Design and Fabrication of low cost portable ECG system for research base analysis

Design and fabrication of low cost portable ECG system for research base analysis

A thesis submitted toward partial fulfillment of the requirements for the degree of
Master of Engineering in Biomedical Engineering

Course affiliated to Faculty of Engineering & Technology, Jadavpur University
Submitted by

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EXAM ROLL NO: M4BMD19007

CLASS ROLL NO: 101630201009

REGISTRATION NUMBER: 137409 of 2016-2017

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CERTIFICATE OF RECOMMENDATION

We hereby recommend that the thesis entitled **"Design and fabrication of low cost portable ECG system for research base analysis."** carried out under our supervision by Sumant Kumar may be accepted in partial fulfillment of the requirement for awarding the Degree of Master in Biomedical Engineering of Jadavpur University. The project, in our opinion, is worthy for its acceptance.

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Certificate of Approval

The forgoing thesis is hereby approved as a creditable study of an engineering subject carried out and presented in a manner satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein but approve the thesis only for the purpose for which it is submitted.

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of his **Master of Engineering in Biomedical Engineering** studies during academic session 2018-2019.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by this rules and conduct, I have fully cited and referred all material and results that are not original to this work.

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Acknowledgement

I am very grateful to my respected thesis advisors Prof. Tarak Das and Prof. Piyali Basak for their mentoring, valuable guidance, suggestions and motivation during the entire tenure of the thesis work. During each and every hurdle over the span of last eighteen months, they have always been by my side. It has been my proud privilege to work under their supervision.

I would also like to express deep felt gratefulness to Prof. Monisha Chakraborty for her constant support.

I would like to thank all my batchmates- Purbanka Pahari, Gouranga Bala, Tathagata Adhikary, Pratik Das and Nilotpal Das for supporting me over the span of last two years. My senior Mr. Debanjan Parbat deserve special acknowledgement for helping me with the graphics of this thesis work.

Words are not enough to express how indebted I am towards my parents and brother for supporting me and attending to my needs in all possible ways. My heartfelt gratitude goes out to my father in particular, for being the source of my energy and passion to go for higher academic endeavors.

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1. ABSATRACT

The cardiac problems to common people are being increasing day to day. It is one of the measure problems in developing country like us. Generally it is more prone in Asia and Africa which are economically backward .The fundamental diagnosis, to detect the heart problem is the recording of electrical activity of heart, is called electrocardiogram (ECG). The device, used to record the electrical activity of heart, is refers to as Electrocardiograph (ECG). The conventional ECG machine used today, required electrical power for its operation and which is highly complex circuitry and costly and difficult to take the ECG data for research based analysis to detect or diagnose different malfunctioning of heart. Here we intended to design a portable ECG system that included advance features to take data of ECG signal (e.gviaLabViewetc). This can be further used by different software as per research requirement to detect the heart problems. It will be environment friendly, low cost and can easily be used everywhere without electrical power.

Keywords – ECG, INA-02, OP-07, ADC, Filter, Data Acquisition, Lab-View, Mat-Lab

2. INTRODUCTION

The cardiovascular system is an important system in our body, that responsible for blood circulation throughout the body, by which the nutrient, oxygen and other essential components are carried to all cells and unwanted waste product of the cells are removed [1]. The main organ of the cardiovascular system is heart that provides pumping action for blood circulation. The pumping action is initiated by the heart itself by contraction and relaxation of heart chambers in rhythms [2]. The heart comprises Special Junction altissuesor conduction system, consisting of Sinoatrial (SA) node, Atrioventicular (AV) node, Bundle of his, Branches of bundle of his, Parkenji fiber. Usually SA node generates an electrical impulse that initially spread over the both atrium, resulting contraction of the atrium and then electrical impulse reaches to AV node that receive the impulse and then, the impulse is transmitted to the ventricular muscles through the Bundle of his, Branches of bundle of his, Parkenji fiber respectively, resulting ventricular contraction [3]. During ventricular contraction, atrium become in relaxation and after ventricular contraction, ventricular relaxation occurs. After that again SA node generates next impulse that causes repetition of same action of contraction and relaxation of atrium and ventricle respectively in rhythms. [4]

The contraction of heart muscles refers to as depolarization and relaxation of heart muscles refers to as repolarization. During heart muscles contraction electrical potential is produced and this electrical potential is spread through our body surface. By the help of this produced electrical potential we can know about various body internal condition and activity.

This signal should be taken on any patient and can be detected cardiac complaint, including suspected acute myocardial infarction, unstable angina, or any unstable patient with a history of cardiovascular disease [5]. As a general rule, pain located between the naval and the head should be investigated with this electrical generated signal.

Electrocardiogram (ECG or EKG) is the recording of the electrical activities of the heart with respect to time. ECG is a somewhat periodic waveform [5a]. A typical time varying ECG [6] waveform is composed of the uniquely distinct PQRST waveform which corresponds to three different physiological phenomena occurring in one cardiac cycle. The atrial depolarization corresponds to the P wave while the QRS complex and the T wave indicate ventricular depolarization and repolarization respectively. T wave becomes extremely narrow and gets closer to the QRS complex during comprehensive physical activities, indicating its strong dependence upon heart rates. The R-peak indicates one heartbeat. Thus, it becomes quite trivial that the number of R-waves generated by the heart in a minute is the number of beats per minute (bpm) which is ideally 72 bpm in a normal healthy adult [7]. So ECG wave consists of certain parts named as the P wave, PR interval, QRS complex, ST segment, T wave, QT interval and then the infrequent presence of U wave. The sino- atrial node or the SA node is positioned on the left atrium and this initiates the electrical signal causing atrial depolarization. The atrium is anatomically divided into two parts, but electrically theyfunction as a single part [8]. Standard method of acquisition of ECG through surface electrodes utilizes twelve leads. There are six chest leads which are named from V1 to V6. The other six electrodes are the limb leads which are named as I, II, III, aVR, aVL and aVF. Leads II, III aVF record the electrical activity of inferior surface of the heart. Anterior surface is covered by leads V1 to V4. Leads I aVF, V5 and V6 cover the lateral surfaces of the heart. Leads V1 and aVR cover the right atrium and cavity of left ventricle of the heart [9]. The typical ECG waveform is shown in the figure 1.1. The subsections of the ECG waveform are described below:

P wave: Atria have very little muscle thus produce a wave of amplitude called the P wave. As the wave of depolarization is directed inferiorly and towards the left, thus the P wave tends to be upright in leads I and II [10]. It remains inverted in lead aVR. Usually leads II and V1 prominently record the sinus P waves.

PR interval: the PR interval is the subsequent part after the P wave. It occurs as the electrical impulse is conducted through the AV node, bundle of His and Purkinje fibers. The PR interval can be defined as the time between the onset of atrial depolarization and the onset of ventricular depolarization

QRS complex: after the PR interval, QRS complex occurs. This complex is generated by the depolarization wave which travels through the interventricular septum via the bundle of His and bundle branches and reaches the ventricular myocardium via the Purkinje fiber network. The impulse first depolarizes the left side of the septum, and then spreads towards the right[11]. The left ventricle has larger muscle mass and thus its depolarization dominates the ECG wave.

<u>ST segment:</u> the QRS complex ends at the J point and from here starts the ST segment. The ST segment which lies between the J point and the onset of the T wave, represents the period between the end of ventricular depolarization and repolarization[12]. Level of the ST segment and TP segment should be fairly flat. TP segment means the segment starting from the end of T wave of one ECH waveform to the next waveform. Sometimes it slopes upwards slightly before merging with the T wave.

<u>T wave:</u> the T wave is the result of ventricular repolarization hence it represents the repolarization of the ventricles. This wave in a normal ECG is asymmetrical. This interval elongates as heart rate decreases so during Measurement of this interval a special attention is given to the heart rate. As no widely accepted criteria exist regarding T wave amplitude, generally T wave amplitude corresponds with the amplitude of the preceding R [13].

<u>QT interval:</u> The QT interval is measured between the end of the T wave and the beginning of the QRS complex. It represents the total time taken for depolarization and repolarization of the ventricles. As this interval lengthens as the heart rate slows, the rate is taken considered when QT interval is measured [14]. The QT interval increases slightly with age and it becomes longer in women than in men.

U wave: the last part of the ECG is the U wave which is found just after the T wave ends[15]. The Subsection of ECG is depicted in Fig: 2.1 [16a].

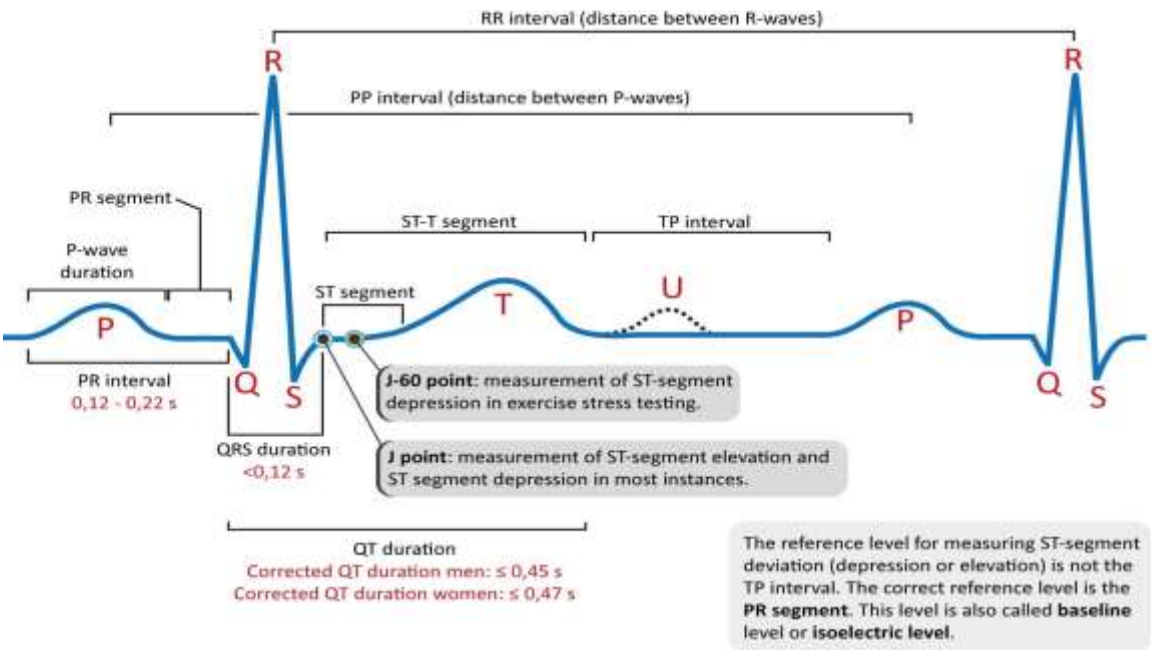

Figure 2.1: Subsections of the ECG waveform

In this project the device I have made, data taken from this device can be used for different comparative study associated with ECG signal like detection of diabetes and sleep apnea disorder using Heart Rate Variability (HRV) also lung disease and other problems associated with ECG, can be detected and analyze from its data.

