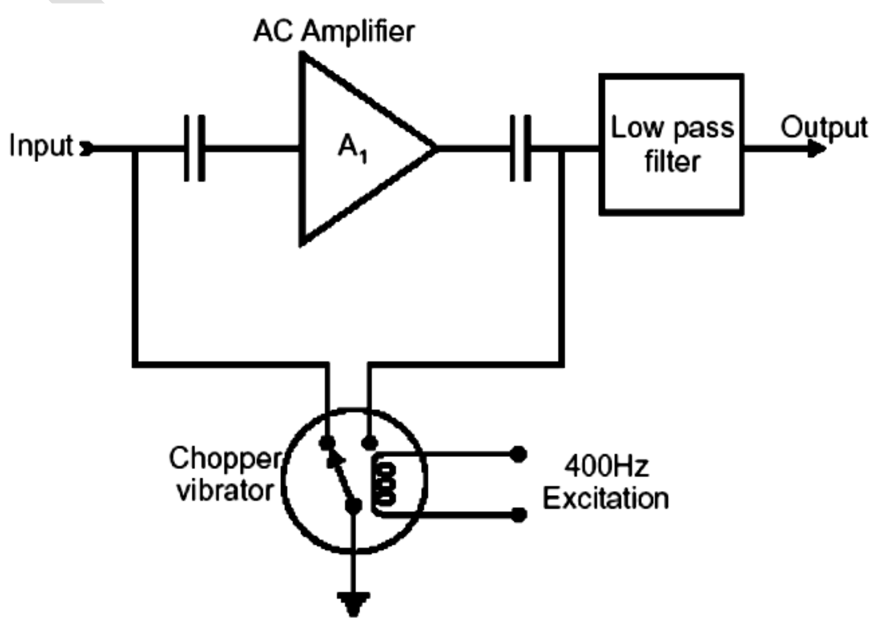
Isolation Amplifier

- Isolation amplifiers provide insulation between the patient connectorand the ac powermains line cord.
- Isolation amplifiers are mainly used to protect hospital patients, susceptible toelectrical shock hazards.
- They break the ohmic continuity of electric signals between the input and output of theamplifier.

- These type of bio-electric amplifiers provide as much as $10^{12}\ \Omega$ of insulation.
- The insulation amplifieris composed of an input amplifier, modulator, an isolationbar ier, a demodulatorand an output amplifier.
- The isolation amplifieris really an energy converter.
- There is an input common and an output common that are electrically isolated fromone another.
- Isolation bar iermay be optical, magnetic transformer, capacitive oreven heat transfer.
- In the isolation amplifierelectrical energy on the modulatorside is converted to some non electrically conductive energy in the bar ierand then converted back to electrical energy on the demodulatorside.
- Isolation amplifiers actually operate on the principle of attenuation.
- A high bar ier impedance acts in series between input and output.
- Isolation amplifierbreak ground loops to permit incompatible circuits to be interfaced together while reducing noise.
- They amplify signals while passing only lowleakage cur ent to prevent shock to peopleordamage to equipment.
- Depending on the design the isolation amplifiers are classified as battery powered,car ier, optically coupled and cur ent loading.

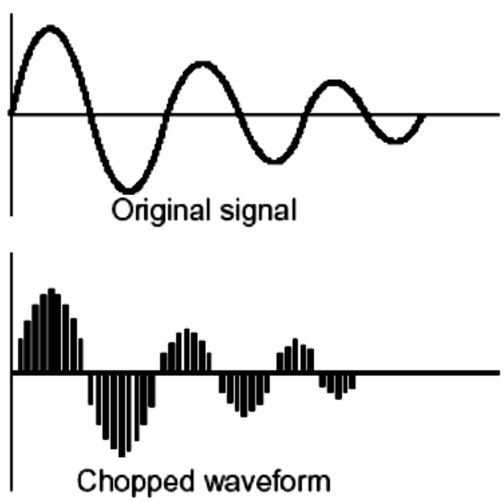
Chopperamplifiers

- Chopperamplifieris used in medical electronic devices as it achieves adequate low frequency response while avoiding drift present in direct coupled amplifier. Drift is thechange in gain caused by thermal effects on the amplifiercomponents.



Chopper Amplifier

- Chopperamplifiers use a chopping device, which converts a slowly varying direct current to an alternating form with amplitude proportional to the input direct current.
- Phase dependent on polarity of the original signal.
- This alternating voltage is then amplified by a conventional amplifier whose output isrectified back to get an amplified direct current.
- The differential input chopperamplifieris shown in figure below,
- The chopperis a vibrator – driven single pole, double throw switch that grounds the amplifierinput and output terminals on alternate swings of the switch.
- The choppervibrator coil is excited by a 400 Hz ac carriersignal.
- The chopperis on the input circuit only.
- The centre tap of the input transformer is connected to the input connector, while thetwo winding extremities are connected to the chopper.
- The pole of the chopperswitch becomes the otherterminal of the input connector.
- Gain is provided by the ac-coupled amplifier.



