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Title

Heart Rate Detection from Ballistocardiograph signal

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Abstract

Patients with heart disease or undergoing therapy at home are in a desperate need of detecting ECG signals under normal living conditions. However, normal ECG detecting systems require electrode contacting with the human body, and it needs medical and specialized staff, which makes it difficult for patients who need to do an ECG periodically.

This project is concerned with the development of Ballistocardiogram (BCG) which accurately represents the sudden flow of blood in the blood vessels in each heartbeat, breathing, and movement of the body. detection and processing system without attaching any electrodes to the patient for monitoring health statues. Where the heart signal will be recorded when the person stands on a load cell platform and monitor the heart rate by building a LabVIEW code using Hilbert and Fast Fourier Transforms, extracting the results, and then verifying them using the MATLAB program.

After applying Hilbert and Fast Fourier Transforms algorithm, showing the results and verifying them, we found that the heart rate can be estimated easily by using this method.

خلاصة

المرضى الذين يعانون من أمراض القلب أو يخضعون للعلاج في المنزل في حاجة ماسة لاكتشاف إشارات تخطيط القلب في ظل ظروف معيشية طبيعية. ومع ذلك ، تتطلب أنظمة الكشف عن مخطط كهربية القلب العادية اتصال قطب كهربائي بجسم الإنسان ، وتحتاج إلى طاقم طبي ومتخصص ، مما يجعل من الصعب على المرضى الذين يحتاجون إلى إجراء مخطط كهربية القلب بشكل دوري.

يهتم هذا المشروع بتطوير مخطط قلبية القلب (BCG) الذي يمثل بدقة التدفق المفاجئ للدم في الأوعية الدموية في كل نبضة قلب وتنفس وحركة الجسم. نظام الكشف والمعالجة دون توصيل أي أقطاب للمريض لرصد التماثل الصحية. حيث سيتم تسجيل إشارة القلب عندما يقف الشخص على منصة خلية تحميل ويراقب معدل ضربات القلب من خلال بناء كود LabVIEW باستخدام Hilbert و Fast Fourier Transforms ، واستخراج النتائج ، ثم التحقق منها باستخدام برنامج MATLAB.

بعد تطبيق خوارزمية Hilbert و Fast Fourier Transforms ، وإظهار النتائج والتحقق منها ، وجدنا أنه يمكن تقدير معدل ضربات القلب بسهولة باستخدام هذه الطريقة

الاهداء

الحمد لله حتى يبلغ الحمد منتهاه ونصلي ونسلم على الرسول المهداة

لعائلاتنا الجميلة نهدي تخرجنا ونرسم على وجوههم البسمة من بهجتنا أباؤنا وأمهاتنا
وأخوتنا وأخواتنا

باقاة ورد فواحة لكل زملائنا وصديقاتنا من دفعة طلبة كليتنا

كلمات شكر و عرفان لكل اساتذتنا ولكل من ساندنا و علمنا لنصل الى نهاية مشورانا
الجامعي

الى روح كل شهيد سقط أمام جامعتة أو في بلدته دفاعا عن وطنه واهله واخوانه

اليكم جميعا نهدي مشروع تخرجنا في كلية الهندسة جامعة بوليتكنيك فلسطين

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List of Abbreviations

Abbreviations.....	Full Word
CVD	cardiovascular diseases
BCG	Ballistocardiography
HR.....	Heart Rate
FIR	Finite Impulse Response
IIR	Infinite Impulse Response
IA	Instrumentation Amplifier
CMRR	Common-Mode Rejection Ratio
AI	Analog Input
AO.....	Analog Output
DIO.....	Digital Input And Output
HT	Hilbert Transform
PCB	Printed Circuit Board
BPM	Beat Per Minute
FFT.....	Fast Fourier Transform

CHAPTER ONE

1.1 Introduction

Ballistocardiograph is a method for obtaining a representation of the heart beat-induced repetitive movements of the human body, occurring due to acceleration of blood as it is ejected and moved in the large vessels. Ballistocardiograph measures mass movements, the mass of circulating blood and to the heart itself during the cardiac cycle of the body, generated by the forces associated with heart contraction, informing about the overall performance of the circulatory system.

1.1.1 Problem Statement

A lot of patients who have to monitor their heart health, where they visit the doctor constantly to find the signal of their heart by attaching the electrodes on their skin directly are sensitive to these electrodes and feel discomfort as well.

1.1.2 Motivation

Cardiovascular diseases (CVDs) are the leading factors of death. One way to alleviate negative consequence of CVDs is visit the doctor constantly for heart rate (HR) monitoring. Various devices for heart rate measurement are available most of them is a wearable devices require to attach sensors on the body, which may irritate some patient's skin and usually present discomfort and nervous to them .we will show a way to monitor HR in a faster and more comfortable way for these patients and the doctors also which is measuring a ballistocardiograph signal(BCG). Ballistocardiograph (BCG) signal records the motions of human body generated by sudden ejection of blood into the vessels at every cycle, such a signal contains rich information, which can offer respiration rate and heart rate, which it can be directly obtained by using a load cell sensor under the feet, so this reason will attract many people to use this method.

1.1.3 Objective

Implement an unobstructive method for monitoring the health of the heart , by standing the patient on a sensor (load cell) , finding ballistocardiogram signal and measuring the heart rate by this signal.

1.1.4 Research Methodology

To do this project, we did researches on the Ballistocardiograph signal and how to find this signal. Then we chose the method that we will follow in finding this signal, which is the patient standing on a load cell sensor. To display and amplify this signal, we used My Rio device and the LabVIEW program after we tried a different method by Using a microprocessor and MATLAB, then we saw that this method is the most appropriate for us.

Finally, to find the heart rate from this signal, we transferred the signal to the MATLAB program and created a special code.

1.2 Previous Studies

The first discovery dated back to 1877, when observed the phenomenon of BCG signals, i.e., when a human body stood on a scale, the scale pointer swung regularly in synchronization with the heartbeat. Then, in 1939, were the first to systematically study body trembling caused by heart contraction. They also designed and made a platform capable of recording body movement, and systematically studied the relationship between the formation mechanism of various waveforms in BCG signals and the heart dynamics, thus laid the foundation for researching the subject of BCG.

Then the researchers continued their studies on the sign for the year 1980 and then stopped for several reasons. First, there had been insufficient standard measurement methods, i.e., different methods had resulted in slightly different signals. Second, the exact physiologic origin of the BCG waveform had not been well-understood. Even, there had been insufficient clear guidelines for interpretation of the results, and therefore the medical community was unwilling to take risks. Third, there had been a dominant focus on some clinical diagnostic, for example, myocardial infarction, angina pectoris, coronary heart disease; these applications need a high level of specificity and reliability that the BCG had not reached at that time. Fourth, there had not yet been the emergence of ultrasound and echocardiography methods that swiftly overhauled BCG and related methods for noninvasive cardiac and hemodynamic diagnostic.[1]

since 2000, BCG has been popular again in research around the world for its medical potential. The signal was extracted in several positions, and this depends on the type of information to be obtained. When the sensor is placed on a chair for the person to sit on, this basically gives us the vital signs of the circulatory and respiratory system.

As in many experiments, two probes were placed, one on the seat of the chair and the other on the back of the chair. The signal was monitored, and the results indicated that the signal derived from the seat of the chair was clearer than the signal taken from the back. This was attributed to the fact that the movement resulting from breathing causes disturbance to the signal.[2]

And when the sensor is placed in a bed for the person to sleep on, we can study sleep states and diseases related to it, such as epilepsy.

Another part of the experiments was concerned with taking the heart's signal through a force plate. Each subject was asked to stand still in an upright position for 60 s on each of the force plate and scale for baseline measurements. After that, each subject performed a stepping exercise for 60 s after which they were asked to stand on the scale as still as possible for 5 min to monitor their full recovery.

There is many experiments and research's they did on this signal, including that they found the heartbeat and respiration and saw what is the relationship of this signal and its change with many diseases such as angina pectoris, panic attacks, epilepsy, and even preeclampsia

The heart signal (BCG) was searched in our university in the form of a graduation project by a group of students, where they extracted the signal and displayed it using a chair with strain gauge sensor attached to it.

In our project, we aspire to do a practical experiment to extract the signal when a person stands on load cell and then detect the heart rate, and compare our results with previous experiments.

1.3 Time Schedule

Week \ Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Finding Project Idea	■	■													
Proposal		■	■	■											
Search and Collecting data		■	■	■	■	■	■	■							
Documentation			■	■	■	■	■	■	■	■	■	■	■	■	
Preparing for presentation													■	■	■
Print documentation															■

Table1: Time Schedule of the first semester

Week \ Activities	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Collection of components	■	■													
Built the project circuit		■	■	■											
Print the project on PCB		■	■	■	■	■	■	■							
Documentation			■	■	■	■	■	■	■	■	■	■	■	■	

Preparing for presentation															
Print documentation															

Table2: Time Schedule of the second semester

1.4 Budget

Electronics	Price\$
load cell platform	200\$
AD620	20\$
Total	220\$

Table3: Project Budget

1.5 Background

1.5.1 Heart Anatomy

The cardiovascular system is sometimes called the blood-vascular, or simply the circulatory, system. It consists of the heart, which is a muscular pumping device and Figure 1.1 shows the heart and its structure, and a closed system of vessels called arteries, veins, and capillaries. As the name implies, blood contained in the circulatory system is pumped by the heart around a closed circle or circuit of vessels as it passes again and again through the various "circulations" of the body.

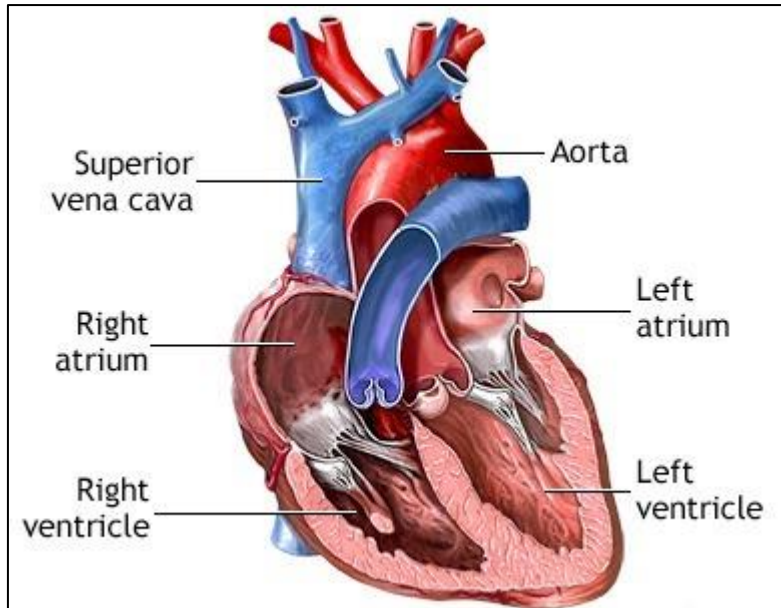


Figure 1.1 Heart Anatomy [3]

As in the adult, survival of the developing embryo depends on the circulation of blood to maintain homeostasis and a favorable cellular environment. In response to this need, the cardiovascular system makes its appearance early in development and reaches a functional state long before any other major organ system.

The vital role of the cardiovascular system in maintaining homeostasis depends on the continuous and controlled movement of blood through the thousands of miles of capillaries that permeate every tissue and reach every cell in the body. It is in the microscopic capillaries that blood performs its ultimate transport function. Nutrients and other essential materials pass from capillary blood into fluids surrounding the cells as waste products are removed.[4]

1.5.2 BCG Signal [6]

Ballistocardiography, a technic which records the movements imparted to the body by the forces associated with contraction of the heart, and acceleration and deceleration of blood as it is ejected and moved in the large vessels as shown in Figure 1.2. (We use the word ballistocardiography not ballistocardiogram in our project name because our project is talk about the method to detect this signal, so the word graphy denoted the technic but gram is the signal).

