CHAPTER - 2

SOME TOPICS RELATED TO ELECTROCARDIOGRAPHY

An **electrocardiogram** is a graphic representation of the electrical activity of the heart. Everytime heart beats, it sets up an electrical field in the body. Various waves in the electrocardiogram are produced by the flow of electricity due to potential differences associated with this electric field. Although, the electromotive surfaces in the heart, which are responsible for the field, have potential differences of the order of 0.1v, surface voltage differences rarely exceed 2 to 3mv. Therefore, for ease of processing, this low voltage signal is amplified.

The electrocardiogram greatly depends on the electrical axis of the heart which will be defined elsewhere in this chapter. In healthy individuals the electrocardiogram remains reasonably constant but under certain pathological condition several changes are found in the electrocardiogram.

Since digital computers accept only digital data, it must be remembered that all input data must be digital in nature for any type of continious or analog wave processing. Thus, when digital computers are used for automated ECG analysis, the ECG must be digitized in such a way that there will be no loss of information content. Hence some sort of data acquisition system is necessary.

In this chapter, electrocardiographic basics relevent to the dissertation are presented.The data acquisition system required for the automated analysis of the ECG has also been discussed.

2.1 Electrocardiogram

The electrocardiogram (ECG) is a graphic recording of the electrical potentials produced in association with the heart beat [114]. The heart muscle is unique among the muscles of the body in that it possesses the quality of automatic rhythmic contraction. The impulses result in excitation of the muscle fibres throughout the myocardiam. Impulse formation and conduction produce weak electric currents which spread through the entire body. By applying electrodes to various positions on the body and connecting these electrodes to an electrocardiographic apparatus, the electrocardiogram is recorded. The connections of the apparatus are such that an upright deflection indicates positive potential and a downward deflection indicates negative potential.

Since the advent of electrocardiography, the accuracy of electrocardiogram has been greatly increased. The electrocardiogram is of particular value in the following clinical conditions.

A. Atrial and ventricular hypertrophy.

B. Myocardial Infarction.

C. Arrhythmias: Not only can more exact diagnosis be made, but unipolar and intracardiac electrocardiography have also contributed substantially to the basic understanding of the origin and conduction of abnormal rhythms.

D. Pericarditis.

E. Systemic diseases which affect the heart.

F. Effect of cardiac drugs, especially digitalis and quinidine.

G. Disturbances in electrolyte metabolism, especially potassium abnormalities.

2.2 The electrocardiograph

It is a highly sensitive moving coil galvanometer which records the passage of electricity and voltage difference between two points on the body surface. The galvanometer deflection is observed from the movement of a heated stylus which causes inscriptions on the electrocardiograph paper running at a uniform speed with the help of a motor. The different leads are selected by means of a lead selector. One end of the patient's cable is fixed to the body surface of the patient by electrodes fixed by rubber straps with a conducting material intervening between the skin and the electrodes and the other end of the cable is fixed to the machine by a suitable adapter.

The **electrocardiograph paper** is a specially prepared graph paper in which horizontal and vertical lines are present at 1mm. intervals. Time is measured along the horizontal lines: 1mm = 0.04 sec. when the tracing paper runs at a speed of 25 mm. per sec. Voltage is measured along the vertical lines and is expressed as mm. (10mm. = 1 milivolt).

2.3 The heart and its activity

The cross section of the interior of the heart is shown

in Fig. 2.1(a).[61].

The four chambers of the heart act as two synchronized two stage pumps. The right chamber supplies blood to the lungs for oxygenation, where as the left chamber supplies blood to the rest of the system. The incoming blood fills the right atrium. When it is completely filled with blood, the right atrium contracts and forces blood through the tricuspid valve into the right ventricle which then contracts to pump the blood into the pulmonary circulation system. From the pulmonary system the oxygenated blood enters the left atrium. From there it is pumped through the bicuspid valve into the left ventricle. When the left ventricular muscles contract, the blood is pumped out to circulatory system. The two atria are synchronized to pump together after which the two ventricles act together. The localized blood stream path is shown in Fig. 2.1(b).

2.4 The conduction system

The heart possesses the property of automatic and rhythmic contraction. It has the inherent ability to initiate and conduct impulses which stimulate muscular contraction. This ability is located in the specialized neuromuscular tissue known as the conduction system. The conduction system consists of (1) the sino atrial node, (2) the atrio ventricular node, (3) the Bundle of His, (4) the right and left bundle branches, and (5) the Purkinje system.

The rate and rhythm of the heart are controlled by the sino atrial node (SA node), which is situated in the wall of the right atrium to the right of the superior vena caval orifice

(Fig. 2.2). The sinus impulse leaves the SA node and spreads through the atrial muscle; this atrial activation is reflected by the P wave of the electrocardiogram. The sinus impulse eventually reaches the atrio ventricular node (AV node) which is situated in the right atrium above the tricuspid valve and just to the right of the interatrial septum. After a delay at the AV node (reflected in the electrocardiogram as the greater part of the PR interval) the impulse travels down the bundle of His,bundle branches and the Purkinje network system. The bundle of His passes horizontally to the left from the AV node, pierces the membranous interventricular septum and divides into right and left bundle branches. These pass down on either side of the muscular interventricular septum and finally divide into the Purkinje network of fibres which proceed vertically to the surface of the heart from the endocardium to the epicardium. The ventricular activation (depolarization) produces the QRS complex of the ECG. The ST segment is normally isoelectric and T wave represents recovery (repolarization) of the ventricles. Finally, a U wave of uncertain cause is sometimes recorded. The electrocardiographic complexes, intervals and segments are diagrammatically shown in Fig. 2.3.

2.5 Nomenclature and location of the electrode leads

In electrocardiography the changes in electrical potential associated with the contraction of the heart are recorded from the body surface. Thus the placement of electrodes on the body plays a vital role in the recording of ECG. Each electrocardiographic lead has a positive pole or electrode and a negative pole or electrode, which could theoretically be oriented

in any relationship to the heart. By convention, however, there are 12 lead placements [64,106,114].

These are:

Standard lead I

Standard lead II

Standard lead III

Lead aVR

Lead aVL

Lead aVF

Leads V1 to V6

Standard leads I,II and III are bipolar leads where as leads aVR, aVL, aVF and V1 to V6 are unipolar leads.

The 12 conventional leads may be divided electrophysiologycally into two groups, one being oriented in the frontal plane of body, and the other in the horizontal plane.

Standard leads I,II and III, and leads aVR,aVL and aVF are oriented in the frontal or coronal plane of the body.

The precordial leads V1 to V6 are oriented in the horizontal or transverse plane of the body.

The bipolar standard leads (I,II and III) are the original leads selected by Einthoven to record the electrical potential in the frontal plane. Proper skin contact must be made by rubbing electrode paste on the skin. The LA (left arm), RA (right arm), and LL (left leg) leads are then attached to their respective electrodes. Most modern electrocardiographs also have a right leg electrode and lead. This acts as a ground wire and plays no role in the production of the electrocardiogram. If the machine does not have this feature it may be necessary to run a ground

wire from the bed or the machine to an appropriate ground to eliminate electrical interference. The bipolar leads represent a difference of electrical potential between two selected sites.

