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Real Time Acquisition and Analysis of ECG Signal

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ABSTRACT: Modern day medical technology deals with the measurement of physiological parameters as an indicator of a person's health condition. The primary purpose of medical instrumentation to determine the presence of some physical quantity to aid the medical personnel to make better diagnosis and early treatment. Development of cost effective devices and instruments to monitor and measure these parameters is the concern. Building simple instruments having similar features as the commercially available devices is the current challenge for a biomedical engineer. This paper discusses the simulation and building of the hardware for the real time acquisition of the ECG signal and subsequent analysis of data to validate the hardware. The ECG database is generated from subjects of different age groups (both men and women). The measured R-R interval of ECG signal is correlated with the BMI and pulse rate of the subject. The mean and variance of R-R interval is estimated for different age groups. The results indicate their inter relation and normal functioning of the heart.

KEYWORDS: Einthoven triangle, differential amplifier, Pulse Oximeter, Electrocardiogram, R-R interval, BMI, correlation coefficient

I. INTRODUCTION

There are three basic types of data that must be acquired, manipulated and archived in the hospital [1,2]. Alphanumeric data includes patient's name, age, gender and address, id number, results of lab tests and physician's notes. Images include X-rays and CT scans, MRI and ultrasound. Physiological signals are the electrocardiogram (ECG), the electroencephalogram (EEG), the electromyogram (EMG) and blood pressure tracing. Each of these needs different systems to manipulate and archive data [3,4].

An electrocardiogram (ECG) is a recording of the electrical activity of the heart in dependence on time. The mechanical activity of the heart is linked with its electrical activity [5,6]. An ECG is therefore an important diagnostic tool for assessing the functioning of the heart.

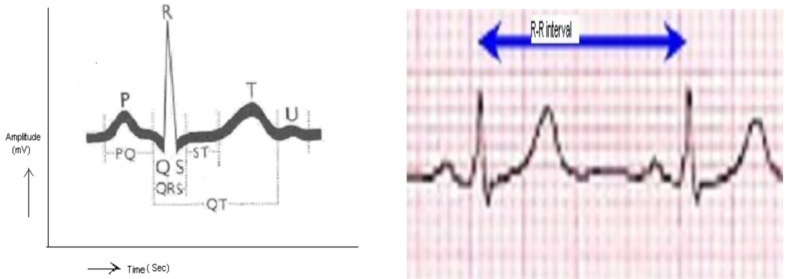

Fig. 1a, 1b Single cycle and R-R interval of a normal ECG

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TABLE I
AMPLITUDE AND TIME INTERVAL OF VARIOUS COMPONENTS OF A NORMAL ECG CYCLE [1,7]

ECG Components	Amplitude	Components	Duration(Sec)
P wave	0.25mV	P-R interval	0.12 to 0.2
R wave	1.60mV	Q-T interval	0.35 to 0.44
Q wave	25% of R- wave	S-T interval	0.05 to 0.15
S wave	0.1 to 0.5mV	P wave	0.11Sec
		QRS complex interval	0.09Sec

Fig. 1a shows the single cycle of the ECG signal of the normal subject and Fig. 1b indicates the R-R interval. Table I indicates the amplitude and time interval of various components of a single cycle normal ECG signal.

II. METHOD AND MATERIALS

A. Block Diagram

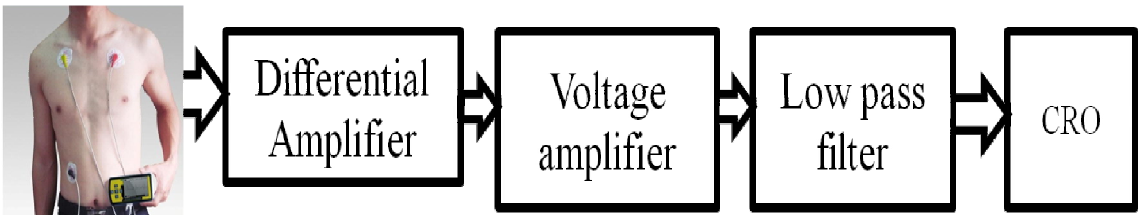

Fig. 2 Block diagram of ECG device

The block diagram consists of a differential amplifier, a voltage amplifier a low pass filter [8,9]. The ECG signal is acquired taken from the human subject by connecting the electrodes in Lead I configuration (left arm, right arm and right leg) based on the concept of Einthoven Equilateral Triangle [1,10]. This input is given to the differential amplifier for processing and the ECG waveform is displayed on the Oscilloscope (CRO).