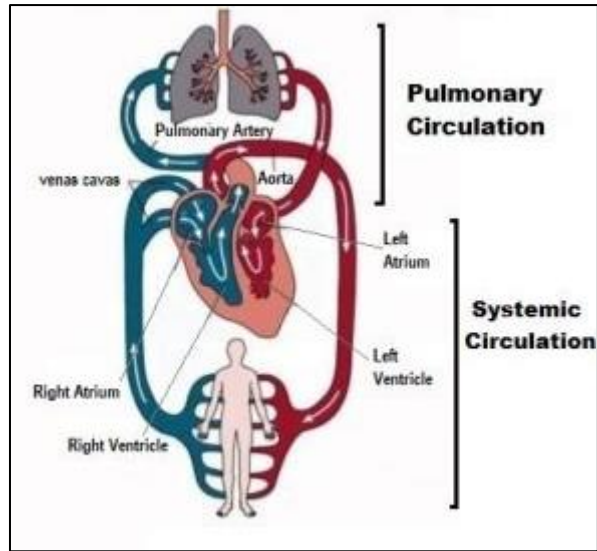


Figure 1.2 circulatory system [5]

It is a vital sign in the 1–20 Hz frequency range which is caused by the mechanical movement of the heart and can be recorded by noninvasive methods from the surface of the body.

BCG waveforms can be divided into three main groups, i.e. Pre-systolic (frequently disregarded), systolic and diastolic see Figure 1.3.

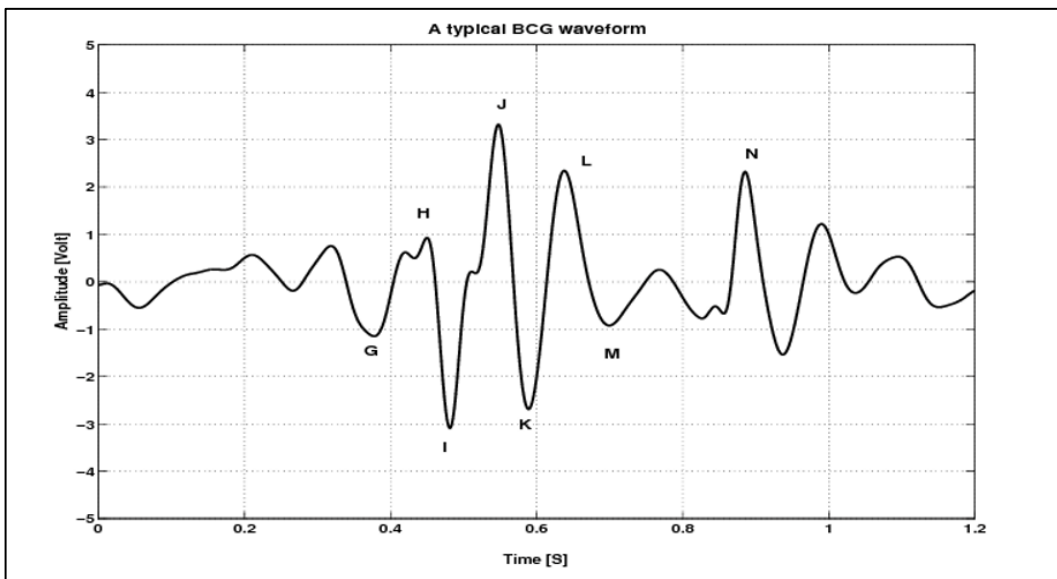


Figure 1.3 BCG Signal

Pre-systolic group

F wave: (rarely seen) head-ward wave preceding G, related to pre-systolic events, not an after-vibration.

G wave: small foot-ward wave which at times precedes the H wave.

Systolic waves

H wave: head-ward deflection that begins close to the peak of the R wave, maximum peak synchronously or near the start of ejection.

I wave: foot-ward deflection that follows the H wave, occurs early in systole.

J wave: largest head-ward wave that immediately follows the I wave, occurs late in systole.

K wave: foot-ward wave following J, occurs before the end of systole.

Diastolic waves

L and N waves: two smaller head-ward deflections which usually follow K.

M wave: foot-ward deflection between L and N.

1.5.3 FIR Filter [7]

In signal processing, a finite impulse response (FIR) filter is a filter whose impulse response (or response to any finite length input) is of finite duration, because it settles to zero in finite time. This is in contrast to infinite impulse response (IIR) filters, which may have internal feedback and may continue to respond indefinitely (usually decaying).

The impulse response of an Nth-order discrete-time FIR filter lasts for $N + 1$ samples, and then settles to zero Figure 1.4.

FIR filters can be discrete-time or continuous-time, and digital or analog.

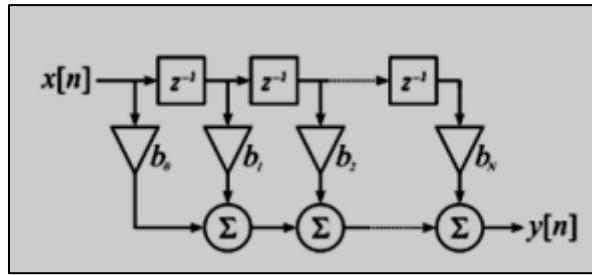


Figure1.4 FIR filter block diagram

FIR Properties

An FIR filter has a number of useful properties which sometimes make it preferable to an infinite impulse response (IIR) filter. FIR filters:

1. Require no feedback. This means that any rounding errors are not compounded by summed iterations. The same relative error occurs in each calculation. This also makes implementation simpler.
2. Inherent stability. This is due to the fact that, because there is no required feedback, all the poles are located at the origin and thus are located within the unit circle (the required condition for stability in a Z transformed system).
3. Phase Issue: can easily be designed to be linear phase by making the coefficient sequence symmetric; linear phase, or phase change proportional to frequency, corresponds to equal delay at all frequencies. This property is sometimes desired for phase-sensi.

1.5.4 Instrumentation Amplifier

An instrumentation amplifier (IA) is used to provide a large amount of gain for very low-level signals, often in the presence of high noise levels. The major properties of IAs are high gain, large common-mode rejection ratio (CMRR), and very high input impedance. They are often used to directly amplify signals from passive sensors, such as strain gages. An IA is a device which only amplifies the difference between the two input lines while ignoring any common-mode noise they both carry. It is usually used for low-frequency signals ($\ll 1$ MHz) as shown in Figure 1.5.

The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 10,000.[8]

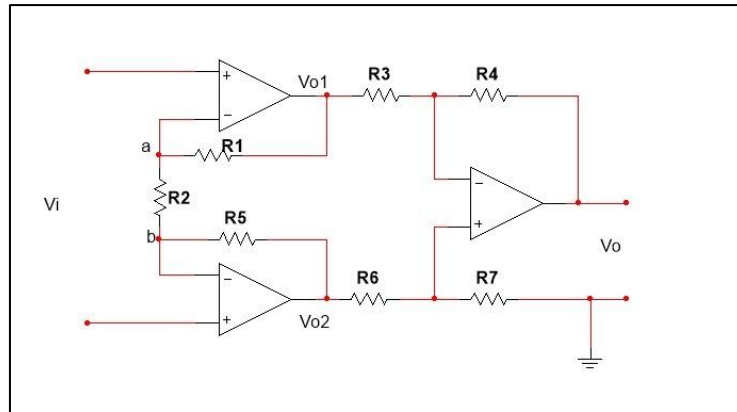


Figure 1.5 instrumentation amplifier circuit

1.5.5 Load cell sensor

Single-points, like all other modern load cells, are essentially transducers that convert force or weight into an electrical signal. They do this by using strain gauges and Figure 1.6 shows the internal structure of this cell (bridge of strain gauge), which are attached to the body of the load cell. When under load, the shape of the load cell deforms slightly. This change is detected by the strain gauges which distort in unison with the body, resulting in a change of voltage. This voltage signal is proportional to the initial force or weight and can thus be used to calculate it.

Single-point load cells come in numerous shapes and sizes to accommodate different types of applications. All of them feature an inner aperture, which is a geometrically precise cut-out of the body. This is often what visually distinguishes them from beam load cells. This aperture controls the thickness of the metal at various points across the load cell body and is the key to the cell's ability to accommodate off-center loading as shown in Figure 1.7.

Single-points are usually constructed of either stainless steel or high-grade aluminum.

The sensor used was placed in the middle of the weighing platform 35 * 45 / 5kg , and on this platform the person will stand to apply pressure on the sensor (mechanical signal) which will be converted into an electrical voltage signal.[9]

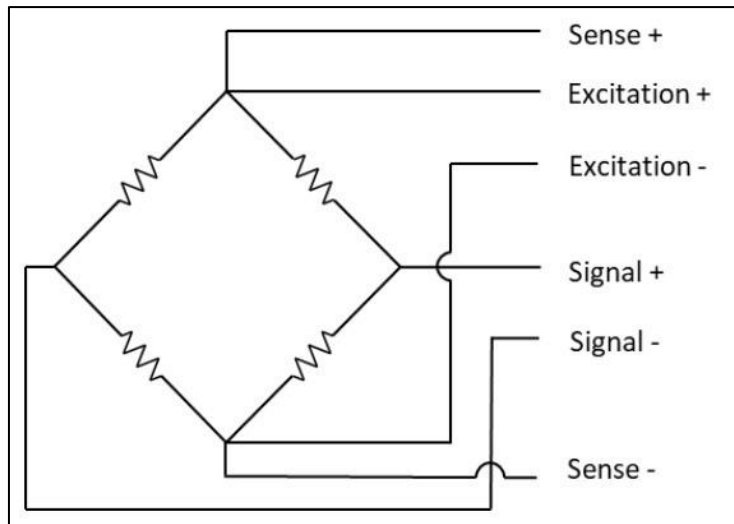


Figure 1.6 bridge circuit of load cell

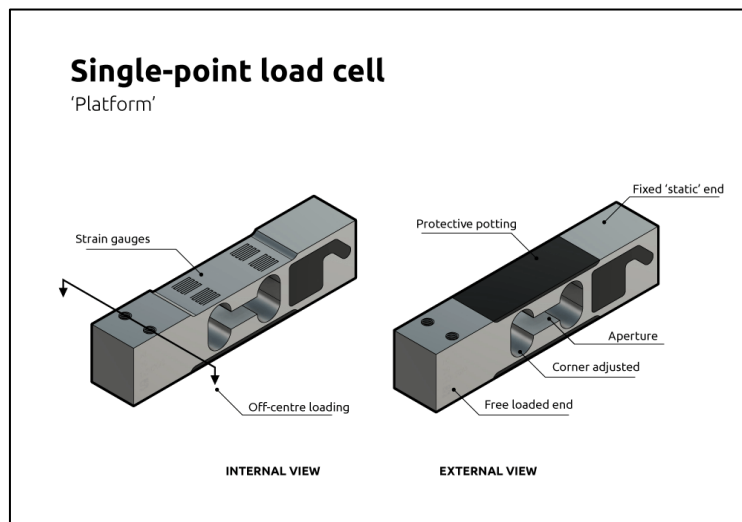


Figure1.7 load cell sensor

1.5.6 Hilbert Transform [10]

The concept of instantaneous amplitude/phase/frequency are fundamental to information communication and appears in many signal processing application. We know that a monochromatic signal of form $\cos(2\pi f_0 t)$ cannot carry any information. To carry information, the signal need to be modulated. Take for example the case of amplitude modulation, in which a positive real-valued signal $m(t)$ modulates a carrier $\cos(2\pi f_0 t)$. That is, the amplitude modulation is effected by multiplying the information bearing signal $m(t)$ with the carrier signal.

$$x(t) = m(t) * \cos(2\pi f_0 t)$$

$x(t)$ is the analytical signal.