Lead I = Difference of potential between the left arm and the right arm (LA.-RA.)

Lead II = Difference of potential between the left leg and the right arm (LL.-RA.)

Lead III = Difference of potential between the left leg and the left arm (LL.-LA.).

The relation between the three leads is expressed algebrically by **Einthoven's equation** :

Lead II = Lead I + Lead III

The electrode potential as recorded from any one extremity will be the same, no matter where the electrode is placed on the extremity. The electrodes are usually applied just above the wrists and ankles. If an extremity has been amputated, the electrode can be applied to the stump. In a patient with an uncontrollable tremor, a more satisfactory record may be obtained by applying the electrodes to the upper portions of the limbs.

Bipolar chest leads demonstrate differences of potential between any given position on the chest (C) and one extremity. Before unipolar electrocardiography was introduced, the left leg(F) was used as the indifferent electrode and the leads were called CF leads. Less commonly, the right arm (CR leads) or the left arm (CL leads) was used. It was assumed that the left leg (or right or left arm) was so remote from the heart that it would act as an indifferent electrode and not interfere with the chest potential. However, it is now realized that the potentials in the

extremities can appreciably alter the pattern of the chest lead. For this reason CF, CR and CL leads are not frequently used today. In principle, the unipolar leads attempt to represent actual local potentials and not difference in potential. Since it is generally accepted that the sum of the potential of the three extremity leads is zero (RA + LA + LL = 0), the connection of these three extremity leads (the central terminal) will, for all clinical purposes, result in a zero potential.

Using the indifferent electrode (RA+LA+LL) as one termimal and placing another electrode on the right arm, a bipolar lead can be taken. This represents the differences between the potential of the right arm and the zero potential of the central terminal (RA - 0 = RA). Therefore the actual potential of the right arm is recorded. Although it is technically a bipolar lead, it represents a unipolar lead since one of the potentials is zero. This is designated as VR (vector of right arm). The left arm (VL) and left leg (VF) potentials are obtained in the same way. This type of connections is known as **unipolar nonaugmented extremity leads**. The connections are described in a systematic way as follows.

A. To take VR, the LA lead is attached to an electrode placed on the right arm at a different site from the RA electrode connected to the central terminal.

B. To take VL, The LA lead is attached to an electrode on the left arm.

C. To take VF, the LA lead is attached to an electrode on the left leg.

The deflections of VR,VL,VF are small, but the amplitude of the deflections can be increased by about 50% by disconnecting

the central terminal attachement to the explored limb. This configuration is known as **augmented extremity leads** and are designated as aVR,aVL and aVF. It must be emphasized that the only difference between leads VR, VL and VF and leads aVR,aVL and aVF is this difference in amplitude.

Unipolar precordial or chest leads are designated by the letter V as the only alphabetical letter. These leads record the differences in potential between any given position on the chest and central terminal. The common precordial positions (as recommended by the American Heart Association) are as follows [66].

V1 : Fourth intercostal space to the right of the sternal border.

V2 : Fourth intercostal space to the left of the sternal border.

V3 : Midway between leads V2 and V4.

V4 : Midclavicular line over the fifth inter space.

V5 : Anterior auxillary line at the same level as lead V4.

V6 : Midaxillary line at the same level as leads V4 and V5.

The lead configurations are shown in Fig. 2.4.

2.6 ECG complexes and intervals

When a complex is partly above the baseline and partly below it, it is **diphasic**. When its excursions above and below the line are approximately equal, it is **equiphasic**.

P wave

This is the first wave of the electrocardiogram and represents the spread of the elctrical impulse through the atria (activation or depolarization of atria). It is normally upright in

leads I and II but is frequently diphasic or inverted in lead III. It is normally inverted in aVR and upright in aVF and in left chest leads (V4-V6). It is variable in the other leads. Its amplitude should not exceed 2 or 3mm in any lead, and its normal contour is gently rounded - not pointed or notched.

Abnormalities that should be looked are:

1. **Inversion** in leads where the P wave is normally upright, or the presence of an upright P wave in aVR (where it should be inverted); such changes are usually found in conditions where the impulse travels through the atria by an unorthodox path.
2. **Increased amplitude:** this usually indicates atrial hypertrophy or dilation and is found especially in AV valve disease, hypertension, cor pulmonale and congenital heart disease.
3. **Increased width:** this usually indicates left atrial enlargement or diseased atrial muscle. The normal P wave does not exceed 0.11 sec. in duration.
4. **Diphasicity:** an important sign of left atrial enlargement when the second half of the P wave is signaficantly negative in lead III or V1.
5. **Notching:** When the left atrium is mainly involved the P wave often becomes wide and notched and is taller in lead I than in lead III. Notching is considered significant when the distance between peaks exceeds 0.04 sec.
6. **Peaking:** right atrial overload usually produces tall pointed P waves taller in lead III than in lead I.

7. **Absence** of P waves: this occurs in some AV junctional rhythms and in SA block.

PR interval

This is measured from the begining of the P wave to the begining of the QRS complex. It measures the time taken by the impulse to travel all the way from the SA node to the ventricular muscle fibres, and this is normally from 0.12 to 0.20 second. It is customary to examine several intervals and record which appears the longest. The interval varies with heart rate, being shorter at faster rates. If the conducting system is diseased or affected by digitalis, the PR may lengthen as the rate increases. Similarly if the atria are paced artificially the PR increases as the paced rate quickens [83]. The PR is proportionately shorter in children, averaging 0.11 sec. at 1 year, 0.13 at 6 and 0.14 at 12 years. An interval prolonged beyond normal limits is regarded as evidence of AV block.

At relatively slow rates a few apparently normal people, with no evidence of heart disease, have been found to have intervals ranging considerably above 0.20 sec.

PR prolongation is more likely to be a pointer to other wise latent rheumatic or coronary disease, but one must not brand an individual as a 'cardiac' whose only stigma is an unconventionally long PR interval. Obviously it is a signal for a thorough search to exclude cardiac abnormality, but if none is found, the heart should be acquitted with reservation.

QRS complex

This complex is the most important in the electrocardiogram, as it represents spread of the impulse through the ventricular muscle (activation or depolarization of ventricles).

Proper labelling of the component waves of this complex should first be mastered.

1. If the first deflection is downward (negative), it is a Q wave.
2. The first upright deflection is an R wave, whether or not it is preceded by a Q.
3. A negative deflection following an R wave is an S wave.
4. Subsequent excursion above the line are labelled successfully R',r", etc. similarly later negative excursions are lebelled S',s", and so on.

Capital letters (Q,R,S) refer to relatively large waves (Over 5 mm.); small letters (q,r,s) refer to relatively small waves (under 5 mm.). The form QRS complex may always be used as a sort of collective noun to describe the ventricular complex no matter what waves actually compose it. The examples of different QRS complexes is shown in Fig. 2.5 [64]. The all complexes may quite correctly be referred to as QRS complexes.