Chopped Waveforms

- In medical field, chopperamplifiers are used in the amplification of small DC signals ofa fewmicro volts. Chopperamplifiers are used with transducers such as strain gauge, thermistors, thermocouples etc.

Electrical safety in medical environment: shock hazards – leakage cur
ent-

Instruments forchecking safety parameters of biomedical equipments

Introduction:

- Medical Technology has substantially improved health care in all medical specialtiesand has reduced mortality forcritically ill patients.
- The increased complexity of medical devices and theirutilization in more proceduresresult in about 10,000 device related patient injuries according to a survey.
- Most of these injuries are attributable to improper use of a device as a result ofinadequate training and lack of experience.
- Medical procedures usually expose the patient to more hazards than the typical home or workplace, because in medical environments the skin and mucous membranes are frequently penetrated oraltered and because there are many sources of potentially hazardous substances and energy forms that could injure the patient.
- Sources of potential hazards in medical environment include fire, air, earth, water, chemicals, drugs, microorganisms, vermin, waste, sound, electricity, natural and unnatural disasters, sur oundings, gravity, mechanical stress and people responsibleforacts of omission and radiation from x-rays, ultrasound, magnets, ultraviolet light, microwaves and lasers.
- Electrical safety is important to be considered in the medical instrumentation field.

Physiological Effects of electricity:

- Fora physiological effect to occur, the body must become part of an electric circuit.
- Cur ent must enterthe body at one point and leave at some otherpoint.
- The magnitude of the cur ent is equal to the applied voltage divided by the sum of theseries impedances of the body tissues and the two interfaces at the entry points.
- The largest impedance is often the skin resistance at the contact surface.
- Three phenomenons can occur when electric cur ent flows through biological tissue:

  1) Electric stimulation of excitable tissue (nerve and muscle)

2) Resistive heating of tissues

3) Electrochemical burns and tissue damage fordirect cur ent and very high voltages.

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Micro-shock & Macro-shock:

Many devices have a metal chassis and cabinet that can be touched by the medical attendants and patients. If they are not grounded, then an insulation failure orshort circuitresults and leads to macro-shock ormicro-shock.

Micro-shock:

A physiological response to a cur ent applied to the surface of the heart that results in unwanted stimulation like muscle contractions ortissue injury is called micro-shock. Micro -shock is caused when cur ents in excess of 10 micro Amperes flowthrough an insulatedcatheterto the heart. The cathetermay be an insulated, conductive fluid filled tube, ora solid wire pacemakercable.

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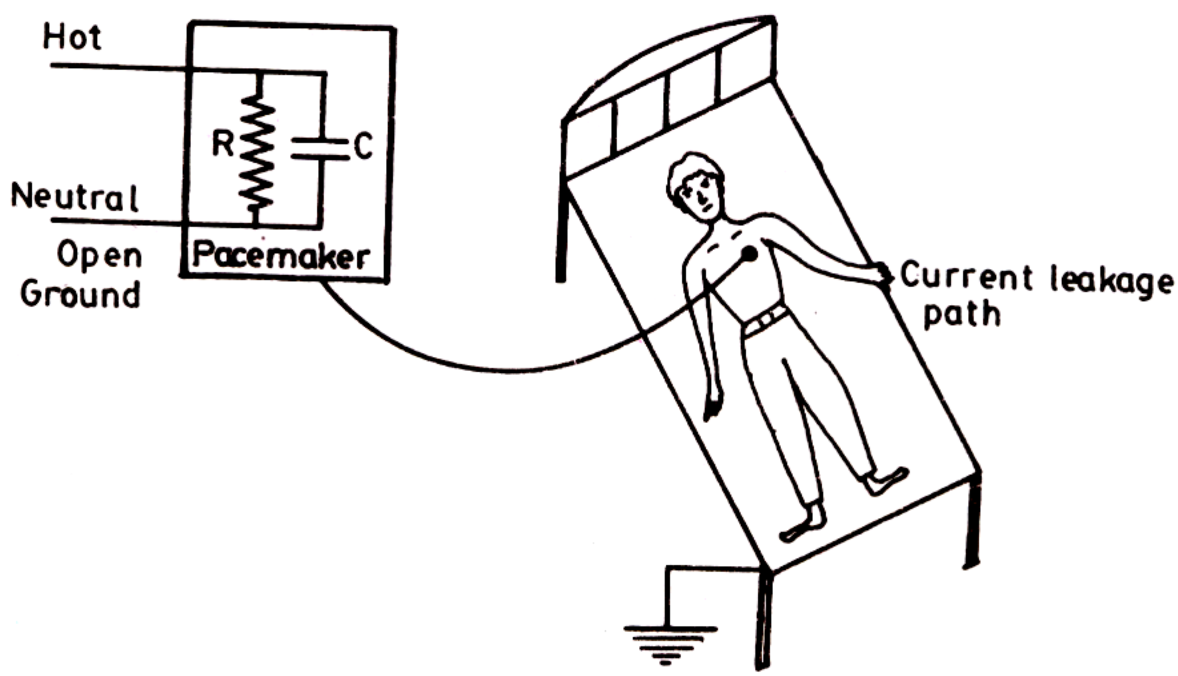
The bed frame is properly grounded to the power system. The patient's left hand is restingon the bed frame. Since the ground of the pacemakeris floating, by capacitive coupling a total of 180 micro Amperes of leakage cur ent is present in the pacemaker. In this case
leakage cur ent is passed from the pacemakerthrough the catheterinto the heart, through
the body core of the left hand and then to the ground via the bed frame. The heart undergoes ventricular fibrillation. This dangerous accident arises because of the open ground of the pacemakerby using a two wire extension cord. The leakage cur ent flowis due to 1) Ungrounded Equipment, 2) Broken ground wire and 3) Unequal ground potentials



