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DIAGNOSIS OF CONGENITAL HEART DISEASE USING FETAL PHONOCARDIOGRAPHY

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ABSTRACT— Congenital Heart Disease (CHD) is a problem in the structure and function of the heart that is present at birth. A prototype system of fetal phonocardiography (fPCG) has been designed to detect congenital heart diseases in the prenatal stage. A phonocardiogram or PCG is a plot of high fidelity recording of the sounds and murmurs made by the heart with the help of the machine called phonocardiograph; thus phonocardiography is the recording of all the sounds made by the heart during the cardiac cycle. This is an effective method for long term monitoring of hidden cardiac diseases. Recording of fetal heart sounds is done on the maternal abdomen. From the recorded sound signal, Fetal Heart Rate (FHR) and several other distinguishing features are found for both normal and abnormal PCG signals. From the features obtained, a type of congenital disorders has been diagnosed.

KEYWORDS— Congenital Heart Disease; Fetal phonocardiography; LABVIEW; Heart rate; Feature extraction

I. INTRODUCTION

This paper is aimed at pregnant women to know their infants heart functions in the prenatal stage. It is focused on the development of fetal phonocardiography. This is non invasive. It allows us to easily diagnose the heart murmurs from the recorded sound signal. Congenital heart defect (CHD) also known as a congenital heart anomaly or congenital heart disease is a problem in the structure of the heart that is present at birth. Signs and symptoms depend on the specific type of problem. Symptoms may include rapid breathing, bluish skin, poor weight gain, and feeling tired. It does not cause chest pain. Most congenital problems do not occur with other diseases. Complications that can result from heart defects include heart failure. Heart defects are the common birth defect. They present in 34.3 million people globally. They affect between almost 1,000 live births depending upon how they are diagnosed. Congenital heart defects are the leading cause of birth defect-related deaths.

F.Kovacs et al. [1] indicate that a congenital heart diseases (CHD), remain undetected because of their low level. Based on the fact that the CHD is a morphological defect of the heart causing turbulent blood flow, the turbulence appears as a murmur, which can be detected by fetal phonocardiography (fPCG). The proposed method applies measurements on the maternal abdomen and from the recorded sound signal a sophisticated processing determines the fetal heart murmur. The Paper describes the problems and the additional advantages of the fPCG method including the possibility of measurements at home and its

combination with the prescribed regular cardiotocographic (CTG) monitoring.

Hassan Ghassemian et al. [] verified that distinguishing a pathological murmur from a physiological murmur is difficult and prone to error. They developed devised a simplified approach to paediatric cardiac scanning. Patients without heart disease and either no murmur or an innocent murmur (n = 40) were compared to patients with a variety of cardiac diagnoses and a pathologic systolic murmur present (n = 53). A specificity of 100% and a sensitivity of 90.57% were achieved using signal processing techniques and a k-nn as classifier.

Arun Kumar Mittra et al. [], analyzed that frequent exposure to ultrasound radiations is not recommended for the fetal well-being**.** The results show that the technique is suitable and effective for long-term FHR home monitoring application. This work presents development of a very powerful, non-invasive, portable and low cost battery operated standalone fetal heart sound recording and monitoring system that can be used in prevailing home environment.

S.M.Debbal says that todays modern technology has provided more powerfull tools to evaluate the information related to heart sounds. One of the most common methods used for listening and tracking heart sounds is to record them with a special devices. A simple model for analyzing the PCG signal in order to distinguish between normal and abnormal heart sounds. This analysis is carried out by using discrete wavelet transform. The analysis of the features shown that discrimination between the normal signals from abnormal signal is possible.

