ECG and PPG Data Capture using Novel Three Lead Electrode and Photodiode

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ABSTRACT
Blood pressure is a vital sign of cardiovascular system. The risk of cardiovascular diseases rises as BP increases. Nearly one billion people from all over the world suffer from hypertension. Hypertension is often named "the silent killer" it shows no significant early symptoms and, yet, greatly increases one's risk of developing heart attack, stroke and target organ damage. The current measurement devices are mostly built on the principle of auscultation, oculometry or tonometry, all of which are bulky also restricts the frequency and ease of their usage. A reliable measurement for ECG is highly desirable. Here we see the ways in which ECG and PPG can be acquired, plot the signal and inspection on it.

Keywords
Blood Pressure, Electrocardiography, Photoplethysmograph, Analog devices TL074d, Analog devices AD620, Monolithic Photodiode OPT101, Biomedical signal processing.

1. HEART
The Heart is a cone shaped hollow muscular organ. It is about 10cm long. The Heart lies in the thoracic cavity in the mediastinum. The heart is divided into four chambers. The two upper chambers, the left and the right atria, are synchronized to act together. Similarly, the two lower chambers the ventricles act together. The right atrium receives blood from the veins of the body and pumps it into the right ventricle. The right ventricle pumps the blood through the lungs, where it is oxygenated. The oxygen rich blood then enters the left atrium, from which it is pumped into the left ventricle. The left ventricle pumps the blood into the arteries to circulate to circulate throughout the body. The vertebrate heart is composed of cardiac muscle, which is an involuntary striated muscle tissue found only within this organ.

The average human heart, beating at 72 beats per minute, will beat approximately 2.5 billion times during an average 66-year lifespan, and weighs approximately 250 to 300 grams (9 to 11 oz.) in females and 300 to 350 grams (11 to 12 oz.) in males.

2. BLOOD PRESSURE
Blood pressure is an important indication of whether the cardiovascular system is in healthy state. Blood pressure is the force that the blood exerts on the walls of the blood vessels. Keeping blood pressure within the normal limit is very important. If it becomes too high, blood vessels can be damaged, causing bleeding. If it is too low, blood flow to the organs may be inadequate.

The pressure produced when the left ventricle contracts and pushes blood into the aorta is the systolic pressure. The complete cardiac diastole occurs and the heart is resting following the ejection of blood, the pressure in the arteries is called diastolic pressure. The normal systolic pressure is 120mmHg and diastolic 80mmHg. The factors affecting the blood pressure are age, gender, time of the day, emotional stress etc.

Table 2.1 Categories for BP levels in adults

Category	Systolic(mmHg)	Diastolic(mmHg)
Low BP	< 90	< 60
Normal	<130	<85
High BP		
Stage 1	140-159	90-99
Stage 2	160-179	100-109

3. BIO SIGNALS (ECG and PPG)
3.1 ECG
Electrocardiography (**ECG**) is a trans-thoracic interpretation of the electrical activity of the heart over time captured and externally recorded by skin electrodes. It is a noninvasive recording produced by an electrocardiographic device. A typical ECG tracing of the cardiac cycle (heartbeat) consists of a P wave, a QRS complex (figure 3.1), a T wave, and a U wave which is normally visible in 50 to 75% of ECGs. An ECG is used to measure:

- Any damage to the heart.
- How fast your heart is beating and whether it is beating normally.
- The effects of drugs or devices used to control the heart (such as a pacemaker).
- The size and position of your heart chambers.

An ECG is often the first test done to determine whether a person has heart disease. The baseline voltage of the electrocardiogram is known as the isoelectric line. Typically, the isoelectric line is measured as the portion of the tracing

following the T wave and preceding the next P wave. The P wave arises when the impulse from SA node sweeps over atria. The QRS complex represents the rapid spread of impulse from AV node. The T wave represents the relaxation of the ventricles.

