Medical Instruments II (Third class)

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Electrocardiogram (ECG)

Lecture 4

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Purpose

Medical Instrumentation II The electrocardiograph (ECG) is an instrument, which records the electrical activity of the heart associated with the heart muscle activity for assessment of cardiac physiology. Electrical signals from the heart characteristically precede the normal mechanical function, and monitoring of these signals has great clinical significance. ECG provides valuable information about a wide range of cardiac disorders such as arrhythmia and the presence of an inactive part (infarction) or an enlargement (cardiac hypertrophy) of the heart muscle. ECGs are used in catheterization laboratories, in coronary care units, and for routine diagnostic applications in cardiology.

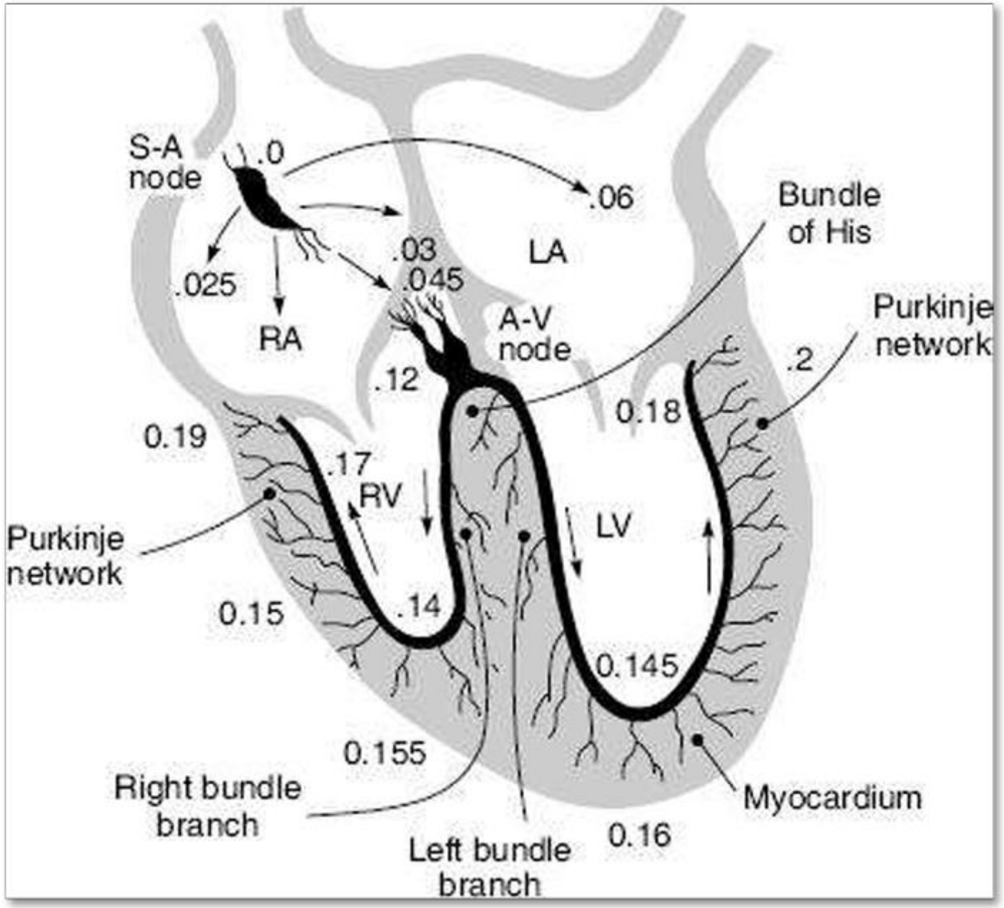
Principle

ECG is an instrument for surface recording of the electrical activity of the heart by connecting various electrodes through which electrical potentials are acquired from the surface of the skin. Although the electric field generated by the heart can be best characterized by vector quantities, it is generally convenient to directly measure only scalar quantities, i.e. a voltage difference of mV order between the given points of the body.

Electrocardiogram (ECG)

The recording of the electrical activity associated with the functioning of the heart is known as electrocardiogram. ECG is a quasi-periodical, rhythmically repeating signal synchronized by the function of the heart, which acts as a generator of bioelectric events.