T.Ayesha Rumana et al. [] analysed that Heart Sounds (HS) interferes with lung sound in the diagnosis of respiratory illness. In the analysis of respiratory disorders, Separation of Respiratory Sound from heart sound plays a major role. The proposed scheme implements a virtual instrument for removing heart sounds from respiratory sounds. The recorded sound is given as output to the HS detection block and the segments of HS are detected using Multi resolution Analysis (MRA). The detected segments are cancelled and localized by the cancellation and localization block. The HS segments are grouped and modelled using Linear Prediction method. The modelled output is RS, presence of asthma is analysed using parameters like Mean, Variance and Standard deviation.

Santos et al. [13] showed that the exact timing of cardiac events, represented by the first (S1) and second (S2) sounds, from the PCG signals(phonocardiogram), presents wavelet based technique for S1 and S2 detection in PCG signals, that is able to perform a good detection in both normal and abnormal cases. This method based on wavelet analysis for correct detection of S1 and S2 even in pathological cases. The method presents 98% of correctness in detection of S1and S2, even in cases where a significant amount of murmur exists. A natural continuity of the present study would be the investigation of the sub-events detection inside each cardiac event S1 and S2, i.e., the timing of their components that are strictly related to the opening/closing of the cardiac valves.

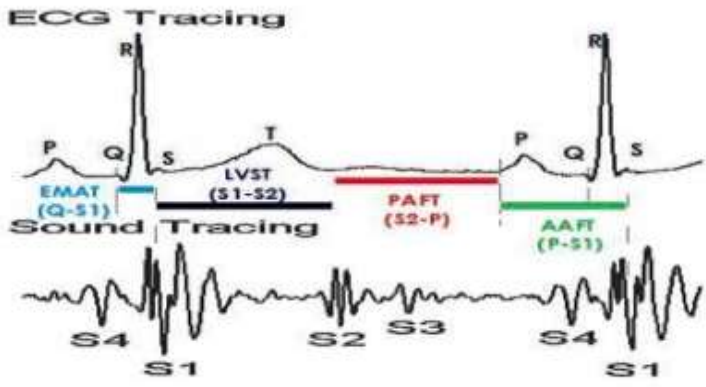

Fig.1. schematic representation of heart sounds

S1 – The first heart sound forms “lub” of “lub-dub”. It is caused by the sudden block

of reverse blood flow due to closure of the atrioventricular valves i.e tricuspid and mitral at the beginning of ventricular contraction or systole.

S2 – The second heart sound forms "dub" of "lub-dub". It is caused by sudden block of reverse blood flow due to closure of semi lunar valves i.e. aortic valve and pulmonary valve at the beginning of diastole.

S3 – Rarely, there may be a third heart sound called a prodiastolic gallop, ventricular gallop. It occurs at the beginning of diastole after S2 and is lower in pitch than S1 or S2 as it not of valvular origin.

S4 – It is audible in an adult is called a presystolic gallop or atrial gallop. This gallop is produced by the sound of blood being forced into a stiff of hypertrophic ventricle. Fig. 1. Represent the heart sounds

II METHODOLOGY

The process is having four stages. They are Wireless hardware configuration and control, Incorporation of the core filtering algorithms, Graphical user interface development, Debugging and testing.

A. HARDWARE USED

A wireless prototype system of fetal phonocardiography (fPCG) is designed for acquiring fetal heart sound from the maternal abdomen. It acts as a multicasting server transmitting the heart and lung sounds to each one of the headphones. This development of a Bluetooth enabled system, which provides the ability to transmit and store biomedical data in the least annoying way for both the patient and the doctor.

B. HARDWARE DESCRIPTION

- Power supply
- wireless module
- Heart beat transmitter kit
- Speaker

C. POWER SUPPLY

A **power supply** is a device or system that supplies electrical or other types of energy to an output load or group of loads. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others.