Microshock due to leakage current

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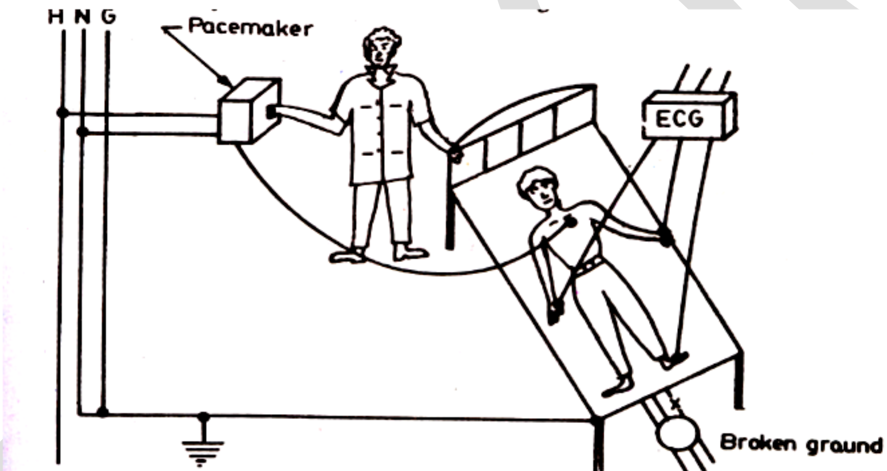
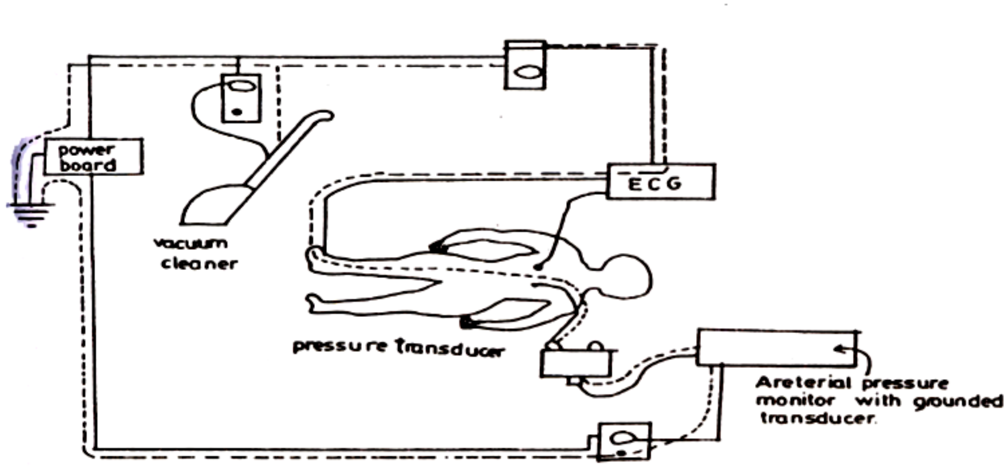
The heart activity is monitored by an ECG recorder. Hence a leakage cur ent flows from themotorof the bed frame to the medical attendants hand and to the patient's heart through the catheterorpacemaker wire and then to the ground of the ECG unit. In the figure below H stands forhot, N forneutral and G stands for Ground.



Microshock for the patient from the broken ground wire

2) Static Electricity:



Mircoshock from static electricity

Static Electricity may be dangerous to people and sensitive equipment having integrated circuits. Sparks from static electricity could ignite flammable gases, causing an explosion. Shocks from static electricity could cause cardiac ar est if applied to a pacemakercatheter. Carpets used on the floorare a source of static electricity build up.