1) *Sub Circuits:*

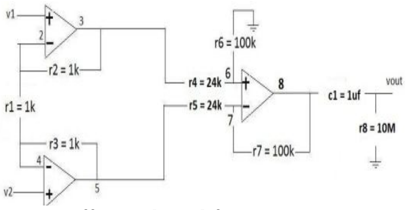

Fig. 3 Differential amplifier

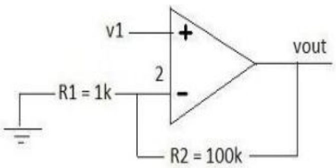

Fig. 4 Voltage amplifier

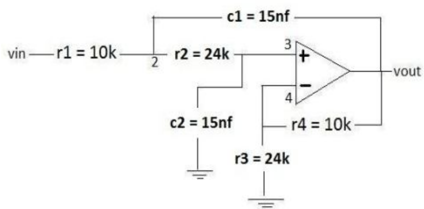

Fig. 5 Low-pass filter circuit

TABLE II
HARDWARE COMPONENTS

	Resistors	Capacitor
Pre amplifier	R1,R2,R3-1kΩ;R4, R5-24k Ω R6,R7-100kΩ;R8-10M Ω	C1- 1μF
Voltage amplifier	R1-1kΩ;R2-100k Ω	
LPF	R1,R4-10kΩ;R2,R3-24kΩ	C1,C2- 15 nF
ICs	IC1-LM324 , IC2-AD741	

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Differential amplifier collects the difference in signal acquired at left and right arm amplified by the voltage amplifier with an amplification factor 100. This signal is filtered with a Sallen-Key low pass filter (LPF) with a bandwidth 159Hz. The bandwidth of the main output signal will be less than 150Hz and greater than 5Hz thereby removing the AC noise. TABLE II lists the hardware components as per the circuit design.

B. Simulation

As this work involves human subjects, the circuits were simulated before building the hardware with MultiSim circuit design suite 12.0.1. Fig. 6-8 show the simulated sub circuits and the corresponding outputs.

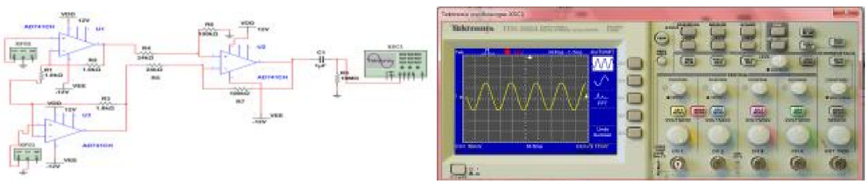

Fig. 6 Simulated Differential Amplifier

Inputs: XFG1-5mV(p-p)100Hz sine, XFG2- 10mV(p-p) 100Hz sine. Output: 120mV (p-p) 100Hz sine