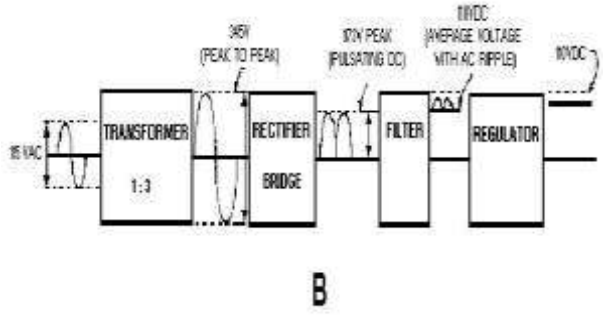

Fig 2. Block diagram of a basic power supply

The transformer steps up or steps down the input line voltage and isolates the power supply from the power line. The rectifier section converts the alternating current input signal to a pulsating direct current. However, as you proceed in this chapter you will learn that pulsating dc is not desirable. For this reason a filter section is used to convert pulsating dc to a purer, more desirable form of dc voltage. The final section, the regulator maintains the output of the power supply at a constant level.

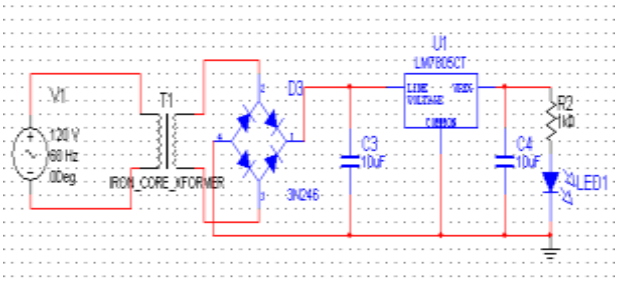

Fig. 3. circuit diagram of power supply

D. WIRELESS MODULE

The wireless environment introduced by wireless technology can be used to increase the productivity in a medical environment by providing the means to an effortless transfer and storage of those data. With the following proposed implementation a doctor will be able to move freely in the clinic examining his patients using a wireless-enhanced stethoscope, which can automatically send the captured sounds to a central workstation for further processing. The need for carrying along different kinds of recording and transmitting devices is alleviated through the use of the proposed wireless.

E. BLOCK DIAGRAM

TRANSMITTER

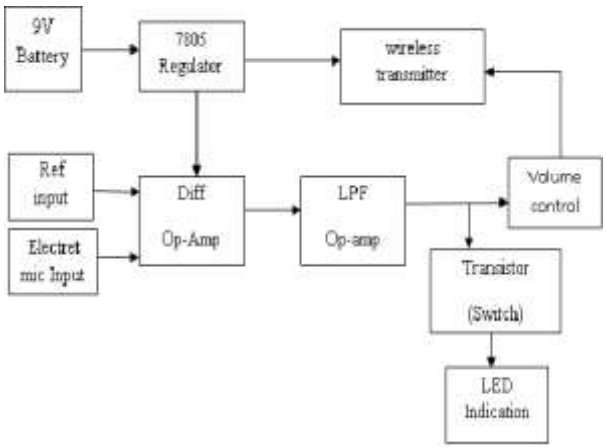

Fig.4. Transmitter section

RECEIVER

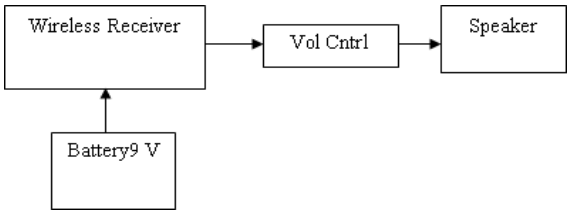

Fig. 5. Receiver section

F. HEART BEAT TRANSMITTER KIT

The heart beat transmitter kit consist of a dual operational amplifier, low voltage audio amplifier and an operational amplifier. These amplifiers amplifies the recorded sound signal and transmits the sound to each one of the headphones.

G. SOFTWARE

Labview is a simple software to design and execute real,complex engineering systems. The data acquisition device is interfaced between the amplifier and PC. It acts as an input and /or output devices. It accepts the PCG waveform as analog signal and delivers analog voltage. Ai0 is chosen as the input channel and A0o is chosen as output channel. It has 8 single ended analog inputs and 2 analog outputs with 12 digital input output lines.