The S-A node is 25 to 30 mm in length and 2 to 5 mm in thickness. It generates impulses at the normal rate of the heart, about 72 beats per minute at rest. The AV (atrio-ventricular) nodeis located in the lower part of the wall between the two atria. The AV node delays the spread of excitation for about 0.12 s, due to the presence of a fibrous barrier of non-excitable cells that effectively prevent its propagation from continuing beyond the limits of the atria.

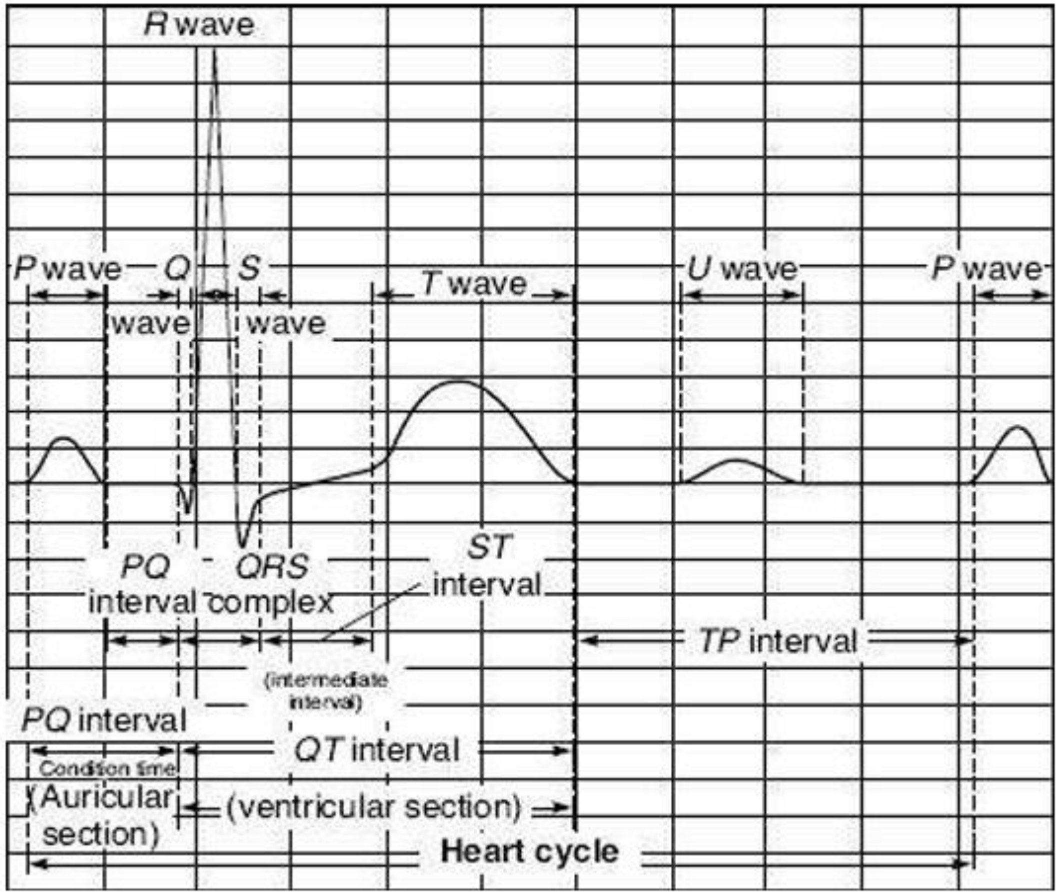


The position of the Sino-atrial node in the heart from where the impulse responsible for the electrical activity of the heart originates. The arrow shows the path of the impulse.Note: The numbers like 0.18, 0.145, 0.15, 0.2… etc. indicate the time taken in seconds for the impulse to travel from S-A node to various parts of the body.