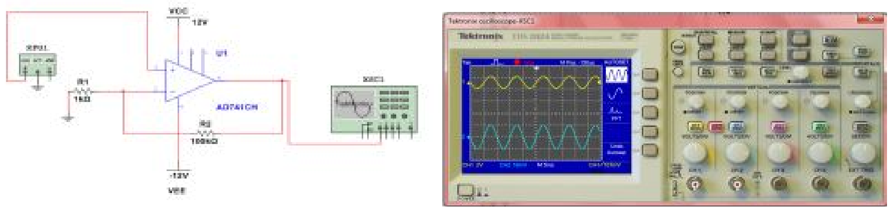

Fig.7 Simulated Voltage Amplifier

Voltage amplifier: Gain=100 Input:10mV(p-p) 100Hz sine. Output:2V

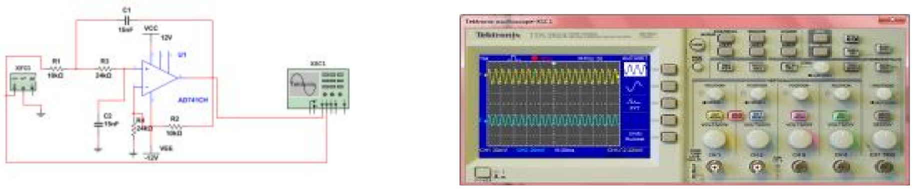

Fig. 8 Simulated Low Pass Filter

Input: output of Voltage amplifier. Output: 5Hz to 150Hz and voltage of 10mV(p-p)

C. Implementation

1) Subject Preparation for real time data acquisition:

1. **Setting up of clinical environment:** As the Real time ECG acquisition requires a pathological lab like environment hence existing lab space was converted into silent zone without any disturbances [13].

2. **Preparation of the subject:** The human subject was conditioned (relaxing) to acquire the normal ECG with normal pulse and heart rate. The electrical contacts were established in right, left arm and right leg of the subject with the help of NIKOTABS Bio-Adhesive Diagnostic ECG Ag/AgCl disposable Electrodes with the application of gel at the contact surface. The subject were made to stay calm and be in supine position without body movements to avoid any other disturbances[10,14].

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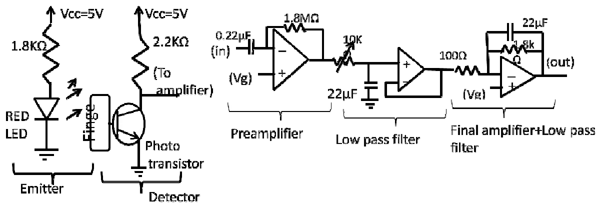

Fig.8 Pulse oximeter circuit

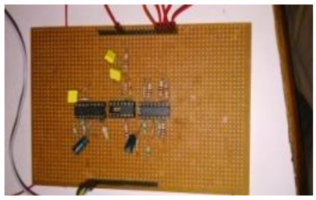

Fig.9 Hardware

In Pulse Oximeter method the clip electrode is attached the left hand forefinger and signal is acquired by the IR sensor. Fig. 8 and Fig. 9 show the circuit diagram of Pulse Oximeter and hardware of the ECG acquisition circuit[15]. The ECG in both the methods were on observed CRO with Tektronix 100TDS and Owon SDS6062 60 MHz bandwidth 2 channel digital storage oscilloscope. Fig.10-12 indicate the acquired signal. R-R interval was noted as the indicator of the physiological condition of the heart. ECG Database(R-R intervals) was generated from 23 normal subjects of different age group. The table III indicates the physical conditions of the subject in terms of Body mass index (BMI). Height, weight, Pulse Rate, previous history of the each subject was also taken during the collection of data. The data is tabulated as in the table IV.

TABLE III
BMI CHART [16,17,18]

BMI(weight(Kgs) / height^2 (mts))	<18	18.6- 24.9	25- 29.9	>30
Status of Subject	under weight	healthy	Over weight	obese