H. PRENATAL HEART SOUND

Prenatal heart beat usually called embryonic heartbeat before approximately 10 weeks of gestational age and the fetal heart beat until birth. It is the contractions during the cardiac cycles of an embryo or fetus.

I. FETAL HEART RATES

Starting at week 5 the fetal heart rate accelerates by 3.3bpm per day for the next month. The fetal heart begins to beat at approximately the same rate as the mother's, which is typically 80 to 85bpm. The approximate fetal heart rate for weeks 5 to 9 is

- Week 5 starts at 80 and ends at 103bpm
- Week 6 starts at 103 and ends at 126bpm
- Week 5 starts at 126 and ends at 149bpm
- Week 5 starts at 149 and ends at 172bpm

- At week 9 the fetal heart beat tends to beat within a range of 155 to 195bpm.

the fetal heart rate generally falls within the range of 120 to 160bpm by week

J. CAUSES OF CHD

The cause of a congenital heart defect is often unknown. Certain cases may be due to infections during pregnancy such as use of ceratin medications or drugs such as alcohol or tobacco, parents being closely related, or poor nutritional status or obesity in the mother. Having a parent with a congenital heart defect is also a risk factor syndrome.

K. SIGNS AND SYMPTOMS

Signs and symptoms are related to type and severity of the heart defect. Symptoms frequently present in early life, but it is possible for some CHDs to go undetected throughout life. Some children have no signs while others may exhibit shortness of breath, cyanosis, fainting, heart murmur, under-development of limbs and muscles, poor feeding or growth, or respiratory infections. Congenital heart defect cause abnormal heart structure resulting in production of certain sounds called heart murmur.These can sometimes be detected by auscultation, however not all heart murmurs are caused by congenital heart defects.

L. SEPTAL DEFECTS

The septum is a wall of tissue which separates the left heart from right heart shown in figure 1.4.

ASD – Defects in interatrial septum will cause oxygen rich blood can flow directly from the left side of the heart to mix with the oxygen poor blood in the right side of the heart.

VSD – Defects in interventricular septum will reduce the heart's efficiency. Which are collectively the most common type of CHD.

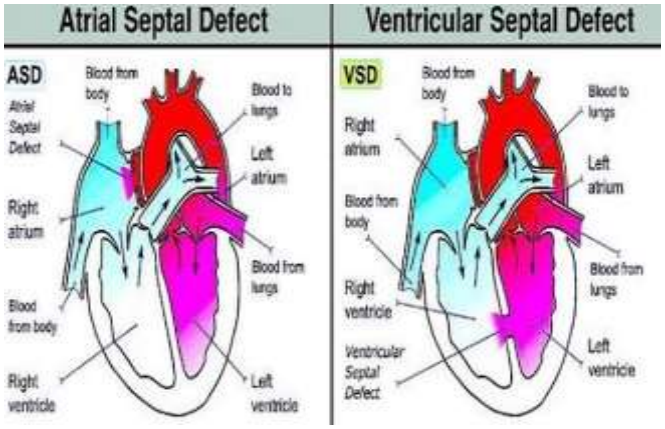

Fig. 6. schematic representation of septal defects

M. PHONOCARDIOGRAM

A phonocardiogram or PCG is a plot of high fidelity recording of the sounds and murmurs made by the heart with the help of the machine called phonocardiography is the recording of all the sounds made by the heart during cardiac cycle shown in Fig 1.5. The sounds are thought to result from vibrations created by closure of heart valves.The first when the atrioventricular valves close at the beginning of systole and the second when the arotic valve and pulmonary valve close at the end of systole. It allows detection of subaudible sounds and murmurs, and makes a permanent record of these events.