If the QRS complex consists exclusively of an R wave, the points at which the complex begins and ends may be labelled Q and S, respectively, though there are no actual Q or S waves. When the complex consist exclusively of a Q wave it is described as a QS complex. The duration of the normal QRS complex is usually given as 0.05 to 0.10 sec. Thus QRS interval is measured from the

begining of the QRS to its end, usually in the standard limb leads. The chest leads frequently display a slightly longer QRS spread (0.01 or 0.02 sec. longer) than the standard leads. A measurement of 0.12 sec. or more is indicative of abnormal intraventricular conduction and usually means block of one of the bundle branches or a ventriucular arrhythmia.

The amplitude of the QRS complexes has wide normal limits. It is generally agreed that, if the total amplitude (above and below the isoelectric line) is 5mm. or less in all three standard leads, it is too low to be healthy ;such low voltage is seen in diffuse coronary disease, cardiac failure, pericardial effusion etc., and any other conditions producing widespread myocardial damage. The minimal normal QRS amplitude in precordial leads waxes and wanes from right to left across the chest, being generally accepted as 5mm. in V1 and V6, 7mm. in V2 and V5 and 9mm. in V3 and V4. Some define low voltage as an average voltage in the limb leads of less than 5mm. with an average in the chest leads of less than 10mm. [64].It is more difficult to set an arbitrary upper limit to normal voltage. Amplitudes up to 20 or even 30mm. are occasionally seen in lead II in normal hearts, while the generally accepted maximum in a precordial lead is 25 to 30mm.

The amplitude or voltage recorded from the lead is dependent on many factors besides the health of the heart; for example, the distance of the heart from the recording electrode (as determined by size of chest, thickness of chest wall, presence of emphysema, etc.) profoundly affects the size of the recorded deflections. Such factors must receive due consideration before

the voltage of any complex is judged too high or too low.

The significance of Q waves is one of the most important, and sometimes the most difficult, assessments in the tracing. Size is important, and yet a diminutive Q wave of less than 1mm. may have real significance, while a QS complex of 10mm. in certain leads may sometimes be within normal limits. A small narrow Q wave of 1 or 2mm. is a normal finding leads I, aVL and aVF, and in chest lead over the left ventricle, e.g., V5. Indeed the absence of the expected small Q waves in these leads may be an abnormal sign [55]. On the otherhand, deep QS or Qr complexes are a perfectly normal finding in aVR and QS complexes are occasionally found normally in lead III and in leads V1 and V2.The Q wave should not be more than 0.03 sec. in width. The importance of Q waves must be viewed in the light of the overall picture and one must take into account i) their depth, ii) their width, iii) the leads in which they appear and, also iv) the clinical setting.

Ventricular activation time (VAT)

It is measured from the begining of the Q wave to the peak of the R wave. Other terms used in the literature for this time interval are **intrinsic deflection** and **intrinsicoid deflections**. Normally it should not exceed 0.02 sec. in V1 and 0.04 sec. in V5 or V6. Increased intrinsicoid deflection indicates ventricular hypertrophy or conduction defect.

ST segment

This is the part of the electrocardigram which immediately follows QRS complex, and ends of the begining of T

wave. It should be studied in all the leads. Normally it is isoelectric(i.e., at the same level as that of base line). Two features of the ST segment should be observed: (1) its level relative to the base line, i.e. wheather it is elevated or depressed below the isoelectric line, and (2) its shape.

It is sometimes normally elevated not more than 1mm. in the standard leads, and even 2mm. in some of the chest leads; it is never normally depressed more than half a millimeter or so.

T wave

The T wave represents the recovery period of the ventricles, when they recruit their spent electrical forces ('repolarization'). Three features of T wave should be noticed. These are (1) its direction, (2) its shape, and (3) its height.

The T wave is normally upright in leads I,II and V3 to V6. It is normally inverted in lead aVR and variable in leads III, aVL,aVF, V1 and V2.

The shape of the T wave is normally slightly rounded and slightly asymmetrical. A sharply pointed symmetrical T wave (upright or inverted) is suspicious of myocardial infarction. The height of the T waves is also important. They are normally not above 5mm. in any standard lead, and not above 10mm. in any precordial lead.

QT interval

This is measured from the onset of the Q wave to the end of the T wave. It meseares the duration of electrical systole. It varies with heart rate, sex and age. The QT interval is lengthened

in congestive heart failure, myocardial infarction [156] and hypokalcaemia. QT interval may be shortened in hyperkalcaemia and after digitalisation. Normally QT interval should not exceed 0.42 sec. in men and 0.43 sec. in women. A useful rule of thumb is that the QT interval should be less than half the preceding RR interval. This holds good for normal sinus rates. The diagnostic value of the QT interval is seriously limited by the technical difficulties of measuring it exactly.

U wave

This is usually a small wave of low voltage, sometimes seen following the T wave. Its normal polarity is the same as that of the T wave and the normal wave is often best discerned in lead V3. It is rendered more prominent by potassium deficiency and its polarity is often reversed in myocardial ischemia and left ventriucular strain. A prominent U wave occurs in hypokalcaemia.

RR interval

The RR interval is the distance between two successive R waves. If the ventricular rhythm is regular, the interval in seconds (or fractions of a second) between the peaks of two successive R waves divided into 60 (seconds) will give the heart rate per minute [117]. This is more easily determined by consulting the Table- 2.1 [114]. If the ventricular rhythm is irregular, the number of R waves in a given period of time should be counted and the results converted into the number per minute. For example, if 20 R waves are counted in a 10 sec. interval, the ventricular rate is counted as 120 per minute.

Table 2.1 The heart-rate table.

To find the heart rate,the figure in column L that represents the cycle duration in seconds measured on the ECG is selected. The corresponding number in column R gives the rate per minute. Thus if the interval between P waves (or R waves) of 2 consecutive beats is 0.60, the heart rate is 100. (Applicable for regular rhythm only.)