As illustrated in figure above an accident due to static electricity may be due to a simple vacuum cleaner.

A vacuum cleaneris plugged into a wall power outlet as the same circuitas the ECG monitorand the arterial pressure monitor. The frame of the vacuum cleaneris

connected to ground. The motorin the cleanerdue to dust collection and moisture may provide a leakage path from line to the outercasing. If a fault cur ent of 1 A flows from thevacuum cleanercasing to ground of the power board and the resistance to power board ground is 0.08 ohms, then a voltage of 80 mV is developed. Fora cardiac cathetersaline solution the resistance may be 500 ohms. 80 mV across 500 ohms drives 160 mA cur ent

which is very much greater than 10micro Ampere, the maximum safe cur ent through the

heart in the case of micro-shock. The micro-shock arises due to static electricity due to dust collection in the motorof the vacuum cleanerand by the saline catheteroffering a lowresistance path thereby raising the cur ent density of the heart. Even a potential difference of 5 mV across the electronic instrument probes can be potentially lethal problem in the case of micro-shock.

3) Inter uption of power:

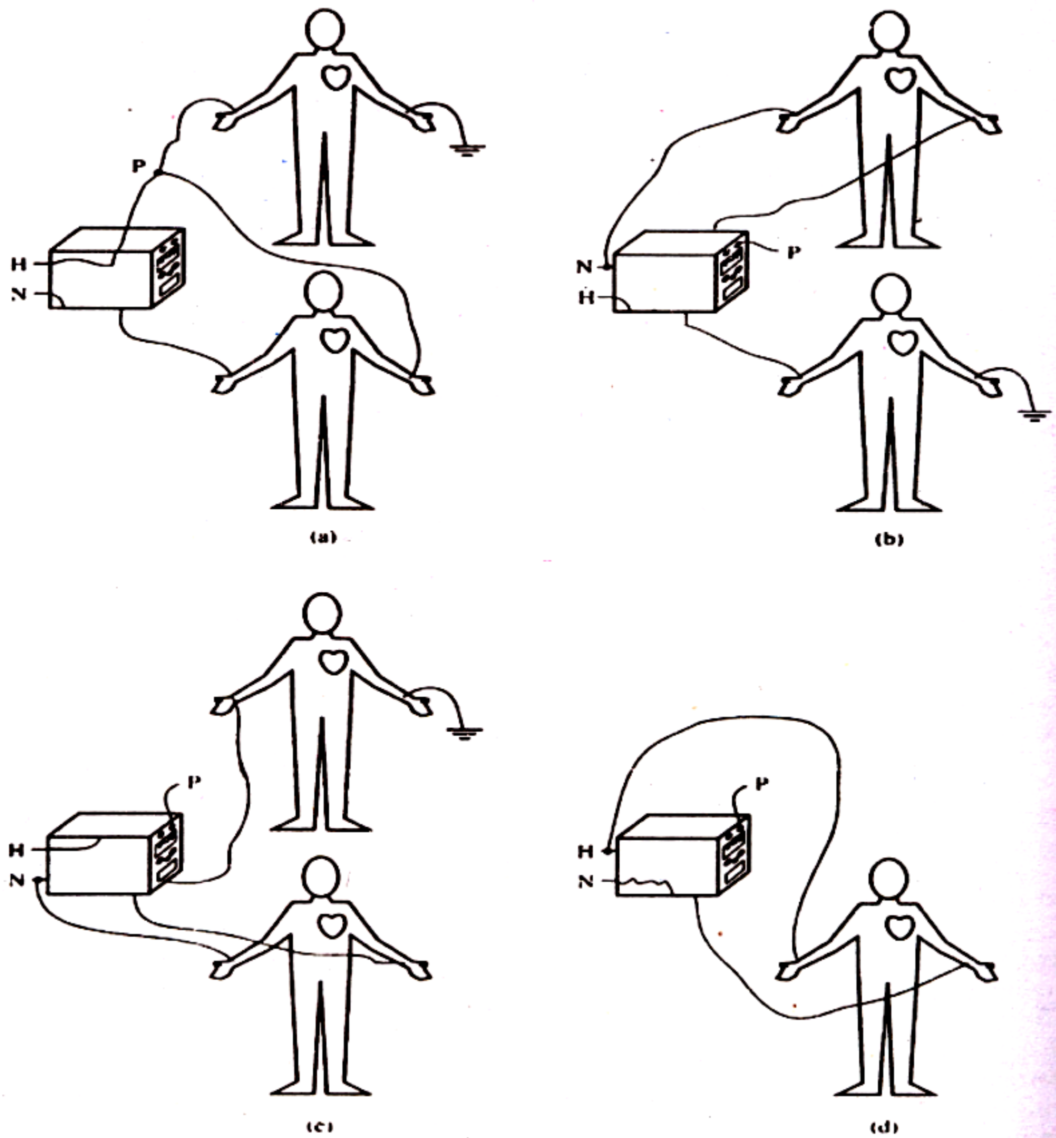
Inter uption of electrical power to life support equipment can be hazardous. If a delay occurs before emergency power is brought into operation, the failure of a respirator, monitor, defibrillator, pacemakerorotherlife support equipment can be fatal. The possibility of a power failure must be considered in the planning of a power distributionsystem. Electrical service to life support system should be un-inte**r** uptible.