So the modulated signal is a real-valued signal. We also take note of the fact that amplitude/phase and frequency can be easily computed if the signal is expressed in complex form. Apply Hilbert transform will convert a real signal to the complex plane without altering the required properties, and form the analytic signal on the complex plane.

If we express the real-valued modulated signal $x(n)$ as an analytic signal, it is expressed in complex plane as:

$$Z(n) = Z_r(n) + jZ_i(n) = a(n) * \cos(2\pi f_0 t) + j a(n) * \sin(2\pi f_0 t)$$

The instantaneous amplitude (envelope extraction) is computed in the complex plane as:

$$G(n) = |Z(n)| = \sqrt{Z_r(n)^2 + Z_i(n)^2}$$

1.6 Research Organization

In the beginning, we gave a small explanation about our project, what it contains and the expected results . first chapter gave an introduction ,the problem we are trying to solve , our motivation and the method we did the project , then we discuss the theoretical background of the system ,and a simple explanation about the Anatomy and Functionality of the heart. In the second chapter, we designed each part of the project separately . third chapter explains the process of installing the system on the ground, hardware and software systems designed in the previous chapter .then in fourth chapter we discuss the results that we got , and the conclusions of the project described in the final chapter of the document.

CHAPTER TWO

SYSTEM DESIGN

The proposed method relies on the action–reaction principle of classical mechanics that explains the BCG signal. Each heart beat exerts a foot ward and a headward force that yield a reaction on the platform where the subject is standing. During early systole, the left ventricle accelerates a volume of blood through the ascending aorta and, as a reaction, the body moves foot ward and exerts a force on the platform, whose supporting beams stress until they balance that force (in addition to the body weight). Similarly, during late systole the blood volume ejected accelerates through the descending aorta due to its compliance and gravity, which makes the body move headward, thus reducing the stress on the platform. In this case, the sensor implanted inside the platform senses the change in pressure and converts it into an electric voltage signal Figure 2.1 shown the block diagram of the system.

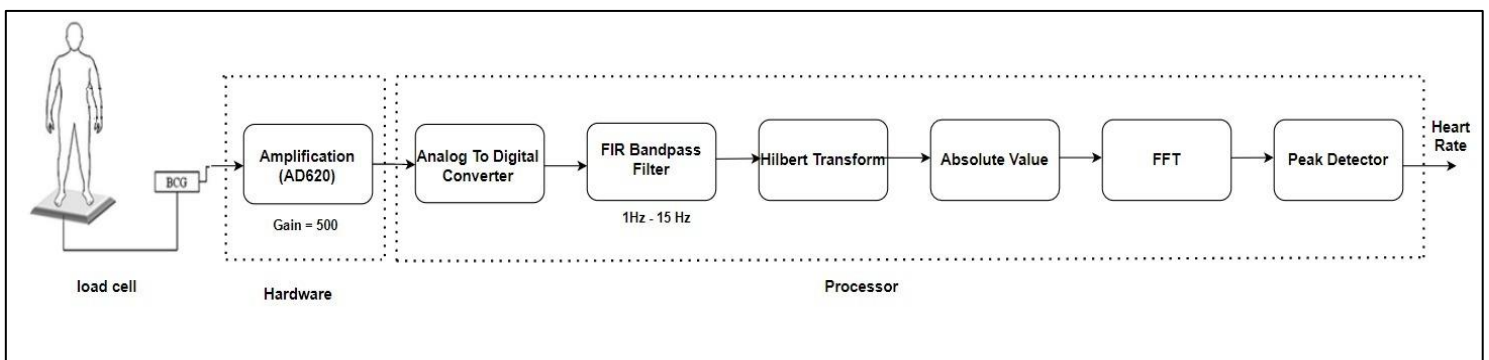


Figure 2.1 block diagram of the system

The maximum weight that the sensor can give a result (electrical signal) is 75 kg (taking into account the weight of the sensor with the platform), meaning that it gives a correct signal within the rated output of the sensor for a person weighing 70 kg .as a maximum.

After obtaining the heart signal which is a very weak signal that carries large noise levels, so we use an instrumentation amplifier (AD620) (appendix B) which used to provide a large amount of gain (G) for very low-level signals, often in the presence of high

noise levels, the input of this IA is the output of the sensor and we amplify this input by $G = 500$ as shown in Figure 2.2 by using this equation:

$$G = 1 + \frac{49.4K\Omega}{R_G} \quad (1)$$

$$500 = 1 + \frac{49.4K}{R_G}$$

$$R_G = 98.9\Omega$$

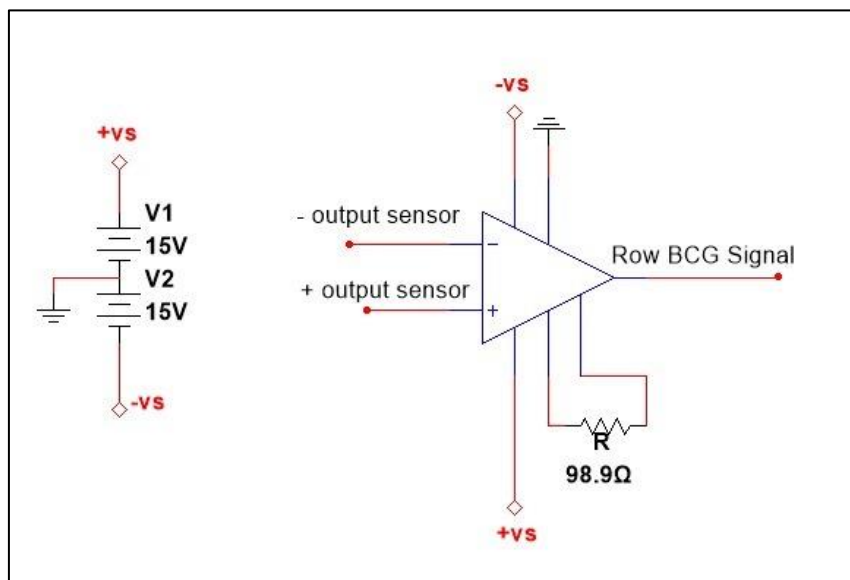


Figure 2.2 Instrumentation amplifier (AD620 circuit)

The maximum rated output from the load cell is 2 mV/V (appendix C), and when we apply 5V input voltage to the sensor with amplification 500, the maximum output voltage from this sensor is 1 volt.

There is a relationship between the output voltage and the weight.

$$75Kg \rightarrow 2mv * 5v * 500$$

$$weight \rightarrow Vout$$

$$weight = Vout * 15 \quad (2)$$

LabVIEW

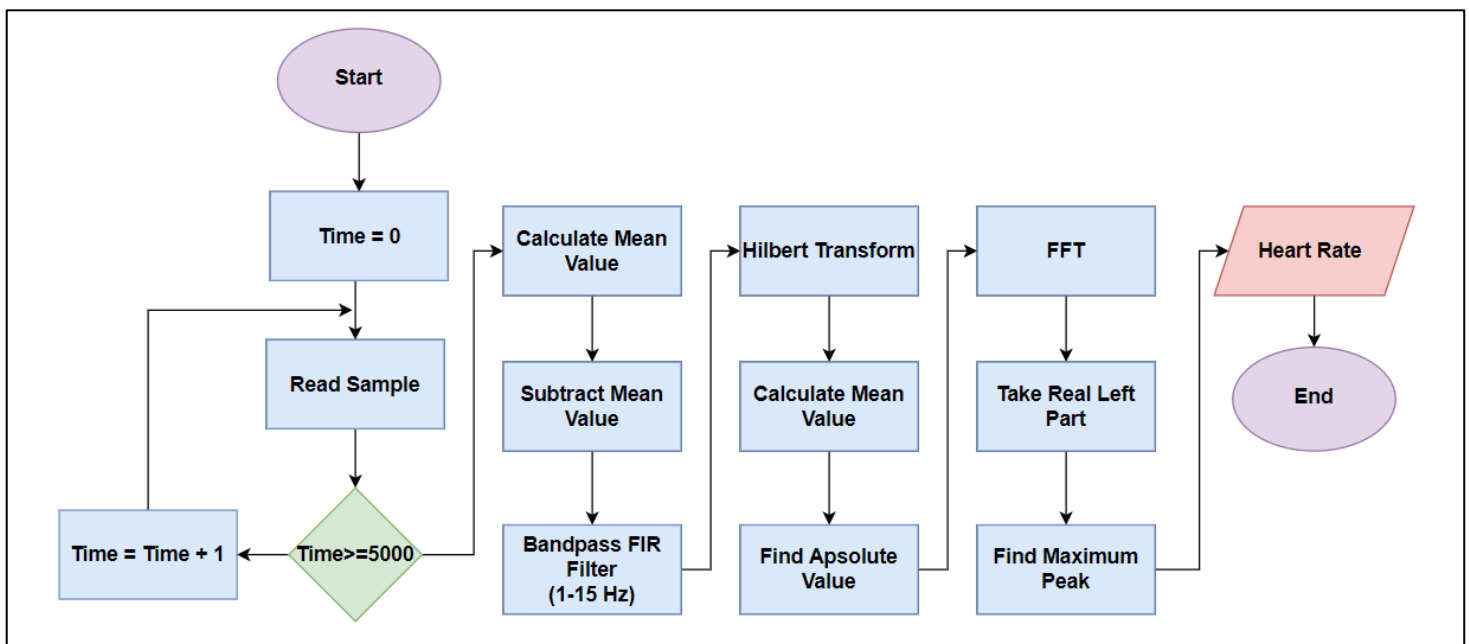


Figure 2.3 flowchart of heart rate estimation algorithm

Our signal entered into the LabVIEW is small and represents a combination of heart signal ($a(n)$) and respiration signal ($r(n)$) in addition to high noise ($e(n)$). Which modelled as:

$$s(n) = r(n) + a(n) * \cos(2\pi f_0 t) + e(n) \quad (3) \quad [11]$$

In the beginning, it was necessary to get rid of the large DC signal in our signal, so we calculated the mean average in the signal which represent the DC value, and then we subtracted it from the original signal to remove the resulting DC shift.

As we mentioned earlier, this signal expresses a combination of signals, so other signals must be excluded (and extract the heart signal), after knowing the frequency range of the BCG signal (1 – 20) Hz.

So we designed a FIR band pass filter with cut off frequencies (1 - 15) Hz as shown in Figure 2.4, which filters the signal from the breathing signal and other signals outside the range of the heart signal.

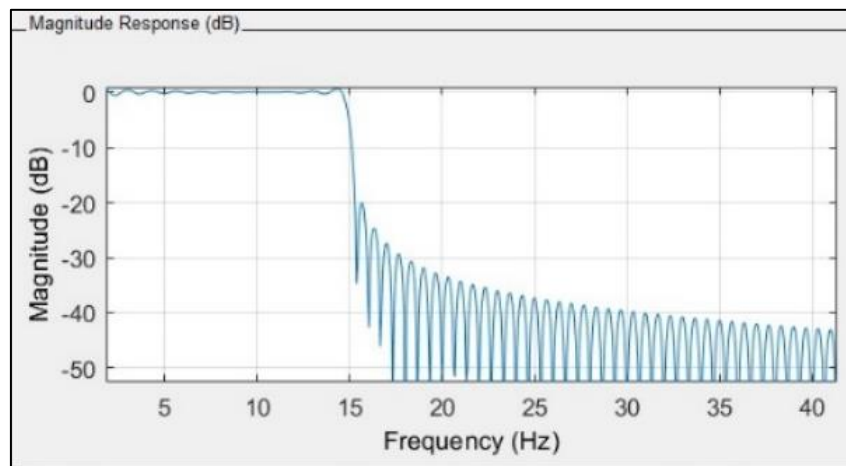


Figure 2.4 FIR filter design response

At this point we should have got the heart signal $a(n)$, but this signal $a(n) * \cos(2\pi f_0 t)$ is modulated by modulation frequency (f_0), so $a(n)$ must be extracted, for this we will use Hilbert Transform.