L	R	L	R	L	R	L	R	L	R
0.10	600	0.38	158	0.66	91	0.94	63	1.58	38
0.11	550	0.39	155	0.67	90	0.95	63	1.64	37
0.12	510	0.40	150	0.68	89	0.96	62	1.68	36
0.13	470	0.41	145	0.69	87	0.97	61	1.73	35
0.14	430	0.42	142	0.70	85	0.98	61	1.77	34
0.15	400	0.43	138	0.71	84	0.99	60	1.82	33
0.16	375	0.44	136	0.72	83	1.00	60	1.86	32
0.17	350	0.45	133	0.73	82	1.01	59	1.92	31
0.18	335	0.46	129	0.74	81	1.03	58	2.00	30
0.19	315	0.47	127	0.75	80	1.05	57	2.06	29
0.20	300	0.48	125	0.76	79	1.07	56	2.15	28
0.21	284	0.49	123	0.77	78	1.09	55	2.22	27
0.22	270	0.50	120	0.78	77	1.11	54	2.30	26
0.23	260	0.51	117	0.79	76	1.13	53	2.40	25
0.24	250	0.52	115	0.80	75	1.15	52	2.50	24
0.25	240	0.53	113	0.81	74	1.17	51	2.60	23
0.26	230	0.54	111	0.82	73	1.20	50	2.70	22
0.27	222	0.55	109	0.83	72	1.23	49	2.84	21
0.28	215	0.56	107	0.84	71	1.25	48	3.00	20
0.29	206	0.57	105	0.85	70	1.27	47	3.15	19
0.30	200	0.58	103	0.86	70	1.29	46	3.35	18
0.31	192	0.59	101	0.87	69	1.33	45	3.50	17
0.32	186	0.60	100	0.88	68	1.36	44	3.75	16
0.33	182	0.61	98	0.89	67	1.38	43	4.00	15
0.34	177	0.62	96	0.90	66	1.42	42	4.30	14
0.35	173	0.63	95	0.91	66	1.45	41	4.70	13
0.36	168	0.64	93	0.92	65	1.50	40	5.10	12
0.37	164	0.65	92	0.93	64	1.55	39	5.50	11
								6.00	10

2.7 Data acquisition system

A data acquisition system is an essential front-end for any processor, which can be looked upon as an interface between the physical world which is of interest and processor. The objective of the data acquisition system is to get all the necessary data in digital form from the analog signal that represents the physical world. The block diagram of ECG data acquisistion system is shown in Fig. 2.6. In order to process the ECG signal by digital computer it is essential to convert the analog signal into digital form. The time continuity of the ECG signal can be replaced by a sequence of discrete intervals or samples and similarly the amplitude continuity can be removed by the process of quantization [69,81,102].

It is possible, providing sufficient samples, to fully represent any waveform by a series of samples which represent the amplitude of the signal at regular intevals of time. The sampling theorem tells us that we have to sample our signal at a rate at least twice as high as the highest frequency component present in the signal. If this is not done, distortion due to aliasing may result. A low sampling rate looses the information whereas high sampling rate generates a huge amount of data and thereby problems of handling and storage. Barr and Spach concluded that the sampling rates as high as 1500 samples/sec. were necessary to reproduce some of the pediatric body surface ECGs and much higher rates were required for sample intercardiac electrocardiogram [141]. Literature on ECG waveform analysis by Fourier analysis informs that the frequency range of the ECG signal may be considered to be approximately 0.4-80.0 cycles/sec. [103]. Thus

the sampling rate of about 200 samples/sec. should be sufficent for all ECG waveform components, except for high frequency. The frequency components beyond 100 cycles/sec has practically no significance to ECG analysis. Therefore, to retain all important details of the original ECG signal, the sampling rate should be arround 250 samples/sec [29] and so the sampling rate of 250 sample/sec. has been used in the present work. The signal is amplified by a DC amplifier and is filtered before sampling with an anti-aliasing filter having a cutoff around 100 cycles/sec. so that the signal can be safely sampled at a rate of 250 samples/sec. Elimination of the continious components of the ECG signal is obtained by storing the average level of the base line for a few milliseconds before the begining of an 8 seconds long acquisition sequences; then by amplifying the difference between the instant signal, and the base-line mean level previously stored [69,126].

The signal samples can take on an infinite range of amplitude levels and are thus just as susceptible to noise as the original signal. The signal amplitude, at this stage, is quantized to the nearest of a range of discrete amplitude levels as shown in Fig. 2.7. Obviously the quantization operation introduces a distortion into the signal which is called **quantization error**. The magnitude of this error is a function of the number of quantization levels used. For ECG signal the analog samples must be approximated by at least 7 digit binary code. Such conversion has an accuracy of 1 part in 128, since by means of 7 bits 128 linearly spaced quantization levels can be obtained. Fig. 2.8 shows the ECG singal digitized with an eight bit accuracy and

sampled at the rate of 250 and 500 samples per sec. [1,63,143].

2.8 Preprocessing of ECG signal

ECG signal must have a fairly steady baseline and smooth contour of the waveform components before it can be effectively analyzed by the computer. Unwanted signals are generally termed as noise and may be caused by muscle potentials which accompany body movement or muscle tremor, frequency variations of alternating current supply, or spikes produced by artificial pacemaker or by malfunctioning equipment. A proper grounding, use of differential amplifier and high accuracy in manual processing usually reduce the noise to levels which do not affect pattern recognition by computer. However, in restless and deep breathing patients in intensive care units, and in patients undertaking excersise tests, noise can be of such magnitude that computerized pattern recognition is seriously affected.

Certain fractions of noise can be eliminated electronically prior to A/D conversion by the use of frequency-selective filters. For discrete-time sequence a common smoothing operation is one referred to as a **moving average**, where the smoothed value y(t) for any t, say t_o, is an average of values of x(t) in the vicinity of t_o, where x(t) is the sampled value at time t. The basic idea is that by averaging values locally, rapid variations from point to point will be averaged out and slow variations will be retained, corresponding to smoothing or lowpass filtering the original sequence. As an example, a three-point moving average of an input sequence x(t) is of the form

$$y(t) = \frac{1}{3} (x(t-1) + x(t) + x(t+1))$$

so that each output y(t) is the average of three consecutive input values [105]. Smoothing of the ECG signal by mathematical methods may affect considerably its amplitude and frequency characteristics. To avoid such consequences the sampling rate should be at least 250 samples/sec. and the length of the interval to be smoothed should not be longer than 20m sec. [103]. It is found that five point moving average filter is sufficient for smoothing of ECG signal sampled at the rate of 250 samples/sec.

2.0 Electrical axis of the heart

The electrical axis of the heart may be normal, or it may be deviated to the right or left.

Leads I and III are to be examined to determine the axis. If there is no large S wave compared to the R wave in these leads, the axis is normal.

If lead I shows a deeper S wave than the height of R wave and lead III shows a taller R wave than the depth of S wave, the axis is right.

If lead III shows a deeper S wave than the height of R wave and lead I shows a taller R wave than the depth of S wave, the axis is left.

Right axis usually occur in right ventricular hypertrophy and left axis in left ventricular hypertrophy.

The electrical axis of the heart may also be expressed in degrees, and determined by using the tri-axial reference system which is obtained as follows: the three sides AB,AC and BC of an Einthoven Triangle ABC (Fig. 2.9) representing the three bipolar standard leads I, II and III respectively are made to intersect

each other at their midpoint 'O' which represents the centre of the electrical activity of the heart; thus the three hundred and sixty degrees are divided into six equal segments by these three straight lines.

