THE METHOD FOR DELECTATING ECG (EKG) SIGNAL IN PHYSIOLOGICAL RESPONSES

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ABSTRACT

The human body generates a wide range of electrical potentials through the firing of neurons, and associated electrical signal that respond to stimuli and control the body's physiological responses. These electrical potentials can be detected at the surface of the body and the measurements are classed according to the functional source of the potential. The methods are proposed for detecting the electrocardiogram (ECG or EKG) which is a measure of the heart's electrical activity for various physiological responses of the body. The frequency of ECG signal is quite low which is enhanced by quick recovery method. This attempt is produced actual response of signal for various physiological responses.

Keywords: ECG, EKG, Physiological responses.

Introduction

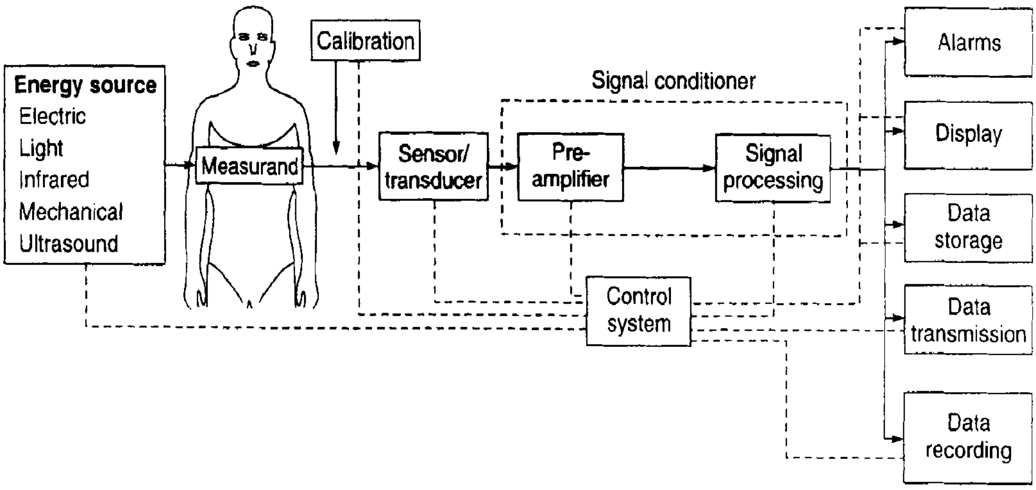
The detection of physiological signal using sensor and the measurement of this signal using biomedical instrument is present need in development of biomedical instrument. A detailed survey is performed for the sensors previously and currently being used in the biomedical instruments. The newly added technology for the sensing of physiological parameters has been studied from the papers currently published in sensor and biomedical engineering journals. In medical science the structure of the body is known as anatomy and its functioning is known as physiology. The human body generates various types of signals such as electrical, mechanical, hydraulic, pneumatic, chemical and thermal. These systems communicate with each other internally and external environment. Galvani demonstrated that most of the physiological processes are performed with electrical changes. Bioelectrical potentials are generated at the cellular level. The source of these potentials is ionic in nature, surrounding the cell of the body fluids, which are ionic and provide conducting biomedical signal for electrical potential. Electrical potential generated in the cell depends on polarized and depolarized condition. Biomedical signal characteristics like frequency range and amplitude has to be continuously monitored by biomedical instruments to investigate the behavior of the body during abnormal condition. The various sources of the signals generated from the body were studied carefully for studying the anatomy of the body. The range, amplitude and frequency range of the signal analysis were selected properly. The biomedical signal condition during normal operation of the body is known and specified as standard signal conditioning. The recorded of rate of heart beat rate, pulse rate (standard specification) etc. are compared with the data recorded by the developed sensor (i.e. QRS) for investigation. It has been observed that the various sensors/transducers used in the biomedical instruments have employed electronic components, some electrodes having capacitive or resistive operations. Presently, various sensors having new technology have been developed for biomedical instruments. What is the role of sensors in biomedical instruments? Is it possible to improve the performance of biomedical instruments by replacing existing sensors with other sensors available or sensors specially designed for this purpose?