HR gives us the input signal $a(n) * \cos(2\pi f_0 t)$ and reserves its amplitude information and introduces 90 degree phase shift of input signal.

$$H(n) = a(n) * \cos(2\pi f_0 t) + j a(n) * \sin(2\pi f_0 t) \quad (4)$$

By taking the magnitude of $H(n)$, we will have the signal which have the heart rate information.

Now to measure the heart rate we applied Fast Fourier Transform. as we now in the frequency domain the frequency with the highest amplitude will represent the repeated

part in the signal with the highest amplitude in the time domain ,which is j peak in BCG signal .

So the frequency of j peak represents the HR in the BCG signal.

CHAPTER THREE

SYSTEM IMPLEMENTATION

In this chapter the hardware & software system designed in the previous chapter is implemented to achieve the project purpose.

3.1 Load Cell Platform

It is the first stage where the patient is stand on the platform . TEDEA - HUNTLEIGH Models 1041 single-point load cells placed in the middle of the steel weighing platform 35 * 45cm ,5kg as shown in Figure 3.1 .We chose this design to make it suitable for placing it on the ground and for the patient to stand firmly on it . The applied force will convert to voltage signal.

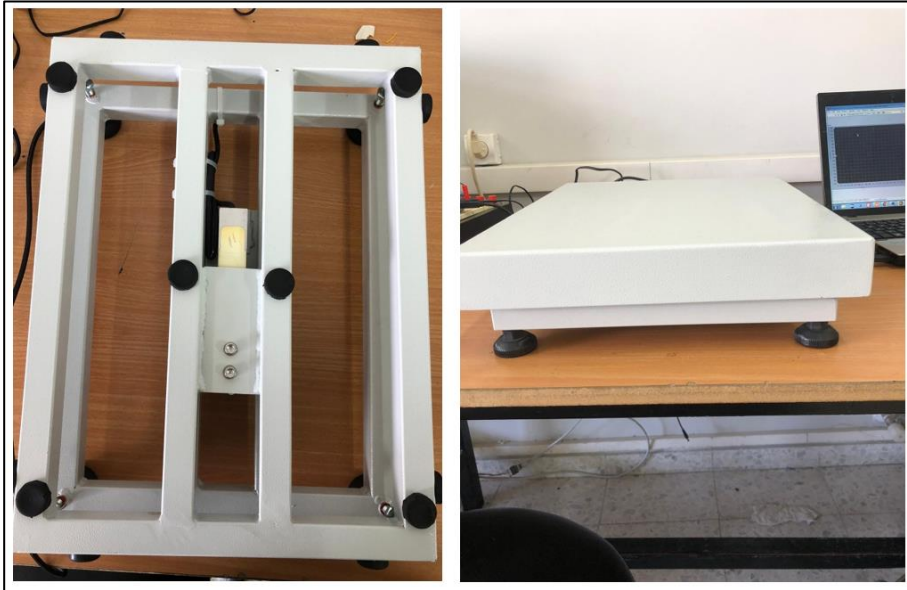


Figure 3.1 load cell platform design

3.2 AD620

In case that the terminals of the sensor are connected to the AD620 with regular wires, the distortion will be very high due to the movement of the wires, and this gives a weak and constantly changing signal, so we designed a PCB board for the circuit.

The output terminals of the sensor were soldered with the AD620 (according to its data sheet [appendix B]) on the PCB board as shown in Figure 3.2.

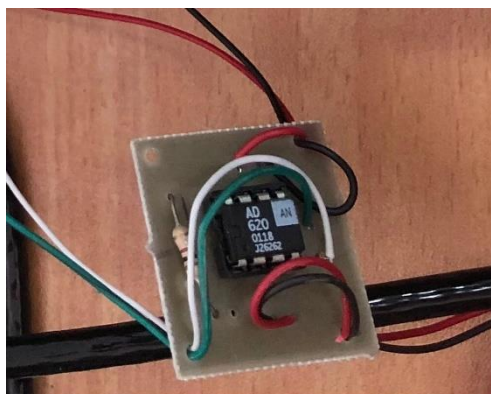


Figure 3.2 PCB circuit

circuit

3.3 my RIO

We used my Rio to transmit the signal to the computer by USB to be processed.

The National Instruments myRIO-1900 is a portable reconfigurable I/O (RIO) device that students can use to design control, robotics, and mechatronics systems .

The NI myRIO-1900 provides analog input (AI), analog output (AO), digital input and output (DIO), audio, and power output in a compact embedded device. The NI myRIO-1900 connects to a host computer over USB. It receives an analog input from 0 – 5 v.

It is a very sensitive device as it senses very small voltage signals(in microvolts).[9]

We used pin 3 (AI0) as analog input , pin 4 (AO1) as analog output , and pin 6 ground. And we used the first microprocessor (real time LabVIEW), see Figure 3.4. [12]

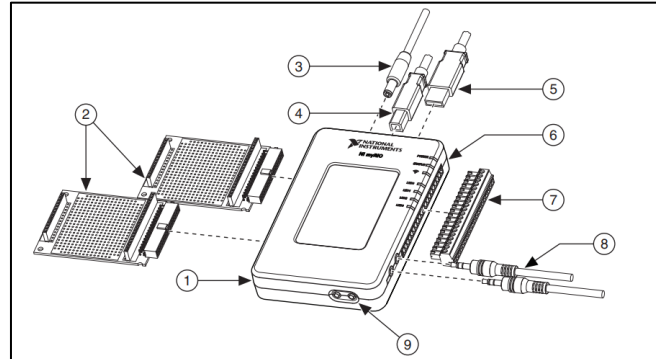


Figure 3.3 NI myRIO-1900

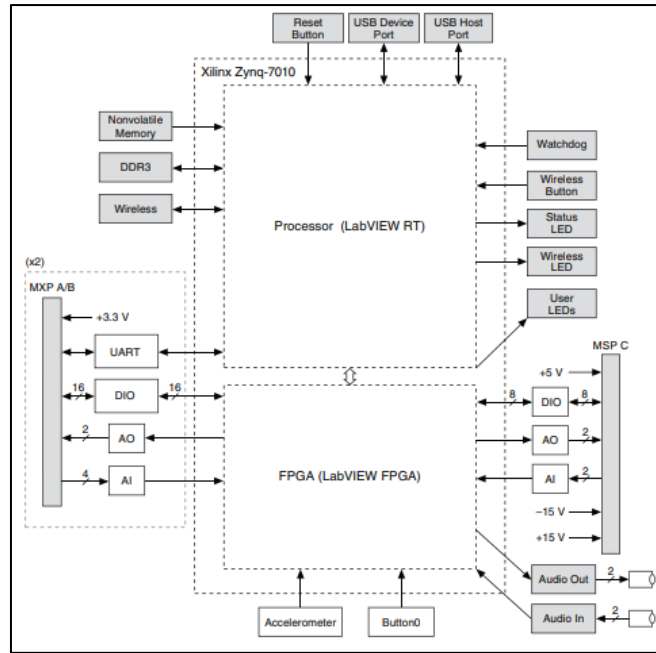


Figure 3.4 NI myRIO-1900 Hardware Block Diagram

3.4 LabVIEW

We entered the signal into LabVIEW, then we divided these signals into samples, where each sample 5000 values within 5 second, then we built a code represent the design we discussed in the previous chapter and Figure 3.4 shows the LabVIEW code for heart rate estimation.

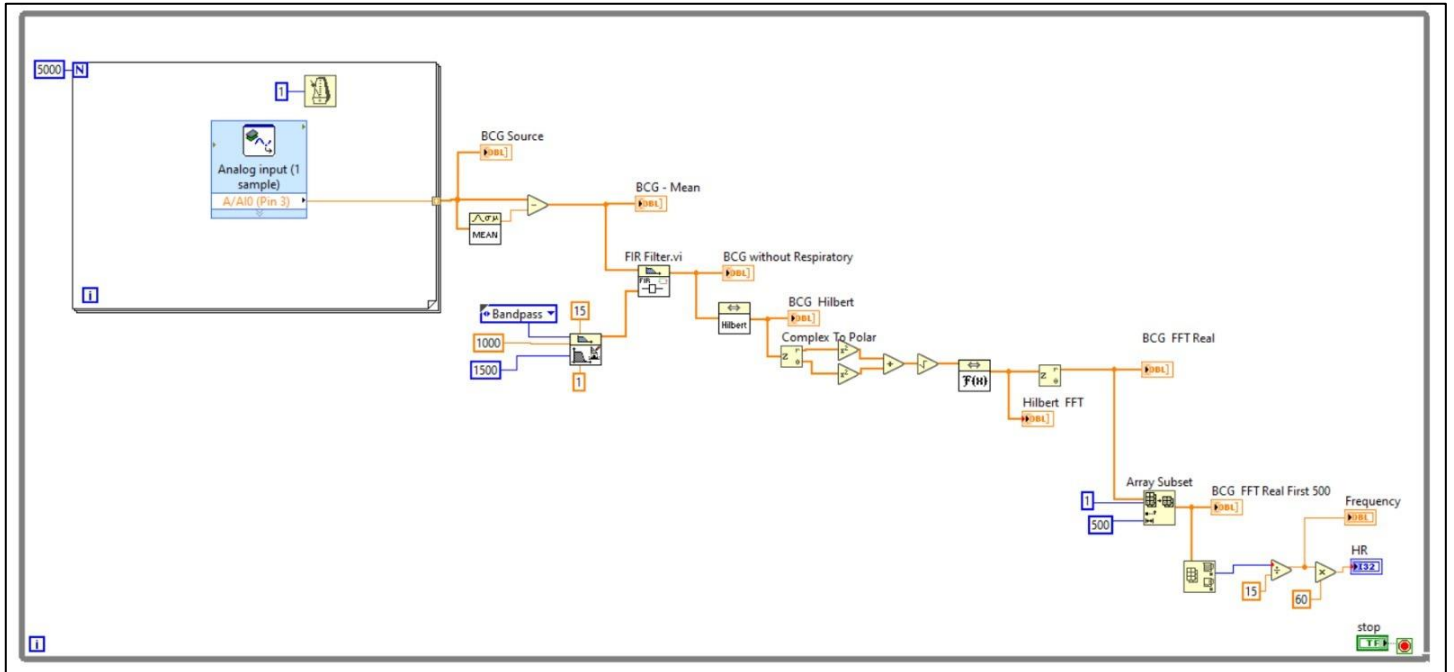


Figure 3.4 LabVIEW code for heart rate estimation

At first, we used for loop with 5000 iteration, see the blue box in Figure 3.5, this loop will collect 5000 value as a matrix in the tunnel (the small orange square on the right edge of the loop), so we will have a sample of 5000 value each 5 seconds.