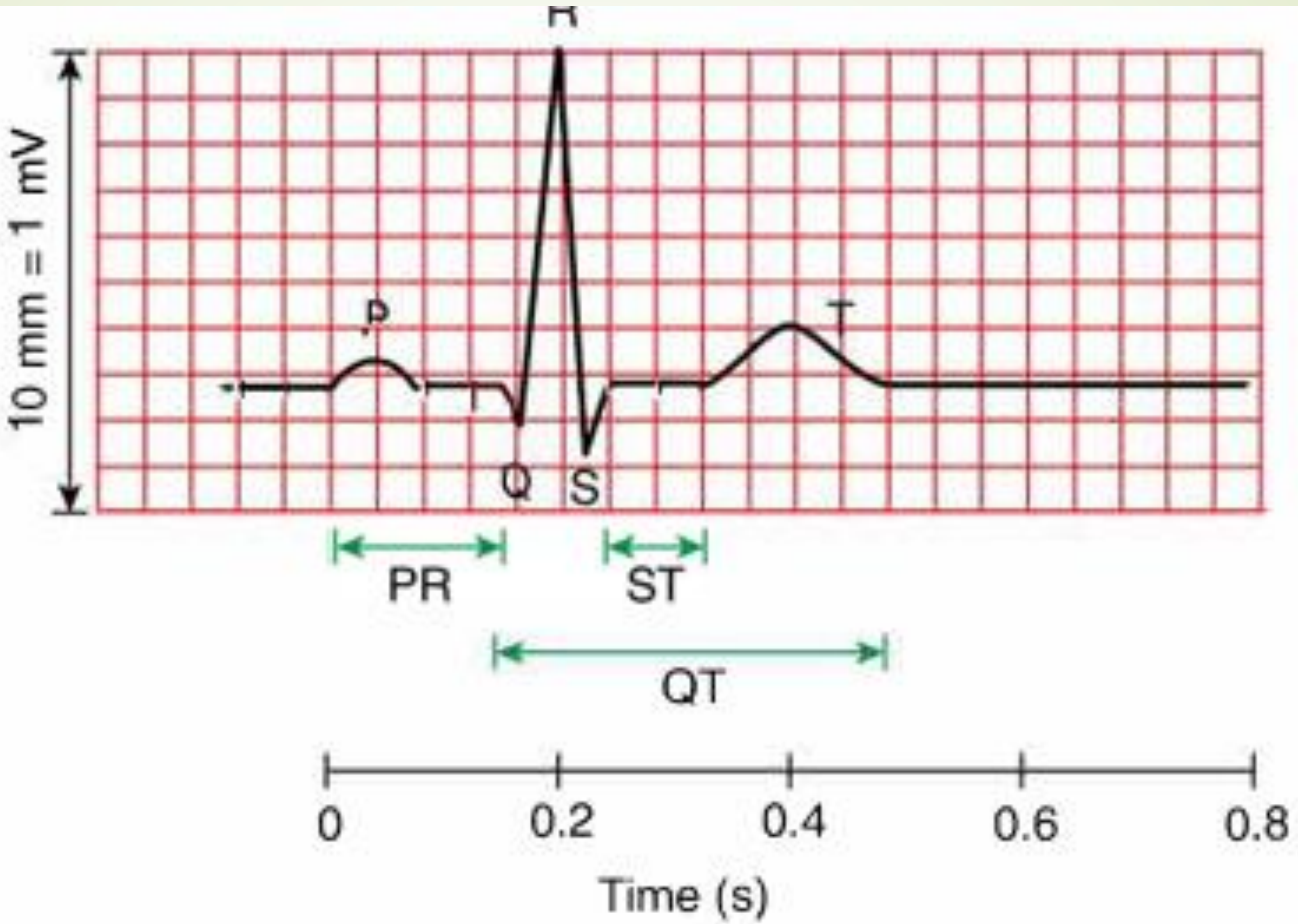
The electrical activity components of the ECG arte described as follows:

1. **The P-wave:** represents the depolarization of the atrial muscles, is caused by contraction of the atria.
2. **The QRS-complex:** is the combined result of the repolarization of the atrial and the depolarization of the ventricles which occur almost simultaneously, caused by contraction of the atria.
3. **The T-wave:** results from the ventricular repolarization, caused by the return of this ventricular mass to the resting electrical state.
4. **The U-wave:** is discernible on the ECG following the T-wave with duration up to 0.24 sec.

The R wave amplitude is 1mV



Normal wave pattern of ECG waveform recorded in the standard lead position.