Hence it becomes very important to record this signal and it can be done using suitable electronic bio amplifier circuitry and electrodes, placing over the specified location of our body surface.

2.1 ECG Electrode:

In standard ECG process, 10 numbers of electrodes are used. Among them four electrodes(i.e. RA, LA, RL, LL) are called limb electrodes that are to be placed over the four limbs and six electrodes (i.e. V1, V2, V3, V4, V5 and V6) that are to be placed over the chest around the heart. Limb electrodes are flat surface type electrodes and chest electrode are suction-cup type electrodes. Applying electrolyte gel (ECG Gel), ECG electrodes are positioned on the specific body surface. The placements of ECG electrodes are as follows given on Table 2.1 [16].

Table 2.1: placements of ECG electrodes

ECG Electrode	Electrode Position
RA	On the wrist of right arm, avoiding thick muscle.
LA	On the wrist of left arm, avoiding thick muscle.
RL	On the lower end of right leg, lower end of medial aspect of calf muscle. (Avoid bony prominences)
LL	On the lower end of left leg, lower end of medial aspect of calf muscle. (Avoid bony prominences)
V_1	In the fourth intercostal space (between 4^{th} and 5^{th} Ribs) just to the right of the sternum (breastbone).
V_2	In the fourth intercostal space (between 4^{th} and 5^{th} Ribs) just to the left of the sternum.
V_3	Inbetween leads V_2 and V_4.
V_4	In the fifth intercostal space (between 5^{th} and 6^{th} Ribs) on the mid-clavicular line.

V_5	Inbetween leads V_4 and V_6, at same level of V_4 & V_6
V_6	On the mid-auxiliary line at the same level of electrode V_4 and V_5.

2.2 ECG Amplifier:

Basically ECG amplifier, amplify the potential (i.e. voltage) difference between indifferent specific combinations of ECG electrodes and then recorded. An instrumentation amplifier is used as ECG amplifier which has two input lines – Inverting and Non-inverting input lines as follows. It has high gain and high CMMR [17].

2.2.1 Theory of operation of instrumentation amplifier INA102

Instrumentation amplifiers are used to accurately amplify the difference of input voltage. Its feedback circuits are included on the monolithic chip. Gains of 1, 10, 100, and 1000 in the INA102 can be found easily without using any external resistances. Its performance is very different from op amps. To achieve same basic function as INA102 by op amp is very difficult. In figure 2.2 a simplified diagram of INA102 instrumentation amplifier is shown that eliminates most of the problems associated with op amps [18].Simplified diagram of INA102 instrumentation amplifier is shown in fig. 2.2 [19].

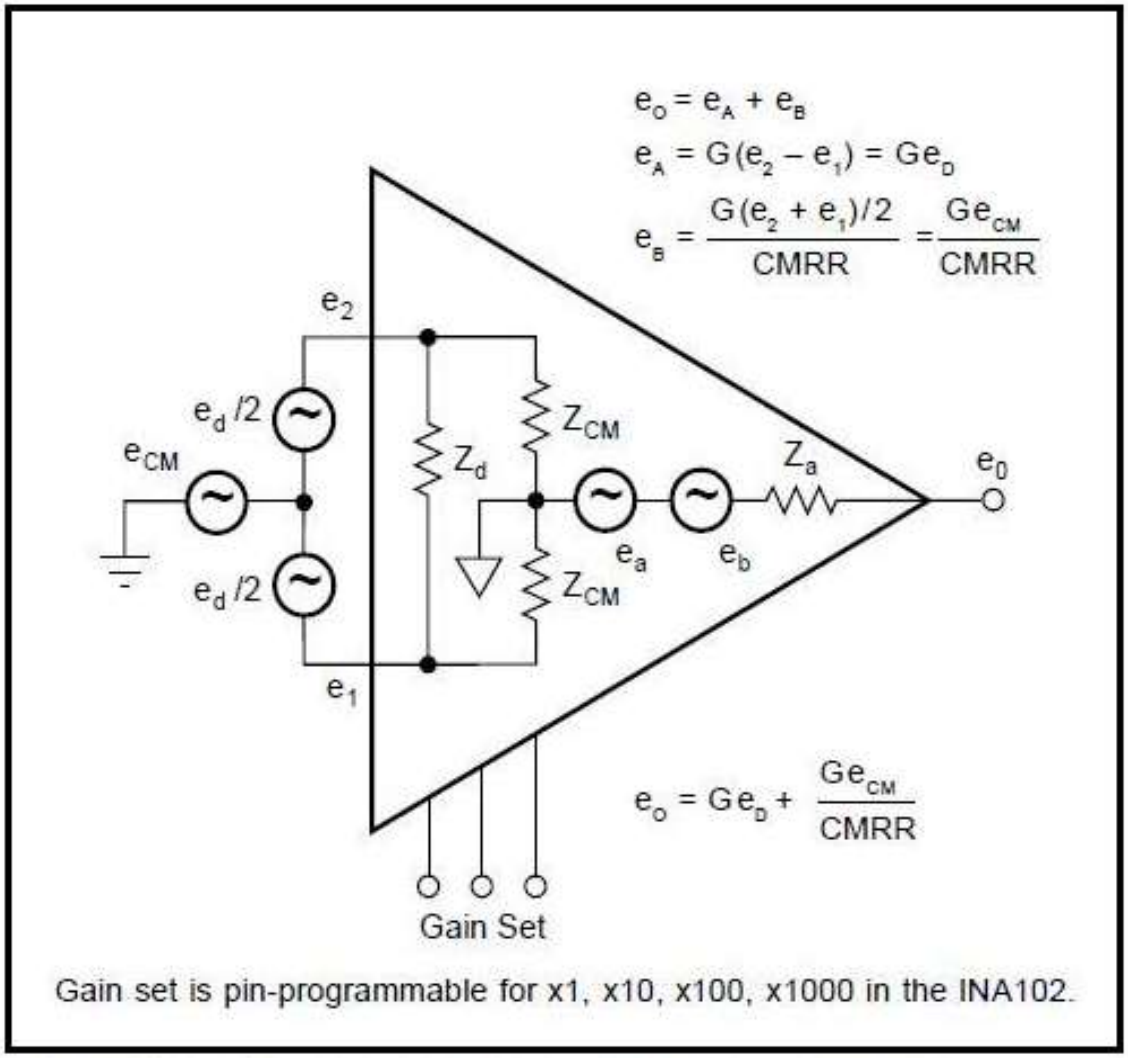

Figure 2.2: Simplified diagram of INA102 instrumentation amplifier

2.3 Theory of operation IC OP07:

The OP07 has a special feature to eliminate any need for external nulling. To achieve this need its offset voltage is kept very low by trimming at the wafer stage.

Its other features are:

Very Low input bias current (±4 nA)

High open-loop gain (200 V/mV).

The low offset

Wide input voltage range of ±13 V

High CMRR of 106 dB (OP07E)

High input impedance

Its high open loop gain makes it useful for high gain instrumentation applications. Its high input impedance is useful in case of non-inverting amplifier which increase its accuracy [20]. Its gain and offset is also very stable even with high variation in temperature and time. It can be used with slander performance between temperature range -400 centigrade to + 850 centigrade ranges.

2.4 ECG Lead:

A specific electrode combination, connected to the two input terminals of the ECG amplifier, produces a record which is commonly known as Lead. In standard ECG procedure, we take 12 records that are commonly known as leads – Lead-I, Lead-II, Lead-III, aVR, aVL, aVF, V1, V2, V3, V4, V5 and V6. There are two types of ECG lead [21]. They are

i) Bipolar Lead

ii) Unipolar Lead

3. LITERATURE REVIEW

Electrocardiography is a fundamental part of cardiovascular assessment. It is an essential tool for investigating cardiac arrhythmias and is also useful in diagnosing cardiac disorders such as myocardial infarction [22]. Familiarity with the wide range of patterns seen in the electrocardiograms of normal subjects and an understanding of the effects of non-cardiac disorders on the trace are prerequisites to accurate interpretation.

The contraction and relaxation of cardiac muscle results from the depolarization and repolarization of myocardial cells. These electrical changes are recorded via electrodes placed on the limbs and chest wall and are transcribed on to graph paper to produce an electrocardiogram (commonly known as an ECG) [23].The sinoatrial node acts as a natural pacemaker and initiates atrial depolarization. The impulse is propagated to the ventricles by the atrioventricular node and spreads in a coordinated fashion throughout the ventricles via the specialized conducting tissue of the His-Purkinje system. Thus, after delay in the atrioventricular mode, atrial contraction is followed by rapid and coordinated contraction of the ventricles. The electrocardiogram is recorded on to standard paper travelling at a rate of 25 mm/s [24]. Large squares the paper is divided into, each measuring 5 mm wide and equivalent to 0.2 s. Each large square is devided in to five small squares in width, and each small square is devided in 1 mm wide and equivalent to 0.04 s. All electrical activities detected by the electrocardiogram machine are measured in millivolts. Machines are calibrated so that a signal with amplitude of 1 mV moves the recording stylus vertically 1 cm. The amplitude of waveforms are expressed as: 0.1 mV = 1 mm = 1 small square. The amplitude of the waveform recorded in any lead may be influenced by the myocardial mass, the net vector of depolarization, the thickness and properties of the intervening tissues, and the distance between the electrode and the myocardium. Patients with ventricular hypertrophy have a relatively large myocardial mass and are therefore likely to have high amplitude waveforms. In the presence of pericardial fluid, pulmonary emphysema, or obesity, there is increased resistance to current flow, and thus waveform amplitude is reduced.

The direction of the deflection on the electrocardiogram depends on travelling of the electrical impulse. It may travel towards or away from a detecting electrode. By convention, an electrical impulse travelling directly towards the electrode produces an upright (“positive”) deflection relative to the isoelectric baseline, whereas an impulse moving directly away from an electrode produces a downward (“negative”) deflection relative to the baseline. When the wave of depolarization is at right angles to the lead, an equiphasic deflection is produced [25].

First human electrocardiogram (ECG) was published in 1891 by Augustus D. Waller which was recorded by a capillary electrometer [26]. After that Willem Einthoven invented a more sensitive galvanometer for producing ECG by the help of fine quartz string coated in silver. By using lead system in ECG He recorded five deflection point P, Q, R, S, T in cardiac cycle which are still being used in the present. Einthoven first started to transmit recorded ECG from hospital to his laboratory on telephone line. After that it was started to use with high demand. Since last few decades electronic equipment’s have been developed which made the ECG recording process easy and noise limited. Now it is available in such a form that one can easily record it without affecting his/her daily routine. Recently, the wearable ECG recorders (W-ECG) are becoming very popular due to their long term recording capability, low cost and ease of use.

The ECG data can be recorded by single-lead or multiple-lead ECG signals depending upon the type and configuration of the ECG recorder. Single lead signal can analysis morphologies, repeatability and spectra of cardiac cycle [27].