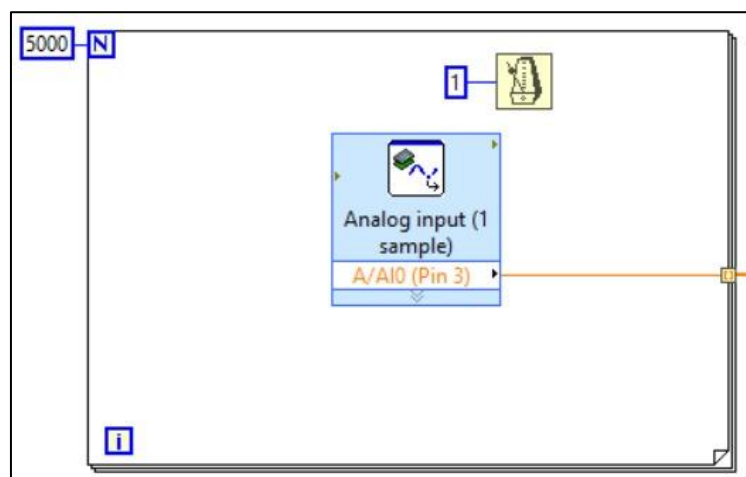


Figure 3.5 Sampling for loop

Then we calculated the mean average and subtracted it from the original signal to remove the resulting DC shift.as shown in Figure 3.6.

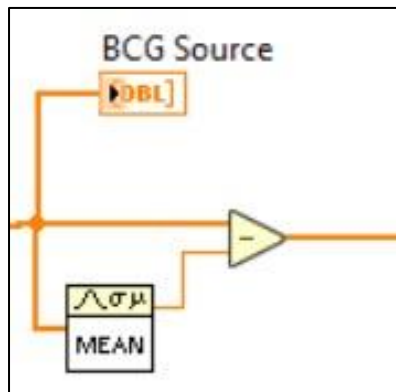


Figure 3.6 BCG signal without DC

The resulting signal will be filtered by using band pass FIR filter which designed with cut off frequencies 1 – 15 Hz , $f_s = 1000$ Hz and 1500 taps. see Figure 3.7.

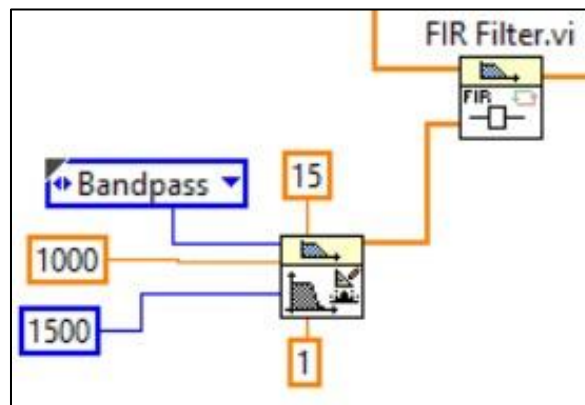


Figure 3.7 Filtered BCG signal

Hilbert Transform is used with a complex to polor block to get the real and complex parts of the signal , then we get the magnitude of the signal , then entered to a FFT ,as shown in Figure 3.8, to get the signal in the frequency domain.

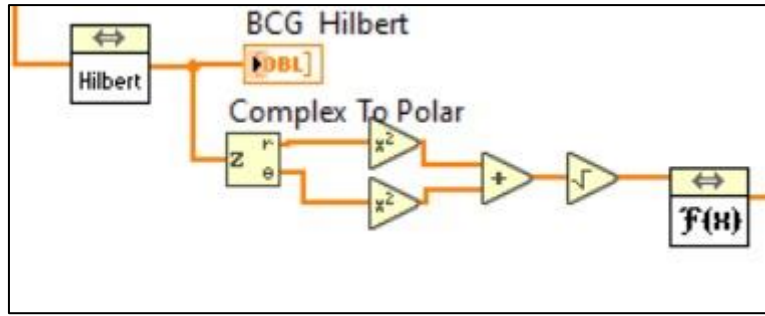


Figure 3.8 Hilbert and FFT transform

The signal resulting from the FFT will be symmetrical on both sides of the axis, so we will take the first part of the signal to the left side of the axis (the first 500 samples) as shown in Figure 3.9.

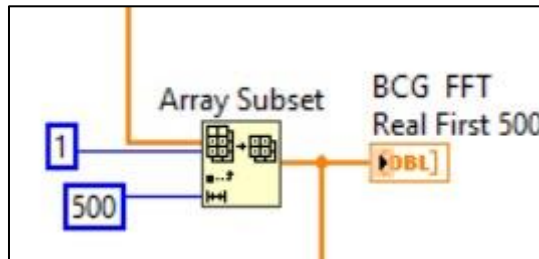


Figure 3.9 BCG FFT real first 500

The resulting signal expresses the index of the values, so we will adjust the maximum value of the signal to a frequency by dividing it by 15, this value will represent the number of j peaks occur in one second, then to calculate the HR we will multiply the value by 60. As shown in Figure 3.10.

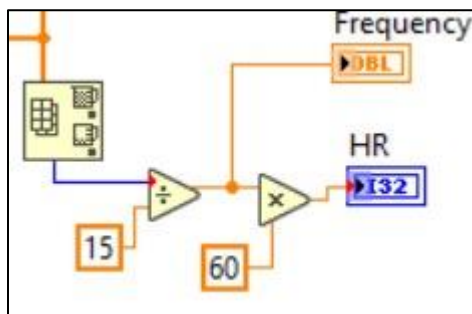


Figure 3.10 Heart detection

To check our practical work that we made in LabVIEW, we applied this code in MATLAB as a theoretical work and compare their results to verify our design.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents discussed the results of the system implemented .

After installing the project ,we took a BCG signals, the signal entered the system we built , and the results were as follows:

Gender	Age	Wight	Extracted HR	Pulse Oximeter
Female	20	55	96	92
Female	23	60	88	85

The following results refers to the first person whose age 20 , and her weight is 55 kg.

The original BCG signal that results when the patient stand on the sensor has a DC shift as shown in Figure 4.1 .

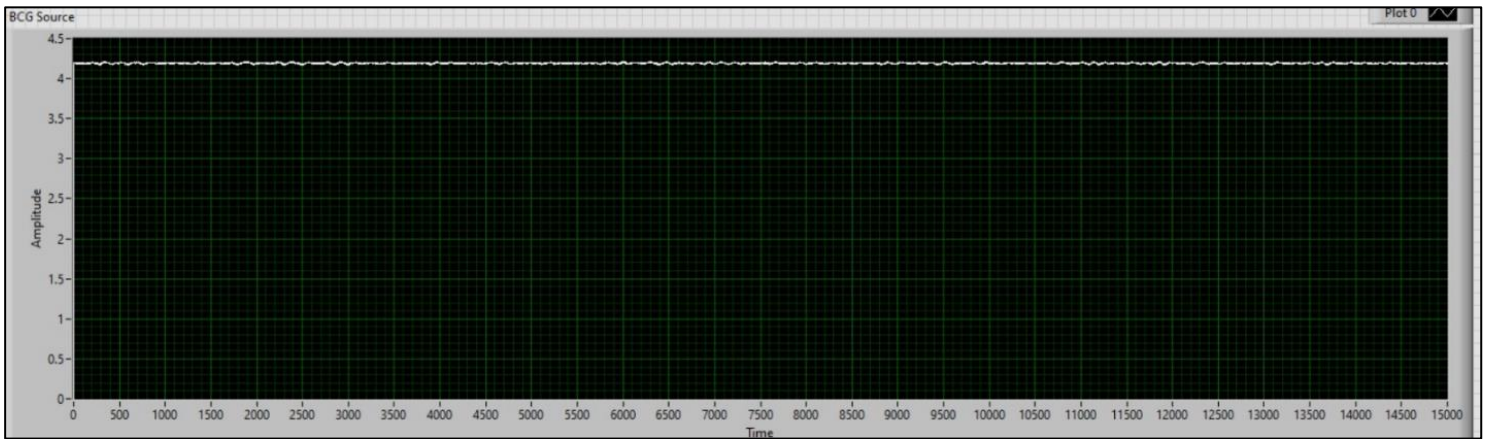


Figure 4.1 Row BCG signal

And after subtract the BCG signal from DC noise it returns to the base line. Figure 4.2.

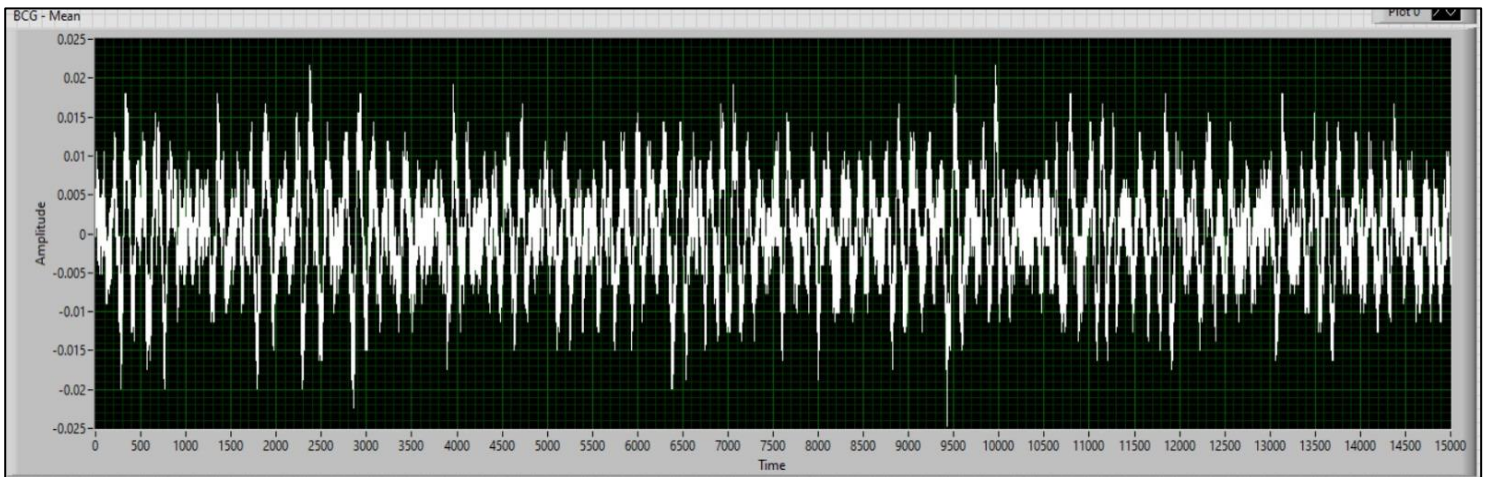


Figure 4.2 BCG signal without DC shift in LabVIEW

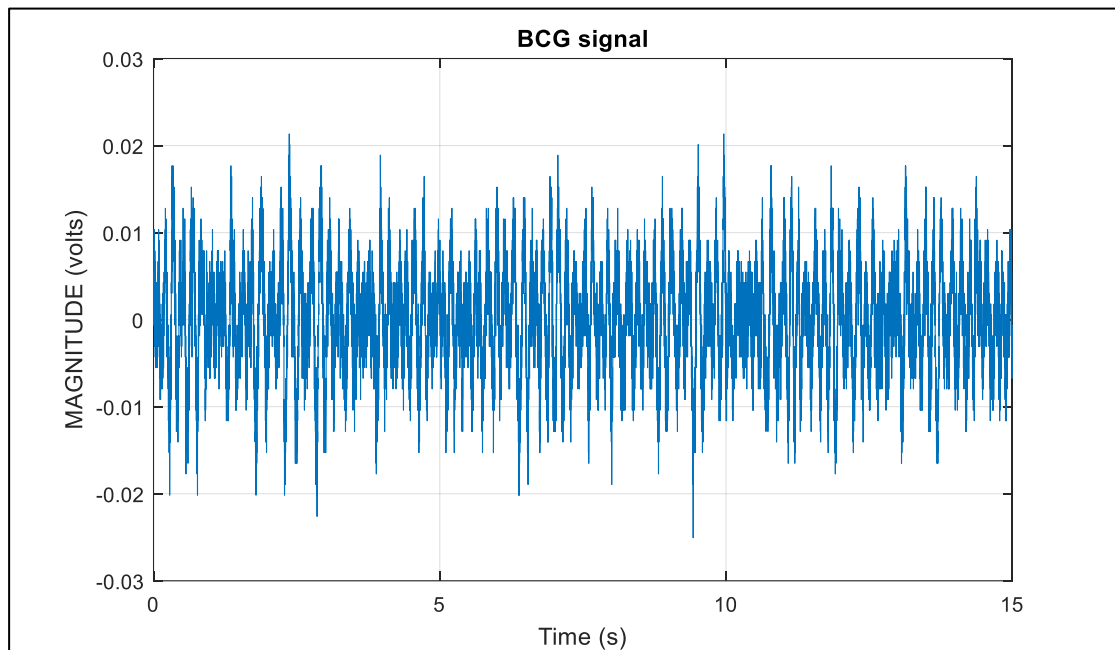


Figure 4.3 Raw BCG signal without DC shift in MATLAB

And as we can see in Figures 4.4 & 4.5 ,the resulting signal after it get filtered becomes more clear as a periodic BCG signal to be processed.

