Electronic Stethoscopes using Arduino

Sonam Talware[1], Pooja Tayade[2], Ashvini Uike[3], N.S. Mundane[4]

[1]Prof. N.S. Mundane, Dept. of Electronics and Telecommunication Engineering, DES'sCOET College, Maharashtra, India

---***---

Abstract - *Most heart diseases are associated with and reflected by the sounds that the heart produces. Heart auscultation, defined as listening to the heart sound, has been a very important method for the early diagnosis of cardiac dysfunction. Traditional auscultation requires substantial clinical experience and good listening skills. The emergence of the electronic stethoscope has paved the way for a new field of computer-aided auscultation. This article provides an in-depth study of the electronic stethoscope technology and the methodology for diagnosis of cardiac disorders based on computer-aided auscultation. The seminar is based on a comprehensive review of literature articles, market (state-of-the-art) products and smartphone stethoscope apps. It covers in depth every key component of the computer-aided system with electronic stethoscope, from sensor design, front-end circuitry, de-noising algorithm, heart sound segmentation, to the final machine learning techniques. Our intent is to provide an informative and illustrative presentation of the electronic stethoscope, which is valuable and beneficial to academics, researchers and engineers in the technical field, as well as to medical professionals to facilitate its use clinically. The paper provides the technological and medical basis for the development and commercialization of a real time integrated heart sound detection, acquisition and quantification system.*

Key words - *Heart sound, Heart auscultation, Heart disorder, Diagnosis, Acoustic technique, Automatic system, Smartphone stethoscope apps.*

1. INTRODUCTION

Stethoscope is one of the most important diagnostic tools in the medical world. Over almost two centuries, the stethoscope has been changed and refined often, but it has never strayed too far from the original design. Rene Theophile, a French physician, is attributed with the invention of the first stethoscope in 1816 when he was examining an obese patient. His first model of the stethoscope was simply a wooden tube resembling a candlestick. Over the years, this model has evolved into the device that we now recognize as the stethoscope through many small changes, such as adding earpieces for each ear and developing the combined bell and diaphragm chest piece. A stethoscope is a very straightforward device. The chest piece consists of a shallow, bell-shaped piece and a clear, stiff diaphragm, which is then connected to the metal earpieces by a flexible tube. The bell is used to pick up lower frequency sounds, and the diaphragm is used for higher frequency sounds. When the chest piece is placed on the skin, vibrations within in the body are amplified by either the bell or diaphragm. These acoustic pressure waves then travel up through the tubing, resonating to the earpieces and into the listener's ears. Very few changes have been made to the overall design of the stethoscope over the years because it does its job so well. However, there are a few problems with current models. For example, with the standard acoustic stethoscope, the listener is not able to amplify the sounds. This is sometimes a problem if he or she is only getting very quiet sounds through the stethoscope. Also, the earpieces of stethoscopes can be quite uncomfortable. Although these are not enormous problems, current technology has introduced alternatives to the acoustic stethoscope. Stethoscopes are not only useful for doctors, but for home mechanics, exterminators, spying etc. Stethoscopes can also be used to check scientific vacuum chambers for leaks, and for various other small-scale acoustic monitoring tasks. Standard stethoscope provides no amplification which reduces its use. A Stethoscope uses op-amps to amplify the signal and includes a low pass filter to remove background noise. A typical electronic stethoscope. A typical electronic stethoscope performs the following functions, for listening to the heart beats for any irregular rate of beating. To verify Electronic Stethoscope the operation of the lungs to know if there is fluid build up. To check the blood pressure running through the veins. To determine the process of digestive system in the stomach. For prenatal care during pregnancy. The field of applied science related to the art of healing by diagnosis, treatment, and prevention of disease. It encompasses a variety of health care practices evolved to maintain and restore health by the prevention and treatment of illness in human beings.