On the other hand, multi-lead ECG processing algorithms has greater immunity against interference signals. Its disadvantage is that it increased patient discomfort and stress, especially for ambulatory testing.

In proposed system I have developed a low cost portable three lead ECG system which can be easily used by the researcher to carry with them and take the ECD data for their research purpose.

4. OBJECTIVE OF THE PROJECT

1. The main objective of this project is to design aportableECG data recording system that is capable to record ECG data from patient's or individual's in real time to his/her Laptop.
2. To develop bio-amplifier that will act as ECG amplifier.
3. To develop a Power system for energy required to run the circuitry. Here we intended to design a Small panel, consisting of two9V batteries that can produce +9V and -9V as per requirement of the system.
4. To develop a suitable Program to acquire the data in laptop through Lab-View
5. To be familiar with the different electronic components, used in this project.
6. Partial fulfillment of pursuing Post-Graduate and award of degree of M.E. in Bio-Medical Engineering.

5. SYSTEM DEVELOPMENT & EVALUATION

The main objective of this project is to design an ECG monitoring system that is capable of recording a patient's or individual's ECG in real time to his/her Laptop.

The system consists of main eight sections:

1. ECG Electrodes
2. Instrumentation amplifier IC INA-102
3. Filter
4. Op-amps
5. Battery
6. Data Acquisition Card Ni-daq.
7. Buzzer and pulse indicator
8. Suitable software (Lab-View) and Mat-Lab.

5.1 Selection of ECG electrode:

ECG electrodes are comprised of a plastic substrate covered with a silver/silver chloride ionic compound. Due to very low solubility in water silver chloride remains stable. The electrode is assembled with an electrolyte gel which mainly contains Cl- anion. Since skin interface contains excess of chloride ions, so cl- anion easily attracted by skin.

Excitable body cells generate electrical potential inside the heart which manifested on the body surface due to conductivity of the human body. The skin impairs the transfer of ions from the tissue to electrons in the electrode. Chloride gel/ saline solution work as a conductive bridge between the patient's skins to a silver/silver chloride sensor. Total impedance of ECG sensor comprise impedance of skin, resistance of gel, resistance between layer of electrode-electrolyte interface as well as half-cell potentials caused by different energies of the electrode, electrolyte, and skin.

In a 12-lead ECG, 10 electrodes are placed on the patient's limbs and on the surface of the chest. The overall magnitude of the heart's electrical potential is then measured from 12 different angles and recorded sensed signal by electrode is send to the ECG amplifier.

Here for simplicity 3 electrode systems is used. For better and noiseless result it is necessary to prepare skin and select designated chest or limb electrode placement sites. Following caution should maintain during electrode placement and skin preparation.

1. Avoid placing electrodes over bony prominences i.e. clavicles
2. To enhance electrode skin contact and patient comfort:
3. Clip /shave excess chest hair in a 1-2 cm diameter of the designated electrode site if necessary with the patients consent

4. With a dry swab gently clean/abrade electrode sites to remove loose skin cells, body oil, and sweat improve skin/electrode contact

5. If alcohol pad is used to cleanse skin, allow to site to dry, before electrode placement

6. ECG Electrodes are small sensor pads (self-adhesive disposable, pre gelled) applied on the skin to enable detection of the electrical activity of the heart, which is transmitted to the monitor, amplified and display of the ECG trace.

RA - RED electrode placed under right clavicle near right shoulder within the rib cage frame or right hand.

LA - YELLOW electrode placed under left clavicle near left shoulder within the ribcage frame or left hand.

LL - GREEN electrode placed on the left side below pectoral muscles lower edge of left rib cage or left leg.

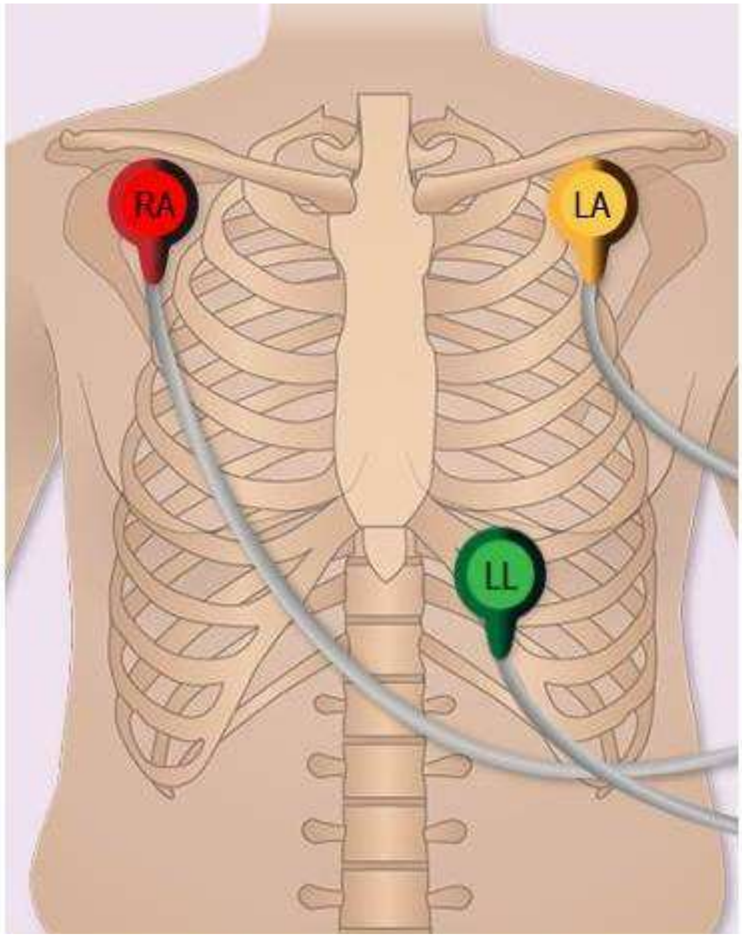

Figure 5.1: ECG electrode placements

5.2 Instrumentation amplifier IC

The amplitude of output signal from ECG electrode is too small to recognize it at Smartphone. It also contains a lot of added noise. The output signal has amplitude approx 0.5mV. Hence for to increase amplitude of output signal and reduce the noise from signal instrumentation amplifier is used. Instrument amplifier is used with very high input impedance and high CMRR. Also it provides differential signal. For perfect signal it is used with a gain of approx.1000, input impedance of 10G ohm and CMRR more than 110db. High value of CMRR reduces most of the noise from desired signal and high impedance protects the driving signal to get distorted.

Feature of instrumentation amplifier:

1. High value of CMRR

2. High input impedance

3. 1000 times gain

5.2.1Model of instrumentation amplifier

Instrumentation amplifier INA102 contains three-amplifier configuration provides desirable characteristics &premium performance. It has some additional feature which generally not found other type instrumentation amplifiers.

Here A1 and A2 two buffers are used which help to get high performance. To providing high input impedance amplifiers are connected in non-inverting configuration. Its monolithic design and applied State-of-the-art laser trimming techniques keep its offset voltage down.

The output stage (A3) is connected in a unity-gain differential amplifier configuration. Four 20 KW resister is used and well matched and it remains matched even at high temperature variation and long to retain good common-mode rejection. All internal resisters are made of thin-film nichrome which provides long term stability and TCR and TCR tracking. It provides gain accuracy and common-mode rejection over wide temperature ranges.

5.2.2 Use of INA102

Simplest configuration of the INA102 is shown in figure 5.1below. A gain of 1, 10, 100, or 1000 is selected by programming pins2 through 7 (see Table I). For the gain of 1000, a special gain sense is provided to preserve accuracy. The output voltage is a function of the differential input voltage times the gain.

Table 5: Configuration of the INA102

GAIN	CONNECT PINS
1	6 to 7
10	2 to 6 and 7
100	3 to 6 and 7
1000	4 to 7 and separately 5 to 6

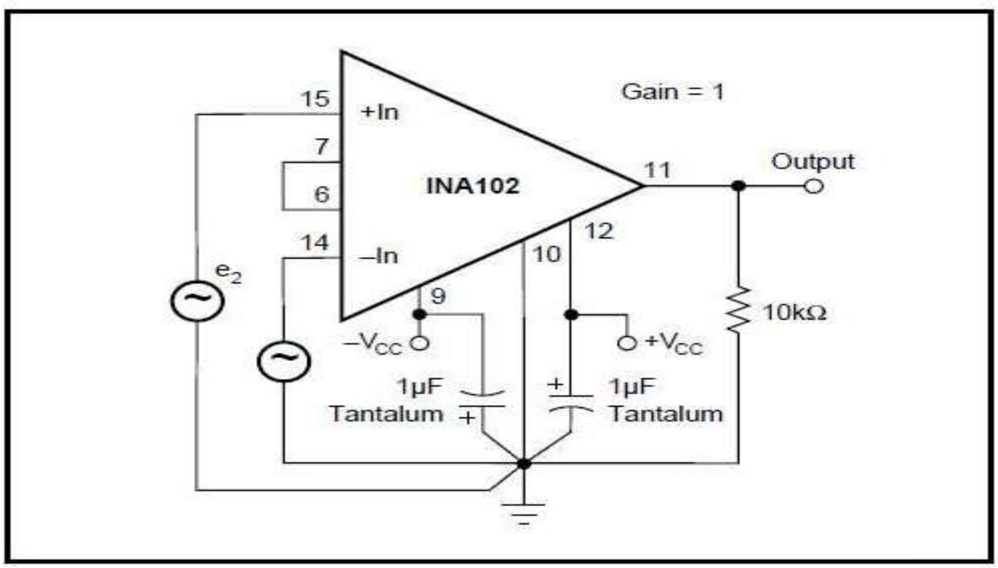

Figure 5.2: TheBasic Circuit configuration of INA-102

2.2.3 Feature of INA 102

Supply .... ±18V
Input Voltage Range .... ±VCC
Operating Temperature Range .... –25°C to +85°C
Storage Temperature Range: Ceramic .... –65°C to +150°C
Plastic, SOIC .... –55°C to +125°C
Lead Temperature (soldering, 10s) .... +300°C
Output Short Circuit Duration .... Continuous to Ground

5.2.4 Description & pin configuration of INA 102

The INA102 is a high-accuracy monolithic instrumentation amplifier designed for signal conditioning applications where low quiescent power is needed. On-chip thin-film resistors provide excellent temperature and stability performance. For high gain accuracy and common-mode rejection a special technology State-of-the-art laser trimming is used. SimplifiedPin configuration with internal construction

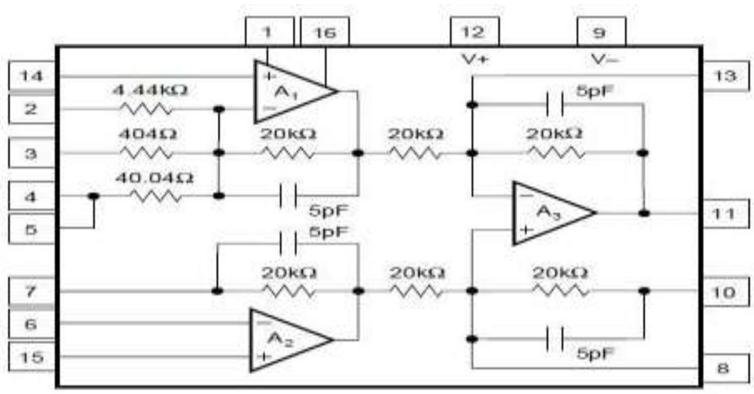

Figure 5.3: Pin configuration with internal construction

And external pin Pin configuration is shown in fig.5.3 [28] and fig 5.4 [29] respectively. The INA102 is convenient to use with a gain of 1, 10, 100, or 1000. It may be selected by simply strapping the appropriate pins together. Without external adjustment a gain drift of 5ppm/°C in low gains can be achieved. When higher-than-specified CMR is required, CMR can be trimmed using the pins provided. According to need a balanced filtering can be added in the output stage.