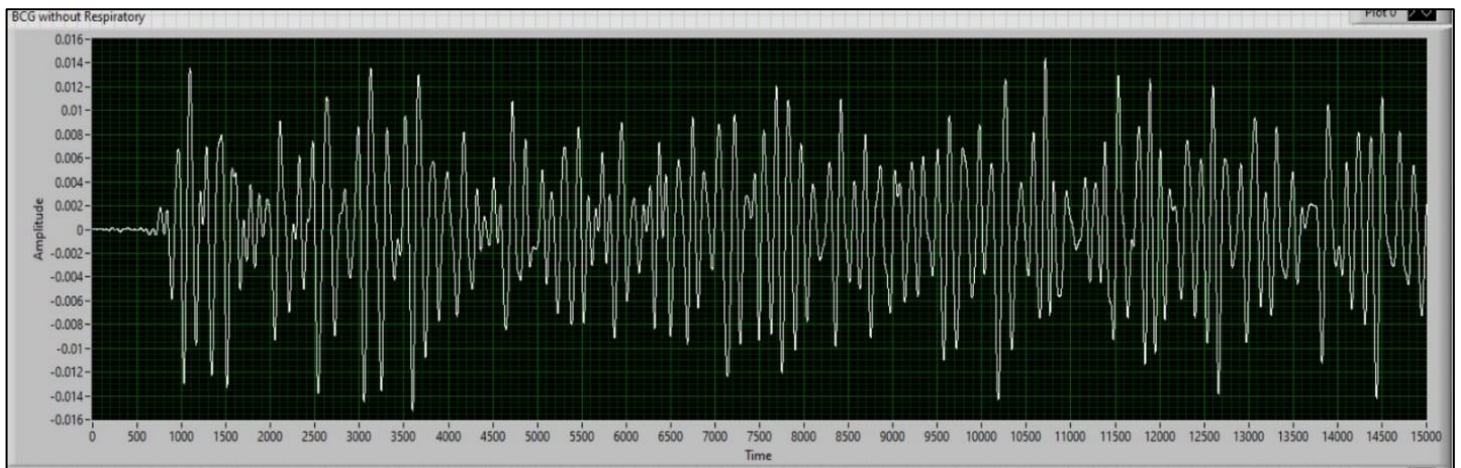


Figure 4.4 Filtered signal in LabVIEW

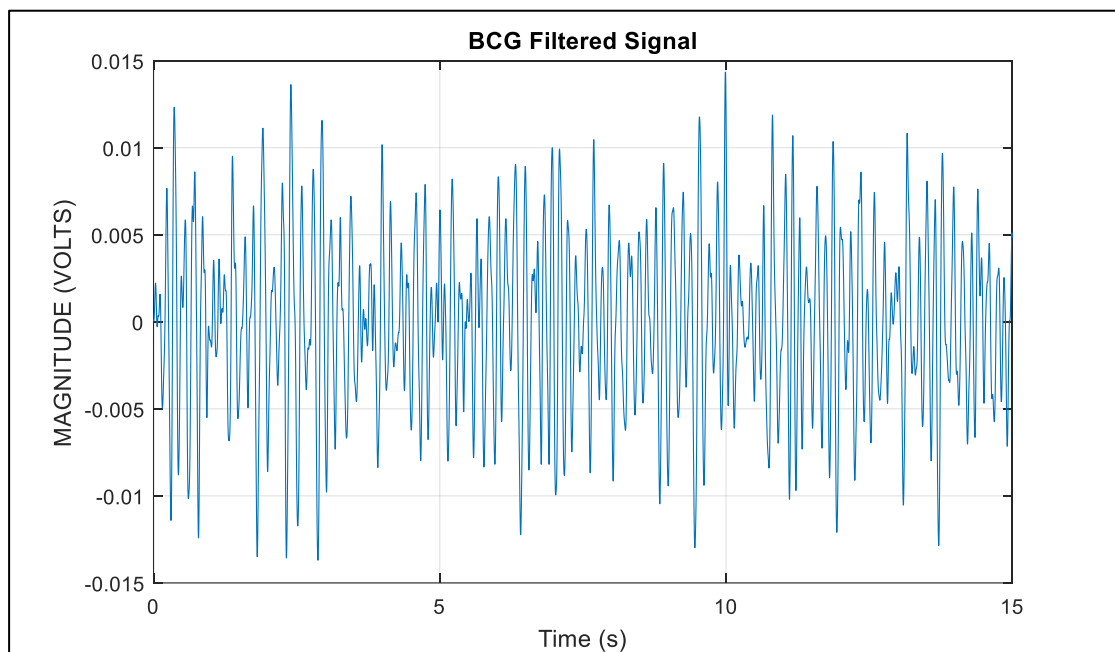


Figure 4.5 Filtered signal in MATLAB

The part of the filtered signal surrounded by a yellow circle as show in Figure 4.6, is a delay caused by the FIR filter and does not affect the signal.

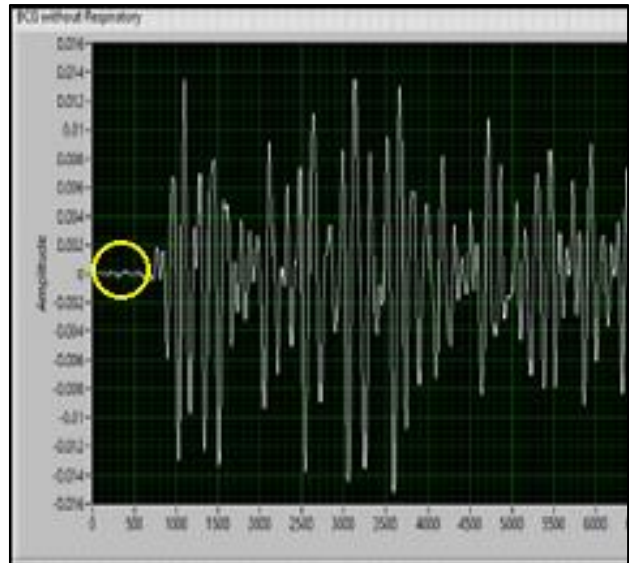


Figure 4.6 Delay caused by FIR filter

After we applied HT to the signal, we can see that the results in both LabVIEW and MATLAB are very similar. See Figures 4.7 & 4.8 .

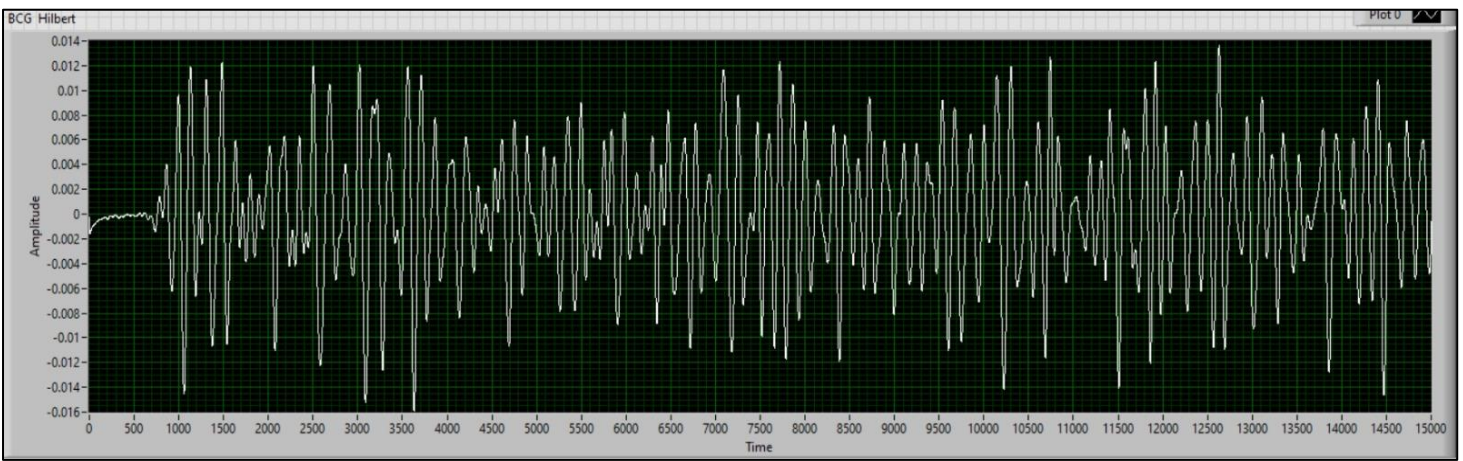


Figure 4.7 Hilbert Transform in LabVIEW

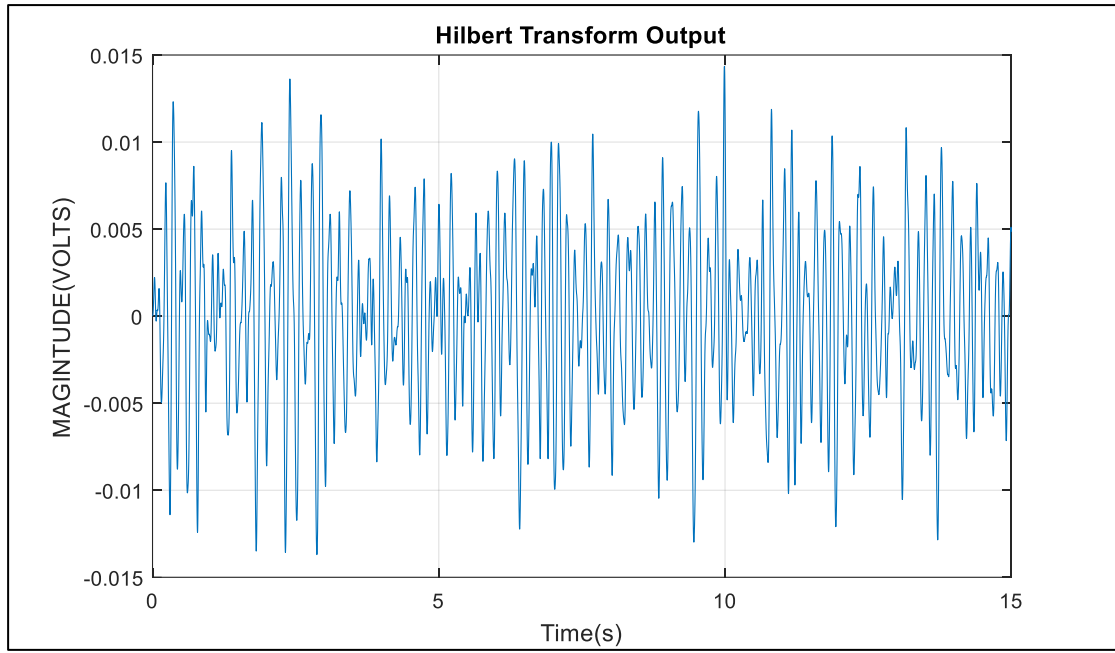


Figure 4.8 Hilbert Transform in MATLAB

The Hilbert absolute signal is seen in Figures 4.9 & 4.10.