Such few questions do arise in the mind of a researcher. Therefore, a review of biomedical instruments and sensors used in them has been done here. The present study has been carried out with following objectives.

1. Function of Display or Recording Unit :

The measure and is displayed or recorded by display system. Display system provides a visible representation of physiological parameters. The display system has been categorized like alarm system, data storage and data transmission. The alarm system adjusted such that it indicates the limit of measure and beyond the range. Data storage device stores the data for further reference during medical treatment. It may be hard copy on paper, magnetic or semiconductor memories. Data transmission system carries out the information to other parts of the integrated system for processing. The calibration unit of physiological parameters is also introduced into the recording unit.

The functioning of a basic biomedical system has been shown in of the block diagram of a basic biomedical system.



Block diagram of basic biomedical system.

2. General Constraints in Design of Biomedical Instrument System :

Some of the important factors considered in designing biomedical instruments which are given below,

a. Measurement range :- The ranges of physiological parameters are quite low as compared to non-medical parameters. Most of the signals are in micro-volts range.

b. Frequency range :- Most of the frequency range of biomedical signals are observed in a low frequency range. The frequencies of these signals lie in the dc signal to very low frequency signal. (<100Hz)

The general characteristics of physiological signals limit the practical choices during design of the biomedical instruments. The constraints considered during designing of biomedical instruments are listed below:

Signal source inaccessibility : It is observed that there is difficulty in accessibility of the physiological variable being measured. The indirect measurement is preferred to obtain the measurement of physiological signals.

Physiological parameter variability : Physiological parameters have measured from a human body are generally time-variant. The physiological variables are represented by some kind of empirical, statistical and probabilistic distribution function.

Interface with physiological system: Proper interfacing is required between the physiological system (human body) and the measurement system to avoid the presence of undesirable physiological signal during measurement.

Transducer interface problems: The biomedical measurement system requires proper interfacing of transducer with the living system. This problem is compounded between the living system and the physical presence of transducer.

High possibility of artefacts: The term artefact is referred to as undesirable signal extracted from physical variable under measurement. A major source of artefacts in the medical instruments is due to the movement of sensors/ transducers.

Safe level applied energy: Energy is required for operating the biomedical instruments, operation of transducers and some energy has to be applied to the living tissue. The safe levels of the various types of energies on human subjects are difficult to establish.

Patient safety consideration: Medical instruments have to be physically connected to the patient. Adequate measures must be taken during the design and use of medical instrument in practice.

Reliability aspects: Biomedical instruments are designed to provide most reliability, simple to operate and capable of withstanding physical abuse due to transportation.

Human factor consideration: The demand for advanced biomedical instruments has continuously increased from physicians and paramedical staff, but it is observed that medical staff does not have sufficient knowledge about the handling of complex medical instrument. This inadequacy can increase the probability error and reduce quality and reliability of clinical procedure.

Government regulation: Government regulations are being introduced to ensure that the equipments perform their intended well function and are safe to operate and function.

Signal consideration: The types of sensor, sensitivity, range, input impedance, frequency response, accuracy, linearity, reliability, differential or absolute input are considered during signal sensing activity.

Environmental consideration: The signal to noise ratio, stability with respect to temperature, pressure, humidity, acceleration, shock, vibration, radiation are the environmental factors considered during designing of biomedical instruments.

Medical consideration : The discomfort to the patient radiation, heat dissipation, electrical safety, material toxicity are medical conditions considered during the operation of biomedical instruments.

Economic considerations: Initial installation cost, cost and availability of patient and compatibility decide the economical factor of the biomedical instruments.