TABLE IV:
ACQUIRED DATABASE

S N		AGE (yrs)	GEN DER	HEIGHT (mts)	WEIGHT (kgs)	NATURE OF WORK	B M I	PULSE RATE	R-R Interval(µs)	R-Amp(mV)
1	Subject 1	12	M	1.27	38	Heavy	23.56	84	**50**	1.8
2	Subject 2	14	M	1.35	42	Heavy	23.05	82	**50**	1.8
3	Subject 16	21	F	1.70	57	Moderate	19.72	74	**60**	1.2
4	Subject 18	21	M	1.70	62	Moderate	21.45	70	**60**	1.6
5	Subject 20	21	M	1.8	60	Moderate	18.5	72	**60**	1.6
6	Subject 15	22	M	1.73	65	Moderate	21.71	76	**50**	2
7	Subject 17	22	F	1.60	47	Moderate	18.36	72	**62.5**	1.6
8	Subject 19	22	M	1.75	76	Moderate	24.82	72	**60**	1.6
9	Subject 21	22	M	1.82	91	Moderate	27.48	78	**50**	1.6
10	Subject 22	22	F	1.63	55	Moderate	20.7	76	**55**	1.4
11	Subject 23	24	M	1.73	73	Moderate	24.39	76	**60**	1.2
12	Subject 8	25	M	1.65	60	Heavy	22.04	74	**60**	2
13	Subject 3	27	M	1.73	85	Moderate	28.40	76	**60**	2
14	Subject 5	29	M	1.80	83	Moderate	25.62	72	**70**	1.2
15	Subject 13	30	F	1.60	51	Moderate	19.92	78	**60**	2
16	Subject 11	32	M	1.73	85	Moderate	28.40	78	**60**	2
17	Subject 7	34	M	1.65	55	Heavy	20.24	72	**60**	1.6
18	Subject 6	35	F	1.52	67	Heavy	28.99	74	**60**	1.2
19	Subject 9	35	M	1.55	65	Moderate	27.06	72	**80**	1.2
20	Subject 14	36	M	1.73	68	Moderate	22.72	76	**70**	1.8
21	Subject 4	48	F	1.42	57	Moderate	28.26	74	**55**	2
22	Subject 12	48	F	1.63	87	Moderate	32.75	72	**60**	1.6
23	Subject 10	49	M	1.83	65	Moderate	19.41	72	**50**	2

Fig. 10 and Fig. 11 show the ECG signal of a normal person using Electrode method and Pulse oximeter method. The output signal is associated with the noise due to muscle activity, movement of the electrodes and power line interference [10]. Noise reduction will be done in further implementations. Fig. 12 and Fig. 13 show the ECG signal acquired by a commercial machine.

Fig. 10 ECG signal from Electrode method

Fig. 11 ECG signal from Pulse oximeter method

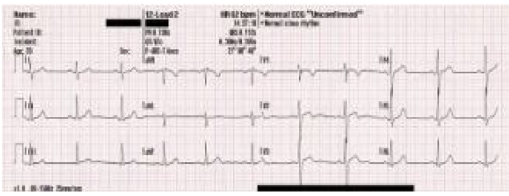

Fig. 12 Normal ECG

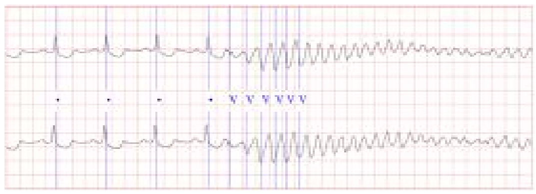

Fig.13: Abnormal ECG by Commercial ECG machine Holter

D. Data Analysis

The total population was divided into two groups - subjects below 25 years of age and subjects above 25 years of age. The acquired data is analysed for sampling distribution of mean and variance for subjects in these two categories. Mean and variance estimates were computed and tabulated as in table V.

Using 95% confidence interval, the upper and lower limits on mean were computed for each sample pair with the formula

$$L = \bar{y} - 1.96SE(\bar{y}), \qquad U = \bar{y} + 1.96SE(\bar{y})$$

Fig. 14 shows the plot of the confidence intervals. This indicates that only 2 out of 55 intervals do not include the mean 62.27. The product Moment Correlation(r) between R-R intervals with the pulse rate and the BMI are computed using the relationship [19,20]

$$r = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sqrt{\sum x2 - \frac{(\sum x)2}{n}}\sqrt{\sum y2 - \frac{(\sum y)2}{n}}}$$

III. RESULTS AND DISCUSSIONS

The mean and variance were estimated with sample size n=2 and n=3. The frequency distribution of the R-R intervals for samples n=2 and n=3 were computed as given in the Table V and plotted as in Fig. 15. The scatter plots of R-R intervals, pulse rate(PR) and BMI are shown in Fig. 16 and Fig. 17 indicate the subjective nature of the data collected.