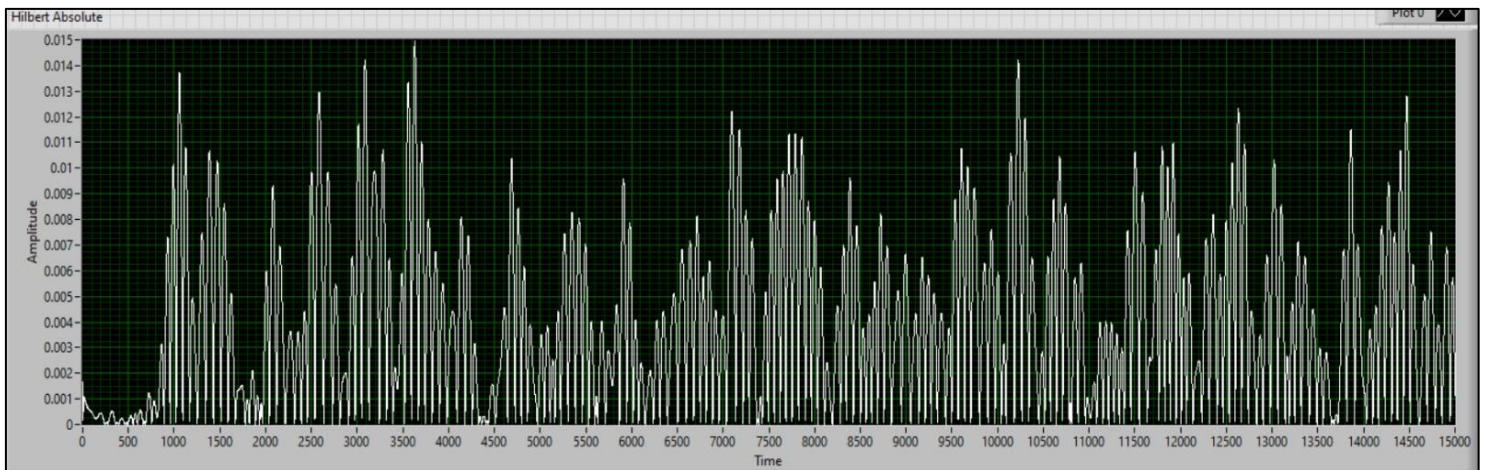


Figure 4.9 Hilbert Absolute in LabVIEW

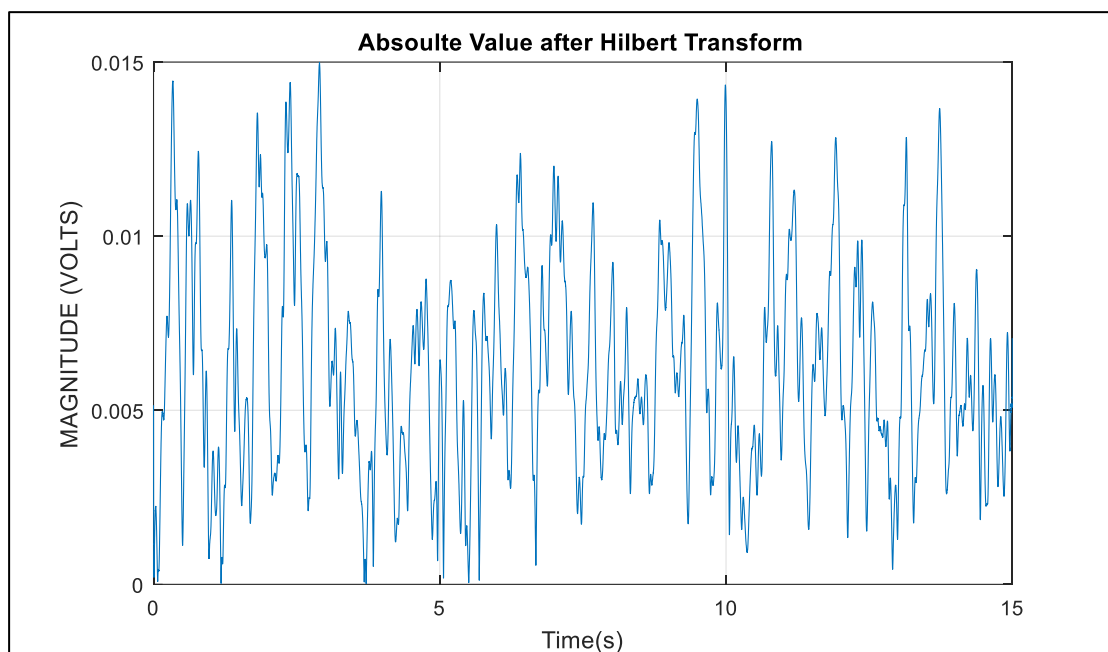


Figure 4.10 Hilbert Absolute in MATLAB

Then we can see the symmetrical parts of the result signal after applying FFT . in Figure 4.11.

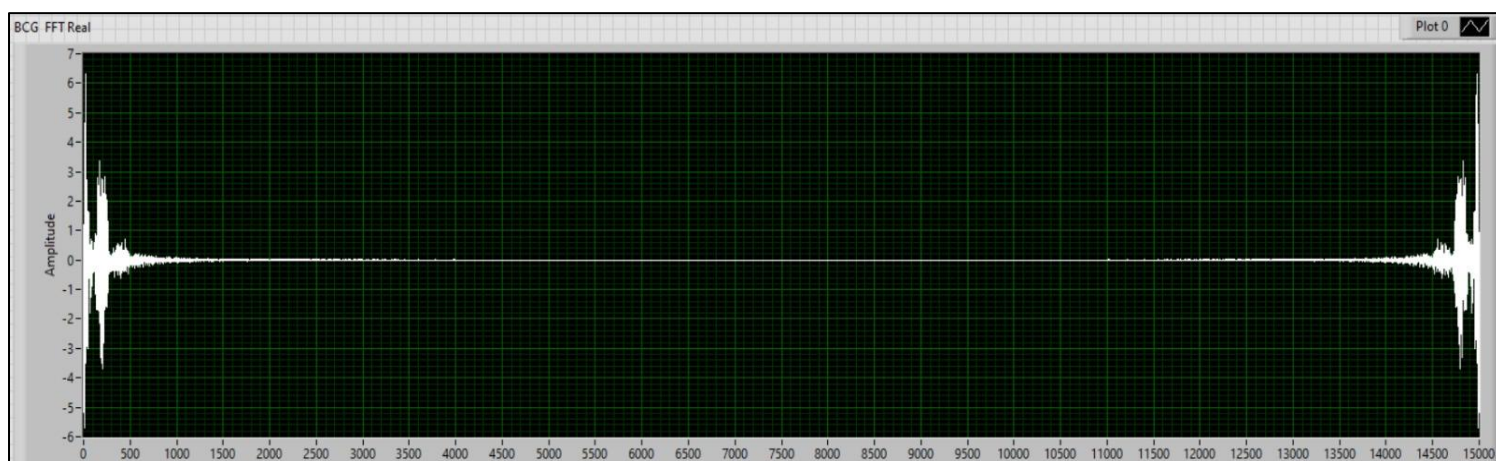


Figure 4.11 BCG FFT

The first part of the signal to the left side of the axis .See Figure 4.12.

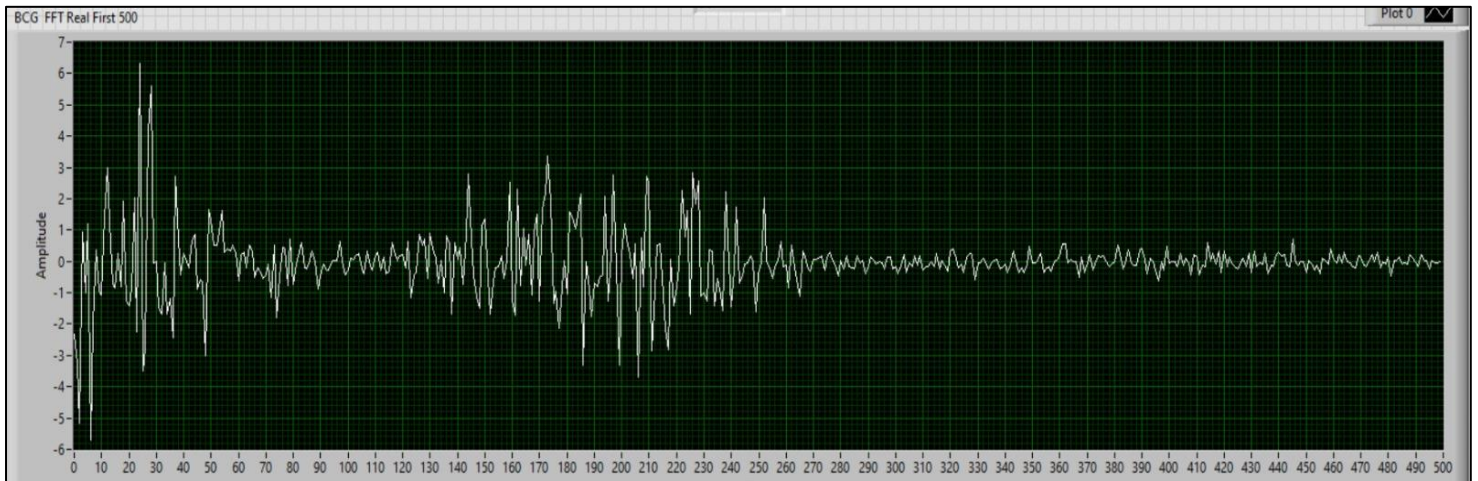


Figure 4.12 BCG FFT real first 500

Finally we can see the calculated Heart Rate in LabVIEW equal to:

$$HR = Frequency * 60 \quad (5)$$

And as we can see in Figure 4.13, the calculated freq. = 1.6 Hz.

$$HR = 1.6 * 60$$

$$HR = 96 \text{ BPM}$$

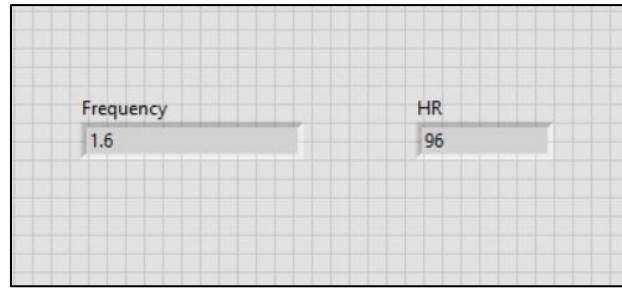


Figure 4.13 Estimated HR in LabVIEW

And if we compare the HR result with MATLAB, we will find that it is very close, as the frequency is equal to 1.5 Hz as shown in Figure 4.14.

$$HR = Frequency * 60$$

$$HR = 1.526 * 60$$

$$HR = 92 \text{ BPM}$$

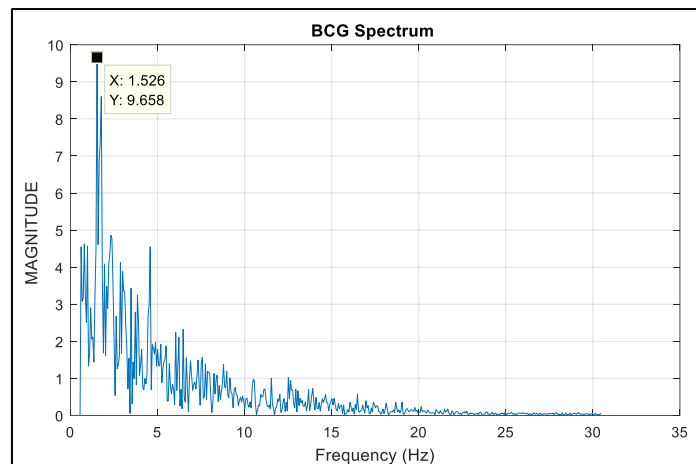


Figure 4.14 Estimated HR in MATLAB

CHAPTER FIVE

CONCLUSION

In this project, we present a method for obtaining a representation of the heart beat-induced repetitive movements of the human body, based on BCG signal obtained from sensors embedded in a platform. The idea of this project was to detect heart rate from the BCG signal by the patient standing on a load cell platform. We built our algorithm as LabVIEW code and Hilbert Transform is used to extract pulse envelope. After that, FFT is applied. Heart rate is finally calculated based on frequency domain.