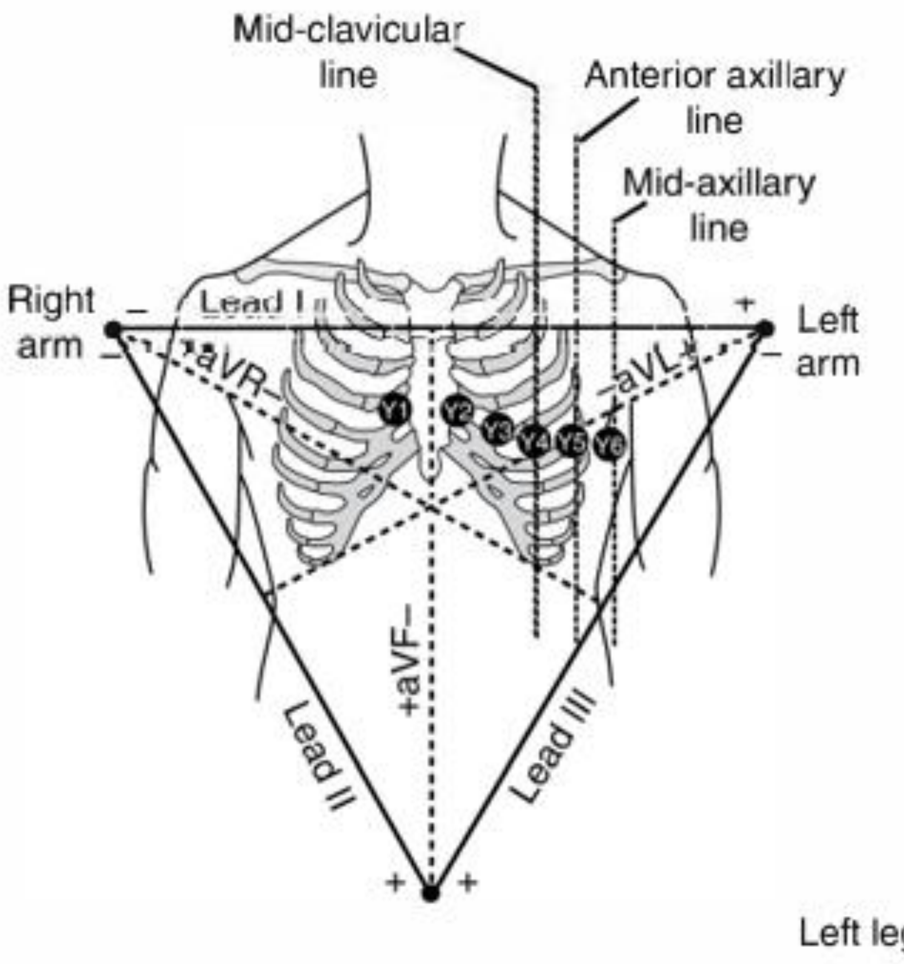
Normal wave pattern of ECG waveform: P wave (0.08–0.10 second), QRS (0.05–0.10 second), PR interval (0.12–0.20 second).

The ECG Leads

Two electrodes placed over different parts of the body will pick up electrical signals generated by the heart, which will represent the potential difference between them. For example, if under one electrode a wave of 1 mV and under the second electrode a wave of 0.3 mV occur at the same time, then the two electrodes will record the difference between them, i.e. a wave of 0.7 mV. The resulting tracing of voltage difference at any two sites of the body due to electrical activity of the heart is called a 'lead'.

1- Bipolar Leads The bipolar leads represents the difference of electrical potentials existing between two electrodes. They are also called standard leads and have been universally adopted. In standard lead I, the electrodes are placed on the right arm and the left arm (RA and LA). The electrodes in lead II are located on the right arm and the left leg, and in lead III, they are placed on the left arm and the left leg. In all lead connections, the difference of potential measured between two electrodes is always with reference to a third point on the body. This reference point is conventionally taken as the 'right leg' (RL). In defining the bipolar leads, Einthoven proposed that the electric field of the heart could be represented diagrammatically as a triangle, with the heart ideally located at the centre. The triangle, known as the Einthoven triangle, is shown in the figure.

2- Unipolar Leaads (V Leads) In this arrangement, the electrocardiogram is recorded between a single exploratory electrode and the central terminal, which has a potential corresponding to the centre of the body. In practice, the reference electrode or central terminal is obtained by a combination of several electrodes tied together at one point. Two types of unipolar leads are employed: **(i) limb leads and (ii) precordial leads.**



The lead system for recording ECG.

(i) Limb leads:

Unipolar limb leads, also called as augmented leads or 'averaging leads; consist in tying together the two of the limb leads and recording the potential with respect to the third limb. They are designated as augmented vector right (AYR), augmented vector left (AYL), and augmented vector foot (AYF). In the AYR lead, the right arm is recorded with respect to a reference established by joining the left arm and left leg electrodes. In the A YL lead, the left arm is recorded with respect to the common junction of the right arm and left leg. In the A YF lead, the left leg is recorded with respect to the two arm electrodes tied together.