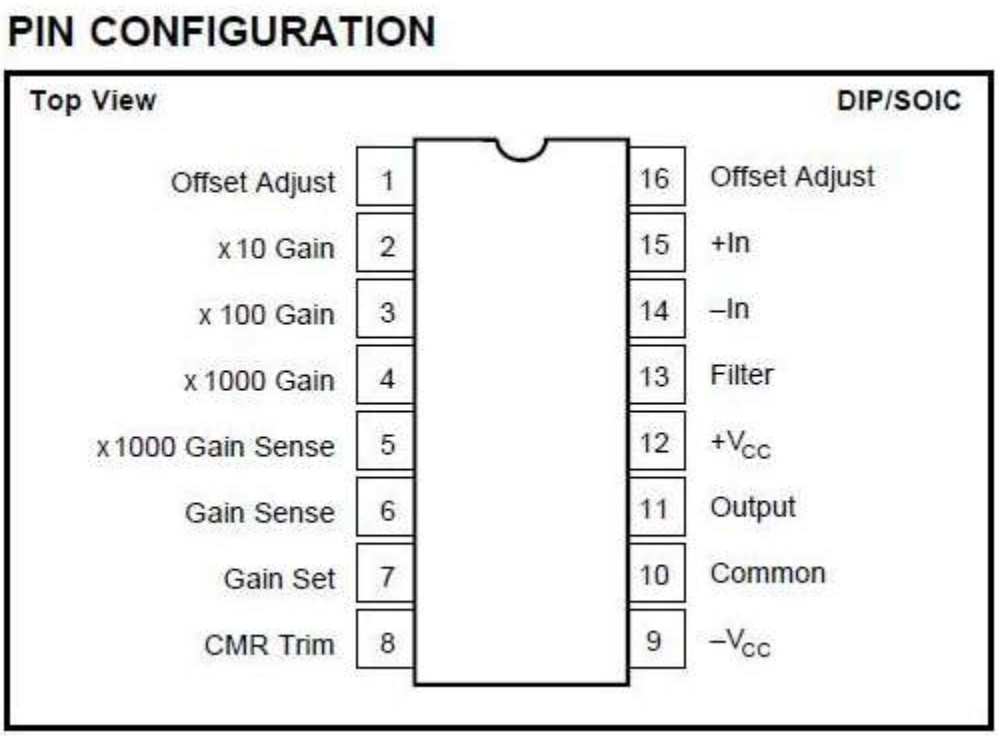

Figure 5.4: Pin configuration of INA 102

5.3 Circuit model using INA102 –

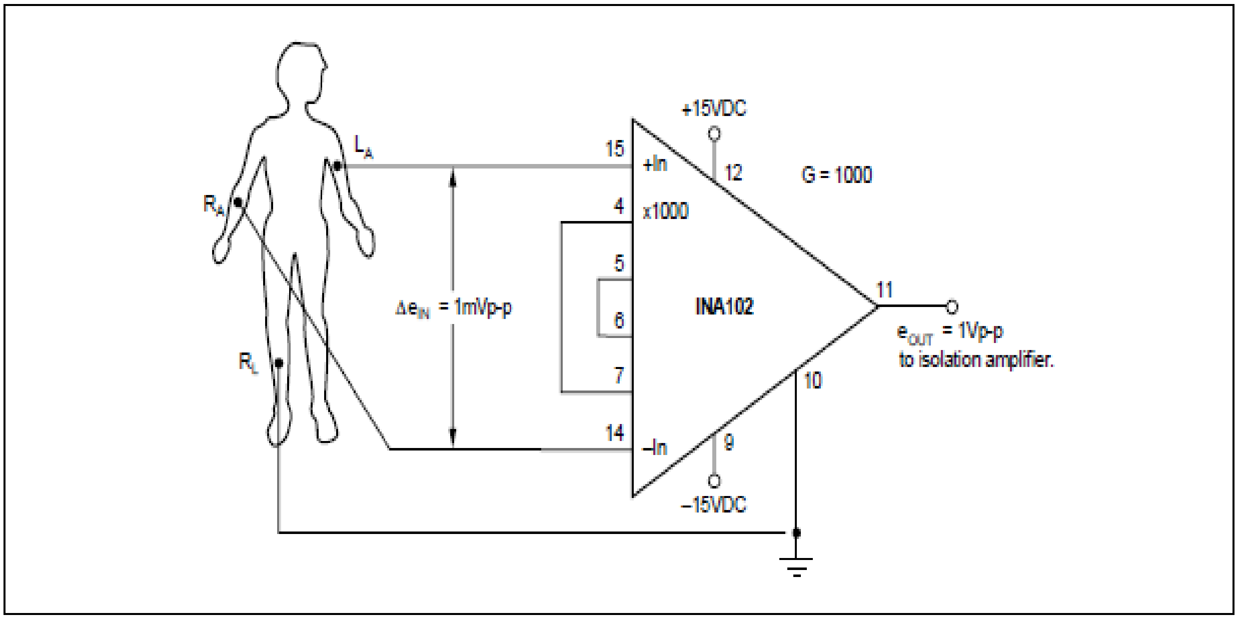

Figure 5.5: Circuit model using INA102

5.3 Filter:

The output of ECG contains large unwanted impulse signal due to Power line interference, Muscle noise, Respiration, Body movements etc, Can cause problems to analysis. It can be suppressed using high pass and low passfilter. To find the signal noiseless we select the high cut off frequency of low pass filter is 150 Hz and low cut off frequency of high pass filter is .05 Hz. Offset voltages in the electrodes, respiration, and body movement is a low-frequency component present in the ECG system, so it can be removed by using high pass filter with low cut-off frequency 0.05 Hz which did not distort ECG signal and remove the low frequency components. Low pass filter with high cutoff frequency 150 Hz is used to remove very high frequencies.

To meet all requirements we have used an active band pass filter with pass band0.05 Hz to 150 Hz.

5.3.1 Active band pass filter

Filter that build up active band pass filter consist of a sallen- key high pass filter and sallen- key low pass filter whose circuit diagram is given below in fig. 5.6 [30].

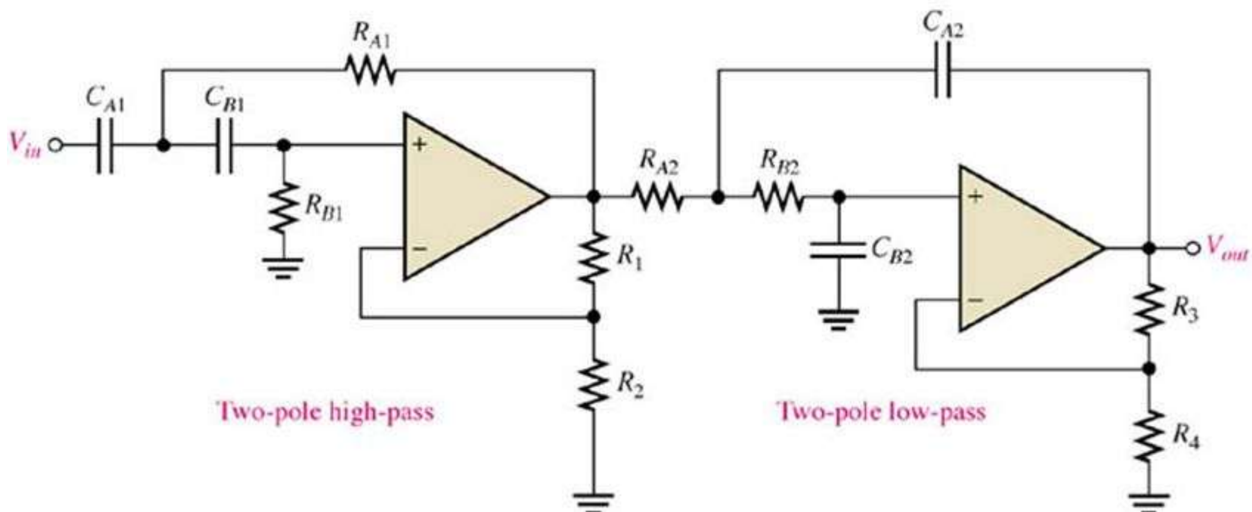

Figure 5.6: Band pass filter formed by cascading a two pole high pass and two pole low pass filters.

5.3.2 Calculation for Sallen- key high pass filter

1. Calculation for the transfer functions for Sallen-Key high-pass filter with R and C values.

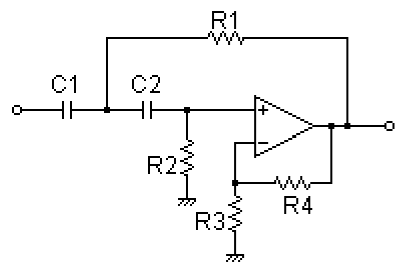

Figure 5.7: High-pass filter for Calculation of transfer functions

$$\frac{vo}{vi}=\frac{Gs^2}{s^2+s\frac{1}{C1R2}+s\frac{1}{C2R2}+s\frac{1}{C1R1}(1-G)+\frac{1}{C1C2R1R2}}$$

$$G=\frac{R3+R4}{R3}$$

2. Calculation for the R and C values for the Sallen-Key filter at a given frequency and Q factor

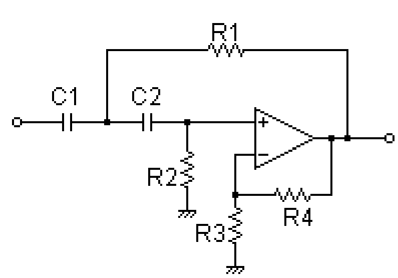

Figure 5.8: High-pass filter for Calculation of the R and C values

Cutoff frequency for high pass filter is kept 150 hz. For unity gain

F = 150
R_1 = 10 megaohm
R_2 = 100 megaohm
R_3 = 75 mega ohm
C_1 = 5 nano farad

Is selected and through calculation we got

R_4 = 1000 mega ohm and
C_2 = 100nf

$$\frac{Vout(s)}{Vin(s)} = \frac{Gs^2}{s^2 + 2\zeta(2\pi f_c)s + (2\pi f_c)^2}$$

$$Q = \frac{1}{2\zeta}$$

$$G = \frac{R3 + R4}{R3}$$

5.3.3 Calculation for sallen- key LOW pass filter

1.Calculation for the transfer function for Sallen-Key low-pass filter with R and C values