Conventionally the pole B (the positive pole of lead I) is taken to be 0 degree, the other pole A is ±180 degree; the poles above the line AB are negative, and those below are positive (Fig.2.9).Now each of these straight lines is divided into small equal segments.To determine the electrical axis of the heart, the algebric sum of the R and S waves of QRS complexes in any two standard leads in mm. is plotted in the negative or the positive side of the respective lead axes of the tri-axial reference system. As for example, in Fig. 2.9 the algebric sum of the R and S waves in lead I is +6mm. and that in lead III is −4 mm. So the value +6 is plotted in the positive side (thick line) of the lead I axis at a distance of 6 segments from the centre 'O'; similarly the value −4 is plotted in the negative side (thin line) of the lead III axis at a distance of 4 segments from the centre. A perpendicular is dropped from each of these points to intersect each other at a point P. The points P and O are now joined by a straight line, and thus the angle POB in degrees is the electrical axis of the given electrocardiogram, which is −12 degree in this case.

The recent and widely accepted criteria to differentiate the abnormal axis deviations from the normal, right, and left axis deviation are as follows [114] :

1. The axis between −30 degree and +110 degree is normal.
2. The axis between −30 degree and −90 degree is abnormal left axis deviation.
3. The axis between +110 degree and ±180 degree is abnormal right axis deviation.

2.10 Concluding remarks

In this chapter the basic concept and definitions of electrocardiography have been studied. The different ECG wave subcomplexes have been studied next. The data acquisition system for the automated ECG analysis has also been discussed.

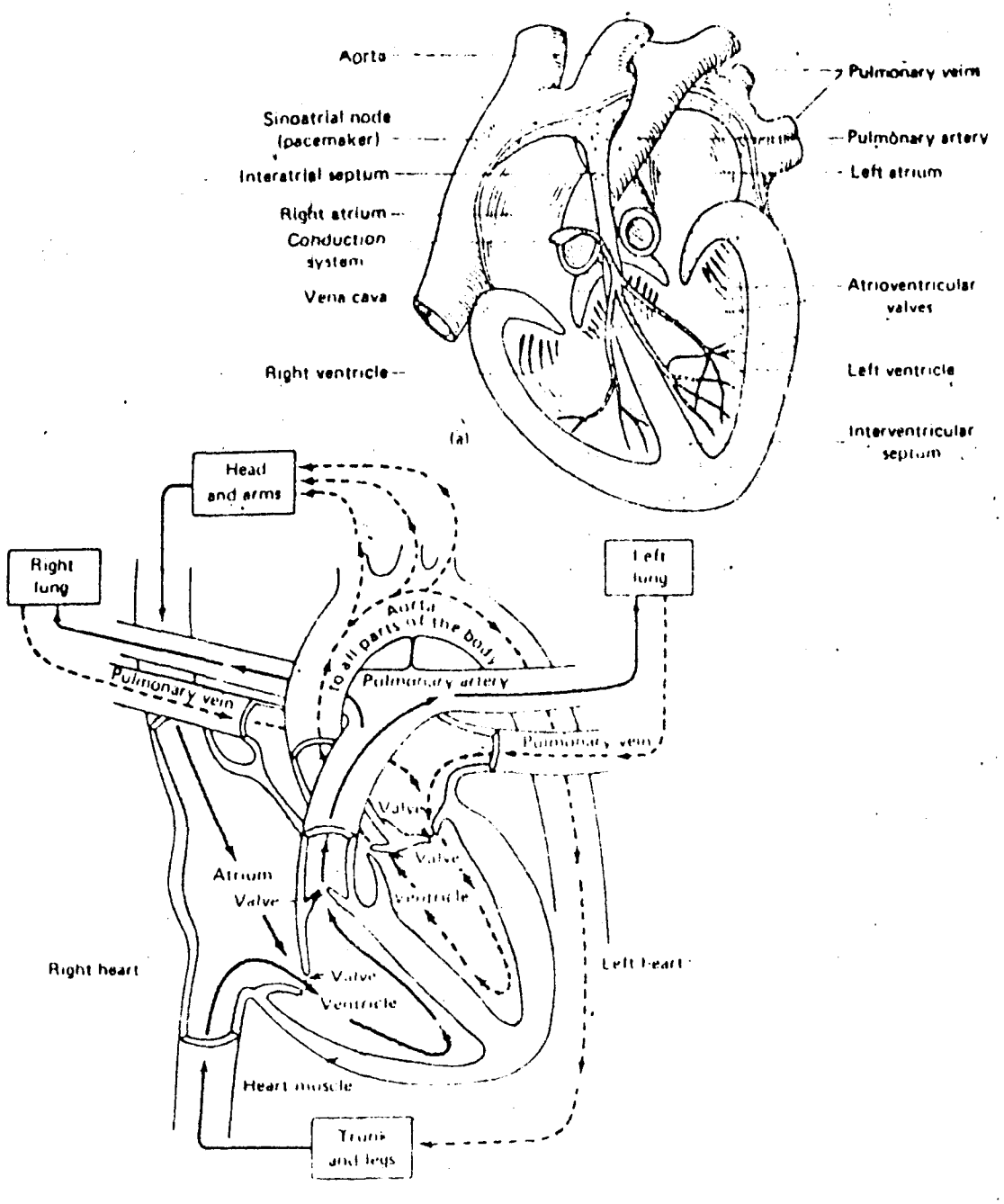


Fig. 2.1 Sections of the heart. (a) Diagrammatic representation.
(b) Localized bloood stream paths.

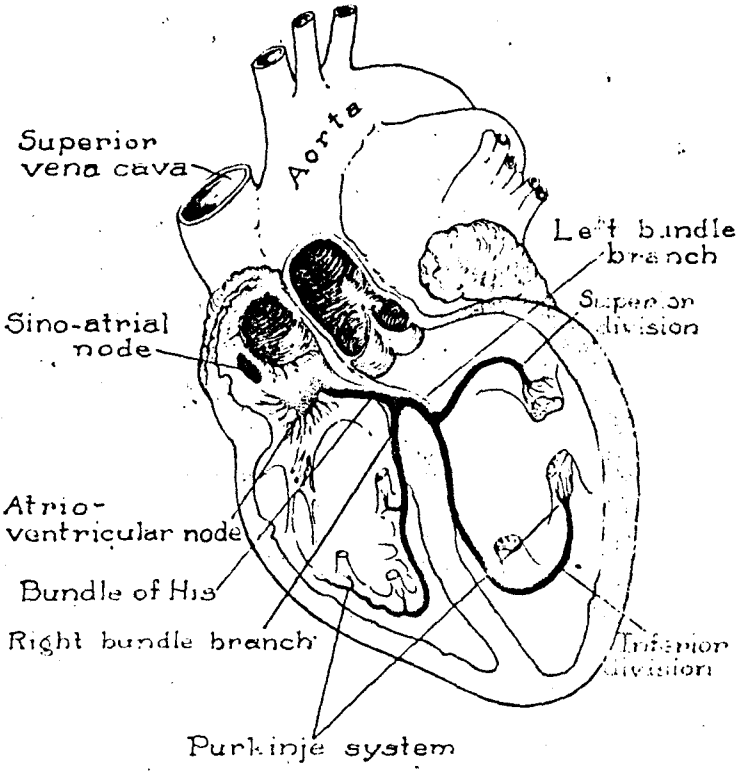


Fig. 2.2 Electrical conduction through the heart.