3. Regulation of Biomedical Instruments :

The medical instrumentation industry in general and hospitals in particular require most regulated operation of biomedical instruments. The following regulations are considered:

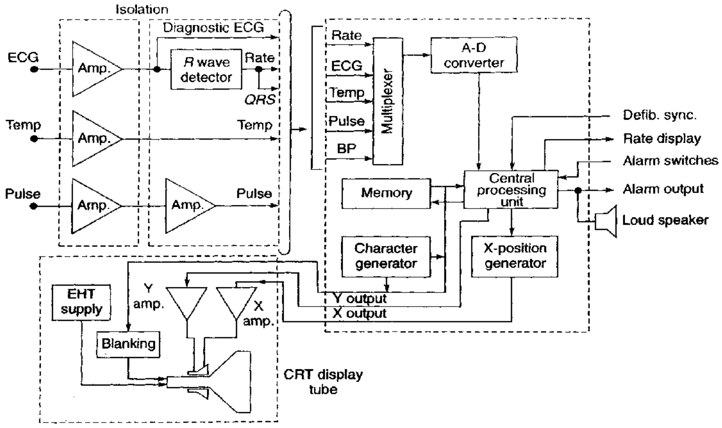
Regulation: A regulation is an organization's way to specify some particular standard for biomedical instrument promulgated by the government.

Standard : A standard is a prescribed set of rules, conditions or requirements, specification of material, performance, design or operation, measurement of quality, quality describing materials, products systems, services or practice.

Codes : A system of operation, regulations or systematized body of law, accumulation of a system of regulations and standard has been specified in terms of some code about the operation of biomedical systems by National Electric Code in USA and National Fire Protection Association (NFPA) in India.

Specification : The documents specify the design criteria, system performance, material and technical data.

Advanced biomedical instruments with their functional blocks are shown in Fig. 3.2.



Block diagram of advanced biomedical system

Proposed Method for measurement of heart rate :-

a. Average calculation: It is most popular technique. An average rate (beats/min) has calculated by counting the number of pulses in given time interval. The average method of calculation cannot show the changes in the time between two beats and thus this technique represent the true picture of the heart response to exercise, stress and environment.

b.Beat to beat calculation : This technique measures the time (T) in seconds between two consecutive pulses and converts it into beats/min using the formula,

Beats/min = 60/T

This technique has been used to measure accurate the heart rate or heart activity .

c.Combination of beat to beat calculation with averaging : This technique has been based on the calculation of the average of four or six beats. The advantage of this technique has been observed over the averaging technique as it has been used for beat-to-beat monitoring system. The normal heart rate measuring is 0-250 beats/min using limb or chest ECG electrodes as sensors.

Limitation of old heart- beat measuring system

Electrodes are employed in the system to measure heart- beat of the heart. The limitations occurred in sensing of heart- beat in previous heart beat measuring system are as under.

a. The metal plates applied to the skin have to be cleaned after every use because the coupling of electrodes with skin is formed by paste or jelly.
b. The preliminary preparation can be irritating and time -consuming for the use of electrode.
c. It is observed that the signal sensed by the electrode has poor quality signals and baseline drift.
d. During the long term monitoring, the use of electrode jelly affects the patient's skin because electrode-skin interfacing dried out after few hours.
e. The electrodes need to be periodically removed for jelly replenishments, which cause discomfort for the patient due to repetitive skin preparations.
f. Bacterial and fungal growth can take place through he use of electrode for long periods.
g. The conductive electrode indicates the baseline drift during the shift in position of the electrodes, when the subject moves.

The above limitations of electrode used in heart- beat monitoring may be replaced by some electronic components for sensing the heart-beat. The review of heart beat measurement by electronics components/devices is the new ideal for heart-beat measuring system. Therefore, the sensors/transducers review is very essential to develop the biomedical instruments.