1.1 STETHOSCOPE BACKGROUND

Although it's a really easy device, the medical instrument is one amongst the foremost vital diagnostic tools within the medical world. Over nearly 2 centuries, the medical instrument has been modified and refined typically, however it's ne'er strayed too aloof from the initial style. Rene Theophile, a French medico, is attributed with the invention of the first stethoscope in 1816 when he was examining an obese patient. His 1st model of the medical instrument was merely a picket tube resembling a candle holder. Over the years, this model has evolved into the device that we tend to currently acknowledge because the medical instrument through several tiny changes, such as adding earpieces for each ear and developing the combined bell and diaphragm chest piece. Very few changes are created to the model of the medical instrument since 1961, when Dr. David Littman proprietary a replacement, lighter model with one two-channel tube that drastically improved the acoustic technology. The stethoscopes that area unit currently unremarkably used area unit referred to as —Littman

stethoscopes for this reason. A stethoscope is a very straightforward device. The chest piece consists of a shallow, bulging piece and a transparent, stiff diaphragm, which is then connected to the metal earpieces by a flexible tube. The bell is employed to select up lower frequency sounds, and therefore the diaphragm is employed for higher frequency sounds. When the chest piece is placed on the skin, vibrations at intervals within the body area unit amplified by either the bell or diaphragm. These acoustic pressure waves then travel up through the conduit, rolling to the earpieces and into the listener's ears. Very few changes are created to the general style of the medical instrument over the years as a result of it will its job thus well. However, there area unit a couple of issues with current models. For example, with the quality acoustic medical instrument, the attender isn't able to amplify the sounds. This is typically a drag if he or she is just obtaining terribly quiet sounds through the medical instrument. Also, the earpieces of stethoscopes will be quite uncomfortable. Although these aren't huge issues, current technology has introduced alternatives to the acoustic medical instrument.

1.2 Current Methods

In 1961, right round the same time that Littman proprietary his new model, a corporation named Amplivox created the primary electronic medical instrument. It was solely meant to be an educational tool thanks to its giant size and weight, and it additionally created clearly completely different sounds than what doctors were wont to hearing. Because of this, the thought was mostly abandoned, and users came back to the traditional medical instrument. However, some firms have came back to the current plan and have introduced new devices to the market. Some enhancements that trendy electronic stethoscopes have square measure sound transducers, adjustable gain amplifiers, and frequency filters. Although these enhancements are created, the electronic stethoscope still has not been embraced by the medical community. This is as a result of the sounds that the auditor receives through the earpieces square measure mixed with electronic noise, causing the sounds to be different than the non-electronic, acoustic stethoscope. Also, electronic stethoscopes square measure terribly sensitive to encompassing noises, and these will overpower the sound of the heart and lungs. Many electronic stethoscopes on the market don't have the first bell and diaphragm or conduit, which help filter background noise and produce a sound that the listener is more familiar with. Electronic stethoscopes, like standard acoustic stethoscopes, only allow one listener, which is not preferable for a teaching environment. They also are about $400 MSRP, which is much more expensive than an acoustic model. Current models on the market solely have one input electro-acoustic transducer, therefore the head of the medical instrument should be rapt to concentrate to alternative areas of the body.

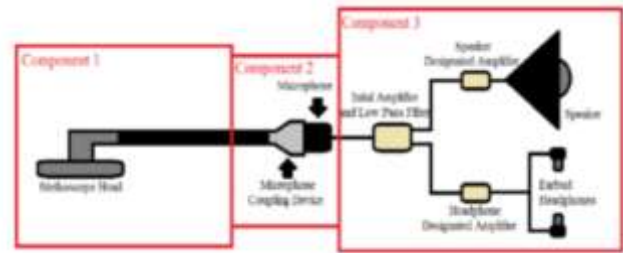## 2.1 BLOCK DIAGRAM OF ELECTRONIC STETHOSCOPE

Figure 2.1 Block Diagram of Electronic Stethoscope

The current prototype follows the general block setup featured in Figure2.1 The target sounds originate from the vibrations of the stethoscope's skinny diaphragm, and also the sound waves reverberate through the rubber tube. This tube acts as a mechanical low pass filter, assisting in imitating the original sound of a non-electronic stethoscope. Located at the end of the tube is a condenser microphone housed in a plastic coupling device designed in solid works and printed on a 3D printer. The signal is then sent through a DC interference condenser followed by a non inverting voltage follower, a second-order low pass filter, and finally an active gain stage providing a gain of 10. The corner frequency for the filter is 800 Hertz. Before the signal is routed to the specified audio outputs, it is subjected to voltage dampening by a potentiometer that acts as a volume control. The speakers presently being used ar rated for five watts at four ohms. For earpiece amplification, the LM386 was chosen and offers a nominal gain of 20. In order to drive the speakers, a high-powered TDA2003 was chosen to provide a gain of 100, which can be altered by varying the resistors and capacitor values within the circuit. Currently the device attracts 12V DC and pulls close to 100mA at peak speaker output from a variable power provide. The collection of single provide operational amplifiers utilizes a virtual ground of half dozen volts, created by a series of buffered voltage dividers.