Comparing the results we got practically from LabVIEW with the theoretical results from MATLAB ,we can say that our design is effective in estimating the Heart Rate non – invasively

5.1 Future Work

BCG signal has a lot of vital parameters can be detect instead of the heart rate like: respiratory rate and blood pressure, and it can be used for diagnose so many diseases such as panic attack, so it is important to work on these studies in the future.

5.2 Challenges

During the work of this project, we faced many problems and challenges

1. The most difficult of which is: lack of availability and inability to request the sensor, as the companies that were contacted did not respond to the request for the sensor we wanted, and when we requested it, it did not reach us, so we had to find another alternative for it
2. The difficulty of writing the LabVIEW code because it was not widely used in our study.
3. The biggest issue, in BCG signal processing is motion artifacts and the vibration of the measuring device itself, both of which constitute to the major amount of noise present in a BCG signal.

References

[1] Shin, J. H., Lee, K. M., & Park, K. S. (2009). Non-constrained monitoring of systolic blood pressure on a weighing scale. *Physiological Measurement*, 30(7), 679–693. T.

[2] Koivistoinen, S. Junnila, A. Varri and T. Koobi, "A new method for measuring the ballistocardiogram using EMFi sensors in a normal chair," *The 26th Annual International*

Conference of the IEEE Engineering in Medicine and Biology Society, 2004, pp. 2026-2029, doi: 10.1109/IEMBS.2004.1403596.

[3] “Heart Chambers: MedlinePlus Medical Encyclopedia Image.” Heart Chambers: MedlinePlus Medical Encyclopedia Image, medlineplus.gov/ency/imagepages/19612.htm. Accessed 25 Dec. 2022.

[4] “Introduction to the Cardiovascular System | SEER Training.” *Introduction to the Cardiovascular System | SEER Training*, training.seer.cancer.gov/anatomy/cardiovascular. Accessed 25 Feb. 2022.

[5] Staff, HowforKids. “Circulatory System [Parts and Functions] for Kids – HowForKids.” Circulatory System [Parts and Functions] for Kids – HowForKids, 20 Mar. 2021, howforkids.com/circulatory-system-for-primary-school.

[6] Sadek, I., Biswas, J. & Abdulrazak, B. Ballistocardiogram signal processing: a review. *Health Inf Sci Syst* 7, 10 (2019). <https://doi.org/10.1007/s13755-019-0071-7>

[7] <https://www.just.edu.jo/~hazem-ot/Lab.4&5.%20FIR%20Filters.pdf>. Accessed 19 Dec. 2022.

[8] https://www.researchgate.net/figure/Schematic-diagram-of-instrument-amplifier-AD620_fig5_325220456. Accessed 19 Dec. 2022.

[9] sdv4299. “What Is a Single Point Load Cell? Its Working Principle.” *Electrical Volt*, 10 Aug. 2021, www.electricalvolt.com/2021/08/what-is-a-single-point-load-cell-its-working-principle.

[10] Mathuranathan. “Extract Envelope, Phase Using Hilbert Transform: Demo - GaussianWaves.” *GaussianWaves*, 24 Apr. 2017, www.gaussianwaves.com/2017/04/extract-envelope-instantaneous-phase-frequency-hilbert-transform.

[11] Q. Xie, G. Wang and Y. Lian, "Heart Rate Estimation from Ballistocardiography Based on Hilbert Transform and Phase Vocoder," *2018 IEEE Asia Pacific Conference on Circuits and Systems (APCCAS)*, 2018, pp. 139-142, doi: 10.1109/APCCAS.2018.8605724.

[12] <https://docs-be.ni.com/bundle/myrio-1900-getting-started/Raw/Resource/Enus/376047d.pdf>. Accessed 2 Dec. 2022.

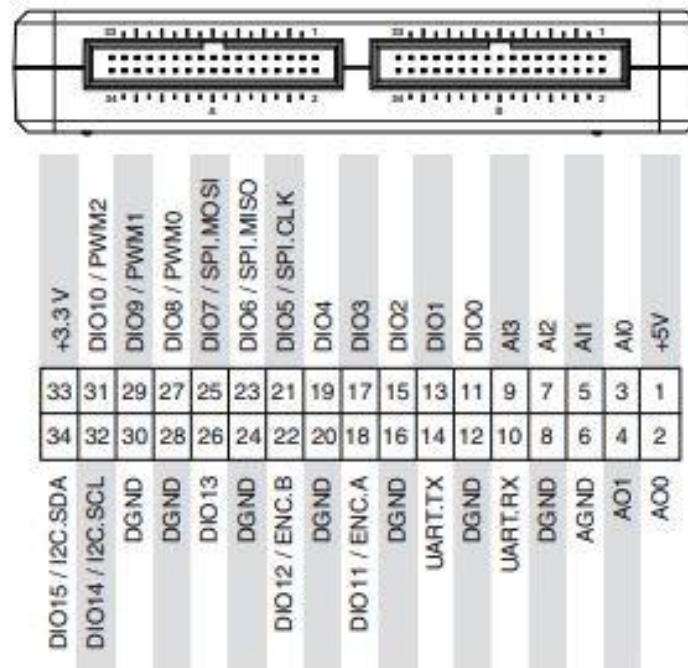
Appendices

Appendix A

Connector Pinouts

NI myRIO-1900 Expansion Port (MXP) connectors A and B carry identical sets of signals. The signals are distinguished in software by the connector name, as in `ConnectorA/DIO1` and `ConnectorB/DIO1`. Refer to the software documentation for information about configuring and using signals. The following figure and table show the signals on MXP connectors A and B. Note that some pins carry secondary functions as well as primary functions.

Figure 3. Primary/Secondary Signals on MXP Connectors A and B



Appendix B



Low Cost Low Power Instrumentation Amplifier

AD620

FEATURES

Easy to use

- Gain set with one external resistor (Gain range 1 to 10,000)
- Wide power supply range (± 2.3 V to ± 18 V)
- Higher performance than 3 op amp IA designs
- Available in 8-lead DIP and SOIC packaging
- Low power, 1.3 mA max supply current

Excellent dc performance (B grade)

- 50 μ V max, input offset voltage
- 0.6 μ V/ $^{\circ}$ C max, input offset drift
- 1.0 nA max, input bias current
- 100 dB min common-mode rejection ratio ($G = 10$)

Low noise

- 9 nV/ $\sqrt{\text{Hz}}$ @ 1 kHz, input voltage noise
- 0.28 μ V p-p noise (0.1 Hz to 10 Hz)

Excellent ac specifications

- 120 kHz bandwidth ($G = 100$)
- 15 μ s settling time to 0.01%

APPLICATIONS

- Weigh scales
- ECG and medical instrumentation
- Transducer interface
- Data acquisition systems
- Industrial process controls

CONNECTION DIAGRAM

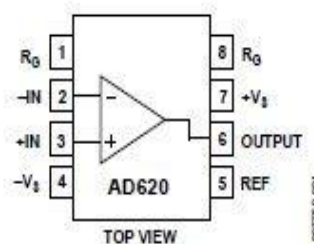


Figure 1. 8-Lead PDIP (N), CERDIP (Q), and SOIC (R) Packages

PRODUCT DESCRIPTION

The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 10,000. Furthermore, the AD620 features 8-lead SOIC and DIP packaging that is smaller than discrete designs and offers lower power (only 1.3 mA max supply current), making it a good fit for battery-powered, portable (or remote) applications.

The AD620, with its high accuracy of 40 ppm maximum nonlinearity, low offset voltage of 50 μ V max, and offset drift of 0.6 μ V/ $^{\circ}$ C max, is ideal for use in precision data acquisition systems, such as weigh scales and transducer interfaces. Furthermore, the low noise, low input bias current, and low power of the AD620 make it well suited for medical applications, such as ECG and noninvasive blood pressure monitors.

The low input bias current of 1.0 nA max is made possible with

Appendix C

1040/1041 SPECIFICATIONS

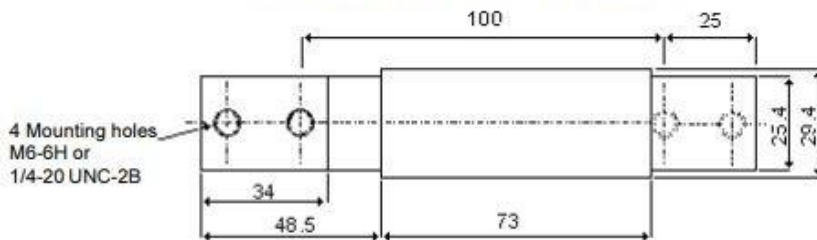
GRADE	E	F	G**	C3***	UNITS
Rated Capacities	5, 7, 10, 15, 20, 30, 50, 75, 100				kg
Rated Output	2.0 ± 10%				mW
Total Error*	0.030	0.020	0.0200	0.0200	±% of Applied Load
Zero Return after 30 mins	0.050	0.025	0.0170	0.0170	±% of Applied Load
Temperature Effect : On Output	0.0030	0.0014	0.0010	0.0010	±% of Applied Load / °C
: On Zero	0.0100	0.0080	0.0040	0.0023	±% of Rated Output / °C
Eccentric Loading	0.0074	0.0074	0.0049	0.0049	±% of Applied Load / cm
Zero Balance	10.0				±% of Rated Output
Temperature range : Operating	-30 to +70				°C
: Compensated	-10 to +40				°C
Safe Overload	150				% of Rated Capacity
Ultimate Overload	300				% of Rated Capacity
Excitation : Recommended	10				Volts AC or DC
: Maximum	15				Volts AC or DC
Input Impedance	415 ± 15				Ohms
Output Impedance	350 ± 3				Ohms
Insulation Impedance	1040 : >5000 1041 : >2000				Mega Ohms
Deflection at Rated Capacity	<0.4				mm
Weight:	1040 : 0.35 1041 : 0.30				kg
Construction	1040 : Anodised aluminum 1041 : Aluminum				
Environmental Protection	1040 : IP54 (IP67 Optional) 1041 : IP55				
Cable	1 Meter Standard (0.5m 1041), 6 Wire, PVC, Single Floating Screen				
Approvals	NTEP and OIML R60				

* Total Error - According to OIML R60

** 85% utilisation

*** Consult factory for utilisation factors

Outline Dimensions All Capacities (in mm)



Wiring Schematic Diagram

(1040 balanced bridge configuration)