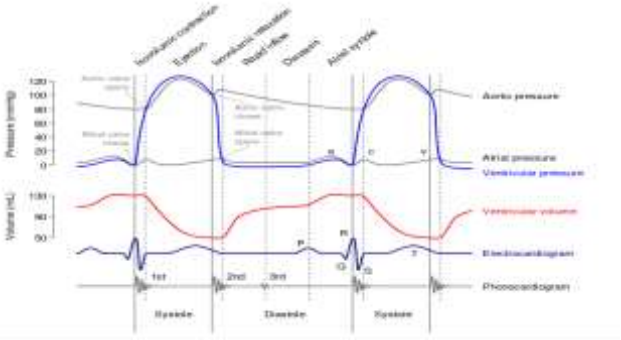

Fig. 7. Schematic representation of PCG

N. RECORDING OF SOUND

The sounds of a fetal can be heared using a normal stethoscope shown in figure 1.6. The stethoscope can be placed at the abdomen of a mother. The heart sound of a fetal can be heared using a head phone. Then the sound can be recorded and it will be viewed as a wave. From the wave the frequency of a heart sound is calculated. The fetal with heart defect can be analyzed with the varying frequency

O. CALCULATION OF FHR

- The normal fetal heart rate (FHR) ranges from 120 – 160 bpm.
- A case structure is implemented to calculate the heart rate.
- FHR is calculated using the formula,

FHR = 1/TS1S1 (60) bpm
TS1S1 = time difference between one systole to another systole

Features of PCG are Fetal heart sound, Peak frequency, Fetal heart rate, Mean, Variance, Standard deviation

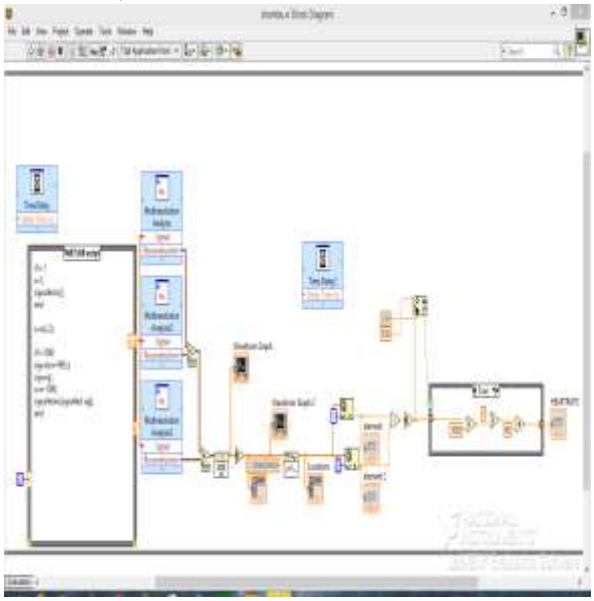

Fig 8. block diagram for calculating Fetal Heart Rate(FHR)

IV RESULTS AND DISCUSSIONS

Fig. 4.1(a) shows the waveform of Normal PCG signal recorded from the maternal abdomen

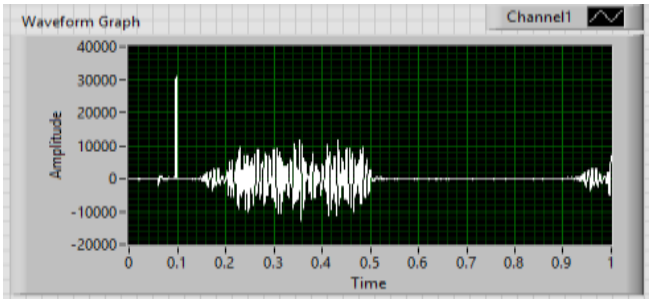

Fig. 4.1(b) shows the waveform of abnormal PCG signal.