Macro-shock:

A physiological response to a cu**r** ent applied to the surface of the body that produces unwanted orunnecessary stimulation like muscle contractions ortissue injury is called macro-shock. All hospital patients and medical attendants are exposed to macro-shocksfrom defective electric devices and biomedical equipment.

Macro-shock Hazards:

Macro-shock occurs with two wire systems. With two wire equipment it is always dangerous to get between the hot H and neutral N wires. If the patient touches H and N wires simultaneously with two limbs, then the cu**r** ents are flowing directly through vitalorgans of circulation and



Macroshock situations in the case of two wire units

respiration. Because N wires are internally grounded, touching H and G wires can producemacro-shock. Figure above illustrates additional hazardous situations that result from faults that may occurin the equipment. In part (a), the H lead shorts to the patient lead P. Thus a macro- shock results if the patient touches ground orthe chassis. In part (b), the hot wire H and neutral N are reserved because the two wire plug has been reserved. A grounded patient istherefore shocked upon touching the chassis. In part (c) the H wire shorted to the chassis, causing the shock configuration shown as the patient touches eitherneutral orground andthe chassis. In part (d) the neutral wire accidentally shorts to the equipment case, leading to a shocksituation of H to chassis or H to ground. If the H line faults to N, no shock occurs unlessthe patient touches H or N and ground.

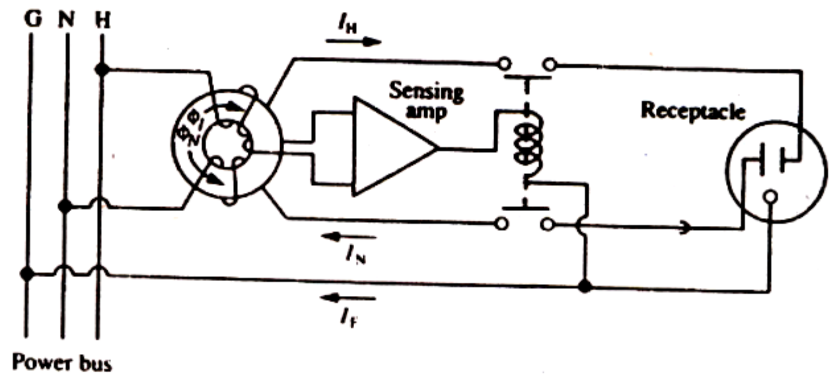
To protect from hazards of a two wire plug, a third ground wire is added as in a 3-pin plug.This wire is usually connected to the chassis of the equipment and ensures that it will not rise to a high voltage. Anothermethod is to double-insulate that chassis that is to place alayerof insulation between the circuit board chassis and the equipment case which is exposed to the user.

Devices to protect against electrical Hazards:

Several devices are available to protect patients from health care coworkers from hazardous electrical cur ents. These range from devices to protect against high voltage macro-shock hazards to procedures that minimize the probability that a micro-shock willoccur. Some of the devices include,

1. Ground Fault Inter upter:

A ground fault inter upter(GFI) protects against a shock that occurs if a person touches the hot lead with one hand and the ground with the other. The GFI opens the power lead if the hot lead cur ent differs by more than approximately 2 mA from the neutral lead cur entfora duration of longerthan 0.2 second. The GFI as shown in figure belowconsists of a magnetic coil on which the hot lead and the neutral lead are mound with the same numberof turns, but in opposite directions. When the system is normal, IN is equal to IH, and the magnet flux, Φ, in the coil due to these cur ents cancels. Underthis condition the sensing coil does not have a voltage induced in it. However, when the hot lead faults, oris touched by a person, the fault cur ent IF is shunted to ground. Then IN = IH – IF and IH is not equal to IN. underthis fault condition the cor esponding fluxes in the coil are unequal, and a net flux exists in the coil. This induces a voltage into the