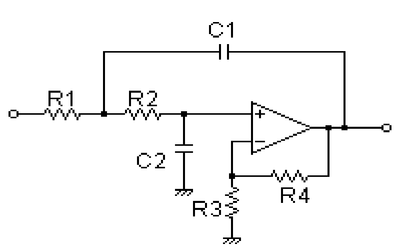

Figure 5.9: Low-pass filter for Calculation of transfer functions

$$\frac{vo}{vi} = \frac{\frac{G}{C1C2R1R2}}{s^2 + s\frac{1}{C1R2} + s\frac{1}{C1R1} + s\frac{1}{C2R2}(1-G) + \frac{1}{C1C2R1R2}}$$

$$G = \frac{R3+R4}{R3}$$

2. Calculation for the R and C values for the Sallen-Key filter at a given frequency and Q factor

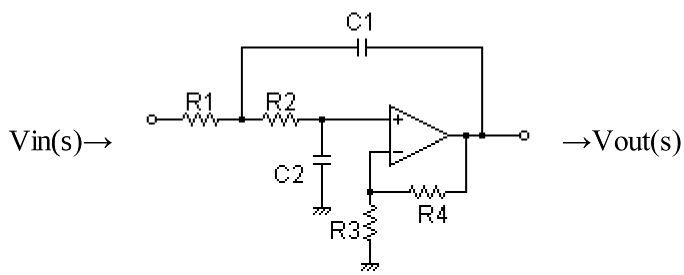

Figure 5.10: Low-pass filter for Calculation of the R and C values

Cutoff frequency for high pass filter is kept 0.05 Hz. For unity gain

F = 150
R_1 = 10 mega ohm
R_2 = 100 mega ohm
R_3 = 75 mega ohm
C_1 = 5 nano farad

Is selected and through calculation we got

R_4 = 1000 mega ohm and
C_2 = 100nf

$$\frac{Vout(s)}{Vin(s)} = \frac{G(2\pi f_c)^2}{s^2 + 2\zeta(2\pi f_c)s + (2\pi f_c)^2}$$

$$Q = \frac{1}{2\zeta}$$

$$G = \frac{R3 + R4}{R3}$$

5.4 Block diagram for ECG sensor

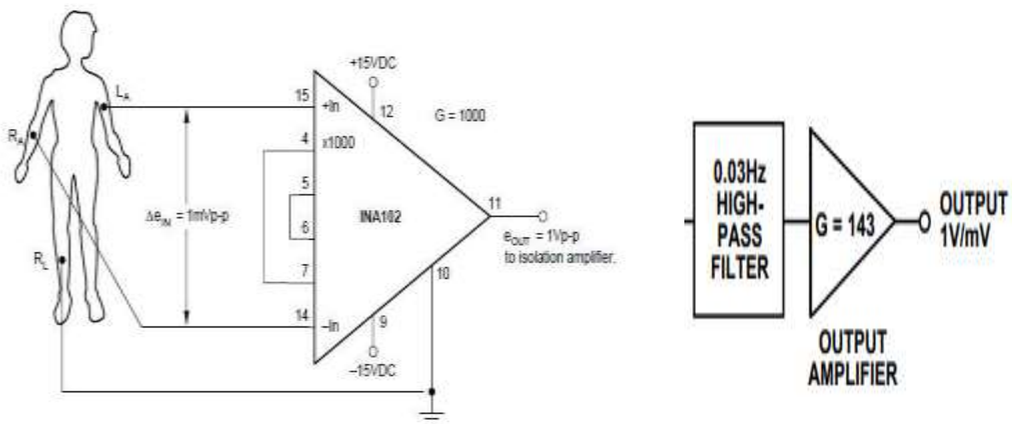

Figure 5.11: Block diagram for ECG sensor with gain

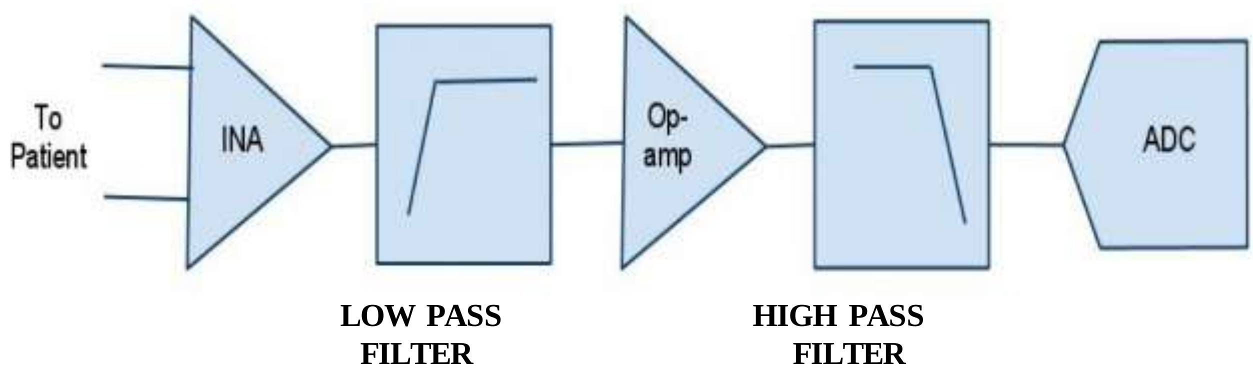

Figure 5.12: Block diagram for ECG sensor with filter and ADC

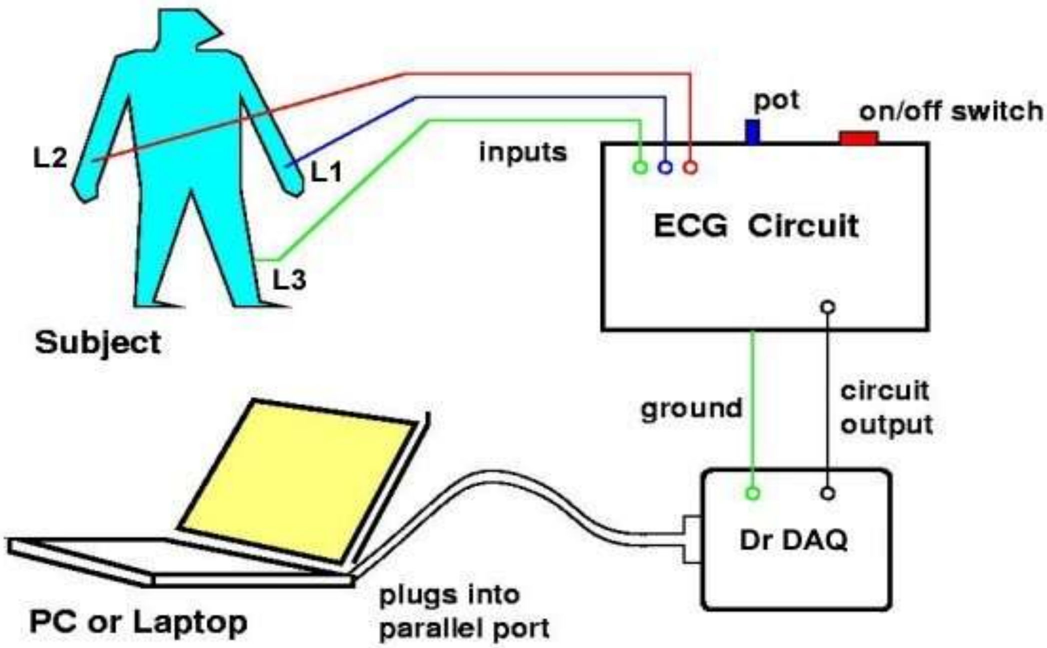

Figure 5.13: Complete block diagram of ECG system

5.5 Specification of Component required for band pass active filter:

For development of active band pass filter to IC op-o7 has been used. This is operating in non-inverting mode so that output signal remains in phase of applied signal and only noise get reduce. Feature of op 07 and working principal of non-inverting operational amplifier are discussed below.

5.5.1 Ultralow Offset Voltage Operational Amplifier Op 07-

The OP07 has a special feature to eliminate any need for external nulling.Its offset voltage is very low and used with high accuracy in non-inverting amplifier. Its gain and offset is also very stable even with high variation in temperature and time. It can be used with stander performance between temperature range -40^{0}C to + 85^{0}Crange.

1. Feature

Low VOS: 75 µV maximum

Low VOS drift: 1.3 µV/°C maximum

Ultrastable vs. time: 1.5 µV per month maximum

Low noise: 0.6 µV p-p maximum

Wide input voltage range: ±14 V

Wide power supply voltage range: ±3 V to ±18 V

125°C temperature-tested dice

2. Absolute maximum rating

Parameter Ratings Supply Voltage (VS) ±22 V

Input Voltage1 ±22 V

Differential Input Voltage ±30 V

Operating Temperature Range

Output Short-Circuit Duration Indefinite

Storage Temperature Range S and P Packages −65°C to +125°C

OP07E 0°C to 70°C

OP07C −40°C to +85°C

Junction Temperature 150°C

Lead Temperature, Soldering (60 sec) 300°C.

Stresses more than above listed value may be cause to permanent damage to the device. Fig. 5.14 [31] and fig. 5.15 [32] showing pin configuration of OP07and front view of IC OP07respectively.