(ii) Precordial leads:

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

<u>Electrocardiograms</u> are almost invariably recorded on graph paper with horizon tal and vertical lines at 1 mm intervals with a thicker line at 5 mm intervals. Most ECG machines use what is called a paper strip recorder.

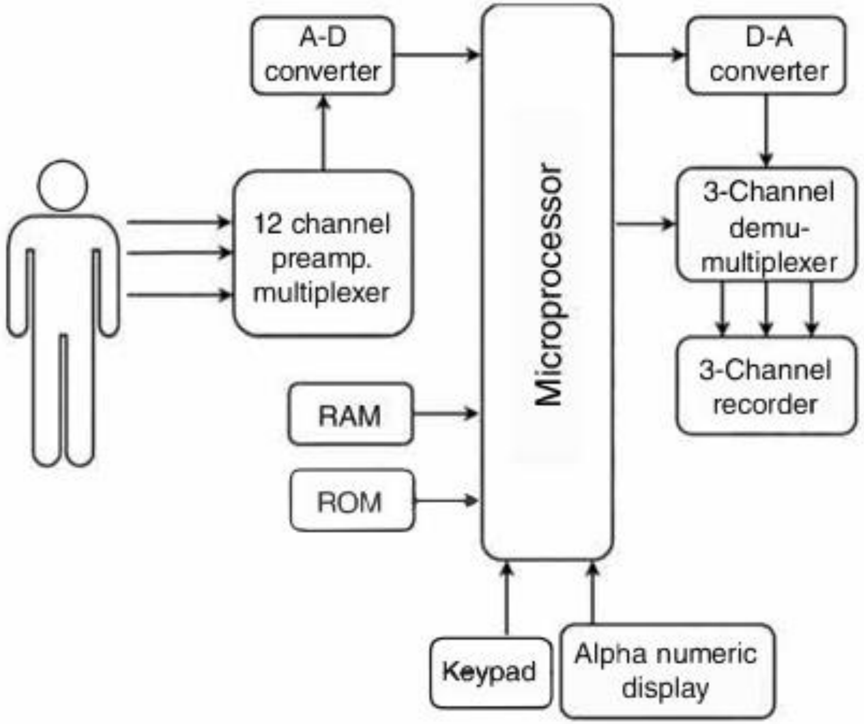
<u>ECG machines</u>

range from battery-operated low-cost portable handheld units to expensive sophisticated machines of the size of a fax machine. Basic machine may even be embedded in a separate piece of equipment, such as a patient monitor or an automatic external defibrillator (AED). The writing mechanism used in most strip chart recorders is hot tip or thermal writing. The writing tip is a heated stylus heated by a resistance wire, which is placed inside a hollow metal tube. Thermal writing occurs when specially treated, thermally sensitive paper gets heated to 90-110 °C by the heated stylus. The paper, which is initially white or off-white, turns a dark colour (usually blue or black) where heated. The dark colour is caused by a chemical reaction resulting from heating the paper. The functioning of the thermal writing system is entirely digital. For writing, the paper is passed over the writing edge, which is necessary to produce an undistorted recording. The writing paper is driven by a constant speed motor to provide time axis. The paper drive of most machines is provided by a stepper motor, which is controlled by a programmable frequency divider for speed control. Some ECG recorders are also based on dot-matrix technology for printing out numerical data patient name and his/her identity, date, time, heart rate, results of rhythm analysis, and results from other sensors.

Interpretative ECG

- Modern ECG machines incorporate computer-based predefined pattern recognition techniques that produces an automated interpretation of the electrocardiogram and identifies normal and abnormal features of the ECG waveform. Each program identi-fies the complete waveform, locates each waveform component, and determines key measurements. Waveform analysis includes P waveforms, QRS complex, and T waveforms from each lead group or a certain number of successive waveforms. The types of measurements calculated vary among units; the most common types include heart rate, waveform amplitude, waveform widths, intervals between the waveform components, and direction of the electrical activity (axis). Irregularities in the morphology (shape) of any portion of the ECG waveform or in the rhythm (timing) of these waveforms indicate abnormalities. The machine prints the interpretation of a specific cardiac abnormality and a plus or minus code, which reveals the severity of the patient's condition.