2.2 Arduino

Figure 2.2 Arduino Board

Arduino is associate ASCII text file natural philosophy prototyping platform supported versatile, easy microcontroller board. The development hardware is simple to use with code writing within the board. For this project by taking associate inputs signal from the sensors, it can also management a crystal rectifier, speaker and wireless communication Zigbee. Referring to Figure, this project used Arduino Nano and Arduino Mega as a microcontroller to receive data and then transfer it through Zigbee Pro Series 1 for wireless communications. Arduino Nano is a small, complete, and bread board friendly board based on the ATmega328 have 14 digital pins with operate supply power at 5 volts. While for Arduino Mega conjointly a microcontroller board supported the ATmega1280 has fifty four digital input and output pins with same operate offer as Arduino Nano. Others for wireless connections is eight pin accustomed receive (RX) and transmit (TX) at serial information for Arduino Mega whereas a pair of pins American state and RX for Arduino Nano. With the Arduino board, you'll write programs and make interface circuits to scan switches and alternative sensors, and to regulate motors and lights with little effort. Many of the photographs and drawings during this guide were taken from the documentation on the Arduino web site, the place to show if you wish a lot of data. The Duemilanove board options associate degree Atmel ATmega328 microcontroller in operation at five V with a pair of kilobyte of RAM, thirty two kilobyte of non-volatile storage for storing programs and one kilobyte of EEPROM for storing parameters. The clock speed is sixteen rate that interprets to concerning corporal punishment concerning three hundred, 000 lines of C source code per second. The board has fourteen digital I/O pins and half dozen analog input pins. There is a USB connecter for reproval the host laptop associate degreed a DC power jack for connecting an external 6-20 V power supply, as an example a nine V battery, once running a program whereas not connected to the host laptop. Headers area unit provided for interfacing to the I/O pins victimisation twenty two g solid wire or header connectors. For additional information on the hardware. The Arduino programing language could be a simplified version of C/C++. If you recognize C, programming the Arduino are acquainted. If you are doing not grasp C, no ought to worry as solely some commands area unit required to perform helpful functions. An important feature of the Arduino is that you just will produce a sway program on the host laptop, transfer it to the Arduino and it'll run mechanically. Remove the USB cable affiliation to the laptop, and also the program can still run from the highest every time you push the push button. Remove the battery and place the Arduino board during a closet for 6 months. When you reconnect the battery, the last program you keep can run. This means that you just connect the board to the host laptop to develop and correct your program, however once that's done, you now not want the laptop to run the program.

3 TYPES OF STETHOSCOPE

3.1 Acoustic stethoscope

The medical instrument is AN instrument used for diagnostic procedure or listing to sounds made by the body. It is used primarily to concentrate to the lungs, heart and internal organ tract. It is conjointly accustomed hear blood flow in peripheral vessels and therefore the heart sounds of development. Acoustic stethoscopes ar acquainted to the general public, and operate the transmission of sound from the chest piece, via air-filled hollow tubes, to the listener's ears. The chest piece sometimes consists of 2 sides that may be placed against the patient for sensing sound; a diaphragm (plastic disc) or bell (hollow cup). If the diaphragm is placed on the patient, body sounds vibrate the diaphragm, creating acoustic pressure waves which travel up the tubing to the listener's ears. If the bell is placed on the patient, the vibrations of the skin directly produce acoustic pressure waves traveling up to the listener's ears. The bell transmits low frequency sounds, whereas the diaphragm transmits higher frequency sounds. This two-sided medical instrument was fictional by Rappaport and Sprague within the early a part of the twentieth century. One downside with acoustic stethoscopes was that the sound level is extraordinarily low. this downside was head in 1999 with the invention of the stratified continuous (inner) lumen, and the kinetic acoustic mechanism in 2002. Acoustic stethoscopes are the most commonly used. A recent independent review evaluated twelve common acoustic stethoscopes on the basis of loudness, clarity, and ergonomics. They did acoustic laboratory testing and recorded heart sounds on volunteers. The results are listed by brand and model.