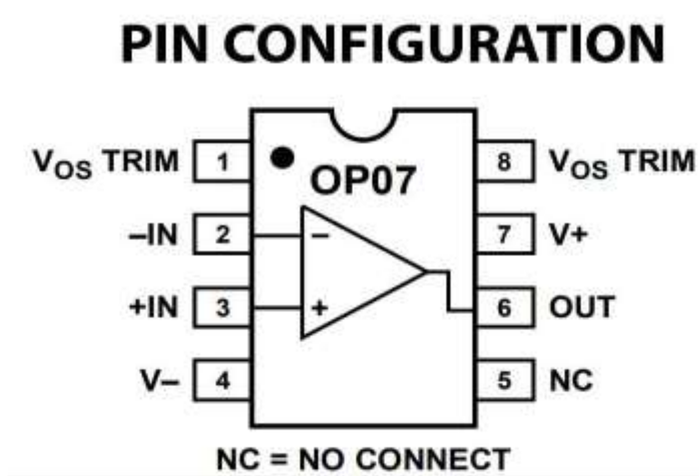

Figure 5.14: Pin configuration of OP07

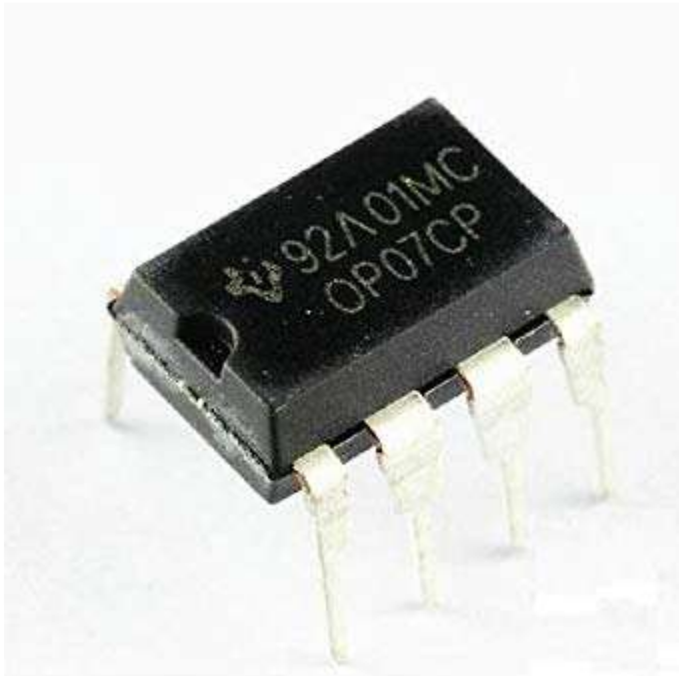

Figure 5.15: IC OP07

5.5.2 Non-inverting Operational Amplifier

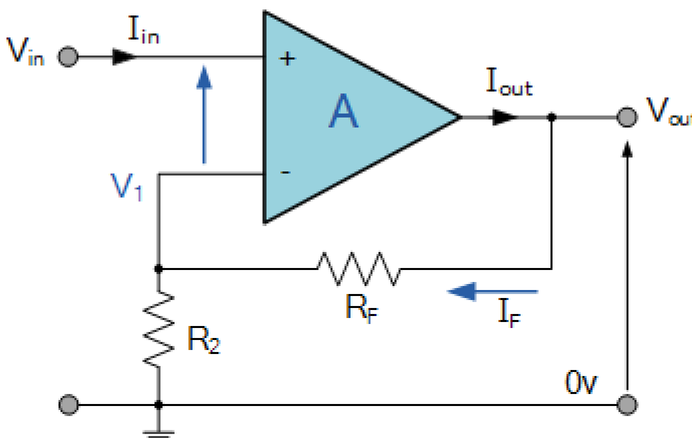

Figure 5.16: Non-inverting Operational Amplifier

In such type (fig. 5.16) [30] of configuration input voltage is applied to non – inverting terminal means + terminal of the op-amp. It provides gain without inverting of the input signal. Its output signal remains in phase with applied signal.

Feedback control can be achieved by applying a small part of the output signal to inverting input terminal. Closed loop configuration is used to provide stability. Its high input impedance (ideally infinity) does notallow to flow any current from negative terminal to positive terminal.

1.Non-inverting Operational Amplifier Configuration

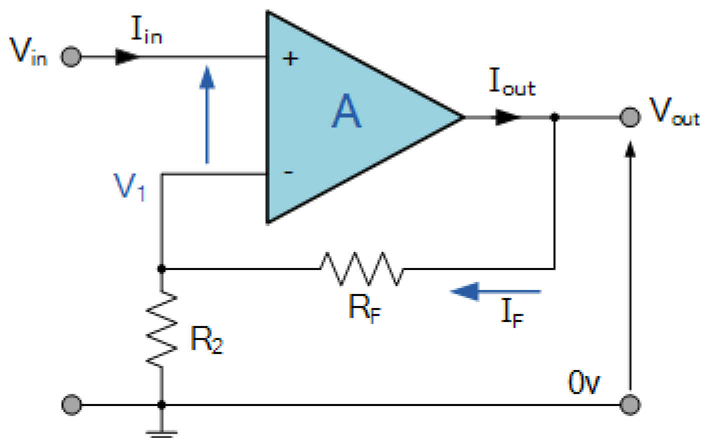

Figure 5.17: Non-inverting Operational Amplifier Configuration

For an ideal op-amp input resistance remains very high (infinity). Due to this reason no current flow through negative terminal to positive terminal or it can be said that both terminals are at equal potential. This is also known as virtual earth summing point.

Because of this virtual earth node the ratio of resistors, R_f and R_2 which is shown in fig. 5.17 provides an amplified output signal in same phase of input.

The voltage gain of the circuit can be determined by following mathematical expression:

$$\textbf{Gain} = \left(1 + \frac{Rf}{R2}\right) \times V_{in}$$

5.6 Development of Power Source:

The circuit of power source was finally placed inside a plastic box of 3”× 2” and connecting cable was used for power supply.

Here two portable 9v batteries are connected with each other inside the box to supply +9v, Ground and -9v. The circuit concept is on Figure 5.18.

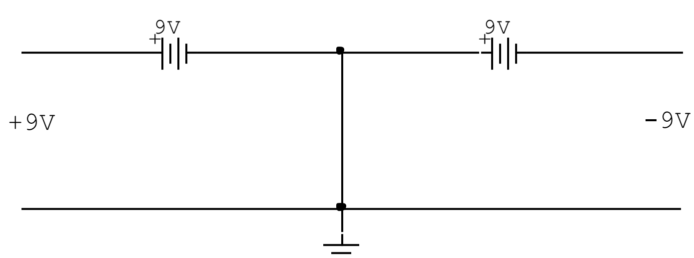

Figure 5.18: +/- 9V Power supply using two 9V batteries

Both the buzzer and Led pulse indicator are connected finally with the system to indicate the ECG pulse.

5.7 Controller or Data Acquisition Card Ni-daq.

The output of ECG is in analog form. In order to transmit, store and display it is necessary to convert It into digital form. Controller contains A TO D converter of appropriate sampling frequency. It also store digitize ECG signal in SD card. Digital storage can keep the data for long time without distorted. Microcontroller uses very less current in order to few millamperes.

5.8 Buzzer and pulse indicator

Additionally, Buzzer and three LED indicator light are used to make it more advance. One red color indicator light is used to be insure that positive power source is working properly and another green LED indicator is for insurance of negative power source supply. Third indicator blinks with the heartbeat. It is an LED indicator light that will pulsate with the rhythm of a heartbeat.

A buzzer or beeper is used as an audio signaling device, which confirms the rhythm of heart beat through an audio beep.

ECG transmitter is used for transferring the data from microcontroller to computer through USB port.

6. SCHEMATIC PRESENTATION OF THE ECG SYSTEM:

The basic block-diagram of the portable ECG with systemis shown in the given figure. Here figure 6.1 showing initial stage of system development. It's all internal parts are shown in given figure. This is simple ECG system device without buzzer, indicator and other advance function.

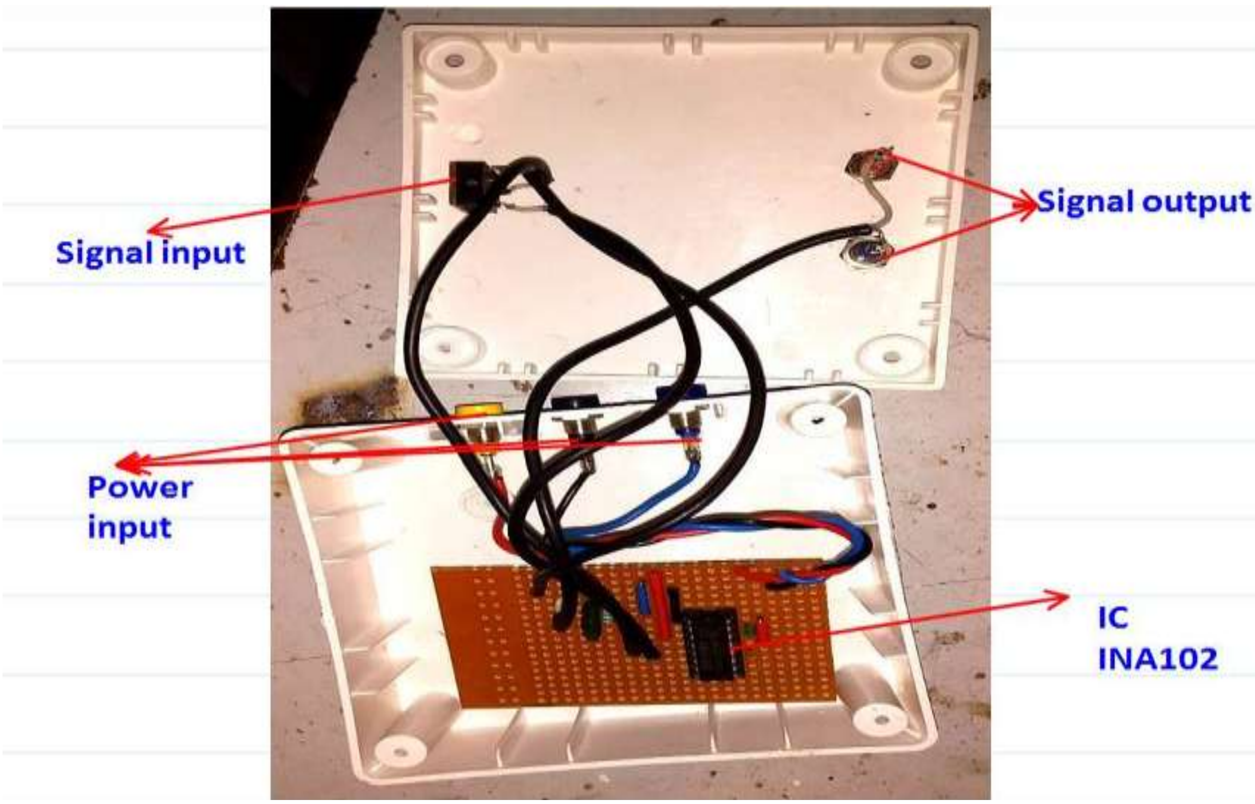

Figure 6.1 Basic block-diagram of the portable ECG

This is(figure 6.2)block-diagram of initial stage of the portable ECG with pulse indicator system. Here all internal parts are shown.