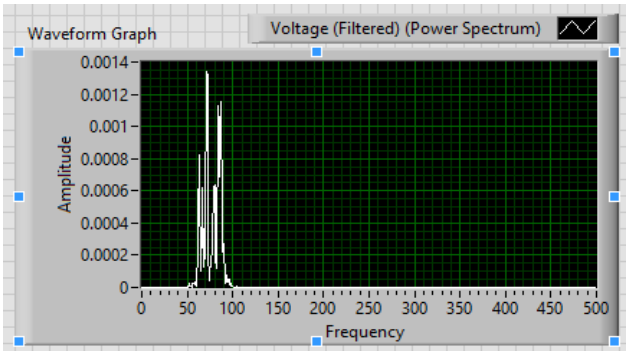

Fig. 4.2 (a) shows the waveform of peak frequency for normal PCG signal. This is a plot of Frequency vs Time. From this plot the peak frequency was measured.

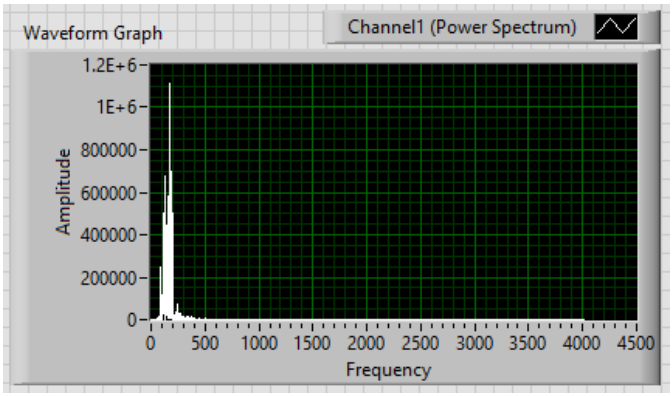

Fig. 4.2 (b) shows the waveform of peak frequency for abnormal PCG signal.

This is a plot of Frequency vs Time. From this plot the peak frequency was measured.

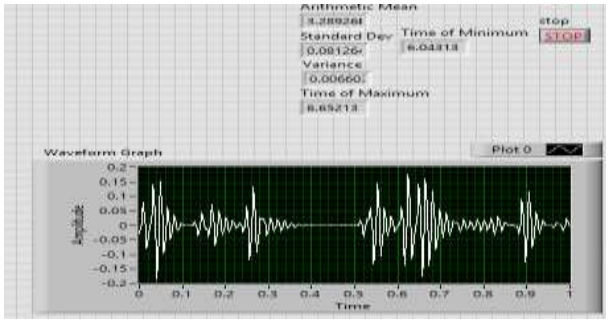

Fig. 4.3(a) shows the values of mean, variance, standard deviation for normal PCG signal.

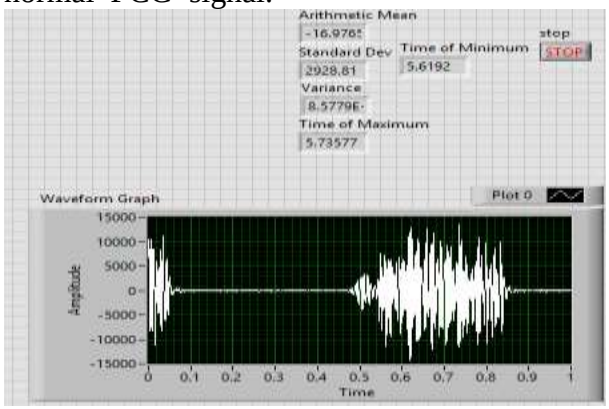

Fig. 4.3(b) shows the values of mean, variance, standard deviation for abnormal PCG signal.