Table 3.1 Characteristics of ECG waveform

WAVE	AMPLITUDE
P	0.25mV
Q	0.6mV
R	1.6mV
T	0.1 to 0.5mV

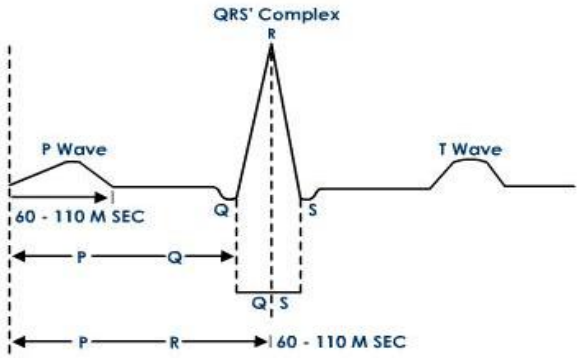

Fig 3.1: ECG waveform

3.2 PPG

A photoplethysmograph (PPG) is an optically obtained plethysmograph, a volumetric measurement of an organ. A PPG is often obtained by using a pulse oximeter which illuminates the skin and measures changes in light absorption. PPG is a signal reflecting changes in a blood flow detected when red light is emitted towards microcirculatory blood vessels. Depending on blood flow volume certain portion of that light is absorbed letting other part to pass or be reflected. An optical sensor detects a quantity of light passed (or reflected from) the blood flow producing a waveform identifying pulse wave.

Fig 3.2: PPG waveform

4. PROPOSED METHODOLOGY

4.1 ECG Design

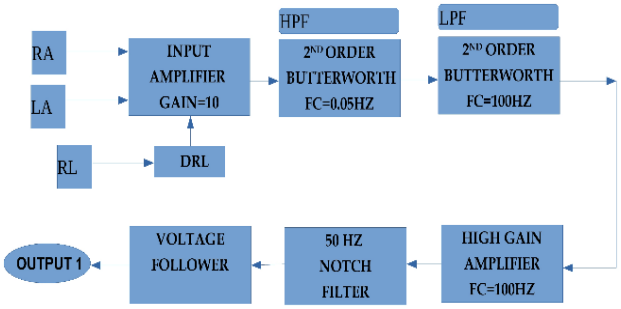

Fig 4.1: Proposed block diagram-ECG

The figure below illustrates the block diagram of the ECG data acquisition system to acquire signals from the ECG electrodes. The analog section receives input from the sensor place on skin. The first stage of gain 10 is an I to V converter, this is because output from the optical sensor is current which has to be transformed to voltage for further processing. In second stage, the signal is fed into a second order High pass Butterworth filter with a lower cut off frequency of 0.05Hz. Next stage is a second order Low pass Butterworth filter with a higher cut off frequency of 100Hz. The band limited signal is then fed into a precision amplifier with a gain of 100. Finally, it is passed through a Notch filter to remove 50Hz noise. Here Electrodes are placed on right and left arm (RA and LA) and Right leg (RL). Driven right leg (DRL) block is used because the common mode voltage is inverted by right leg drive circuit. The resultant voltage is applied to the patient's right leg. Just several microamperes or less is actually driven into the patient. This type of noise canceling voltage is applied to the patient to reduce 50Hz noise.

4.2 PPG Design

The figure below illustrates the block diagram of the PPG data acquisition system to acquire signals from the PPG sensor. The analog section receives input from the sensor place on skin, Monolithic Photodiode OPT101is used as sensor. The first stage is an I to V converter, this is because output from the optical sensor is current which has to be transformed to voltage for further processing. In second stage, the signal is fed into a second order High pass Butterworth filter with a lower cut off frequency of 0.5Hz. Next stage is a second order Low pass Butterworth filter with a higher cut off frequency of 20Hz. The band limited signal is then fed into a precision amplifier with a gain of 10. Finally, it is passed through a Notch filter to remove 50Hz noise.

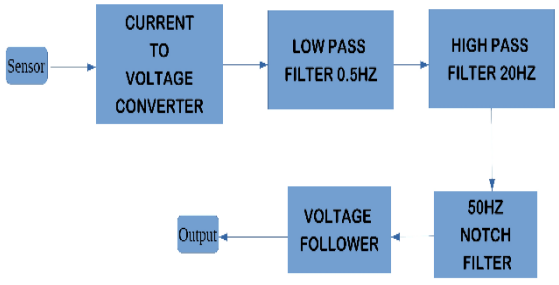

Fig 4.2: Proposed block diagram-PPG

5. HARDWARE AND INTERFACE

5.1 Instrumentation Amplifier

An instrumentation amplifier is a type of differential amplifier that has been outfitted with input buffers, which eliminate the need for input impedance matching and thus make the amplifier particularly suitable for use in measurement and test equipment and it is easy to set the gain with the variation of a single resistor. The instrumentation amplifier used here is Analog Devices AD620. It consists of LPF, HPF and Notch filter. It is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 1000. It offers low power only 1.3mA (max supply current), making it a good fit for battery powered, portable (or remote) applications.