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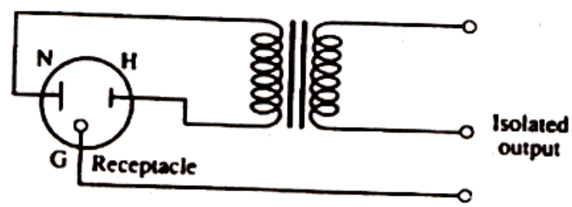
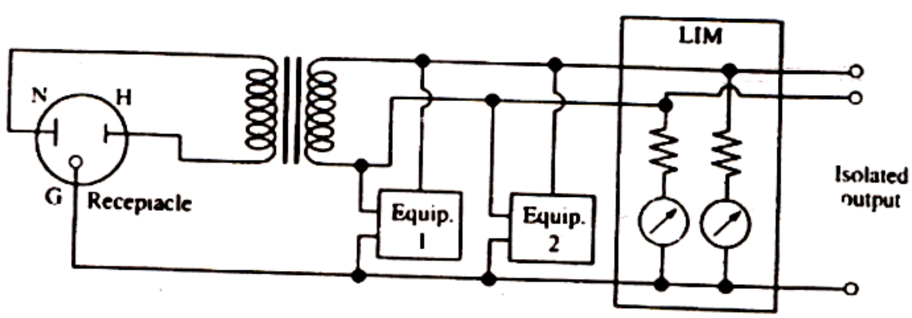


(a) An isolation transformer



(b) An isolation transformer connected to a line isolation monitor and other equipment

sensing amplifier. If the cur ent IF exceeds 2 mA for 0.2 second, the relay opens the line and prevents a macro-shock from injuring the person, as well as preventing further damage to the equipment. The GFI can be conveniently mounted in the power receptacle. Itis required in wet areas.

2. Isolation Transformer:

The isolation transformer provides a second means of protecting against an H-lead to G- lead macro-shock. It also prevents sparks when the H lead touches ground, a particularlyimportant protection I an explosive orflammable environment, such as when flammable anesthetics orexcessive oxygen is present. Figure belowclearly shows that a fault such as a short circuit from eithersecondary lead of the transformer to ground will car y no cur ent. Therefore, a secondary lead to ground spark, orshock, is prevented. However, when the isolation transformer is in use, and equipment is plugged into the secondary, thestray capacitance and the input impedance of the hardware tend to make a conductive path to ground. This reduces the isolation by completing the circuit from eithersecondary lead to ground and then to the othersecondary lead. If a fault occurs in the secondary, a hazardous cur ent will flow.

3. Line Isolation Monitor:

A Line Isolation monitor(LIM) puts a relatively large impedance from eithersecondary leadthrough an ammeterto ground of the isolation transformer. If there is a conductive path through the equipment shown in figure below, the meterin the LIM will read a cur ent. The meteron the LIM is calibrated to read what cur ent would flowthrough a short circuit fault if it should occurfrom eithersecondary to ground. An alarm in the LIM is usually set off when it is calculated that a short circuit fault between a secondary lead and ground would draw 2 to 5 mA of cur ent. This alarm merely indicates that the back up system failed and the equipments is no longerisolated. It does not mean that the dangerous cur ents are already flowing. Therefore, if the equipment is critically needed, the LIM alarm may, sometimes, justifiably be over idden.

Power Line Interference

Electrical safety in medical environment: shock hazards – leakage cur ent-
Instruments forchecking safety parameters of biomedical equipments

Introduction:

- Medical Technology has substantially improved health care in all medical specialtiesand has reduced mortality forcritically ill patients.
- The increased complexity of medical devices and theirutilization in more proceduresresult in about 10,000 device related patient injuries according to a survey.
- Most of these injuries are attributable to improper use of a device as a result ofinadequate training and lack of experience.
- Medical procedures usually expose the patient to more hazards than the typical home or workplace, because in medical environments the skin and mucous membranes are frequently penetrated oraltered and because there are many sources of potentially hazardous substances and energy forms that could injure the patient.
- Sources of potential hazards in medical environment include fire, air, earth, water, chemicals, drugs, microorganisms, vermin, waste, sound, electricity, natural and unnatural disasters, su**r** oundings, gravity, mechanical stress and people responsibleforacts of omission and radiation from x-rays, ultrasound, magnets, ultraviolet light, microwaves and lasers.
- Electrical safety is important to be considered in the medical instrumentation field.

Physiological Effects of electricity:

- Fora physiological effect to occur, the body must become part of an electric circuit.
- Cu**r** ent must enterthe body at one point and leave at some otherpoint.
- The magnitude of the cu**r** ent is equal to the applied voltage divided by the sum of theseries impedances of the body tissues and the two interfaces at the entry points.
- The largest impedance is often the skin resistance at the contact surface.
- Three phenomenons can occur when electric cu**r** ent flows through biological tissue:

4) Electric stimulation of excitable tissue (nerve and muscle)

5) Resistive heating of tissues

6) Electrochemical burns and tissue damage fordirect cur ent and very high voltages.