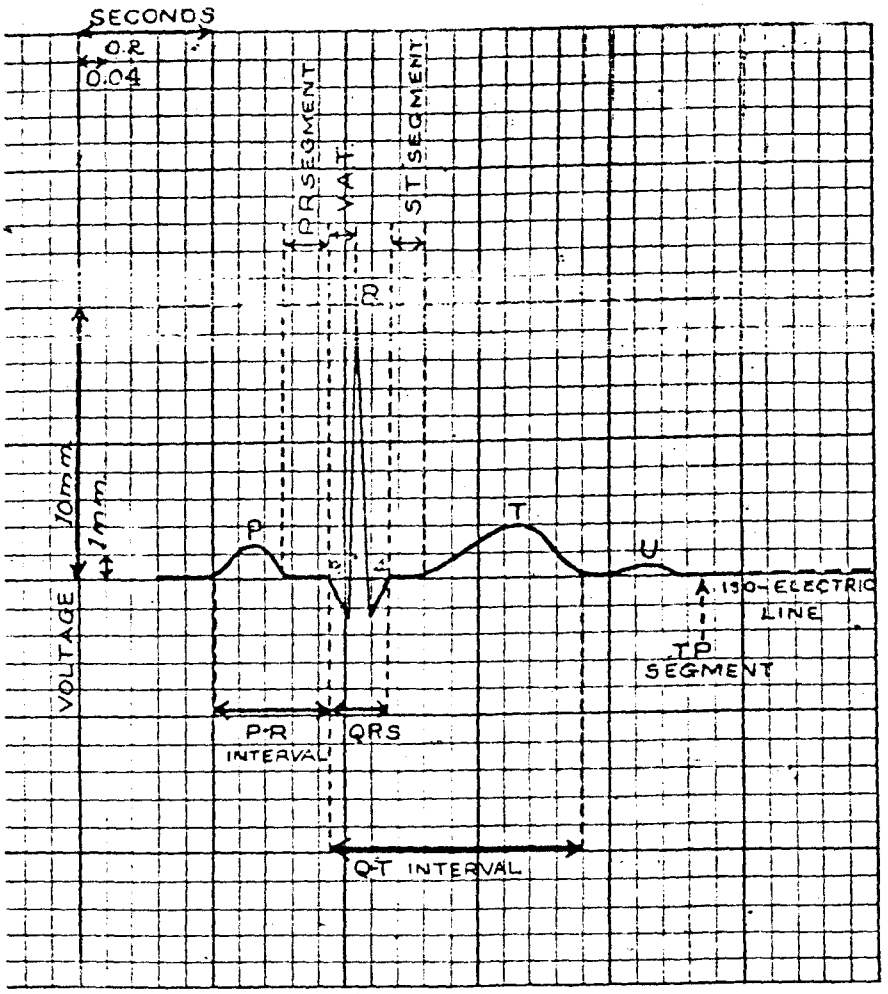
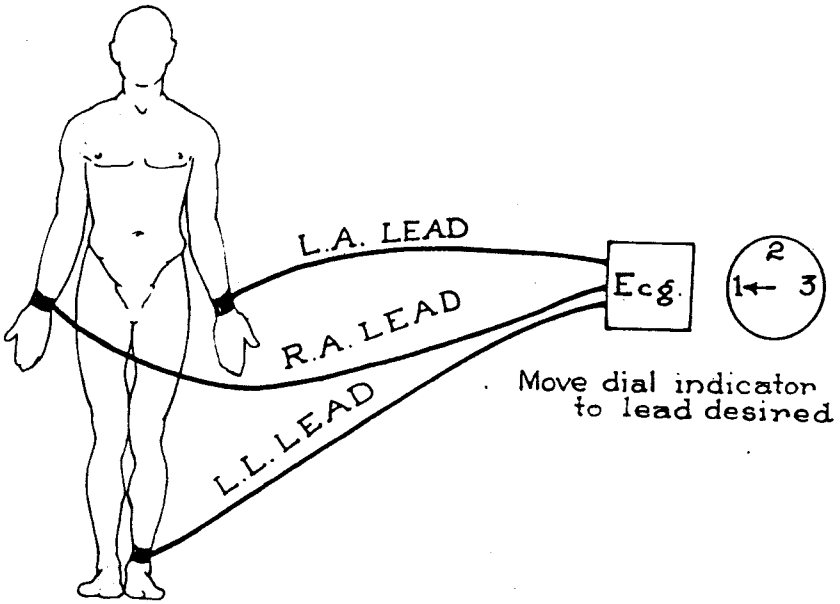
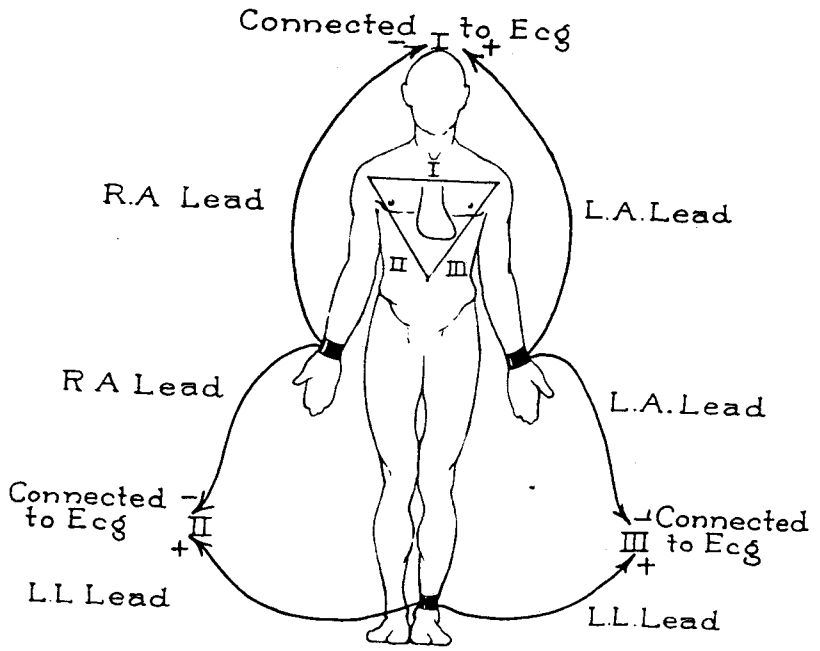