Design Technique of Quick Recovery Heart Beat Sensor/Transducer

The quick recovery heart beat sensor/transducer is constructed using time-based oscillating circuit, LDR (light dependent resistor), LED (light emitting diode). The function of time-based oscillating circuit is already explained in section 4.7.2 of this chapter. In the time-based oscillating circuit, the frequency of output sweep signal depends on the series combination of resistor R_E and C_E connected to emitter. The resistance R_E has been replaced by LDR resistance $R = R_0e^{KL}$ Ω. The resistance of LDR is changed with intensity of light. This property of LDR is used to change the frequency of output sweep signals with the intensity of light. The light emitted from LED is focused on the surface of LDR, which is transmitted through the finger. The blood concentration in the body part is changed according to heart activity or heart beat signal. This activity of heart is measured in terms of charge intensity change of the light transmitted through body part such as the finger, which is detected by LDR. The resistance of LDR is changed with variation in light intensity according to heart activity. This heart activity (heart rate) is measured in terms frequency of output of sweep signal. The arrangement of QRHBS is shown in Fig.4.6.

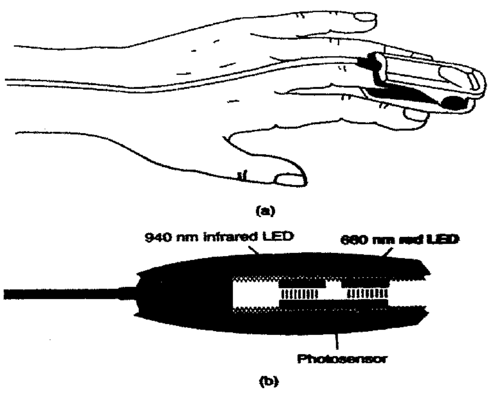


Fig. 4.6: Arrangement of QRHBS

Heart Operation:

In resting adult, the heart pumps approximately 3 to 5 liters of blood per minute. This figure has been reflected as Cardiac Output (CO). The product of heart pulse rate (beats/min) and volume of the blood injected from the ventricles during systole is known as cardiac output.

CO = Heart-beat rate (beats/min) *x* stroke volume (liter/beat)

For most of human, CO values have been noted in the range of 3 to 5 liters/min pumping of blood and heart-beat rate of the human has been observed in the range of 25 to 300 beats/min. The heart beat rate is noted in the range of 60 to 90 beats/min for human at rest position.

Techniques for Heart Beat Rate Measurements

The most common techniques have been used to measure pulsatile blood volume changes using photoelectric methods. These methods have been described with two concepts.

a. Transmittance method

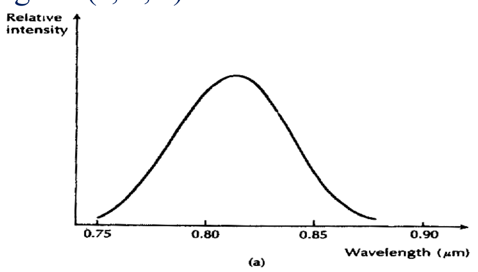
b. Reflected method

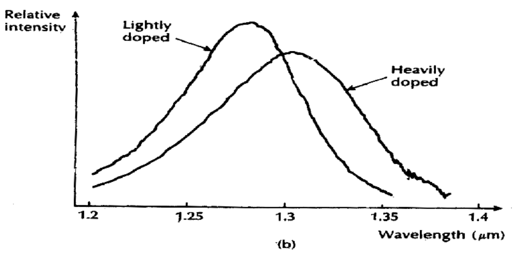
a. Transmittance method *:* A light emitting diode (LED) and phototransistor is mounted in an enclosure that is fitted over the tip of the patient's finger. Light is transmitted through the fingertip of the subject and the resistance of phototransistor is determined by the amount of intensity of light reaching it. With each contraction of the heart, blood is forced to the extremities and the amount of blood in the finger increase. The blood concentration in finger is altered to the optical density of the light transmitted through the finger and the resistance of phototransistor is also changed accordingly. The phototransistor output is further connected to voltage divider circuit, which produces the variable voltage according to change in the intensity of light transmitted through the finger. The intensity of light is changed with change in the concentration of blood in the finger. But the blood concentration is altered according to expansion and contraction activity of the heart. This technique has been used to measure the heart-beat rate in terms of variable voltage using this method.