- Psychophysical and physiological effects that occurin human as the magnitude ofapplied electric cur ent progressively increases.
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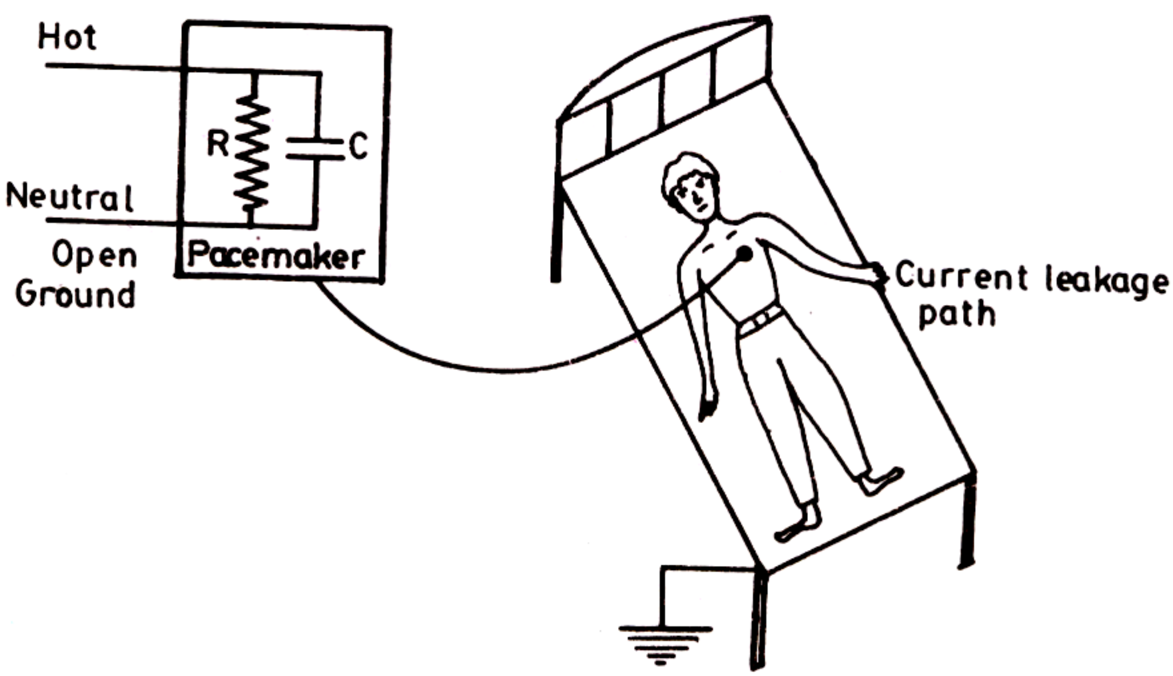

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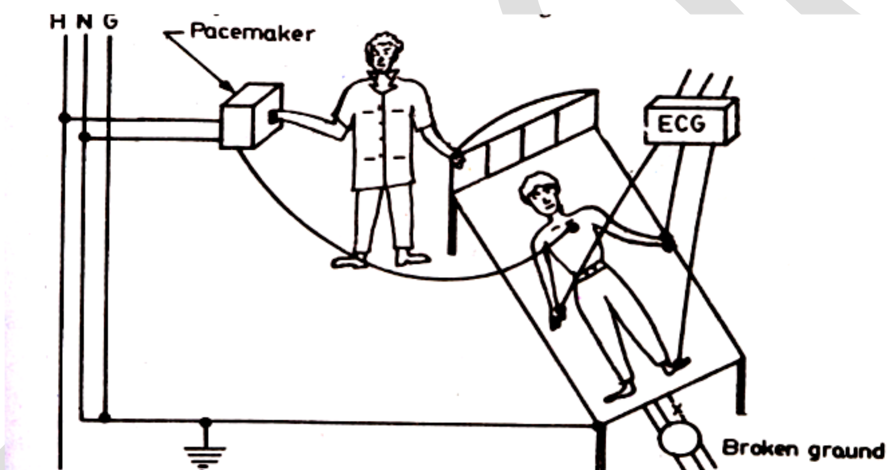

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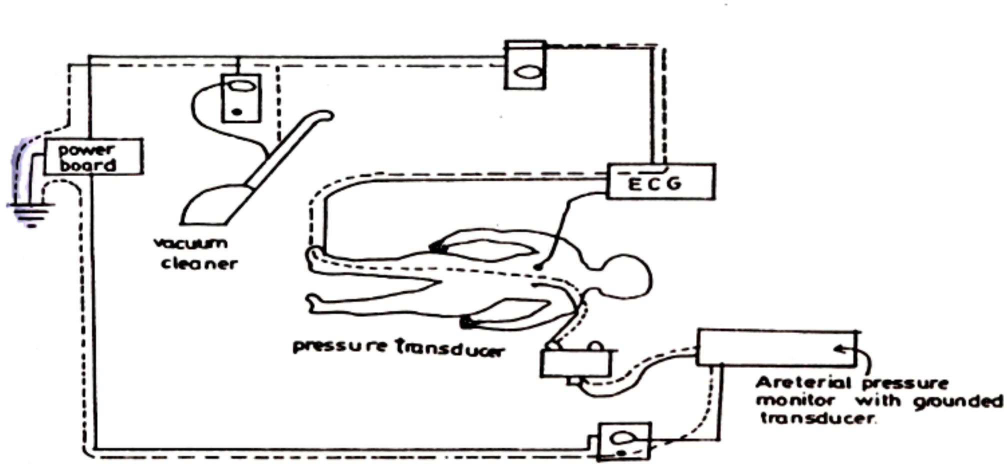