Applications ECG machine is one of the most useful noninvasive medical diagnostic device, which is in very wide use. It finds numerous applications in modern patient care as ECG machines, cardiotachometers, Holter monitors, and exercise and stress testing. Compared to single channel recorders, multi-channel ECGs improve diagnostic ability by providing a more complete view of the heart during the same beats and are finding increasing applications.



Block diagram of a multi-channel ECG machine.

Typical single channel, three channel, and twelve channel ECG machinesoptically isolated and sent via a high speed serial link to the main ECG instrument. Here the 32 bit CPU or DSP chip perform all the calculation and hard copy report is gener-ated on a standard A4 size paper. The recording system also operates digitally.

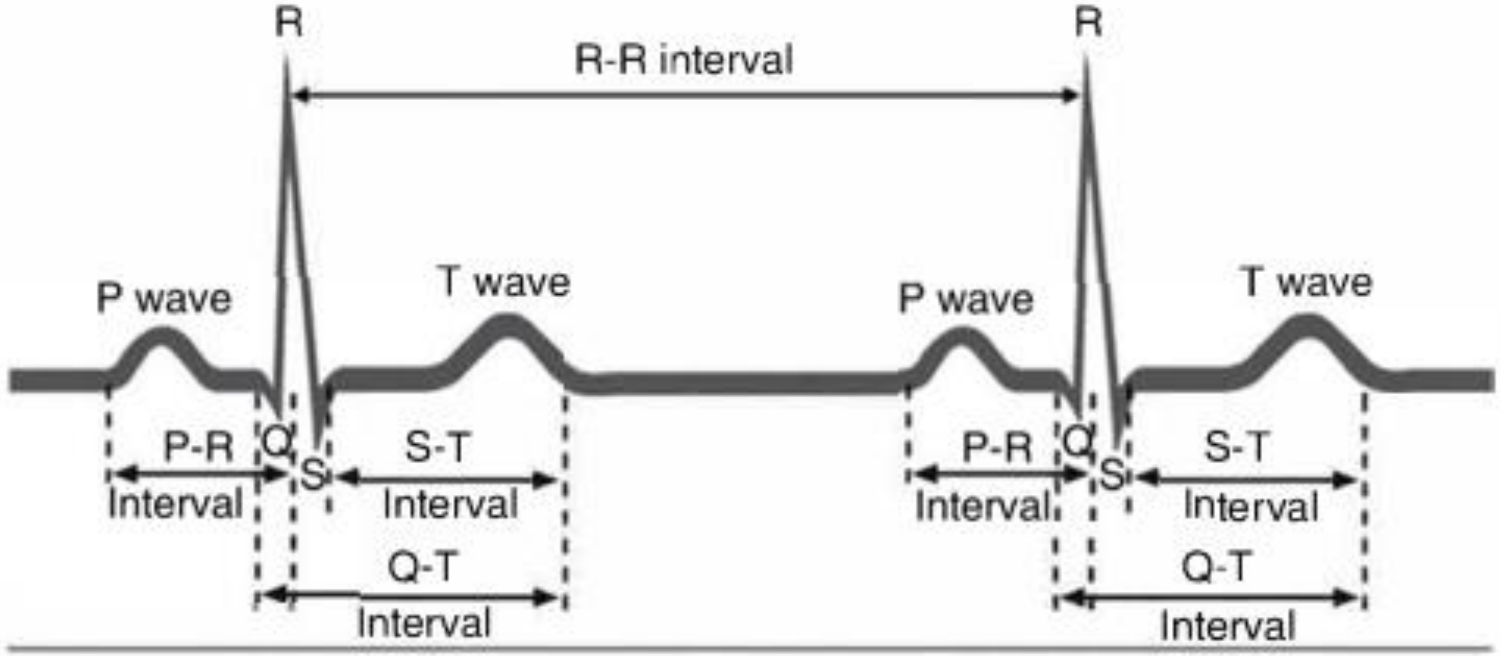
Heart Rate Monitor (HRM)

Purpose

Medical Instrumentation II A heart rate monitor (HRM) is designed to measure heart rate in real time. These instruments form an inherent part and important step for diagnosis in medical field over the ages. However, their usability has increased manifold with the availability of present generation of portable monitors as an average person is able to use it during his/ her routine day-to-day activities such as exercise and sports. The HRMs are an impor tant component of vital signs monitors used commonly in intensive care units, but this chapter covers only standalone HRMs, which mostly find applications in fitness studies.