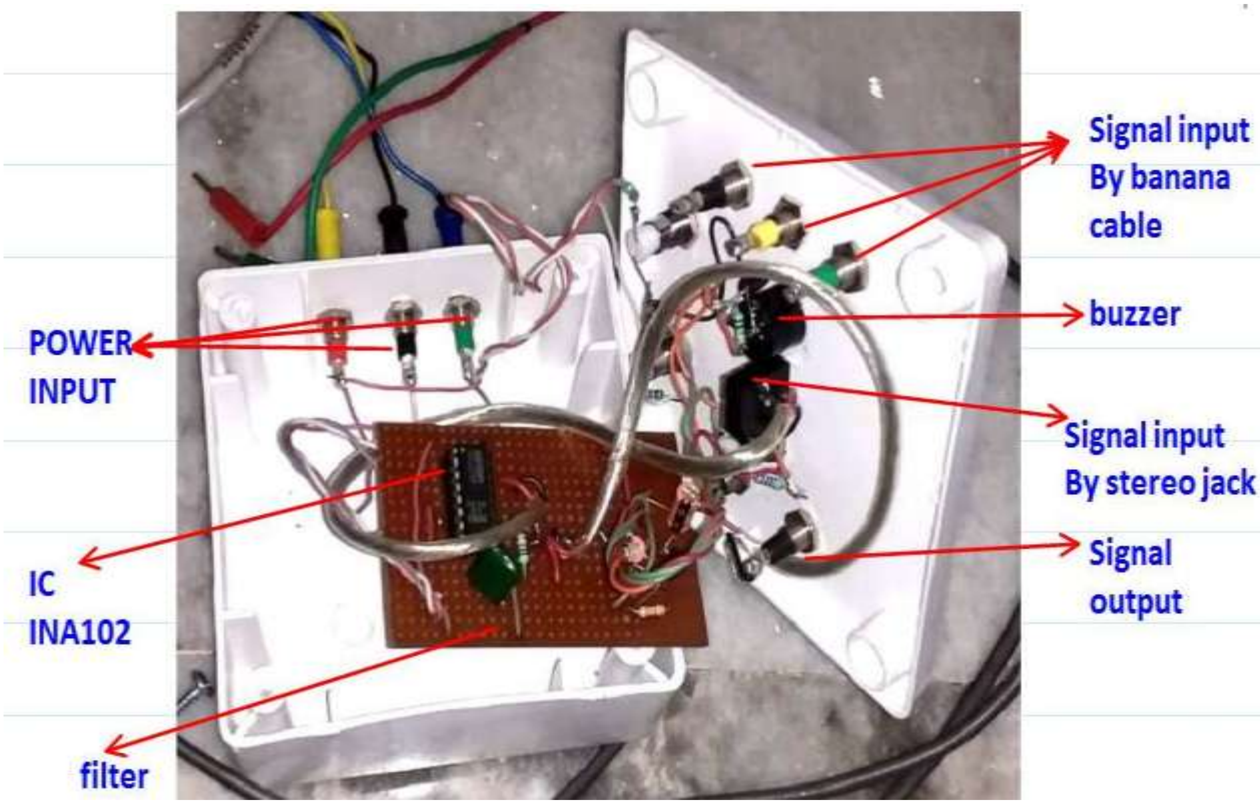

Figure 6.2: Internal circuit connection of complete ECG

In the figure 6.3 all three LED indicator are shown. Here green LED light indicates correctly working of –ve power source while red LED light is indication of correctly working of +ve power source supply. Third indicator blinks with the heartbeat. It is an LED indicator light that will pulsate with the rhythm of a heartbeat.

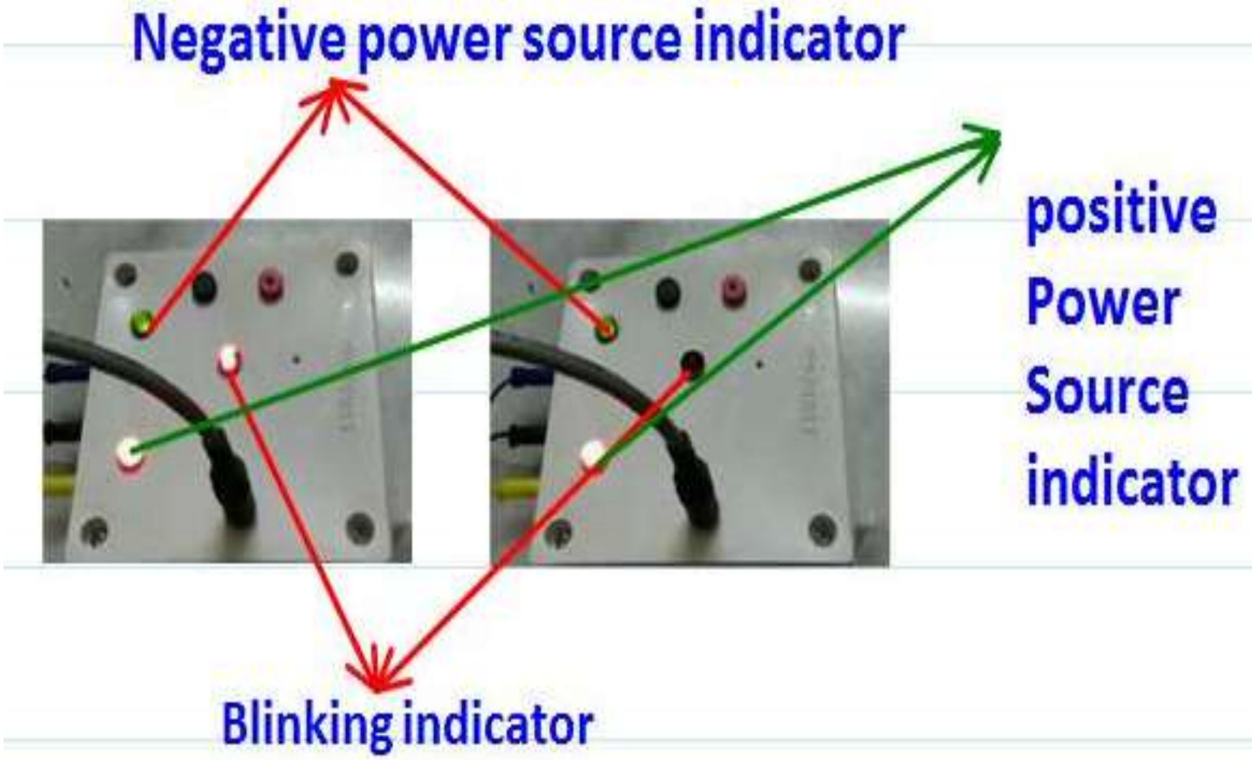

Figure 6.3: LED pulse indicator

7. COMPLETE CIRCUIT DIAGRAM

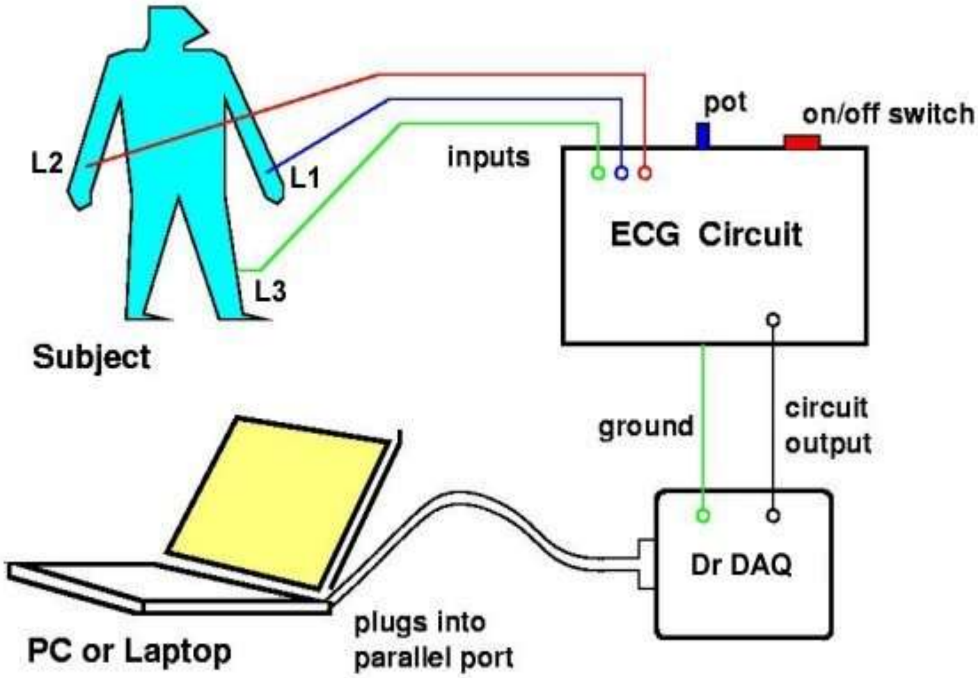

Figure 7.1: Complete circuit diagram

8. REQUIREMENT FOR THE PROJECT

The requirement for the project as follows:

1. Buzzer and pulse indicator
2. Battery: Two nine Volt battery having sufficient current source.
3. Instrumentation amplifier IC: it has high input impedance.
4. Op-amps: It is used for increase the gain.
5. ECG Electrodes: It works as bridge between cardiac system and instrumentation amplifier.
6. Data Acquisition Card Ni-daq.
7. Suitable software (Lab-View).

9. FINAL DEVELOPED SYSTEM

Here in the figure whole developed system is shown.

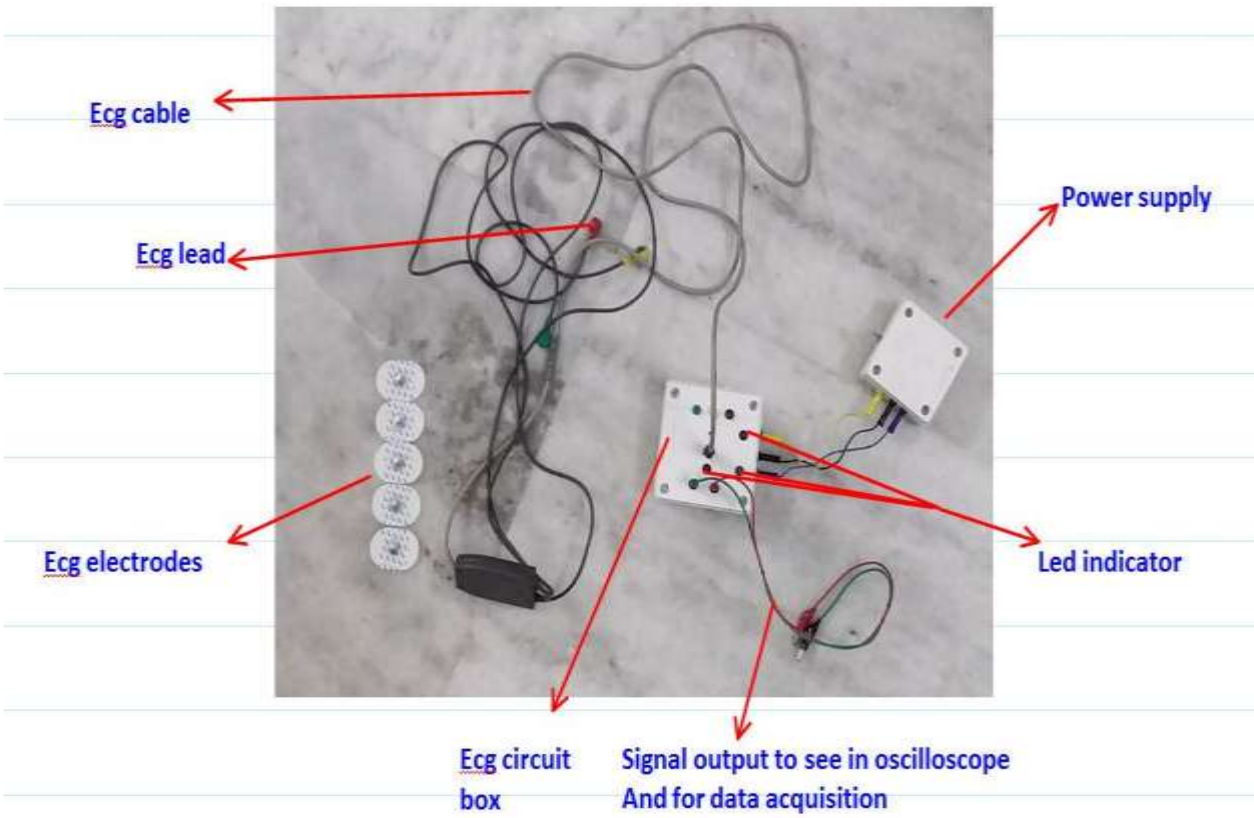

Figure 9.1: Final developed system

Power supply box contain two 9 volt batteries which provides required power to the ECG system. Another box containing ECG system with pulse and alarm indicator, where connected signal input leads are also shown. Signal output is also shown which is used for data acquisition and to see the data in oscilloscope.