3.2 Electronic stethoscope

An electronic medical instrument (stetho-phone) overcomes the low sound levels by electronically amplifying body sounds. However, amplification of medical instrument contact artefacts, and part cut-offs (frequency response thresholds of electronic medical instrument microphones, pre-amps, amps, and speakers) limit electronically amplified stethoscopes' overall utility by amplifying mid-range sounds, whereas at the same time attenuating high- and low-frequency vary sounds. Currently, a number of companies offer electronic stethoscopes. Electronic stethoscopes need conversion of acoustic sound waves to electrical signals which might then be amplified and processed for best listening. Unlike acoustic stethoscopes, that square measure all supported a similar physics, transducers in electronic stethoscopes vary widely. The simplest and least effective methodology of sound detection is achieved by inserting a electro-acoustic transducer within the chest piece. This methodology suffers from close noise interference and has fallen out of favour. Another methodology, employed in Welch-Allyn's Meditron medical instrument, comprises placement of a piezoelectric crystal at the head of a metal shaft, the bottom of the shaft making contact with a diaphragm. 3M additionally uses a piezo-electric crystal placed among foam behind a thick rubber-like diaphragm.

Think labs' Rhythm thirty two creator, solon Smith uses associate magnetism Diaphragm with a semiconducting inner surface to make a electrical phenomenon device. This diaphragm responds to sound waves identically to a standard acoustic medical instrument, with changes in an electrical field exchange changes in atmospheric pressure. This preserves the sound of associate acoustic medical instrument with the advantages of amplification. Because the sounds square measure transmitted electronically, associate electronic medical instrument will be a wireless device, will be a recording device, and may offer noise reduction, signal sweetening, and both visual and audio output. Around 2001, Stetho-graphics introduced PC-based package that enabled a phonocardiograph, graphic illustration of medical specialty and pulmonology sounds to be generated, and taken consistent with connected algorithms. All of these features are helpful for purposes of telemedicine (remote diagnosis) and teaching. Electronic stethoscopes are used with Computer-aided diagnostic technique programs to analyse the recorded heart sounds pathological or innocent heart murmurs.

3.3 Recording stethoscopes

Some electronic stethoscopes feature direct audio output which will be used with AN external recording device, like a portable computer or MP3 recorder. The same association will be accustomed hear the previously-recorded diagnostic technique through the medical instrument headphones, leaving additional elaborate study for general analysis also as analysis and consultation concerning a specific patient's condition and telemedicine, or remote designation.

4 CHARACTERISTICS OF HEART SOUNDS

HSs are generated by the beating heart and also the resultant flow of blood through it. In healthy adults, there are two normal HSs. the first HS (S1), produced by the closing of the atrioventricular valves; and the second HS (S2), caused by the closure of the crescent-shaped valves. In the case of abnormal HS, there could be other several signal activities between S1 and S2 such as S3, S4, murmur, etc. The third HS (S3) may be a rare further sound caused by a fulminant retardation of blood flow into the heart ventricle from the atrium cordis. This sound is traditional in kids and adults up to age 35–40 years. After the age of forty, a third HS is usually abnormal and correlates with dysfunction or volume overload of the ventricles. The fourth HS (S4) is caused by the vibration of valves, supporting structures and the ventricular walls. S4 is tested to be a symptom or symptom of coronary failure throughout heartbeat amount. In general, the frequency of S1 is not up to that of S2, and the duration of S1 is longer than that of S2. The S3 occurs from 0.1 to 0.2 s after S2, while S4 occurs from 0.07 to 0.1 s before S1—both of them are low pitched. In addition to those HSs, varied heart murmurs could arise in the main from heart issues or diseases. The murmurs are extra or unusual sound heard during a heartbeat and broadly classified as systolic, diastolic and continuous.
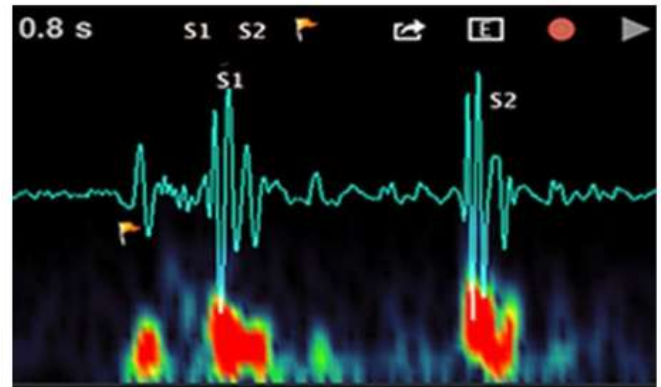