5.2 Operational Amplifier

The operational amplifier used is the Analog devices TL074d. The TL074d has very low input offset voltage (6 mv max). The TL074d also features low input bias current (200 Pico ampere) and high open loop gain. The wide input voltage range of 7 V minimum combined with high CMRR of 100dB and high accuracy in the non-inverting circuit configuration. Excellent linearity and gain accuracy can be maintained even at high closed loop gains.

5.3 Voltage Follower

A voltage follower or buffer amplifier (called as buffer) is one that provides electrical impedance transformation from one circuit to another. Buffers are used in Impedance matching, the benefit of which is to maximize energy transfer between circuits or systems.

5.4 Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

5.5 Interface

This code uses the internal analog multiplexer to measure analog voltages on two different channels one for ECG signal and one for PPG signal (up to 8 different analog inputs are available). Results are printed to a PC (Hyper terminal) terminal program via the UART. The inputs are sequentially scanned, beginning with input 0 (A0), and then input 1 (A1). The total sample time per input is comprised of an input setting time, followed by a conversion time.The system is clocked using the internal 16.0 MHz oscillator by the on-chipAT mega 2560. This loop periodically reads the ADC value from a global array, which is given in below program.

```
void setup( __ )
{
Serial.begin(9600);
}
void loop()
{
Serial.print(analogRead(A0));
Serial.print(backslasht);
Serial.print(analogRead(A1));
Serial.println(backslasht);
delay(3);
}
```

The electronic signal from skin captured using electrode, The only conductive path between the skin and the metal is the electrolyte paste. The silver-silver chloride electrode is the most commonly used electrode type. These electrodes or leads are placed on the right arm, left arm and right leg, so that ECG signals are captured. Results are captured using the UART from a loop with the rate set by a delay of 3 with baud rate of 9600.

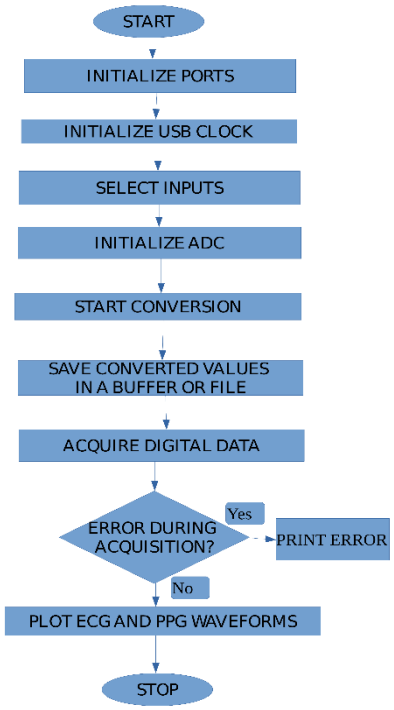

Fig 5.1: Program flowchart

6. CONCLUSION

The data acquisition circuits for ECG and PPG signal acquisition were built and tested on a breadboard. Later on, the same circuits were fabricated and implemented on a Printed Circuit Board as per the specifications and requirements. This analog section was tested using a simulator and also with a subject. Data was successfully recorded with the circuit from the subjects of fifty members. Below figure

shows one of the plotted data which was recorded using the above circuit.

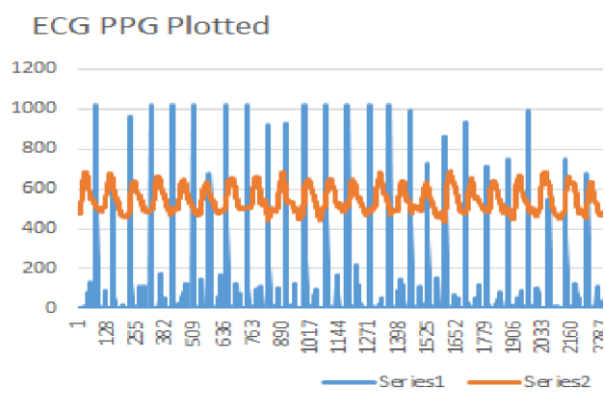

Fig 6.1: ECG and PPG data plotted on excel

7. ACKNOWLEDGMENTS

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