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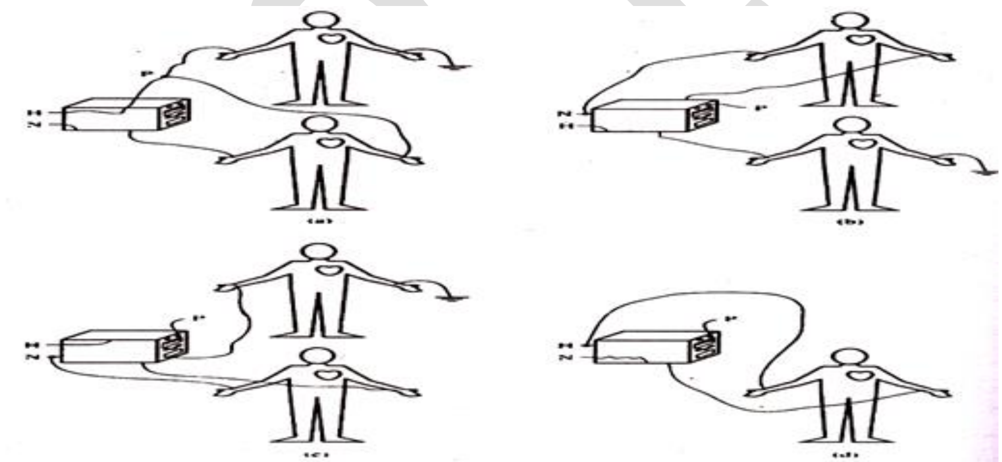

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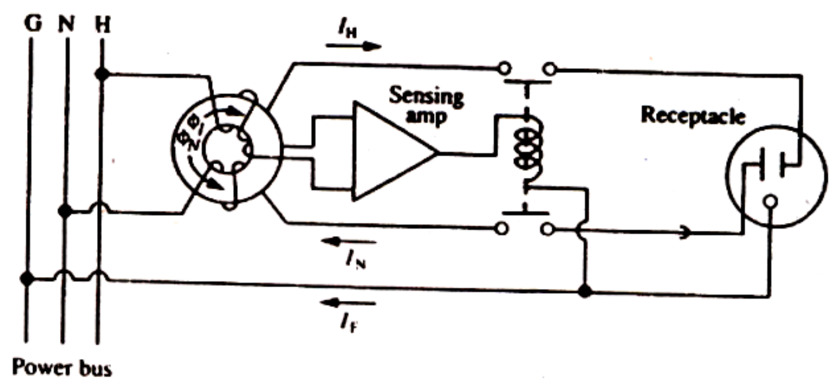
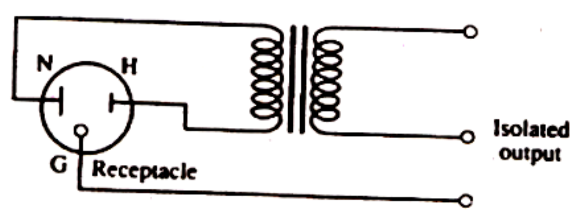


Ground fault interrupter



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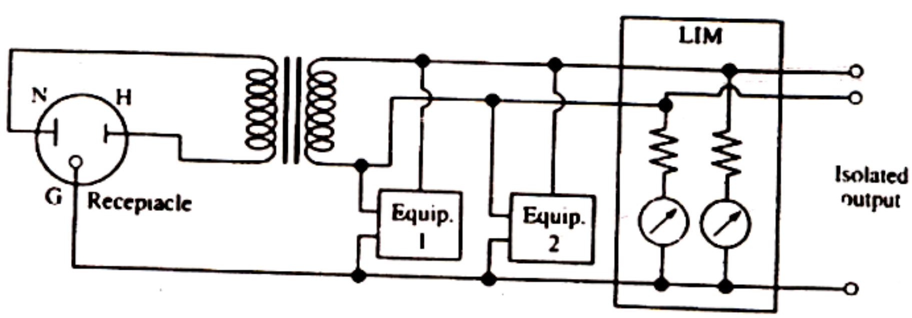

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