Figure 4.1 Two primary heart sounds: S1 and S2

The complete types and characteristics of the HSs are listed in Figure 4.1 Each heart disorder is associated with one or more HSs. The disorders that are associated with each sound are also detailed in Figure.
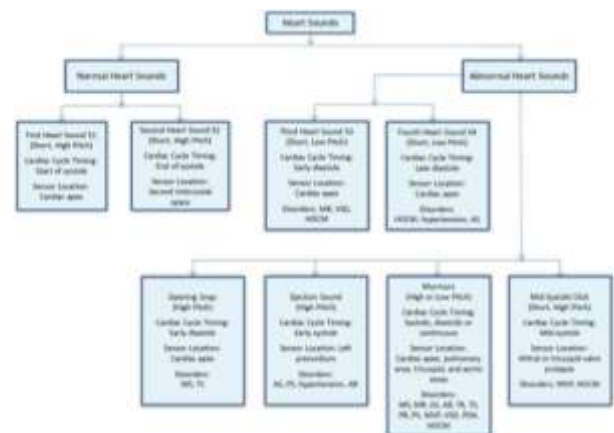

Figure 4.2 Characteristics of Heart Sounds

The summary of characteristics of some common murmurs is provided. In some miscellaneous HSs, the opening snap is a high-pitched diastolic sound produced by rapid opening of mitral valve in mitral stenosis (MS) or tricuspid valve in tricuspid stenosis (TS). The ejection sound (ES) is the most common early systolic sound which results from abnormal sudden halting of the semilunar cusps as they open during early systole. The mid-systolic click (MSC) is a HF sound in mid systole that results from the abrupt halting of prolapsing mitral valve leaflets' excursion into the atrium by chordae. During cardiac auscultation, the physicians are particularly interested in abnormal sounds, and various types of murmurs, which may suggest the presence of a cardiac pathology and also provide diagnostic information.
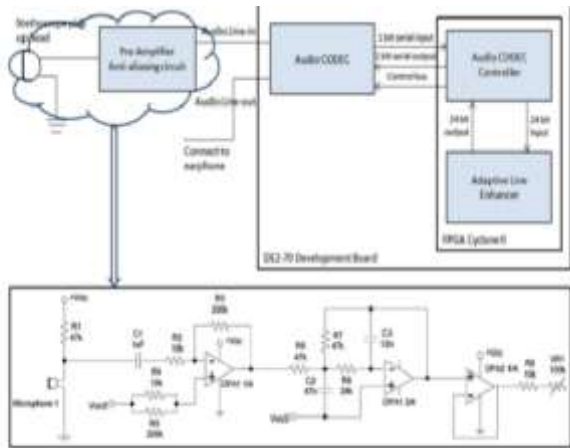
CIRCUIT DESCRIPTION

Figure 4.3 Circuit Diagram of Electronic Stethoscope

The housing for the main receiver box is a clear polycarbonate box, which contains the speakers and all the user controls including power switches and volume controls for both headphones and speakers. On the aspect of the box may be a tiny hole for the input wires from the mike, with the lid to the housing being secured by six screws. Considerations for improvement this semester embrace shrinking the general dimensions of the housing to form the device additional sensible for clinical use. The target size is not any bigger than a 5‖ cube. The loose wires will ought to be secured and guarded in accordance with rising aesthetics and safety. An additional input mike are additional to permit for the user to match and distinction 2 separate respiratory organ sounds, which is able to be particularly helpful in deciding that bronchi the endotracheal tube enters during pediatric procedures.

A final thought would be to ideally create each input microphones wireless. Despite having a general schematic (see Figure 3.1) for how the final prototype will look, there are three main components of the design that need to be evaluated. Therefore, the look choices square measure choppy into 3 totally different categories: mike sort, wireless technology, and amplifiers. As can be seen in Figure 3.1, the final prototype will consist of a main receiver box holding the speaker and headphone jack, all the internal circuitry components, and the wireless receivers for the two microphones. Attached to every medical instrument head are a mike, a metal coin battery for power provide, and a wireless transmitter.

5. SOFTWARE DETAILS

Software that's required to manage this wireless medical instrument system will be monitored and analyzed the heartbeats by the doctors or Dr.. The system that is used for this method is capturing the input signal in voltage that is from condenser microphone sensor and then being read by the software programming system to convert from analog signal into digital signal for ending within the development of wireless medical instrument.