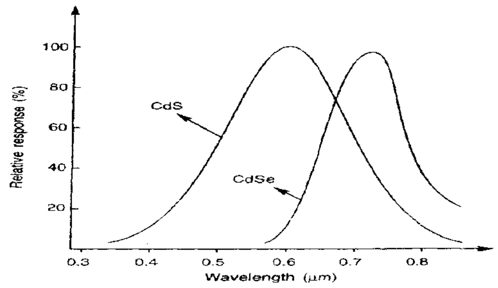
b. Reflected method *:* In this method, the part of the light emitted by LED is reflected and scattered from the skin and tissue. The reflected light falls on the phototransistor. The quantity of light reflected from the skin determines the blood saturation of the capillaries in the finger. The voltage drop across phototransistor is changed with the intensity of reflected light from the finger or a part of the skin. The intensity of reflected light is altered with the blood concentration of blood in the finger, which is changed with heart activity. Thus, heart- beat rate (heart activity) is measured in terms of variable voltage using this method.

c. Design Technique of Quick Recovery Heart Beat (QRHBS) Sensor/transducer :

The quick recovery heart beat sensor/transducer has been developed using transmittance method. Light emitting diode (LED) is used as light source. The peak spectrum of LED used is at 0.94 µm to 0.707 µm peak with bandwidth of 0.4 µm. This light is focused on the surface of light dependent resistor (LDR). The resistance of LDR is changed with the light focused from LED through finger arrangement. The resistance of LDR is photosensitive. The spectral response of LDR is used between 0.4 µm to 1.1 µm. The spectral responses of LED (GaAs) and LDR (Cds) are shown in Fig. 4.7(a, b, c).



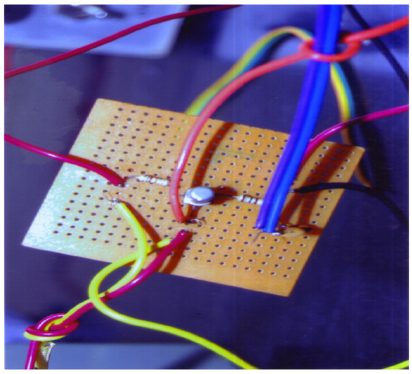




d. Spectral responses of LED and LDR

The concentration of blood in the finger is changed according to expansion and contraction activity of the heart. Under the dark condition, the manufacturer specifies the resistance of LDR. The dark resistance of LDR was noted in the range of 1K - 100K in dark condition.

The arrangement of quick recovery heart beat sensor/transducer (QRHBS) probe (using LED and LDR) probe is shown in Fig. 4.5 and time-based oscillating circuit in photograph below.



Photograph showing QRHBS

In time-based oscillating circuit, emitter resistance (R_E) is replaced with the resistance of LDR and series resistance R. Capacitor (C_E) is chosen to the fixed value such that the frequency output sweep signal is measured in the range of 50 Hz to 200 Hz. The frequency of output sweep signal is noted in absence of the finger between LED and LDR and it is known as reference frequency. The resistance of LDR is a dark resistance in which light was focused on LDR. The surface of LDR is closed with a light obstacle material like a thick plastic sheet. Under this condition, the time-based oscillating circuit generates the constant frequency output sweep signal. The frequency of output sweep signal under dark condition has been noted as,

$$f = \frac{1}{(R_0 + R)\, C_E \ln(1/1-\eta)\, e^{-KL}} \text{ in Hz}$$

The meaning of various parameters in the equation is noted as below :

Where, R_0 -- The resistance of LDR in dark condition (range 1K - 100K)

R -- The series resistance with LDR resistance R_0 to adjust the frequency in measurable range.

C_E -- Emitter capacitor between emitter (E) and base (B1) leads of UJT (2646).

η -- Intrinsic stand off ratio, in the construction of UJT (2646), (range 0.5 to 0.75).

K-- Constant depending on structure of photoresistive cell and it is given by the manufacturer.