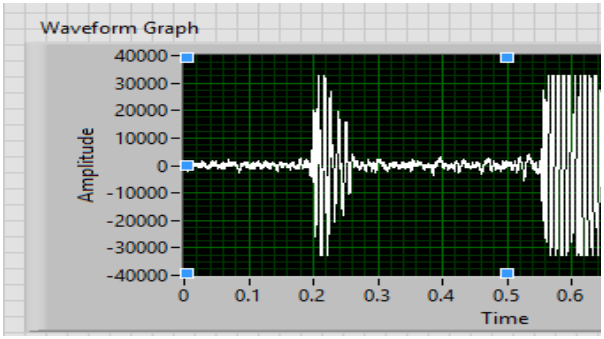

Fig. 4.4(a) shows the waveform of atrial septal defect.

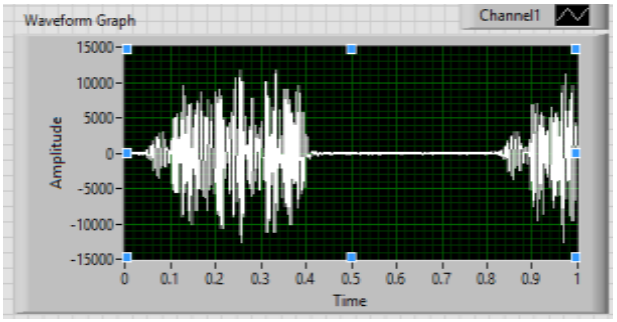

Fig. 4.4(b) shows the waveform of ventricular septal defect.

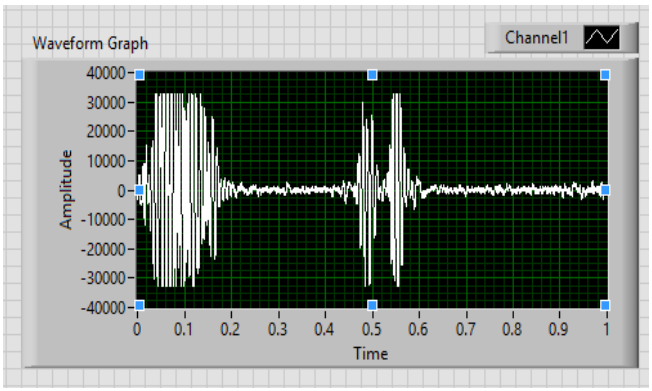

Fig. 4.4(c) shows the waveform of mitral stenosis.

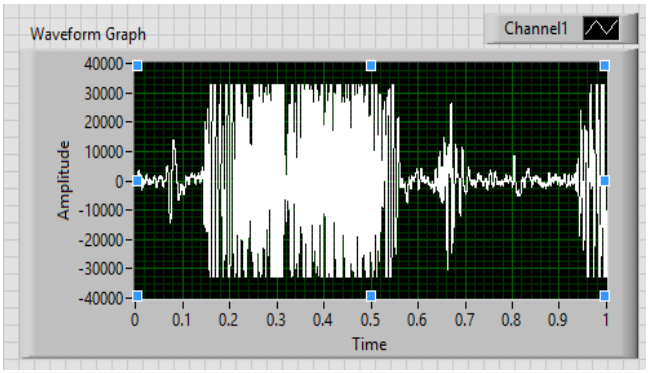

Fig. 4.4(d) shows the waveform of mitral regurgitation

From the above results, both normal and abnormal PCG signals are shown in Fig 4.1(a) and 4.1(b). We conclude that depending on the presence of murmurs between first and second heart sounds, features like peak frequency, mean, variance and standard deviation are extracted and they differ for both normal and abnormal signals. Therefore,

congenital disorders such as atrial septal defect, ventricular septal defect, mitral stenosis, and mitral regurgitation are diagnosed.

FUTURE WORK

A fetal phonocardiography system is now developed to record fetal heart sound which is used for the diagnosis of congenital heart disease. It uses a wireless module which provides the ability to transmit and store biomedical data in the least annoying way for the patient and the doctor. This can be improved by designing the circuit with a microcontroller and liquid crystal display in which fetal heart rates can be displayed. This is efficient for long term monitoring in home care application with low cost for patients.

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