5.1 ARDUINO C++ PROGRAMMING

The Arduino integrated development setting (IDE) may be a crossplatform application written in Java. It is capable of aggregation and uploading programs to the board with one click. A language reference in Arduino programs that may be divided in 3 main components that's structure, values for variables with constants, and functions. It runs code compiled from either C, C++, Java4 or any other language that has a compiler for the Arduino instruction set (Amir Hoshang Kioumars 2011).

5.2 SETUP USING X-CTU PROGRAM

X-CTU may be a complete tool for configuring ZigBee modules. By transfer the installation through web, it will easily install in the personal computer. Then assemble the frequency Modules that's launching the X-CTU computer code below computer setting by verify the baud in 9600. The baud of a knowledge communications system is that the variety of symbols per second is transferred. They are straightforward devices that may use to line up serial communications between the applications. Once put in, it is ready for configuring the ZigBee it will construct a point-to-point network for two devices are going to communicate together. For this project 2 ZigBee is required to transmission knowledge and receiving knowledge for wireless communications. The Heart rate signal was send to the pc through serial communication. MATLAB software will show the result through GUI. Baud rate is set to 9600 to establish the communication between Matlab and serial communication. The 9600 information measure implies that the port is capable of transferring a most of 9600 bits per second of information.

5.3 MATLAB ASCII

MATLAB could be a matrix laboratory that's numerical computing surroundings and fourth-generation artificial language. Developed by mathematics Works, MATLAB permits matrix manipulations, plotting of functions and knowledge, implementation of algorithms, creation of user interfaces, and interfacing with programs written in alternative languages, including C, C++, Java, and FORTRAN.. MATLAB has structure knowledge varieties. MATLAB supports developing applications with graphical computer program options. MATLAB includes GUIDE (GUI development environment) for diagrammatically coming up with GUIs. It also has tightly integrated graph-plotting features. It is a high-performance language for technical computing. ASCII stands for yank normal Code for info Interchange. Computers will solely perceive numbers, therefore associate degree computer code code is that the numerical illustration of a personality, text in computer, and communications equipment. Matlab is the user interface that only understands base on the ASCII code for 10 characters includes description numbers. It is associate degree graphic symbol for decimal variety that may convert Arduino knowledge input into computer code code at MATLAB.

6. CONCLUSION

In this seminar it is concluded that, cardiac auscultation constitutes an important part of clinical medicine. Electronic medical instrument could be a device wont to live vital sign by sleuthing the blood instantaneous sound pressure, heart and lungs beat, digestive system of the stomach, prenatal care (pregnancy). The seminar aim at designing an electronic stethoscope, a circuit is design to perform the same function as the conventional stethoscope. Recently, techniques related to advances in electronic medical instrument are developed to method diagnostic procedure HS signals also as analyze and clarify the ensuing sounds, to make diagnosis based on quantifiable medical assessment. The availability of automatic interpretation of HSs opens interesting perspectives in the context of cardiovascular diagnostic measures. The stethoscope is used by each and every doctor and nurse. So if we will incorporate into the electronic medical instrument the technology of machine-controlled detection of viscus disorders, then it'll become even a lot of helpful. As soon as the doctor applies the stethoscope, right away will s/he be able to know the disorders.

REFERENCES

[1] Bassiachvili E, Stewart R, Shavezipur M, Patricia N. A MEMS electrical phenomenon, "Passively powered pulse rate monitor: style and analysis". In microsystems and Nano electronics Research Conference (MNRC); 2008. p. 81–4.

[2] Chai KTC, Han D, Ravinder PS, Duy DP, Chin YP, Jian WL, et al. 118-db "Dynamic vary, continuous-time, openedloop capacitance to voltage converter readout for capacitive MEMS accelerometer". In IEEE Asian Solid-State Circuits Conference; 2010. p. 345–8.

[3] Chao CT, Maneetien N, Wang CJ. "On the development of Associate in Nursing electronic medical instrument with period of time heart sound de-noising feature". In continuing of thirty fifth International Conference on Telecommunication and Signal process (TSP); 2012. p. 521–4.

[4] Giustina DD, Riva M, Belloni F, Malcangi M. "Embedding a multichannel environmental noise cancellation algorithmic program into Associate in Nursing electronic stethoscope". Int J Circuits Syst Signal Process. 2011; 5(2):184–91.

[5] Hu YT, Xu Y: "An ultra-sensitive wearable accelerometer for continuous heart and lung sound monitoring". In proceeding of 34th International Conference on IEEE Engineering in Medicine and Biology Society (EMBS); 2012. p. 694.