L -- Intensity of light in flux

f -- Frequency of the output sweep signal; selected in the range of 50 Hz - 200 Hz to measure the heart -beat rate.

The parameters values of C_E, R_0, R, η, K are selected to the fixed values. Then the frequency of output sweep signal is changed with the intensity of light focused on the surface of LDR from the LED source after transmitting through the finger.

Under dark conditions, the frequency of quick recovery sensor/transducer QRHBS is noted f_{ref} (reference frequency) equal to 200Hz. The condition under which the finger is placed between LED and LDR, the frequency of output sweep signal is obtained in terms of two frequencies values referred as f_1 and f_2. The frequency f_1 is related to contraction of heart while the frequency f_2 is related to expansion activity of heart. The frequency values of f_1 and f_2 are measured using digital frequency meter or storage CRO, after filter the frequency of output sweep signals by low pass circuit. The frequency difference between f_1 and f_2 is Δf ($f_1 - f_2 = \Delta f$). It indicates the variation in the frequency of output sweep signal due to expansion and contraction activity of heart. One heart beat cycle is related to Δf. The time required for one heart -beat cycle is calculated by knowing the value of the Δf. It is $T = 1/\Delta f$. Time period (T) is the time required for one heart- beat cycle in one second. Thus, heart beat rate of the heart operation calculated after dividing to 60 by T.

Experimental Study of Quick Recovery Heart Beat Sensor/ Transducer

The following steps have been followed for experimental study of quick recovery heart-beat sensor/transducer (QRHBS).

a. The reference frequency (f_{ref}) is adjusted to the values 200 Hz, 135 Hz, 100 Hz, 50 Hz by selecting the series resistor R and resistance of LDR i.e. (R_0 + R) where, (R_0 is resistance of LDR in dark condition and R is the series resistor) and emitter capacitor (C_E) is selected to fixed value 1.0 µF. The Reference frequency is noted in the absence of the finger between LED and LDR.
b. The frequency values f_1 and f_2 are noted in presence of finger between LED and LDR of the sample (person) using digital frequency-meter or storage CRO.
c. The frequency difference between f_1 and f_2 is calculated as Δf (i.e. $\Delta f = f_1 - f_2$).
d. The time interval of heart-beat cycle is calculated by taking the reciprocal of Δf i.e. ($T = 1/\Delta f$).
e. The heart- beat rate for a sample (1) is calculated by beat to beat heart beat rate calculation method. The heart rate of sample (1) is measured as 60/T.
f. Steps 2 to 5 have been repeated for ten samples.
g. Experimental observations have been repeated for three to four times to calculate the heart beat rate for ten samples each time.

Experimental data was recorded as follows in Tables 1-4.

Table - 1

f = 200 Hz (R + R_0) = 6.25 KΩ C_E = 1.0 μF

Sample	f_2	f_1	f_1 - f_2 = Δf	T = 1/Δf second	Heart beat rate (60/T)
S1	40	43	3	0.33	181
S2	45	48	5	0.2	300
S3	50	53	3	0.33	180
S4	41	46	5	0.2	300
S5	42	47	5	0.2	300
S6	43	45	2	0.5	120
S7	44	49	5	0.2	300
S8	40	43	3	0.33	180
S9	43	46	3	0.33	180
S10	44	48	4	0.25	240

Table - 2

f = 135 Hz (R + R_0) = 9.25 KΩ C_E = 1.0 μF

Sample	f_2	f_1	f_1 - f_2 = Δf	T = 1/Δf second	Heart beat rate (60/T)
S1	25	27	2	0.5	120
S2	28	32	4	0.25	240
S3	29	34	5	0.2	300
S4	30	33	3	0.33	180
S5	25	29	4	0.25	240
S6	26	28	2	0.5	120
S7	28	30	2	0.5	120
S8	24	28	4	0.25	240
S9	23	26	3	0.33	180
S10	24	28	4	0.25	240