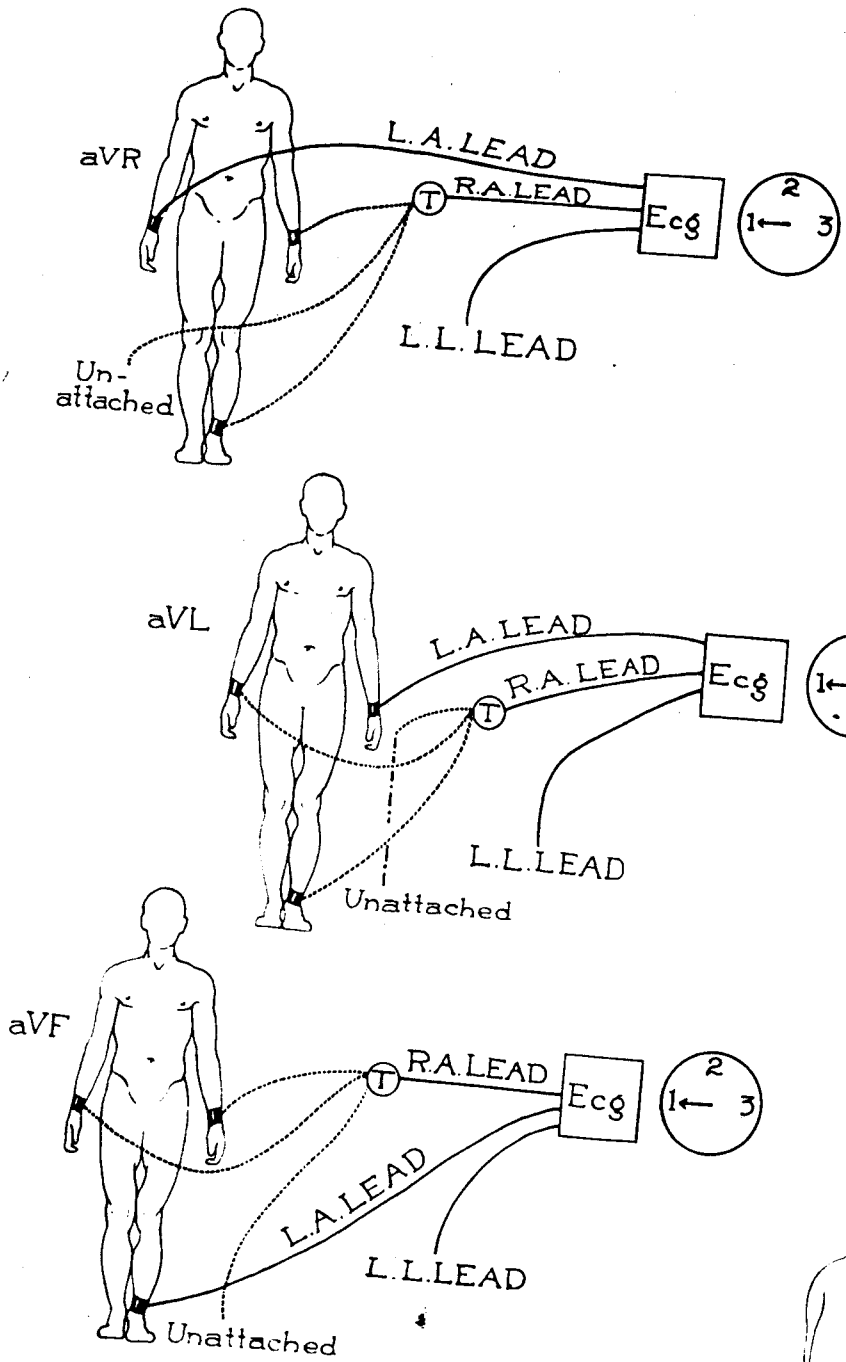
Fig. 2.3 Diagram of electrocardiographic complexes, intervals, and segments.



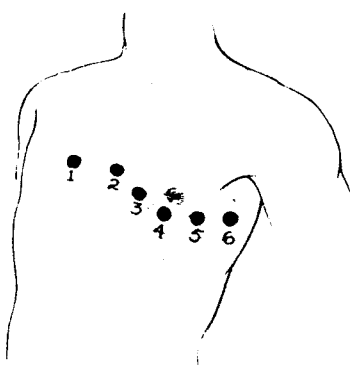


(a)

Fig. 2.4 Different lead configurations. (a) Bipolar standard lead I, II, and III.



(b)



(c)

Fig. 2.4 Different lead configurations. (b) Augmented extrimity leads aVR, aVL, aVF.

Fig. 2.4 Different lead configurations. (c) Location of unipolar chest leads.

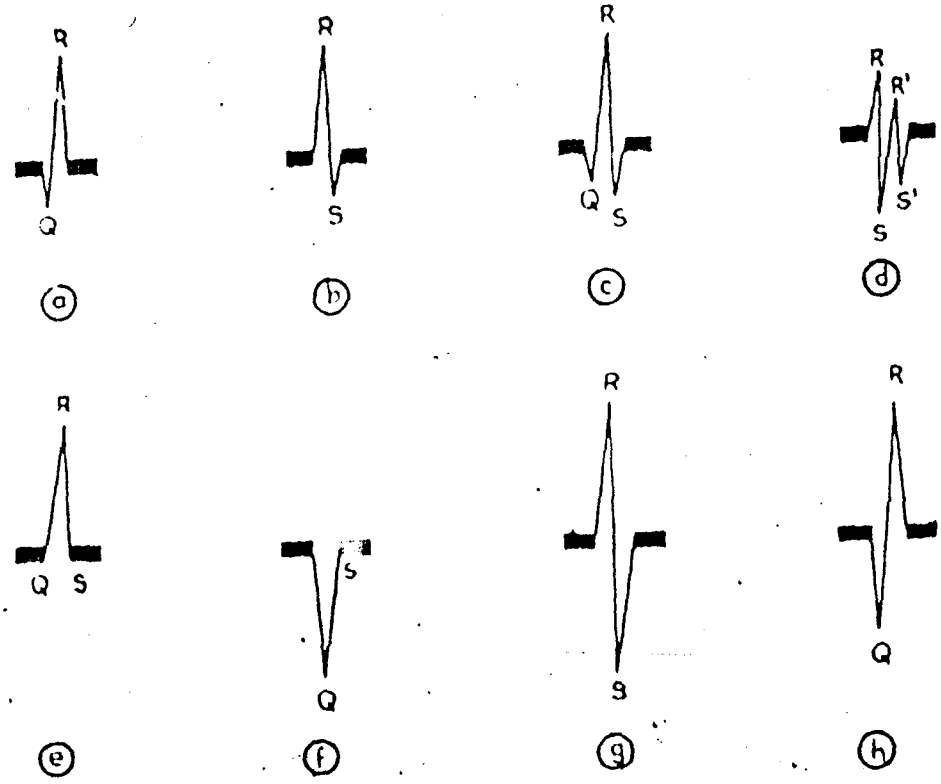


Fig. 2.5 Labelled QRS complex. (a) qR complex. (b) Rs complex. (c) qRs complex. (d) RSR'S' complex. (e) R complex. (f) QS complex (g) RS complex. (h) QR complex.