10. EVOLUTION OF THE SYSTEM

Observation of output ECG signal in CRO

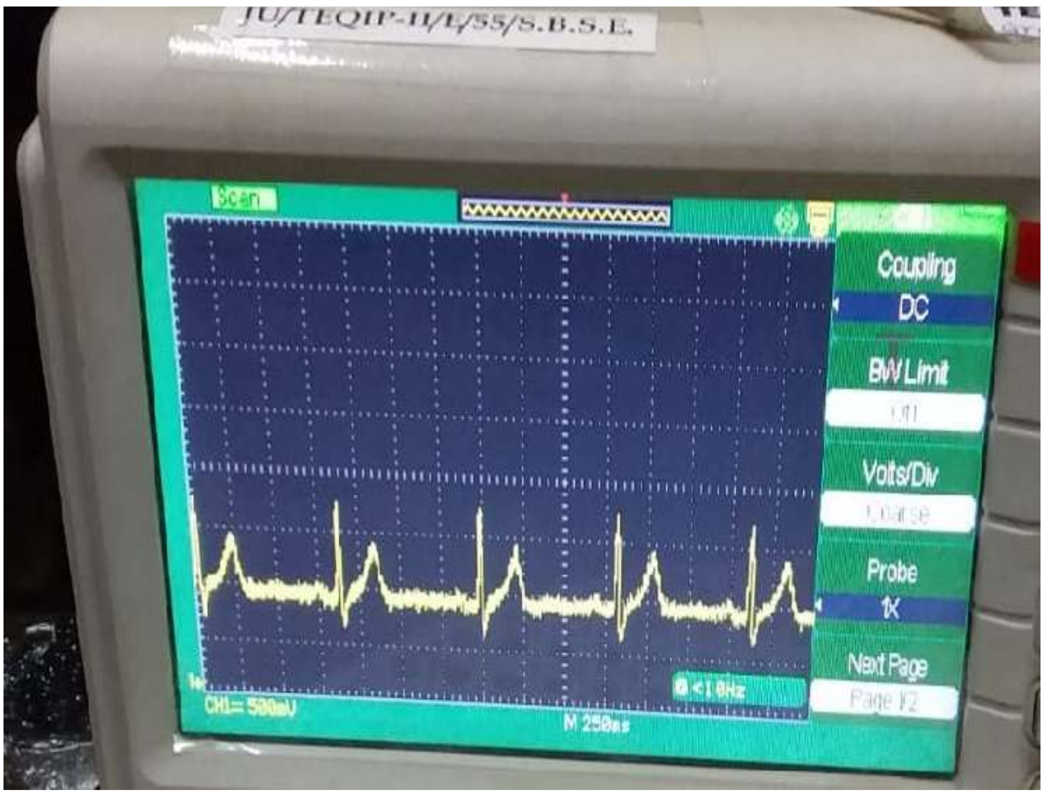

Figure 10.1: Output ECG signal in CRO view - 1

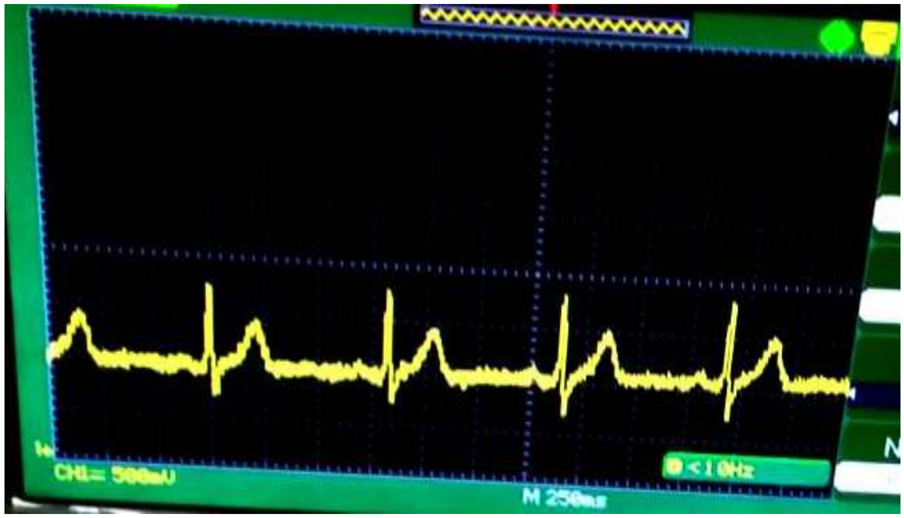

Figure 10.2: Observation of output ECG signal in CRO view – 2

Figure 10.3: Output ECG signal in CRO view - 3

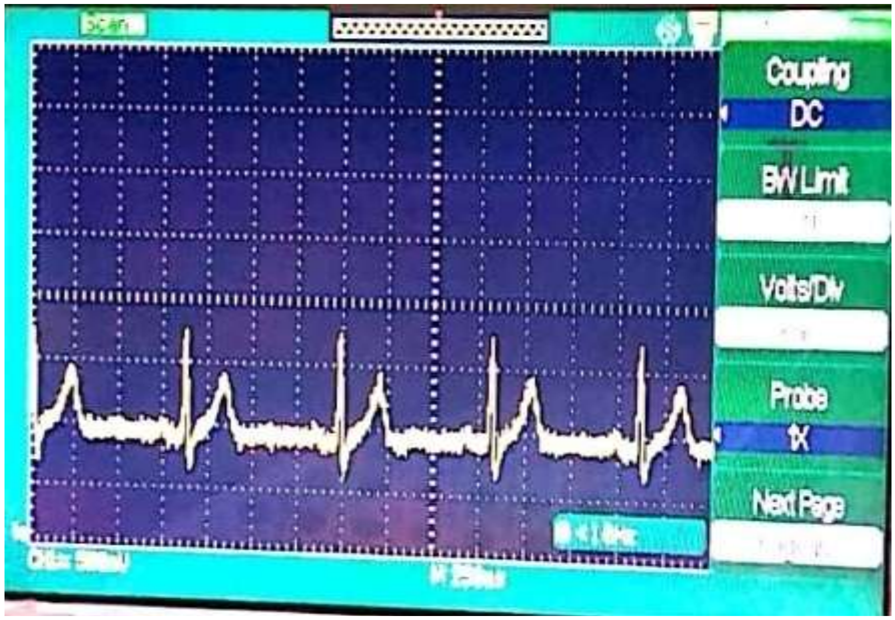

Figure 10.4: Output ECG signal in CRO view – 4

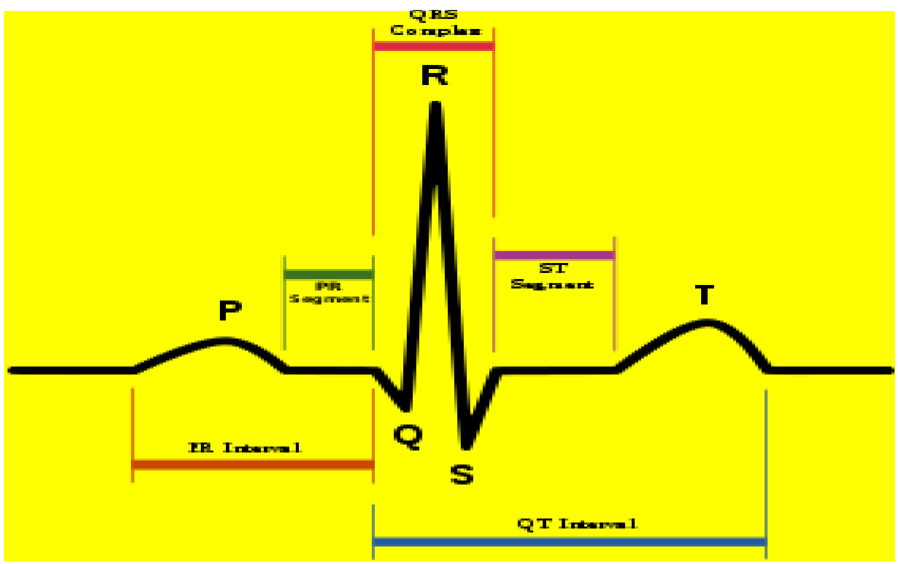

Figure 10.5: Comparison with actual ECG system

11. APPLICATION

- It can assess heart rhythm
- diagnose poor blood flow to the heart muscle (ischemia)
- diagnose a heart attack
- diagnose abnormalities of heart, such as heart chamber enlargement and abnormal electrical conduction

12. ADVANTAGES & LIMITATIONS

Advantages:

- It uses DC power source
- Can be used any time
- Environment friendly
- Can be used where no electricity available properly
- Easy measurement
- No noise and power line interference
- No need to develop Noch-filter

Limitations:

- Cannot be used for long days due to low capacity of battery.
- Cannot be used using any electrode system due to problems in impedance matching.
- Use of particular Electrode.
- Battery displacement after a certain period.

13. FUTURE SCOPE OF THE PROJECT

Existing ECG system is operated by the electricity whose 69% parts in India is generated by the cost of oil, coal, gas and nuclear whose source is limited. In such a situation there is need of such electrical equipment's which uses natural renewable resources for operation. Proposed system will fulfill these criteria and is operated by normal battery which is a renewable resource. This time whole world is suffering from environment pollutions. Perish agreement is an effective step towards it. This system fulfills the agreement and is environment friendly. It does not generate any pollutant which happens during generation of electricity from oil, coal, gas or nuclear resources. System is simple and light so it can be carry easily anywhere for diagnosis of patient in case of natural disasters where electricity stops working. During the use of proposed system there is no fear of dangerous electric shock so it can be operated without electrical operator.

One of the major future scopes of the work is to use rechargeable battery so that cost effect due to power source can be minimized.

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