The product moment correlations between these parameters were established with the corresponding coefficients as shown in the table VII. Positive Correlation co-efficient indicates close relation between the R-R interval and the pulse rate. Product moment correlation exists between R-R interval and BMI also. Moderate magnitude indicates the healthy subjects of different age group. The frequency distribution of R-R intervals does not follow the standard pattern because of its subjective nature.

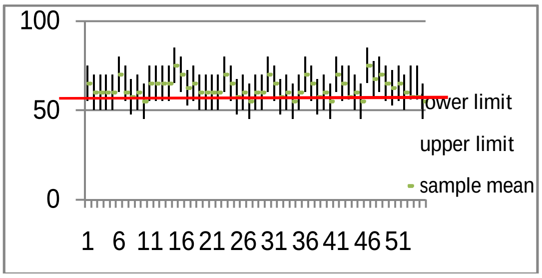

Fig.14 Confidence intervals n=2

TABLE V
SAMPLE DISTRIBUTION FOR SAMPLE SIZE=2

Age Group	**Subjects**	**Sample pairs**	**mean**	**variance**	**Estimated mean**	**Estimated variance**
<25yrs	11	55	62.27	60.74	60.36	25.61
>25yrs	12	66	56.45	23.39	53.27	23.03
Total population	23	254	59.24	49.37	59.59	21.69

TABLE VI
DISTRIBUTION FOR AGE<25 YEARS

Sample Mean	No. of Samples	
	n=2	n=3
55-57.5	6	21
57.5-60	7	50
60-62.5	17	12
62.5-65	2	45
65-67.5	13	22
67.5-70	1	13
70-72.5	7	0
72.5-75	2	1

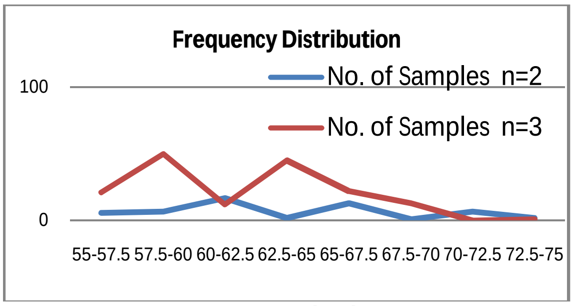

Fig.15 Frequency distribution

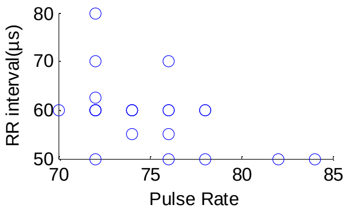

Fig. 16 Scatter plot of RR interval Vs PR

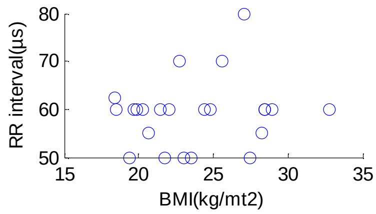

Fig. 17 Scatter plot of RR interval Vs BMI

TABLE VII
CORRELATION COEFFICIENT CHART

Product moment Correlation(r)	RR interval & pulse rate	RR interval & BMI
Age<25years	**0.029**	**0.005**
Age>25years	**0.113**	**0.0396**
Total Population	**-0.0056**	**1.518**

IV. CONCLUSION AND FUTURE SCOPE

The design of ECG acquisition device and implementation is very much satisfactory for the preliminary detection of normal functioning of the Heart. The methods used in this work are simple and non-invasive with

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minimum number of electrodes. This work is a low cost design approach and these circuits used are not completely noise free.

Isolation transformers can be used for subject's safety [1]. Microcontroller can be used to obtain the precise digitised version of ECG output [21]. Increasing the number of leads (chest leads) to get a more clear ECG waveform with P, T waves for better analysis, diagnosis and early medication by a medical doctor. Standard sensors usage will enhance the better acquisition of the ECG signal. Analysis of R-R interval can be done to generate the heart rate variability (HRV) signal with additional mathematical computations [6].

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