Table – 3

f = 100 Hz (R + R_0) = 12.5 KΩ C_E = 1.0 F

Sample	f_2	f_1	f_1 - f_2 = Δf	T = 1/Δf second	Heart beat rate (60/T)
S1	19	24	5	0.2	300
S2	18	23	5	0.2	300
S3	19	22	3	0.33	180
S4	15	18	3	0.33	180
S5	19	23	4	0.25	240
S6	18	24	6	0.16	360
S7	15	18	3	0.33	180
S8	19	21	2	0.5	120
S9	18	21	3	0.33	180
S10	15	19	4	0.25	240

Table - 4

f = 50 Hz (R + R_0) = 25 KΩ C_E = 1.0 μF

Sample	f_2	f_1	f_1 - f_2 = Δf	T = 1/Δf second	Heart beat rate (60/T)
S1	10	14	4	0.25	240
S2	12	15	3	0.33	180
S3	11	14	3	0.33	180
S4	12	16	4	0.25	240
S5	12	16	4	0.25	240
S6	11	14	3	0.33	180
S7	12	16	4	0.25	240
S8	11	13	2	0.5	120
S9	12	15	3	0.33	180
S10	12	15	3	0.33	180

Comparison of quick recovery heart beat sensor with existing sensor in heart beat monitoring biomedical instruments

Sr. No.	Parameter	Quick recovery heart beat sensor developed by researcher	Limb electrode	Floating electrode	Pregelled disposable electrode	Capacitive pasteless electrode	Air jet
1.	Heart beat	100-240 beats/min	50-300 beats/min	50-400 beats/min	5-400 beats/min	1-400 beats/min	1-400 beats/min
2.	Contact Impedance	1 - 30 GΩ at 10 Hz	2 - 5 KΩ at 10 Hz	50 KΩ at 10 Hz	564 Ω at 10 Hz	1000 - 30000 MΩ at 10 Hz	30000 MΩ at 10 Hz
3.	Shape	Round flat surface	Round flat surface	Round flat surface	Round shape	Round shape	Niddle shape
4.	Cost	Low	Low	Low	High	High	High
5.	Output	Frequency	Capacitance	Capacitance	Capacitance	Capacitance	Capacitance

Conclusion

The study of various concepts of sensors/transducers used for the measurement heart-beat rate in biomedical instruments is carried out during development of QRHBS. The limitation of existing sensors/transducers is also studied in their characteristics. The Q QRHBS is designed with detailed study of the characteristics of quick recovery device (QRD as UJT 2646), characteristics of LDR. The properties of LED and LDR have been used in time-based oscillating circuit to design QRHBS.The measurement of heart beat rate with QRHBS is obtained in term of frequency difference. This frequency difference Δf can be recorded by digital storage CRO for analysis of heart- beat rate. QRHBS is designed with the time-based oscillating circuit and photosensitive components such as LED and LDR. These components can be built up in a single circuit by IC technology. The special arrangement is used to detect blood concentration in the part of body with LED and LDR arrangement. The direct read out of heart beat rate is possible in digit form by using counter circuit (SISO). QRHBS is comparatively the best sensor/ transducer to measure the heart beat rate in medical instruments.

The researcher has QRHBS is developed to measure heart-beat rate. The effectiveness of QRHBS was for checked for various samples a number of times. QRHBS effectiveness is observed nearly equal to existing sensors such as limb electrode, floating electrode, pregelled disposable electrode, capacitive pasteless electrode, air-jet electrode used in biomedical instruments for heart-beat detection. The problem of skin impedance is not much effective in the measurement of heart-beat because there is no direct contact with the body part to detect heart beat as in existing sensors. The frequency obtained from heart-beat action is quite low. Therefore, proper filtering of heart beat signal is required to detect the heart-beat signal at output without noise. In temperature measurement probable error is about 3 Hz/°C and therefore output produced is 70% correct in the body temperature measurement. In case of QRHBS, probable error is equal to 0.01 Hz. To measure heart beat rate more effective by QRHBS the probable error should be minimized.

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