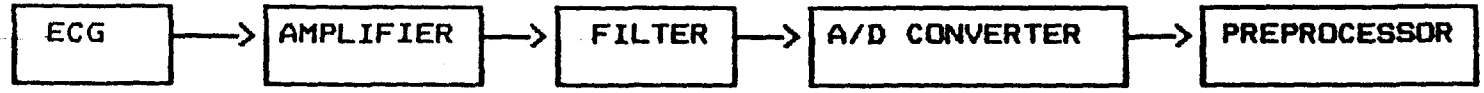


Fig. 2.6 Block diagram of ECG data acquisition system.

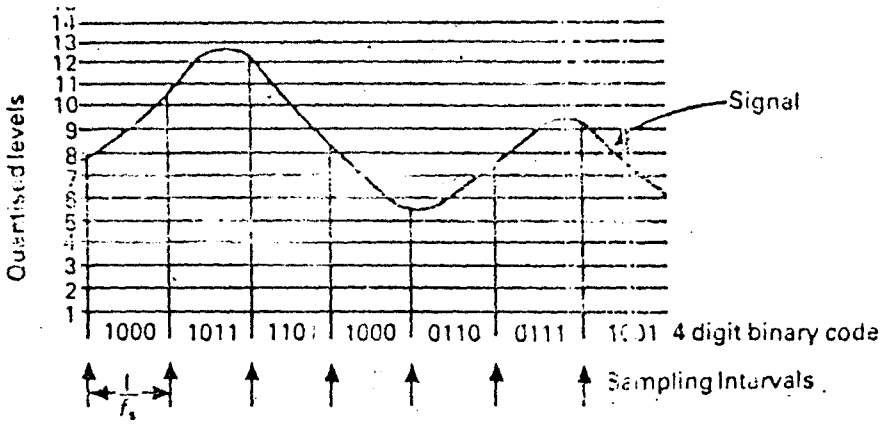


Fig. 2.7 Diagram to illustrate sampling and quantizing of a continious signal.

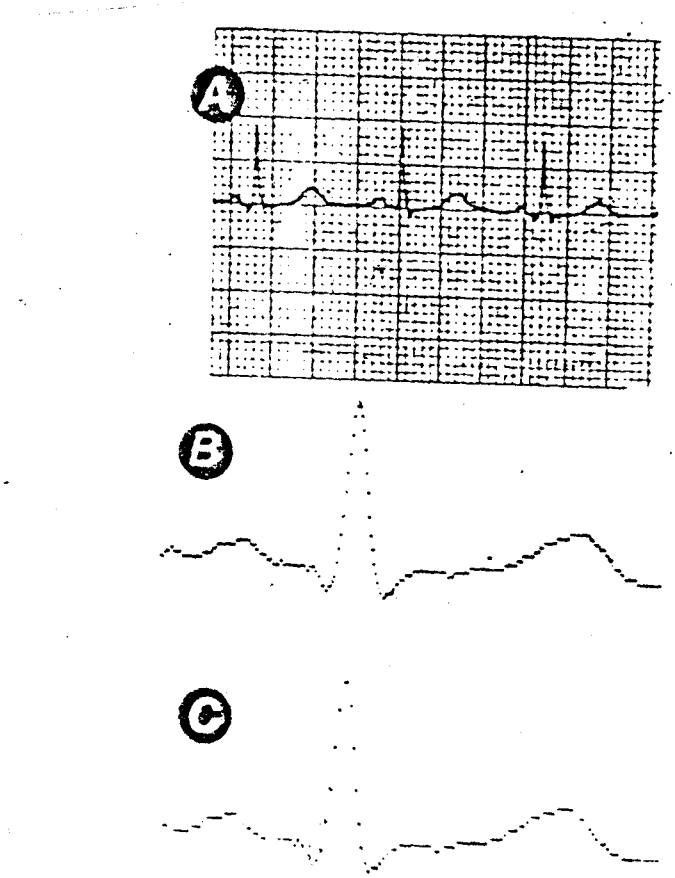


Fig. 2.8 The ECG signal. (A) Analog form. (B) Digital form at the sampling rate of 500 samples per second. (C) Digital form at the sampling rate of 250 samples per second.

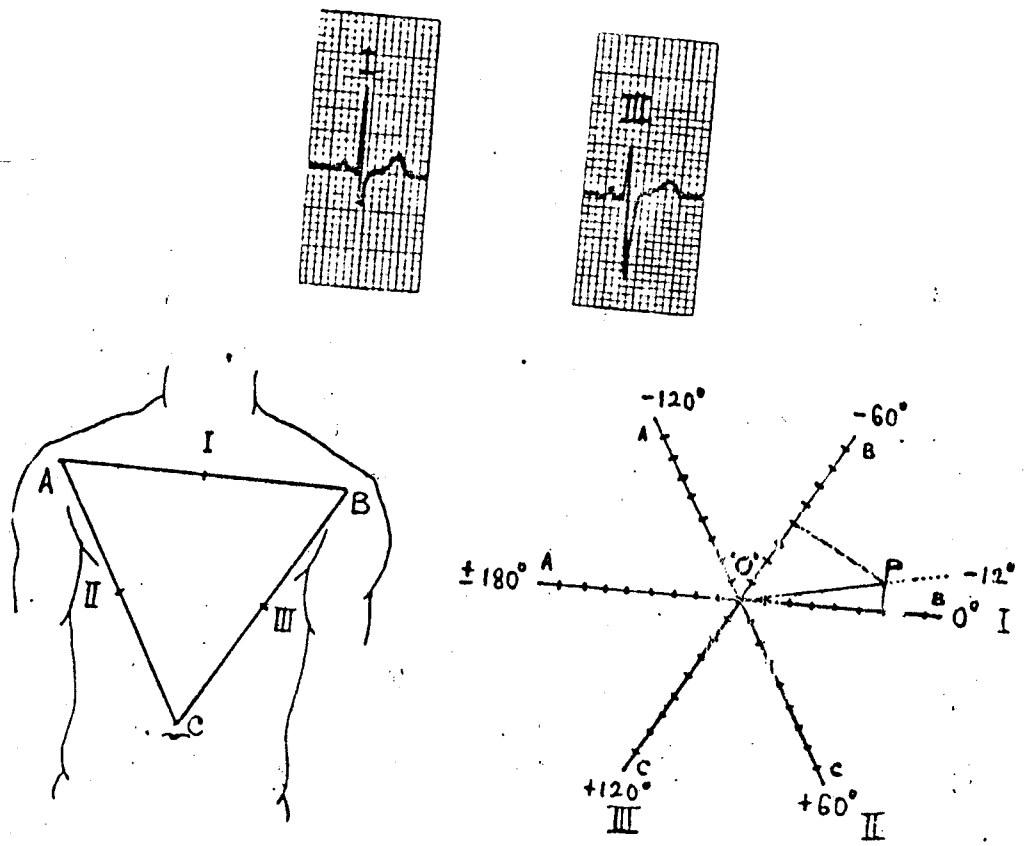


Fig. 2.9 Diagrams to illustrate the electrical axis of the heart from the tri-axial reference system.