Principle

Most of the HRMs are based on picking up an ECG signal from the surface of the body. The signal is generated due to pumping action of the heart and can be sensed with elec trodes. Figure below shows a typical ECG signal in which P wave represents an atrial depolarization; Q, R, and S waves and T waves represent the depolarization and repolarization of the ventricles, respectively.



Typical ECG signal waveform.

HRMs generally come as two types:

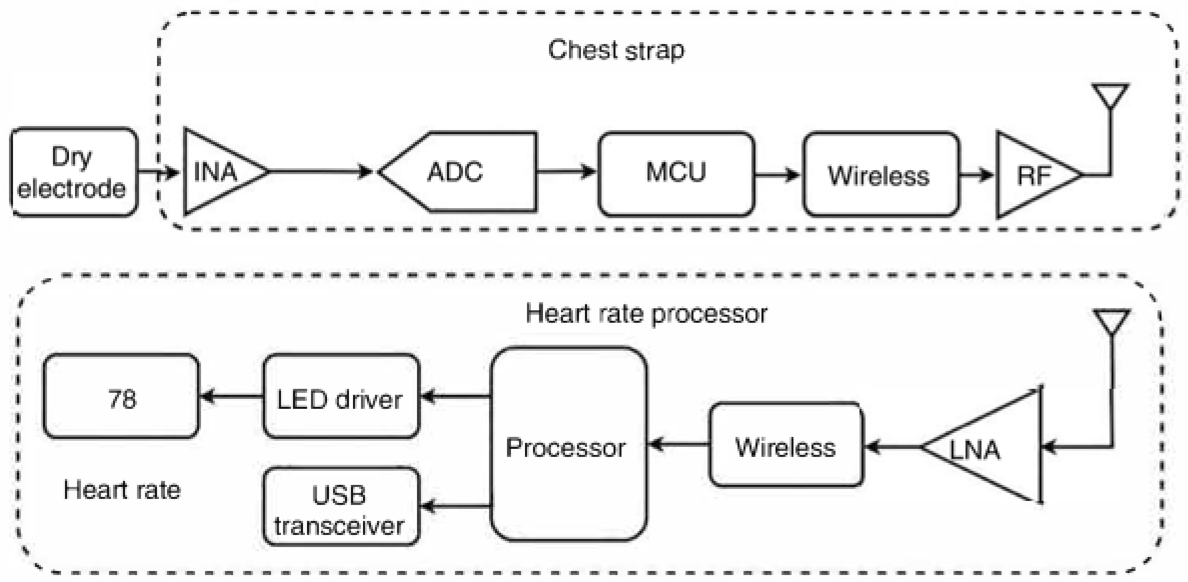
chest-strap models and strapless models.

1- Chest-strap models:

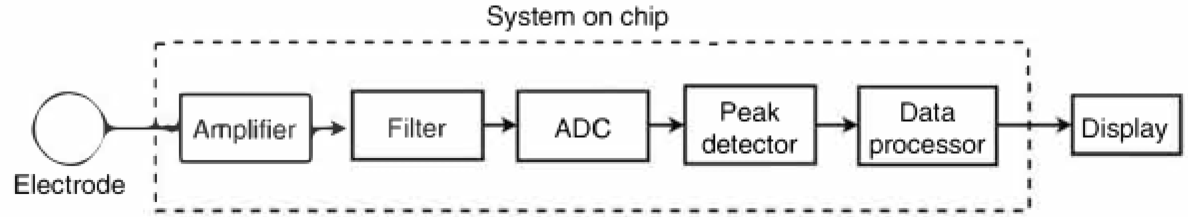
These devices make use of a wireless chest strap that is put around the torso. The strap carries the sensors and wirelessly transmits continuous heart rate data to a receiver worn by the user on the wrist. The wrist receiver usually doubles as a watch.

2- Strapless models:

These devices can be worn on the wrist and the rate is measured by built into the case back or wrist strap. They can track real-time heart rate data without causing any discomfort and eliminate wireless interference, which may be sometimes associated with chest-strap models. However, they are less accurate than chest-strap HRMs.



Block diagram of a chest-strap-type heart rate monitor.



Block diagram of traditional heart rate monitor. Most of the functional blocks have now been integrated on a single system-on-chip.

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